EPA-600/R-95-011c
December 1995

SOLVENT-BASED TO WATERBASED ADHESIVE-COATED SUBSTRATE RETROFIT - VOLUME III: LABEL MANUFACTURING CASE STUDY: NASHUA CORPORATION

By:

Beth W. McMinn
W. Scott Snow
Dan T. Bowman

TRC Environmental Corporation
6340 Quadrangle Drive, Suite 200
Chapel Hill, North Carolina 27514

EPA Contract No. 68-D2-0181
Work Assignment No. 2/017

EPA Project Officer: Chester A. Vogel
Air Pollution Prevention and Control Division
Research Triangle Park, North Carolina 27711

Prepared for:

U.S. Environmental Protection Agency
Office of Research and Development
Washington, DC 20460

FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for reducing risks from threats to human health and the environment. The focus of the Laboratory's research program is on methods for the prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites and groundwater; and prevention and control of indoor air pollution. The goal of this research effort is to catalyze development and implementation of innovative, cost-effective environmental technologies; develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

EPA REVIEW NOTICE

This report has been peer and administratively reviewed by the U.S. Environmental Protection Agency, and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

ABSTRACT

This volume discusses Nashua Corporation's Omaha facility, a label and label stock manufacturing facility that no longer uses solvent-based adhesives. Information obtained includes issues related to the technical, economic, and environmental barriers and opportunities associated with the use of waterbased adhesives. Specific objectives of the visit were to collect information necessary to characterize Nashua's market profile, manufacturing supplies, manufacturing process profile, environmental issues, and waterbased adhesive coating experience, as well as the limitations of waterbased adhesive coatings. The case study report consists of eight chapters. Chapter 1 give background information related to Nashua's conversion efforts, including market profile, process description, and a general description of its conversion efforts. Chapter 2 identifies Nashua's motivations for converting its solvent-based operations to waterbased adhesives. Chapter 3 briefly describes the marketing factors that affected the process conversion. Chapter 4 identifies the various raw material issues, including costs, involved in the process conversion. Chapter 5 details the process equipment issues of the conversion, including specific equipment impacts, costs, vendor selection, and maintenance. Chapter 6 discusses the adhesive product performance requirements. Chapter 7 describes the effects of conversion on Nashua's process emissions and waste streams. Chaptee 8 summarizes the conclusions.

TABLE OF CONTENTS

Chapter		Page
Abstract		iii
List of Figures		vi
Acronyms		vii
Conversion Factors		viii
1	INTRODUCTION	1-1
1.1	Background	1-1
1.2	Company and Product Description	1-2
1.3	Process Description	1-5
1.4	Comparison of Waterbased and Solvent-based Adhesives	1-8
1.5	Description of the Conversion	1-10
1.6	Unresolved Issues	1-11
2	MOTIVATION FOR CONVERSION TO WATERBASED ADHESIVES	2-1
2.1	Deciding on Waterbased Coatings	2-1
2.2	Regulatory Concerns and Costs Associated with Using Solvent-based Adhesives	2-1
2.3	Costs Associated with Waterbased Adhesive Use	2-3
2.4	The Decision to Convert	2-4
3	MARKETING FACTORS AFFECTING PROCESS CONVERSION	3-1
3.1	Customer Approval Requirements	3-1
3.2	Nashua's Marketing Techniques	3-1
4	MATERIAL ISSUES INVOLVED IN THE PROCESS CONVERSION	4-1
4.1	Introduction	4-1
4.2	Finding Replacement Waterbased Adhesives	4-2
4.3	Formulation of Solvent-based and Waterbased Adhesives	4-4
4.4	Costs of Alternative Waterbased Adhesives	4-6
4.5	Cleaning Agents	4-6
5	EQUIPMENT ISSUES INVOLVED IN THE PROCESS CONVERSION	5-1
5.1	General	5-1
5.2	Process Design Modifications and Equipment Trials	5-2
5.2.1	Storage Tanks	5-2
5.2.2	Mixing and Holding Tanks	5-3
5.2.3	Resin Heating Oven	5-3
5.2.4	Adhesive Filters	5-3
5.2.5	Piping	5-4
5.2.6	Pumps and Motors	5-4
5.2.7	Heat Exchangers	5-5
5.2.8	Coating Head and Related Equipment	5-5

TABLE OF CONTENTS (Continued)

5.2.9 Drying/Curing Ovens 5-8
5.2.10 Carbon Adsorber 5-10
5.3 Maintenance and Operational Issues 5-11
5.4 Vendor Selection and Costs of Modifications 5-12
5.4.1 Storage Tanks 5-12
5.4.2 Mixing and Holding Tanks 5-13
5.4.3 Resin Heating Oven 5-13
5.4.4 Adhesive Filters 5-14
5.4.5 Piping 5-14
5.4.6 Pumps and Motors 5-14
5.4.7 Heat Exchangers 5-15
5.4.8 Coating Head and Related Equipment 5-15
5.4.9 Drying/Curing Ovens 5-15
5.4.10 Carbon Adsorber 5-16

6 ADHESIVE PRODUCT PERFORMANCE REQUIREMENTS 6-1
6.1 Adhesive Performance Criteria 6-1
6.2 Nashua Performance Criteria 6-2
6.3 Ensuring Quality 6-4

7 PROCESS EMISSIONS AND WASTE STREAMS 7-1
7.1 General 7-1
7.2 Changes in Waste Stream Generation and Emissions 7-1
7.2.1 Air Emissions 7-1
7.2.2 Hazardous Waste 7-2
7.2.3 Wastewater 7-2
7.2.4 Solid Waste 7-3
7.3 Waste Disposal Costs and Savings 7-3

8 SUMMARY AND CONCLUSIONS 8-1
8.1 Characterization of Success/failure of Process Conversion 8-1
8.2 Technology Transfer Opportunities 8-3

LIST OF FIGURES

Number		Page
1-1	Nashua Plant Layout	1-4
1-2	Coating Line Operation for Lines 1 and 3	1-6
4-1	Flowchart of Replacement Waterbased Adhesive Selection Process	4-3
5-1	Adhesive Application Equipment	5-6
6-1	Example Application Range of Adhesive-coated Products	6-3

