National Pollution Prevention Center
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CASE STUDY

Corporate Strategy
Operations Management

Agent Regeneration and Hazardous Waste Minimization

The IBM Corporation
Endicott, New York Facility

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INTRODUCTION

International Business Machines Corporation (IBM) was given its initial impetus by Thomas J. Watson, Sr. in Endicott, New York. In 1915, as the new president of the Computing-Tabulating-Recording Company, his concepts for business success marked the beginning of the firm's growth. He changed the company's name to IBM in 1924, as a reflection of the growth achieved up to that time.

IBM's growth was sustained and continuous from that period on. The excellence of its accounting machines was responsible for its success up to the start of World War II, which brought about a product change from business machines to ordnance. In 1946, IBM helped to initiate the age of electronics through the introduction of its first commercial electronic computer. Today, the company is primarily a manufacturer and marketer of a full range of computing information equipment and software, with sales revenues in 1991 of approximately $65 billion.

IBM is now aggressively working toward improving both its competitiveness and efficiency. Work force reductions have been accelerated to reduce operating expenses. The general product line has been strengthened, and a series of strategic alliances have been announced with firms

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such as Apple Computing, Motorola, Siemens, etc. In addition, IBM continues to build upon its position as an industry leader in the areas of research, development, and engineering.

These changes were made in recognition of the fact that the information technology industry is currently undergoing a fundamental transition. This transition is "characterized by rapid technological advances, shorter product life cycles, growth of software and services, and increasing competition. As a result, IBM will change from a single, vertically integrated, very complex world-wide enterprise to one of increasingly autonomous businesses. Each business, empowered with varying degrees of independence, will be focused and responsible to its markets." (IBM 1991 Annual Report, p. 35).

THE REGULATORY ENVIRONMENT

The Pollution Prevention Act of 1990 establishes pollution prevention as a national objective. The Act notes that:

> There are significant opportunities for industry to reduce or prevent pollution at the source through cost-effective changes in production, operation, and raw materials use. The opportunities for source reduction are often not realized because existing regulations, and the industrial resources they require for compliance, focus upon treatment and disposal, rather than source reduction. . . . Source reduction is fundamentally different and more desirable than waste management and pollution control.

Manufacturing firms are impacted by the above Act as well as other federal environmental laws, such as the Resource Conservation and Recovery Act, Toxic Substances Control Act, the Clean Air Act, and the Clean Water Act.

Because of increasing demands by this complex regulatory system, which includes state and local laws as well, the cost to U.S. industry is escalating rapidly. The projected annual cost of compliance with hazardous waste controls alone is expected to exceed $12 billion by the end of this decade. This will be double the amount spent for such compliance in 1991. Cleaning up hazardous waste sites will add another $8 billion annually by 1999; with an added $5 billion needed to clean up leaking underground chemical/petroleum storage sites.

Expanded coverage of existing laws on National Ambient Air Quality Standards and toxic air emissions will likely hasten the renovation of some manufacturing facilities. However, many older plants are likely to close, as their revenue production potential falls below the cost of clean-up.

In this case, the specific Environmental Protection Agency Regulation for Solid Waste, 40 CFR 258, "Criteria for Municipal Solid Waste Landfills" applied and could not be met, given the amount of chromium contained in the waste sludge produced by the problem manufacturing process (to be described in detail in the next section of this case). A more definitive and limiting part of the regulations is 40 CFR 261, "Regulation for Identifying Hazardous Wastes." Again, the waste sludge failed to pass the test because of excessive chromium leaching potential.

The effective managerial approach for the future to all of this new legislation calls for a new approach. Manufacturers can no longer wait to see what new regulatory requirements will demand. In order to survive in the changing environmental dynamic of the rest of this decade, they will have to become much more proactive. This new strategy will call for an alliance between manufacturers, regulators, and environmentalists. As is the lesson provided in this case, other firms will have to learn that waste minimization can be environmentally as well as competitively sound.

PROBLEM IDENTIFICATION

In the evolution of this case and as a matter of stated corporate policy, IBM is fully committed to the minimization of the environmental impact from all of its various manufacturing operations. Hazardous waste reduction programs are in place throughout the firm to:

1. Effect waste reduction at the source.
2. Encourage recycling.
3. Develop and implement waste treatment technologies.

IBM's Endicott, New York facility has expanded its operations to include science centers, research laboratories, product development activities, and manufacturing. It currently employs approximately 8,500 people and its primary mission is to:

1. Develop and manufacture technology packaging.
2. Develop systems software.
3. Manufacture bank systems.

Composed of five million square feet of floor space, Endicott is one of IBM's largest plant-lab sites. Its product line consists of a variety of computer processors, banking systems, circuit packaging, and printers. It is this latter product series which serves as the focus of the case. More specifically, a component part—printbands—of most of the impact printers manufactured at this location.