ACRONYMS

ASTM	American Society of Testing and Materials
BOD	biological oxygen demand
CAAA	Clean Air Act Amendments of 1990
C/B	cost/benefit
EPA	U.S. Environmental Protection Agency
IR	Infrared
LEL	lower explosive limit
MEK	methyl ethyl ketone
NH_3	ammonia
OSHA	Occupational Safety and Health Administration
PM-10	particulate material, nominally 10 μm and less in diameter
POTW	publicly owned treatment works
PVC	polyvinyl chloride
QA	Quality Assurance
QC	Quality Control
R&D	research and development
TCA	1,1,1-trichloroethane
USTs	underground storage tanks
VOC	volatile organic compound

CONVERSION FACTORS

To Convert From	To	Multiply by
LENGTH		
feet (ft)	meters (m)	0.3048
meters (m)	feet (ft)	3.281
inches (in)	centimeters (cm)	2.54
MASS OR WEIGHT		
pounds (lb)	kilograms (kg)	0.454
pounds (lb)	tons	0.0005
tons	pounds (lb)	2,000
tons	kilograms (kg)	907.2
VOLUME		
gallons (gal)	liters (l)	3.785
gallons (gal)	cubic inches (in^3)	231
gallons (gal)	fluid ounces (oz)	128
gallons (gal)	cubic meters (m^3)	0.00379
PRESSURE		
millimeters of mercury or torr (mmHg)	pounds/$inch^2$ (psia)	0.1934
TEMPERATURE		
Fahrenheit (°F)	Celsius (°C)	subtract 32, then multiply by 0.5556
Celsius (°C)	Fahrenheit (°F)	multiply by 1.8, then add 32

CHAPTER 1
INTRODUCTION

1.1 Background

As part of the overall effort by the U.S. Environmental Protection Agency (EPA) to identify pollution prevention opportunities associated with manufacturing entities, EPA is currently assessing the potential for using waterbased adhesive coatings as replacements for solvent-based adhesive coatings in the adhesives-coated and laminated flexible web substrate industry. TRC Environmental Corporation (TRC) is supporting EPA in this effort by investigating the manufacturing barriers and opportunities associated with process conversions to waterbased adhesives under EPA Contract Number 68-D2-0181, Work Assignment No. 2/017.

For the purposes of this report, the term "solvent" is used to refer to volatile organic compound (VOC) containing materials used as carriers for adhesive solids and as cleaning agents in the adhesive coating process. Common examples of solvents used in these ways are methyl ethyl ketone (MEK), toluene, cyclohexanone, and acetone, although a number of other organic liquids are used in these capacities as well. Although water is a solvent, for the purposes of clarity these other VOC-containing liquids are referred to as solvents in this report.

Nashua Corporation's Omaha, Nebraska facility (Nashua), a label and label stock manufacturing facility, was selected as a case study subject for this assessment. Nashua was chosen due to its current efforts to convert a solvent-based adhesive coating line to waterbased adhesives. During the two-day site visit and follow-up telephone interviews, TRC gathered information on Nashua's process conversion including issues related to the technical, economic, and environmental barriers and opportunities associated with the use of waterbased adhesives. Specific objectives of the visit were to collect information necessary to characterize Nashua's market profile, manufacturing supplies, manufacturing process profile, environmental issues, and waterbased adhesive coating experience, as well as the limitations of waterbased adhesive coatings.

This report was written immediately following the completion of the site visit to Nashua. At the time the report was written at the end of 1993, Nashua had not yet completed its conversion to waterbased adhesives. Since this time, according to Nashua personnel, Nashua

completed its conversion to waterbased adhesives on schedule. All three lines are running with non-solvent-based formulations, and the facility is no longer producing solvent-based adhesives. However, *the remainder of this report has not been revised to reflect this completion.*

This case study report includes eight chapters. Chapter 1 gives background information related to Nashua's conversion efforts including market profile, process description, and a general description of its conversion efforts. Chapter 2 identifies Nashua's motivations for converting its solvent-based operations to waterbased adhesives. Chapter 3 briefly describes the marketing factors which affected the process conversion. Chapter 4 states the various raw material issues, including costs, involved in the process conversion. Chapter 5 details the process equipment issues of the conversion including specific equipment impacts, costs, vendor selection, and maintenance. Chapter 6 discusses the adhesive product performance requirements and how Nashua selected replacement waterbased adhesives. Chapter 7 describes the effects of conversion on Nashua's process emissions and waste streams. Finally, Chapter 8 summarizes the conclusions of Nashua's conversion effort to waterbased adhesives.

1.2 Company and Product Description

Nashua Corporation began operating its Omaha, Nebraska plant in 1966. The plant was originally built in 1959 and operated by the International Paper Company. Nashua's Omaha facility currently employs approximately 90 administrative and management personnel and 200 to 300 production personnel. Since it employs approximately 300 to 400 personnel and annually produce approximately 200 to 300 million square yards of end-product, Nashua considers itself a large facility for its industry. The unionized Omaha plant operates 24 hours per day, five to seven days per week depending on customer demand and produces pressure sensitive labels, roll-stock, and custom label products. The Omaha facility, a tape plant in Albany, New York, and a coated products facility at the headquarters in Nashua, New Hampshire, all operate within Nashua Corporation's Coated Products Group.

Nashua produces 30 to 40 adhesive coating and paper substrate combinations (*i.e.*, finished products) for its customers. The Nashua operation can be considered a batch operation, since it produces different products on its individual coating lines. However, it generally sets up a coating line to run for many hours (ten or more) before switching to another product. Also,

while an adhesive's chemical makeup and the paper substrate to which it is applied may differ, the coating process generally remains the same for each product line, excluding several relatively easily controlled variables such as line speed, coating thickness, and oven temperature and configuration. In light of these attributes (*e.g.*, long product runs, similar coating processes for different products), Nashua believes the term dedicated processor most accurately describes its operations.

Nashua considers itself a commodity processor. While possessing the capability to manufacture end-products meeting a wide range of specifications, Nashua generally produces large amounts of a small number of end-products for application in moderate environmental conditions (*e.g.*, low humidity, small temperature exposure range). Nashua considers processors who produce adhesive products for extreme environmental conditions (*e.g.*, high humidity, corrosive exposure), or who produce small amounts of adhesive products for a specific range of functions (*i.e.*, batch operations) to be specialized, or specialty processors.

Nashua currently produces approximately 90 percent of its end products using waterbased adhesive formulations, and is seeking to replace its remaining solvent-based adhesives (ten percent of end products) with suitable waterbased adhesive formulations by December 31, 1993. Nashua personnel indicated that it may be necessary to drop one or two product lines in order to meet this goal, since finding a suitable waterbased adhesive formulation to replace the solvent-based coating currently used for these product lines has been difficult. However, these products are a relatively small percentage of the plant's output, and Nashua expects that the loss can be offset with increased sales of its other products.

Figure 1-1 shows the layout of the Nashua facility. There are three coating lines in the plant located in the coating room east of the adhesive mixing and filtering rooms. Line 1 is an adhesive coater/laminator which currently coats with either solvent-based or waterbased adhesives. Prior to 1989, Line 1 ran full time with solvent-based adhesives, however, it currently runs approximately 25 percent of the time with solvent-based and 75 percent of the time with waterbased products. Nashua engineers expect that by the end of 1993, Line 1 will produce only waterbased products. Line 2 is the release coating line which currently applies either a solvent-based silicone release coating or a 100 percent solid-catalyzed silicone release coating to paper stock. Nashua plans to fully convert Line 2 to the solvent-free solid-catalyzed silicone by the end of 1993. Line 3 is another adhesive coater/laminator and has operated entirely with

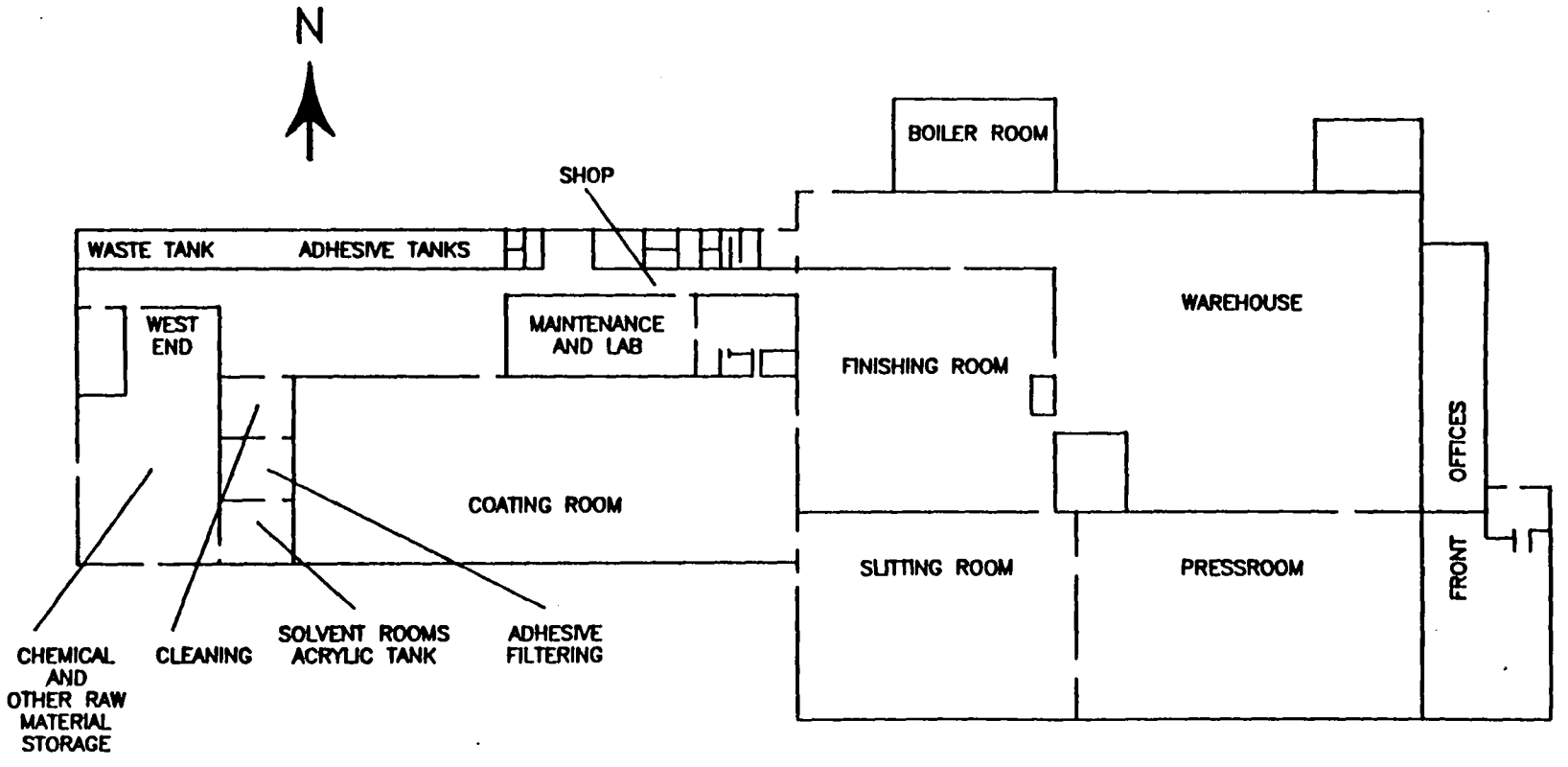

Figure 1-1. Nashua's plant layout.

waterbased coatings since 1982 when it was converted from a waterbased heat seal coating line.

1.3 Process Description

Nashua's adhesive storage and transfer operations are quite different for its waterbased and solvent-based adhesives. Waterbased adhesives are purchased pre-mixed from suppliers and stored in stirred glass-fiber mixing tanks until being transferred to the process holding tanks for each coating line. Some additives may be added to the waterbased adhesives in the mixing or holding tanks to improve its performance and coating properties. Solvent-based adhesives are formulated on-site in stainless steel mixing/holding tanks. To form a solvent-based adhesive, adhesive solids (*i.e.*, resins) and additives are first transferred to a tank, and then solvents are mixed into the tank. These solvents are stored in underground storage tanks (USTs) until transfer to the mixing/holding tanks.

Both types of adhesive are pumped through piping into mixing/holding tanks before application to a substrate in the coating head. The piping network used for waterbased adhesives is made up of polyvinyl chloride (PVC) piping, while the solvent-based adhesives travel through stainless steel piping. Air pumps are used to transfer the waterbased adhesives, while vane pumps are used to transfer solvent-based adhesives. Nashua did not reveal any more specifics about its pump type, as company officials felt this would be revealing potentially beneficial information to competitors.