Impact printers have over two hundred component parts. Printbands are stainless steel belts which are used in most such printers. Panels of raw stainless steel, measuring one foot by five feet by 1/2 the thickness of a dime, from which ten printbands can be produced, are used in the basic manufacturing process described below. The resultant printbands are approximately 3/4 of an inch wide with raised characters for printing. The character sets on the bands are subject to change, based upon specific customer requirements.

The manufacturing process used to produce printbands at the Endicott facility involves a photolithographic process in which the stainless steel panels are chemically machined using a strong ferric chloride etching solution containing hydrochloric acid. The waste material which results from this chemical reaction is a solution composed primarily of ferrous chloride.

The chemical process which takes place involves an oxidation/reduction reaction in which the iron (Fe^{+3}) ions are reduced, while iron (Fe) is oxidized. The net product of this reaction is the formation of, or dissolution of iron in the solution in the form of iron ions in the +2 oxidation state, called ferrous ions (Fe^{+2}). This reaction may be chemically represented as:

$$\overset{o}{Fe} + 2\,\overset{+3}{Fe}\,Cl_3 = 3\,\overset{+2}{Fe}\,Cl_2$$

Stainless Steel	Etchant	Dissolved Steel Spent Etchant

Typically, approximately 50,000 printbands are manufactured annually through this process at the Endicott plant. In 1986, this chemical process consumed 158,300 gallons of ferric chloride etching agent, and generated 1,890 tons of hazardous waste sludge, along with 34,200 gallons of concentrated waste etchant which was trucked off site for treatment prior to its disposal in a landfill.

For each printband panel, up to that period, 1.48 pounds of material had to be etched away from the surface to form the final product. This waste material included 1.24 pounds of iron, .2

pounds of chromium, and .04 pounds of molybdenum. On the average, 32 gallons of the ferric chloride solution were required for the etching of one print band panel. This solution weighed 400.5 pounds, including 60.3 pounds of iron.

The manufacturing process was a batch operation. Etching machines were filled with fresh etchant solution once a shift. The etchant was heated to 130 degrees F, 15 pints of hydrochloric acid was added, and the etchant was balanced by the addition of water. The operator started the printband panels through the machine and, because the etching solution was new, the bath's oxidation-reduction potential (ORP) was high. Thus, the etch rate was swift for the first group of panels to be etched.

As additional panels entered the solution, the bath lost some of its etching power as the chemical reaction took place. The operator had to keep adjusting the conveyor speed to compensate for this decrease in etching power. After 12 to 14 panels had been etched, the conveyor speed would have dropped to less than half of the original starting speed. Thus, the efficiency of the process was dependent, in large part, on the skill of the operator to make a high quality product in an environment of constantly changing etching parameters.

At the end of each of the three daily work shifts, the etching solution bath was dumped, the solution-spray nozzles were removed, the etched machine sump was cleaned, clean nozzles were installed, fresh etchant added, and the bath heated up for the next shift. This set-up operation required about two hours per shift to complete, making it a fairly expensive operation in terms of both downtime and labor.

The spent etching solution, plus the waste flow from the panel rinsing operations, was dumped into the site waste collection system for treatment. This waste was pumped to the facility's waste treatment plant where the soluble iron ions were converted to a precipitate by combination with hydroxide ions, the usual practice used in treating heavy metal wastes. This treatment resulted in clean water, which could be safely discharged, and a sludge which was hauled away from the plant in large containers by a vendor and disposed in a landfill at some considerable expense. At that time, the plant shipped its waste to a specific location in Quebec, where it was formulated into a non-leachable, stabilized matrix prior to burial.

The waste etch solution contained a large quantity of hydrochloric acid, which made its extremely corrosive. This acid was neutralized via the addition of a hydrated lime slurry solution. All

(99.9%) of the metals end up in the precipitate. As noted, the chemical composition of the sludge is ferrous chloride. It also includes a residual of the chromium deposits contained in the stainless steel, which was etched away in the chemical reaction. This metal is the component which classified the sludge as "hazardous" and added to its disposal cost.