Figure 1-2 depicts the coating line operation for Lines 1 and 3. Both types of adhesives are pumped from holding tanks to the coating head, where they are applied to paper substrate by a reverse-roll coater. During application of solvent-based adhesive at the coating head, a constant drip of 1,1,1-trichloroethane (TCA) is used to dissolve buildup of adhesive solids at the edges of the paper. The spent TCA and dissolved solids are collected for disposal. Scraping blades are used at the edges of the paper to prevent buildup of waterbased adhesives on the paper edges. Paper is the only substrate used in products manufactured at Nashua. The facility uses approximately ten types of face stock papers.

Before the paper substrate is adhesive-coated on Line 1 or 3, a release coating is applied to the substrate. Nashua uses approximately five types of release liner papers. The 100-percent solids silicone or a silicone-tolusol mixture is applied to master rolls of raw paper on the Line 2

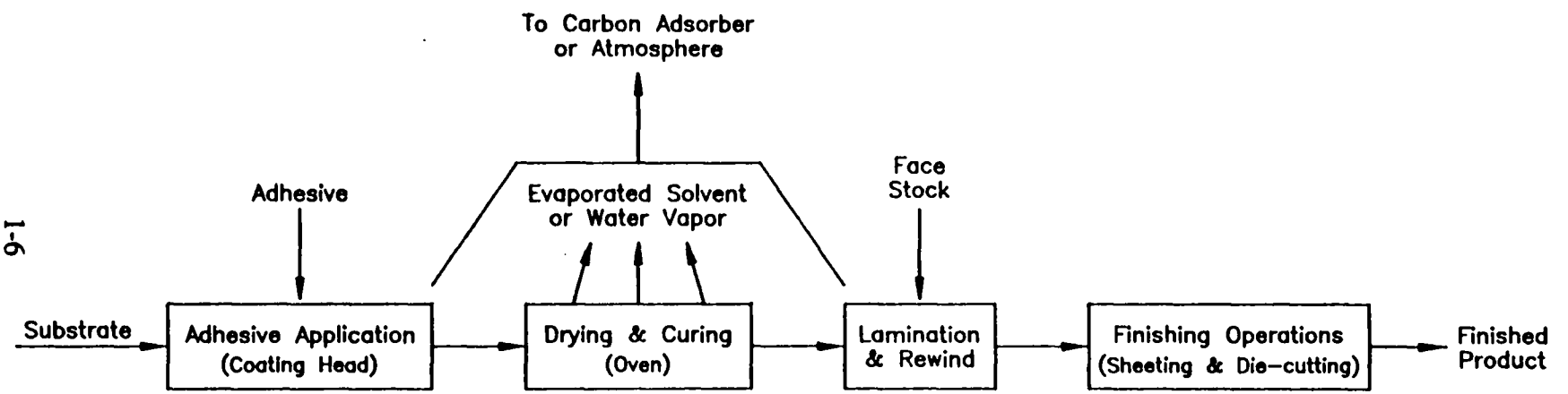

Figure 1-2. Coating line operation for Lines 1 and 3.

coating machine. The coated release liner is then dried in an oven heated by steam coils for approximately five to ten seconds. Oven exhaust systems on Line 2 vent directly to the atmosphere. After drying, the coated release liner is wound onto rolls and transported to either Line 1 or Line 3 for coating/lamination.

Line 1 can coat either solvent-based or waterbased adhesives. The line typically requires a downtime of approximately one to two hours to change coating heads and clear the lines when switching adhesives. Line 1 uses either solvent-based adhesives consisting of natural rubber and resins dissolved in toluene, which Nashua formulates, or waterbased acrylic adhesives which are purchased ready-to-use.

After passing through the coating head, the coated paper is conveyed to an oven. The drying ovens on Line 1 and Line 2 are identical steam-supplied ovens, although the emissions on Line 1 are vented to a carbon adsorption system when processing solvent-based adhesives. The Line 3 dryer uses direct-fired natural gas burners and cannot process solvent-based adhesive products due to fire and explosion hazards. These ovens have five zones, each of which can be set at a different temperature and air flow. When processing waterbased product, the dried/cured adhesive and paper is moistened by a water spray mist as it exits the oven. The adhesive-coated product is then laminated under pressure rollers with the label face stock creating a three-layer lamination (face stock, adhesive, and release liner).

Once the adhesive-coated paper has been dried and rewound, it is transferred to the slitting room for cutting and sizing. Nashua has several high-speed slitting machines which cut the rolls of coated paper into narrow widths for use on its own printing presses or for shipment as finished product. Excess edge portions of the paper, known as off-cuts, are removed by a trim system which conveys them to a cyclone separator, and ultimately to a dumpster for transport to the city landfill. The cut rolls are moved to the pressroom for custom orders or the finish room for packaging before warehousing and shipment as a finished product. The warehouse holds custom orders and stock label products awaiting shipment.

1.4 Comparison of Waterbased and Solvent-based Adhesives

While the production of solvent-based and waterbased products may conceptually be similar, there are several differences between the processes. Nashua purchases bulk raw materials for solvent-based adhesives and then mixes all of these components on-site in stainless steel tanks. When mixing solvent-based adhesives, the solid adhesive products (*i.e.*, the resin and any additives) are put into the mixing tank first. These products may be heated in an oven prior to mixing to reduce their viscosity. Next, toluene (Nashua's primary adhesive solvent) stored in an UST is piped into the mixing tank, where the ingredients are mixed with stationary dispersers.

Waterbased adhesives are stored in glass-fiber tanks. All of Nashua's waterbased acrylic adhesives is purchased from suppliers pre-mixed and in bulk quantities. The adhesives are pumped directly from a supply truck into a glass-fiber storage tank. The adhesives can then be pumped from the storage tank to a holding tank where additional performance-altering materials may be blended into the adhesives.

Three to four hours are generally required to make a batch of solvent-based adhesive. For most waterbased coatings, three to four hours are also needed to blend in all required additives to a batch. However, some waterbased adhesive formulations require several hours of agitation between additive additions. During these periods, no labor is expended, but the total time to manufacture the waterbased batch can extend up to eight hours.

The stainless steel tanks used to mix and store solvent-based adhesives require very little maintenance. Several tanks installed approximately 20 years ago were thoroughly cleaned for the first time in 1992. The glass-fiber tanks used to store waterbased adhesives must be thoroughly cleaned approximately every six months. Cleaning the glass-fiber tanks can take 16 or more man-hours. This lengthy cleanup process is due to the fact that when waterbased adhesive solids come out of emulsion, either by drying or settling, they do not readily go back into emulsion. Adhesive solids accumulate over time in the glass-fiber tanks and must be removed by thorough cleaning of the tank. The cleaning process does not usually interfere with production on the coating lines, as other tanks can be used while one of the tanks is cleaned. However, the amount of labor required to clean the waterbased tanks is a significant added expense not associated with solvent-based adhesives.

Transfer of solvent-based adhesive to the coating head is accomplished with a vane pump and a stainless steel piping network. Transfer of waterbased product is performed by air pumps and PVC piping. The transfer process for waterbased adhesives is complicated by cleanup difficulties. While the piping for solvent-based adhesives requires minimal maintenance, the waterbased adhesive piping can become clogged over time. Instead of cleaning, Nashua simply removes the PVC piping as necessary and replaces it with new piping. Some PVC piping has required replacement after three years.

Nashua has experienced difficulty with the air pumps used to transfer waterbased acrylic adhesives. Waterbased adhesives have a tendency to dry in the pumps and cause valves to become jammed. Nashua first attempted to use diaphragm pumps for waterbased adhesives, but maintenance problems developed, so these were replaced with the current type of air pump (Nashua did not wish to reveal the exact type of air pump currently used). Nashua personnel indicated that the pumping system for waterbased coatings does not approach the reliability of the solvent-based adhesive coating pumping system. In the future, Nashua hopes to obtain a more dependable pump system for waterbased adhesives.

The coating head setups used for application of waterbased and solvent-based adhesives are quite different. The coating thickness, controlled by pressure applied by the coating head roller system to the paper, is usually greater for waterbased adhesives. While this does not affect process speed, it does increase the volume of adhesive required for each unit of final product. Paper speed varies from coating to coating, but the speeds are generally similar for waterbased and solvent-based coatings and range from 300 to 1,200 feet (91 to 366 meters) per minute. An additional piece of equipment sometimes employed with waterbased coatings is a heat exchanger, which is used to ensure a constant adhesive viscosity (via temperature control). The heat exchanger is not used during a solvent-based coating application.

An important difference in the drying process between solvent-based and waterbased adhesives is the temperature zoning within the drying ovens. During waterbased coating drying, the first zone in the drying oven is usually the hottest [up to 250°F (121°C)]. This temperature is low enough that the adhesive-coated paper is not damaged. The temperature then drops through the remaining zones to a low ending temperature. For solvent-based coating drying, the first zone is set to a relatively low temperature. The temperature then increases in the next

zones, until enough solvent is driven from the adhesive. Usually the last one or two zones are not heated.

Care must be taken when drying waterbased adhesives to ensure that some water remains in the adhesive and paper. When the paper is dried below its normal water content it tends to curl, which is detrimental to the lamination process.

One hazard associated with solvent-based adhesive drying not associated with waterbased adhesive drying is the risk of buildup of explosive concentrations of solvent. Monitoring of the oven air is necessary to ensure concentrations stay well below the lower explosive limit (LEL) of the solvent. The LEL is the minimum airborne concentration at which the solvent will combust with a sufficient ignition source (*i.e.*, a spark). Solvent air concentration monitoring is an additional cost associated with solvent-based coating that is not required for waterbased coating. LEL meters can cost several thousands of dollars, are relatively expensive to maintain, and require monitoring by properly trained personnel. There is an additional hazard insurance cost as well.

The wind-up operation after adhesive drying is the same for both waterbased and solvent-based adhesives. The cured web is wound in concert with a non-stick backing into a roll, which is either finished and shipped, or cut, printed, and made into labels. Finishing and printing operations were generally unaffected by the changeover from solvent-based to waterbased adhesives.

1.5 Description of the Conversion

Nashua began coating waterbased pressure-sensitive products in 1982. At that time, Nashua converted what was a waterbased heat seal coating line to the waterbased adhesive pressure-sensitive label line. Nashua made this change to waterbased adhesives because management executives felt that waterbased products would have a strong future in the label manufacturing industry. To effect the changeover, Nashua purchased several new adhesive holding tanks, made of glass-fiber, in which adhesive could be stored and agitated before use. PVC piping and new pumps were installed to transfer the product to the coating heads. Nashua experimented with coating speeds, thicknesses, and drying oven temperatures to determine the

optimum conditions. Within one week, Nashua was able to produce a viable waterbased adhesive-coated product.

Nashua began a complete facility conversion from solvent-based adhesives to waterbased adhesives in the Omaha plant in 1987. The decision to convert was made by Nashua's President at that time. The time frame for the changeover apparently was not specified. The main factors driving the conversion were the economic and environmental advantages of waterbased adhesives. Nashua adopted a policy to replace its solvent-based products with waterbased products which had qualitative improvements, such as lower production cost and increased temperature range before adhesive failure. The company's research and development (R&D) department was charged with seeking out and testing new waterbased formulations. Where product improvements were feasible, Nashua incorporated new waterbased adhesives into its products and offered the improved products to its customers.

Nashua's new waterbased products were offered to its clients as product improvements. The products were not marketed as replacement products for its solvent-based adhesive-coated products. Nashua has been able to successfully replace most of its solvent-based adhesives with improved waterbased adhesives, has lost few clients, and has remained profitable during the changeover to waterbased coatings.

With the passage of the Clean Air Act Amendments of 1990 (CAAA), Nashua decided to expedite its conversion to waterbased coatings, and to eliminate all solvent use. At that time, Nashua decided to attempt to be solvent-free by December 31, 1993. Despite some setbacks, they have managed to remain on schedule, and still believed it was possible to meet their goal.