During the second quarter of 1986, the production of 80 printband panels per day created excessive demands on the waste treatment plant equipment. The sludge processing equipment simply could not keep up with the waste etchant output. As an expedient alternative, the etchant which could not be processed on site was hauled in tank trucks to outside vendors for treatment. About ten large tank trucks of such material were removed from the plant that year—again, at considerable expense.

Environmental engineers at the Endicott plant were aware at the time that ferric chloride solutions had a market that was readily available. At many sewage treatment plants in the region, such a solution is injected into the treatment process as an aid to accelerate flocculation. They pursued this alternative option as an attractive means of disposal. Unfortunately, the chromium content of the solution caused it to be unacceptable for any alternative use application.

As noted, the above manufacturing/treatment/disposal process was utilized in 1986 and for at least 15 prior years. Demand projections for printbands from 1986 to 1991 showed a sharp increase. Such an increase would normally require either:

1. Additional sludge handling equipment to be installed at the plant's waste treatment site; or
2. An increase in off-site waste treatment/disposal dependency. (1991 printband production plan volumes would necessitate a 300% increase.)

In late 1986, this complex problem situation was brought to a head. A chemical outage occurred on the ferric chloride supply system which resulted in a printband production shut-down for several days. This shut-down occurred at a time when some critical printband orders were being processed. This shortage served to heighten management's sensitivity to the chemical supply/waste generation problem associated with this manufacturing process.

Management's response to the above critical situation was to immediately appoint a task force to directly address this problem. The task force was charged to:

1. Ensure adequate virgin ferric chloride storage capacity to prevent manufacturing interruptions.
2. Increase the conservation practices of ferric chloride in the manufacturing cycle.
3. Enlist engineering groups throughout the company to invent a process to *regenerate* the ferric chloride solution used to manufacture printbands (in line with the basic IBM site strategy of waste minimization).

STRATEGIC ALTERNATIVES

Since the volume of ferric chloride etchant was so great, and the waste formed in the printband manufacturing process was so voluminous, the incentive to investigate the various methods of effecting ferric chloride etchant regeneration was considered to be not only justifiable, but imperative.

All chemical reactions are reversible. However, the ease and cost of reversibility varies widely, depending upon the chemicals involved. In the case of the ferric chloride etching solution, it was recognized that various methods existed which could be utilized to reverse the chemical process and reform the iron (Fe^{+3}) ions from the spent etchant. However, it was also clearly understood that regeneration of the etchant was the *only* alternative which could result in a significant reduction in the volumes of etchant used in the manufacturing process and the waste created by that same process.

Inherent in all of the regeneration processes examined up to that time was the use of extremely reactive, hazardous, and toxic chemicals, or electrical energies which were extremely high. Chemicals such as chlorine gas, hydrogen peroxide, sodium chlorate, and other strong oxidants were often employed. Although effective in regenerating ferric chloride etchant, personnel safety would almost certainly be at risk when chemicals of this nature were employed.

Rather than place its employees in a hazardous manufacturing environment which employed such strong chemicals (specifically, the three cited in the above paragraph), IBM scientists and engineers decided to investigate three strategic, problem-solving alternatives:

1. Creation of an electrochemical process of regeneration via as yet undeveloped equipment.
2. The injection of ozone gas into the ferric chloride solution during the manufacturing process.
3. The use of air oxidation as the regeneration agent.

A. The Electrochemical Option

This option was initiated at the behest of the Environmental Engineering Department at the IBM Endicott plant. The management of Printband Manufacturing was provided an in-depth briefing of the significant impact of their etching process on the site's waste treatment systems. In order to show good faith in addressing this concern, Printband Manufacturing management sponsored and funded the electrolytic process as part of the Endicott Technical Development (ETD) organization's annual budget for development projects.

A high-ranking member of the ETD organization had prior experience with an electrolytic process, and he assigned the investigation of this option to an employee with whom he shared the responsibility for its development. An aggressive approach was taken, which projected enormous waste volume reductions. Progress was presented in highly technical terms at monthly development status meetings.

In presenting the results of this option, many negative references were made to the Ozone option—which was not being developed at the Endicott plant and, as a result, *not* represented at these meetings. When rebuttals of arguments against the Ozone option were presented, Endicott ETD management countered that the sort of competition presented by this (the Ozone) option was not beneficial to the Electrolytic option and should not be pursued. Consequently, only viable test results were reported at these meetings, with development project assessors being led to believe that *every* test was successful.