1.6 Unresolved Issues

Two issues must be resolved before Nashua can complete the transition to solvent-free operations. First, Nashua has one or two remaining solvent-based adhesive-coated product lines. To complete conversion, Nashua will either have to find satisfactory waterbased adhesive replacements or eliminate those product lines. Second, equipment cleaning solvents will have to be eliminated. Nashua uses toluene and TCA to dissolve adhesive buildup on coating equipment during cleaning operations for both solvent-based and waterbased adhesive coating equipment. Cleaning solvent replacement is particularly difficult because of the chemistry of

acrylic waterbased adhesives. Waterbased adhesives are in an emulsion form. Once the acrylic solids have left the waterbased suspension (*i.e.*, once the water has evaporated, or the adhesives have accumulated on the bottom of the tank), they will not readily reenter the suspended state. However, the acrylics are low-polarity or non-polar substances which easily dissolve in non-polar solvents like toluene and TCA. One potential alternative cleaner being considered by Nashua is mineral spirits. Whatever alternative cleaning method is chosen, Nashua expects that machine operators will have to perform much more manual scraping and peeling of dried adhesive. Nashua was optimistic that both of these issues could be resolved to allow solvent elimination by their self-imposed deadline of December 31, 1993. Nashua met its major goal by changing its remaining solvent-based adhesive-coated product lines to waterbased products in January 1994. However, as of November 30, 1995, alternate cleaners have not been found.

CHAPTER 2
MOTIVATION FOR CONVERSION TO WATERBASED ADHESIVES

2.1 Deciding on Waterbased Coatings

When Nashua made the corporate decision to phase out the use of solvent-based adhesives in 1987, it did not seriously consider any adhesive coating technologies other than waterbased coatings. There were two reasons why waterbased adhesives were the sole alternative: (1) Nashua had considerable experience with waterbased coatings, as it already operated one coating line dedicated to waterbased adhesives, and prepared the company for a complete conversion to waterbased adhesives; and (2) waterbased adhesives have proven effective at Nashua and throughout the industry. At the time of Nashua's decision, other technologies such as hot melt, two-part reactive, and radiation-curable coatings had not been proven effective in the marketplace to the same degree as waterbased adhesive coating technology. These two considerations made the decision to convert to waterbased adhesives Nashua's only logical choice.

In the future, Nashua personnel believe that other technologies like those mentioned above, or combinations of those technologies, will be researched and possibly employed by Nashua, especially when the limitations of waterbased adhesive coatings appear to be reached. In the near term, Nashua will only employ and develop waterbased adhesive coating technology.

2.2 Regulatory Concerns and Costs Associated with Using Solvent-based Adhesives

As previously discussed, Nashua's commitment and conversion to waterbased adhesive coatings began well before the advent of the CAAA. There were a number of regulatory and monetary influences in making the decision to convert. At the time of the corporate decision to convert to waterbased adhesives, Nashua had three main regulatory costs associated with solvent use. These were the costs for maintaining the solvent recovery system, monitoring costs, and cleaning solvent disposal costs.

The solvent recovery system is used to collect vapors produced in the drying oven on Line 1 after coating solvent-based adhesives. The system employs a carbon adsorption system which uses a charcoal bed to adsorb solvent vapors. The system is approximately 85 to

90 percent efficient (*i.e.*, 10 to 15 percent of the captured solvent vapor escapes into the atmosphere).

The solvent recovery system has been very expensive to maintain and has been unreliable at times. The charcoal bed used to adsorb solvent vapors must be replaced about every five years at a cost of approximately $75,000. Some industries replace their charcoal every two to three years (for maximum control efficiency) depending on economic feasibility. However, many companies capture solvents not only for environmental reasons, but also for reuse as a solvent. Therefore, some facilities located in attainment areas where solvent emissions requirements are relatively less stringent may not replace their charcoal until it is required or economically feasible.

Additional costs associated with the carbon adsorption system are monitoring and repair of the system. Nashua personnel stated that maintenance problem with the system occurred weekly. While most problems are minor, the cost of the maintenance crew's time to repair the solvent recovery system becomes significant when viewed as an added cost of using solvent-based adhesives. Nashua representatives could not quantify the time spent monitoring, maintaining, and repairing the solvent recovery system. However, a simple calculation shows that if three maintenance personnel each spend ten hours per week on the solvent recovery system, and their average pay is $25 per hour with benefits, the labor costs to Nashua would be approximately $39,000 on an annual basis. While this a rough estimate, it is likely that the additional annual cost to Nashua for operating the solvent recovery system is in the tens of thousands of dollars.

Once the conversion to waterbased adhesives is complete, Nashua will sell the solvent recovery system. Nashua officials believe that the system will sell for approximately $50,000, although Nashua will have to pay to remove the system and dispose of the charcoal. Since these costs could approach the selling price of the system, Nashua does not expect to make a profit from the sale.

The second major cost associated with the use of solvent-based adhesives has been the cost of monitoring. Nashua has several LEL meters which it uses to ensure that solvents are not venting into the plant. These instruments cost approximately $8,000 to $10,000 each, and must be calibrated and repaired every few years.

The third major cost associated with the solvent-based adhesive use is disposal of waste adhesive and solvents used for cleaning. Nashua must pay between $100 to $600 to dispose of a 55-gallon drum of waste solvent. In addition, shipping costs average $25 to $50 per drum. The solvents, primarily TCA and toluene, are disposed of by an incineration company who uses the liquid wastes for fuel blending.

An additional cost factor associated with the use of solvent-based adhesives is regulatory fees for air emissions. Nashua has been exempt from paying air emission regulatory costs (*i.e.*, air discharge permit fees), as its emissions have been grandfathered from current regulations. However, future permitting requirements (*i.e.*, Title V operating permits) would likely impact Nashua's emissions. If Nashua continued to use solvent-based adhesives in the future, it would probably have to pay permitting fees for its emissions.

2.3 Costs Associated with Waterbased Adhesive Use

While there are significant costs associated with solvent-based adhesives, the conversion to waterbased adhesives required a much greater investment of time and capital. Since 1987, Nashua has purchased 13 glass-fiber tanks for blending and storage of waterbased adhesives. These tanks range in cost from $5,000 to $75,000, excluding installation costs which are approximately two to three times the purchase cost of each tank. Nashua has purchased new piping and air pumps for transfer of the waterbased adhesive to the coating heads on an as-needed basis as their capacity to coat waterbased adhesives has increased. Piping is relatively inexpensive while air pumps range from $500 to $2,000 each. Nashua also installed three heat exchangers to ensure that the waterbased adhesive remains at a constant temperature during coating. These cost under $5,000 each plus installation costs of $2,000 to $3,000 each.

Nashua has incurred additional cleaning costs associated with waterbased coatings. While the stainless steel tanks and piping of the solvent-based system rarely need cleaning, the glass-fiber tanks must be cleaned every six months. Cleaning the tanks requires approximately 16 man-hours and a labor cost per tank of about $1,000 per year. Also, waterbased adhesives are more difficult to clean from equipment resulting in an increased labor effort.