B. The Ozone Gas Option

Like the Electrolytic Option, the Ozone approach to agent regeneration was sponsored by Printband Manufacturing management. It was initiated via a paper presented at an IBM technology-based meeting, authored by a development chemist at the East Fishkill, New York, plant. His etchant regeneration system was in the process of being implemented at that location after months of testing and approvals. Like the Endicott plant, the Fishkill process involved a ferric etchant.

Printband Manufacturing management only became aware of the proposed Ozone regeneration system *after* they had already authorized the Endicott Technology Development organization to investigate the Electrolytic option. ETD had already been provided the funding for its activities and no funds were available to support the Ozone option development efforts without a considerable loss of "face."

The Ozone option development team at the East Fishkill location wanted very badly to sell its system elsewhere, and so had agreed to do the development testing at no cost to Printband Manufacturing management. Some minimally valued equipment was made available to the Ozone process developers and it was refurbished for use at that location.

Infrequent trips were made to visit the Ozone project by Printband Manufacturing engineering personnel for feasibility and review purposes. Two or three development status memorandums were weekly transmitted to the Endicott facility. All testing and results continued to be favorable. No unsuccessful test results, of which there were a number, were ever reported directly to Endicott, nor was the development chemist free to travel to that location to directly report progress and status.

C. The Air Oxidation Option

Early in 1987, two Printband Manufacturing engineers and an Environmental Engineering acquaintance began work at the Endicott facility on an idea being used in the copper etching process areas in the plant. They investigated the injection of compressed air into the piping loop through which the etchant was circulated during etching. This method worked with some degree of success with cupric chloride etch systems, but chemical thermodynamics did not appear to favor a simiiar promise for ferric chloride.

Etchant conservation practices were immediately implemented to:

1. Monitor the etchant bath thru-put to better define bath life and ensure complete bath exhaustion prior to dumping to the treatment/disposal process.
2. Modify a preliminary step in printband manufacturing called "flash etch" to decrease ferric chloride consumption.

However, with a minimal investment of both time and capital, the engineers were authorized by Printband Manufacturing management to set up a pilot test system using compressed air on one of three ferric chloride etchers in the manufacturing area. The net result of the preliminary tests for this simple $12,000 system was a repeatable 17% decrease in the volume of the etchant required in the etch process. Most of the components of this air oxidation system were either used, donated from inactive systems, or fabricated on site to expedite installation.

These six month test results and the consequent savings were significant enough to warrant implementation of similar systems on two new etchers being installed at that time (at a total cost for all etchers of less than $50,000). This investment was readily recouped through chemical and waste volume reductions. The return was over 130%, and the payback period was achieved in about *nine* months. As a result, no further off-site treatment of the ferric chloride waste would be necessary.

Additionally, planned follow-up testing, employing oxygen enriched air and pure oxygen, was conducted in 1988. The net result of the oxygen testing was a system which would regenerate etchant at a rate which matched normal production requirements. Etchant regeneration could now be carried out in a working etcher at such a rate that no fresh etchant was required to maintain the etch rate.. The printband panel conveyor could be set at a standard speed, thus reducing operator time and expense, and simplifying the etching process.

These tests came at a very critical moment. An equipment problem on the bulk ferric chloride system made it impossible to pump virgin etchant from either of the two 5,000 gallon bulk supply tanks to the etchers. This would have shut down production for several days had it not been for the (then) pilot oxygen regeneration system in place. Manufacturing continued on an uninterrupted basis during the period when this pumping failure was being corrected.

These test results were presented to management and capital funds were made available to enhance and upgrade the initial air-oxidizing systems to the more effective oxygen systems. Oxygen generators were installed and the regeneration of ferric chloride etchant was fully operational in October of 1989, three months ahead of schedule. Further testing was being conducted on this process at the very same time that the Ozone and Electrolytic options were still being developed. Additionally, a patent application was filed and remains active today.

No toxic or hazardous chemicals were employed, no exotic, sophisticated equipment requiring a trained staff of maintenance personnel was necessary, and operational costs were minimal.

ALTERNATIVE TECHNOLOGY COMPARISON

Technology	Pros	Cons
Ozone	Fast reaction Complete regeneration Developed at IBM Being pilot tested Reaction by-product is water Process in multiple use applications	Highly reactive Toxic as by-product Filtration may be required Cost estimate set at $650,000
Electrolytic	Proven feasibility in labs Complete regeneration Developed at IBM	No full-scale operating system Labor intensive High electrical cost and usage High voltage hazard Cost estimated at $650,000 (Plus)
Oxygen	Proven feasibility Developed at IBM Filtration not required Minimal labor involved Low operating costs Easy installation Actual cost-$150,000	Slow reaction No successful operations* Potential for full regeneration not known* IBM would be first application

*Situation at the initiation of the testing of this option.

THE DECISION PROCESS

The Oxygen Option was ultimately approved on economic grounds. Since it was not developed by the Endicott Technical Development organization, some of the ties to that unit were severed as a result of this decision.

The "winning" system was easily implemented by making simple hookups to replace plant compressed air with oxygen generators. While some bugs had yet to be fully worked out of the system, Printband Manufacturing management was satisfied with its overall effectiveness. The approval for purchase, installation and testing of the full system was *not* shared with the Ozone and the Electrolytic development teams at the time the "go-ahead" decision was made—on the grounds that the "politics" were not right.

The air oxidation option was a unique method of ferric chloride regeneration, developed and implemented utilizing a simple combination of readily available hardware and a non-toxic gas (Oxygen). The final return on investment (ROI) was over 185%, with a four month payback period. The entire system was actually paid for in the savings associated with virgin chemical and waste costs experienced during the engineering pilot testing periods for this project. Because of the reduced virgin ferric chloride demand, the additional bulk holding capacity was never required. Additionally, this system is now being installed to replace regeneration methods on other etch systems at the Endicott plant.

This new regeneration system requires minimal maintenance and repair activity, as well as very infrequent operator attention. The cost savings and environmental benefits, in terms of reduced volumes of solid, hazardous waste for landfilling, continue with every printband produced today.

CONCLUSIONS

In 1991, only 4,122 gallons of ferric chloride etchant were consumed in the printband manufacturing process. This resulted in only 78 tons of hazardous waste sludge shipped to a landfill. This represented a production normalized reduction of 94.2% in etchant use and a 90.8% reduction in the hazardous waste generated by this manufacturing process.

A total system to support the oxygen regeneration option for all printband manufacturing etchers could be purchased and installed for less than one quarter the cost of either the ozone or the electrochemical alternative methods still in the development stage. The inherent risks to personnel associated with those two options were thus avoided.

It is understood that without management's commitment to continuing development efforts, a project such as this would never have realized its full potential. It is the never-ending quest to continually improve on existing processes that can sometimes lead to dramatic advancements, as evidenced in the case presented.

Waste minimization at IBM Endicott is not a targeted activity that is done on a periodic basis. Rather, it is the daily activity for many of the engineering and manufacturing personnel on that site, and at all other IBM manufacturing facilities. New waste minimization opportunities are identified and tracked at high levels of management. It is this constant focus that has aided IBM to significantly reduce its waste volumes in the past few years.

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INTRODUCTION

As a matter of corporate policy, the IBM Corporation is committed to the minimization of the environmental impact from all of its various manufacturing operations. It has hazardous waste reduction programs in place to:

1. Effect waste reduction at the source.
2. Encourage recycling.
3. Develop and implement waste treatment technologies.

Increasingly restrictive and expensive environmental regulations on the federal, state, and local levels call for pro-active measures on the part of the management in all industrial sectors. This case demonstrates the innovative approach taken by engineers at IBM's Endicott, New York facility in creating a successful solution for a complex problem which was both operational and environmental in nature.

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OBJECTIVES

The primary goal of this case is to provide the basis for the assessment and comparison of strategic solution alternatives for a complex operational/environmental problem. These alternatives must be analyzed; their long-term viability examined; and the decision process employed for problem resolution purposes assessed. In addition, the criteria employed in that decision process, to select one option over the other two, should be clearly understood by students using this case.

CASE SYNOPSIS

One of the components which IBM produces at its Endicott, New York manufacturing/ research facility is printbands. These are stainless steel belts, imprinted with raised character sets to meet specific customer requirements, which are installed in many IBM impact printers. In raw metal form, printband panels are etched in a bath of strong ferric chloride/hydrochloric acid solution to remove surface impurities. The resultant chemical reaction process annually consumed (in 1986) almost 160,000 gallons of the ferric chloride etchant, and generated 1,890 tons of hazardous waste sludge, along with 34,200 gallons of concentrated waste etchant which had to be trucked off site for treatment and disposal.