Nashua also stated that increased output of wastewater has resulted from the conversion. Wastewater disposal costs are approximately $350 per week higher than before conversion. This cost includes increased wastewater generated and shipping costs.

In addition to these relatively quantifiable costs above, Nashua has incurred some costs associated with learning to use waterbased coatings. The amount of time spent by Nashua personnel learning to mix, transfer, coat, and dry waterbased adhesives is significant, although it is not easily quantified. Nashua's largest learning costs have revolved around the pumping system for transferring waterbased adhesives to the coating head. Nashua has found that waterbased acrylics have a strong tendency to dry in the valves of the pumps, causing them to stick. Cleaning the pumps is costly, time consuming, and can interfere with the production process. Nashua could not quantify the labor hours that have been spent on pumping problems, however, the company considers it a significant cost of using waterbased adhesives.

2.4 The Decision to Convert

Nashua has invested significant capital to effect the conversion to waterbased adhesives. While initial savings are obviously not the reason Nashua decided to convert, costs did play a central role in its decision. Nashua personnel indicate that there were three motives behind the corporate executive decision to switch to waterbased adhesives: regulatory costs, research and growth, and environmental benefits.

The first motive in the decision was to avoid future regulatory costs. While its coating lines are not currently regulated for air emissions, Nashua felt that future regulations might become stringent enough to make solvent-based adhesive use unprofitable. Nashua believed that since the trend towards higher-priced permits would continue, solvent-free waterbased adhesives seemed an appealing alternative to solvent-based adhesives.

A second motive for converting to waterbased adhesives was to become involved in a developing field of adhesive technology. Nashua plays an active role in professional organizations and in development work with adhesive formulators and equipment suppliers. According to Nashua personnel, there was essentially no continuing research aimed towards improving current solvent-based adhesives. Nashua personnel believed that adhesive formulators realized that solvent usage would be phased out and were concentrating their research and

development efforts on other adhesive technologies, such as waterbased, hot melt, and two-part reactive adhesives. Nashua found that, for its purposes, waterbased adhesives possessed the performance levels (*e.g.*, tack, adhesion, temperature sensitivity) required by its customers. Currently, the costs of formulating solvent-based adhesives and purchasing waterbased adhesives are approximately the same for Nashua ($1 to $2 per dry pound). With continuing research, Nashua feels that future waterbased adhesive prices may drop as performance levels increase.

A third motive expressed by Nashua personnel for the conversion to waterbased adhesives was the company executives' belief that moving toward waterbased adhesives was environmentally correct. Nashua personnel indicated that the company had other compelling reasons to convert to waterbased adhesives, as mentioned in the previous paragraphs. However, they believed that the executive decision to convert to waterbased adhesives was an attempt to move into a more environmentally sound means of production, above and beyond monetary considerations.

CHAPTER 3
MARKETING FACTORS AFFECTING PROCESS CONVERSION

3.1 Customer Approval Requirements

For Nashua's clients, performance characteristics and price are currently, and likely to remain, the two most important factors in their decision to buy adhesive-coated products. Nashua marketing personnel indicated that only very recently has a third factor, environmental impact of the product, become important to some clients.

In order to retain its client base during the conversion to waterbased adhesives, Nashua must cover the same range of applications achieved with solvent-based adhesives at competitive prices. It has taken Nashua several years to acquire a range of waterbased adhesives that covers its application needs while providing competitive prices. Nashua began the conversion to waterbased adhesives in 1987 and has been replacing products incrementally since. Nashua's technique of incremental replacement is described in Chapter 4.

3.2 Nashua's Marketing Techniques

When the executive decision to convert to waterbased adhesives was made in 1987, the timetable for the conversion was not definitively set. To keep Nashua profitable during the conversion process, it was decided that the conversion would be performed incrementally over time. Nashua's laboratory was charged with locating waterbased adhesives that were less expensive and had improved performance over Nashua's solvent-based adhesives. When a suitable waterbased adhesive was obtained, it was introduced as a new and improved product to their customers.

Nashua's clients have responded positively to the new adhesives. Nashua's incremental replacement technique has allowed the company to find high quality adhesives, satisfy is clients performance and pricing requirements, and reduce its use of solvent-based adhesives. Nashua planned to be solvent-free by the end of 1993.

CHAPTER 4
MATERIAL ISSUES INVOLVED IN THE PROCESS CONVERSION

4.1 Introduction

Nashua uses three primary raw materials for label stock manufacturing: adhesive (and its components), release coat, and paper substrate. Although all three materials are affected, adhesive formulations have undergone the most change during the conversion to a waterbased process, and are the focus of this chapter. To formulate solvent-based adhesives, Nashua purchases raw chemicals, baled rubber, and toluene, and mixes them on-site. Formulating solvent-based adhesive from raw materials is less expensive for Nashua than buying them coater-ready from a supplier. The Omaha facility does not yet formulate its own waterbased adhesives, but hopes to in the future.

During the adhesive conversion, Nashua has also been converting its release coating from a solvent-diluted silicone to a 100 percent solids silicone. This release coat conversion was prompted by Nashua's corporate decision to eliminate all solvent usage in its processes. Nashua has experienced some difficulties with the new solids silicone release coating. Nashua attributes these difficulties to limited time spent on development, not to inherent problems with the solids silicone coating.

To be compatible with the higher pH of the waterbased adhesives, Nashua had to purchase slightly different types of paper stock. The costs and performance quality of this new paper are very close to the old paper and Nashua uses the same vendors as before the conversion. Untreated paper has a relatively high surface energy on which waterbased adhesives can generally be coated effectively. For this reason, coating modifications needed to process waterbased adhesives may be very different at a facility that coats lower surface energy materials, such as plastic films. Another material issue relevant to the conversion is the cleaning agents used for coating equipment. This issue is discussed briefly in this chapter.

Nashua has experience with coating waterbased pressure-sensitive products since 1982 when Line 3 was converted from a waterbased heat seal to a waterbased label stock coating line. In 1987, a corporate mandate put the entire company on a six year plan to convert its solvent-based adhesives to waterbased adhesives. Since then, the Omaha facility has been

gradually converting Line 1 to solvent-free waterbased adhesives. These efforts were accelerated in the last six months of 1993 to reach the corporate goal of complete conversion by December 31, 1993. For this reason, many of the facets of conversion discussed in this chapter are currently being reviewed and may change depending on Nashua's needs.