The costs of the virgin etchant, treatment, and disposal were on the rise. The plant's own waste treatment facility, at full capacity, could not treat the by-product waste of this manufacturing process (hence, the need to truck a large portion off site). A shortage of the etchant in the referenced year caused a production shut-down for two days, resulting in management's creation of a task force which was charged with the responsibility of resolving that type of production problem and its contributing elements as soon as possible.

Three teams of engineers began to address this operational/ environmental problem situation via three technical alternatives. All three were designed to regenerate the ferric chloride etching agent during the manufacturing cycle, and, in addition, minimize the hazardous waste produced by that same production process. Electrochemical, ozone, and air (Oxygen) regeneration options were investigated simultaneously.

While each of the three possible solutions for the problem had its supporters and detractors in an internal operating environment of intra-organizational competition, the latter alternative began to achieve a recognizable degree of success in its pilot test stage. It was eventually selected by top management as the solution. It proved its capability to almost completely regenerate the ferric chloride etchant, thus reducing a major hazardous waste treatment/removal problem.

No toxic chemicals were employed, which would have increased employee risk. No sophisticated equipment, calling for a trained staff of maintenance personnel, was necessary. Operational costs were minimal; and capital cost facilitation was far below that level expected for the implementation of the other two options.

COURSES AND LEVELS

This case is designed to be used by undergraduate students (seniors) in courses which deal with Environmental Strategy, Policy Formulation, or Business Policy. Students at that level should be well able to appreciate and thoroughly analyze the position of IBM in this situation. The case can also fit an MBA-level course by the same titles. Students on that level would normally be expected to provide more sophisticated assessments of the firm's strategic choices and its decision process.

SUGGESTIONS FOR USING THE CASE

IBM engineers and management are faced with an immediate need to ensure both the continuity of manufacturing cycles for printbands, and the reduction of a costly and environmentally critical waste problem (which is a direct by-product of this production process). The two aspects of this problem are interdependent. If the ferric chloride etchant can be economically regenerated; i.e., the chemical reaction in the manufacturing process reversed; then a large portion of the waste treatment/disposal issue will be resolved in good order.

The case provides an opportunity for students to analyze a business situation (stabilizing production operations) which is complicated by its environmental impact. Classroom discussion should focus on, but not necessarily be limited to, questions such as:

1. What controls should have been in place to prevent the types of manufacturing shut-downs caused by limited ferric chloride storage capacity on site?
2. What other choices did IBM management have available to it (other than the three options cited)?
3. What were the basic decision criteria (five or more) which could have been used

by management to compare the three strategic alternatives chosen for examination?

4. What policies/procedures could be suggested to reduce any negative overtones of intra-firm competition in the examination of the three options chosen be management as possible solutions?
5. What lessons can be learned from the successful process adopted?
6. What are other applications for this solution approach which might be considered by both IBM management and by other firms?

ANALYSIS AND EVALUATION

Problem identification on the part of students is not necessary. The case spells this activity out in clear detail. The interdependency of the two basic issues should, however, receive serious appraisal. This process should bring students to the conclusion that priorities cannot be set on these issues; i.e., this is not a series event. Both issues must be addressed in parallel in order to achieve a successful solution.

During the evaluation of the three strategic options chosen by management for consideration, students should be expected to employ some combination of the following (among others) forms of analysis:

1. SWOT
2. Cash-Flow
3. Risk
4. Cost-Benefit
5. Critical Incident

Increasing the on-site storage capacity for the ferric chloride etchant may be a reflex recommendation on the part of many students. This would indeed resolve the problem of manufacturing process continuity. However, it is, at best, a tactical resolution for a strategic problem, and can be considered a form of short-term sub-optimization. The cost involved with such a recommendation may be uneconomical when related to the rising costs of waste treatment/disposal, which are not addressed by this proposal.

Some considerable classroom discussion should be devoted to the regulatory issues involved and the environmental responsibilities of any company (not just IBM). As noted, waste treatment and disposal are expensive and these costs are escalating. In addition, the "treatment" of waste materials usually means that the waste has been made less toxic or just "safe" waste. However, some form of waste must still be disposed of.

The current locations for that purpose may not be as secure, from an environmental point of view, as one may think. Other alternatives will have to be invented in the future. The proactive approach employed by IBM may be a model for other firms to follow in the context of the pollution prevention emphasis of this case.