4.2 Finding Replacement Waterbased Adhesives

Although conversion of each adhesive-coated product line was different, Nashua was able to follow general guidelines while choosing replacement waterbased adhesives. Figure 4-1 is a flowchart of the general steps Nashua has used to replace solvent-based adhesives. The first step in finding an alternative waterbased adhesive is to define the customer performance specifications required of the end-product. This task was relatively simple for Nashua since it already knew most of its customer requirements. In some cases, tests were performed to determine customer specifications, which allowed Nashua to improve its adhesives' properties before introducing them to customers.

Depending on the end-use application, customer specifications can require varying amounts of adhesion and tack. Customer specifications depend on the application environment, expected adherents (substrates the end-product will be applied to, such as frozen food packages), and required bond strength. Variables in the application environment include temperature, humidity, and chemical or water exposure. The nature of the adherend for which the adhesive is intended is critical to adhesive performance, because it must be compatible with the adhesive. Also, the bond strength must be adequate for the application, whether it be a permanent vertical label (*e.g.*, 55-gallon drum label), or an easily removable/reusable label.

After determining a profile environment for which a solvent-based adhesive will be used, Nashua can determine whether one of its current waterbased adhesives will meet the performance specifications of the end-product it wants to change. If a potentially suitable adhesive is found in-house, research and development (R&D) and cost/benefit (C/B) analyses are performed to determine the feasibility of using that adhesive for the new application. Nashua can attempt to modify the adhesive's properties by addition of tackifiers, plasticizers, other performance enhancers, and/or fillers (as stated previously, Nashua does not formulate its own waterbased adhesives, however, it does have the capability to slightly modify its purchased adhesives by

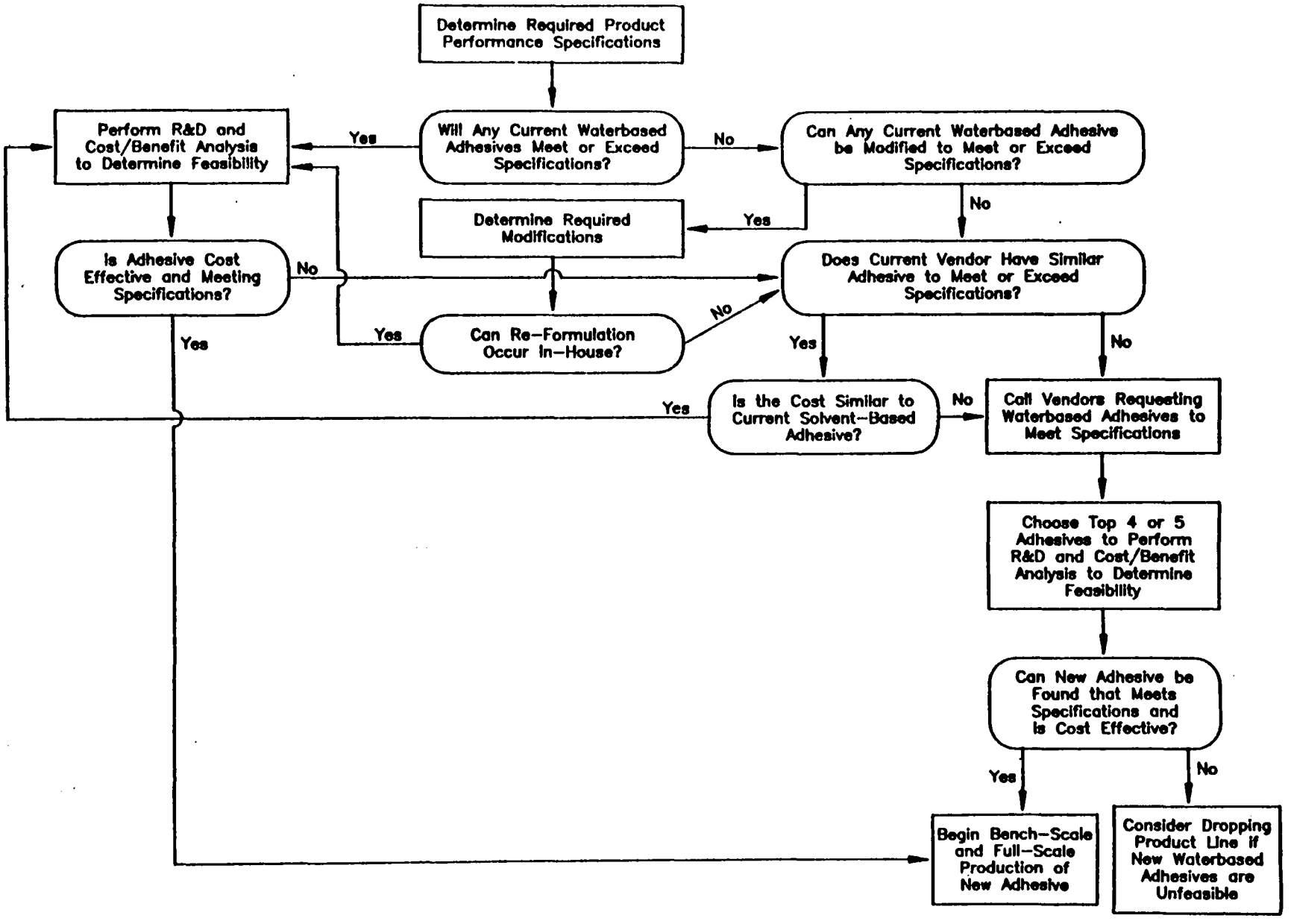

Figure 4-1. Flowchart of replacement waterbased adhesive selection process.

blending additives into the formulation). If its current adhesive does not meet the required specifications, Nashua may consult with its adhesive vendor to determine if different formulations of the adhesive are available. If so, Nashua will perform R&D and C/B analyses on a more suitable version of the adhesive to determine its application feasibility.

If Nashua is unable to locate a suitable waterbased replacement or improvement (from the current vendor), various adhesive vendors are contacted with requests for product samples of their waterbased adhesives that meet the proper specifications. Nashua may receive 10 to 20 new adhesive formulations as a result of these requests, and tests each of the samples. Measurements taken may include shear strength, viscosity, tack, and adhesion using a bench-scale coating apparatus. This testing narrows the field to a few candidates. At this point, all other factors such as cost, compatibility, marketability, and ease of application enter the decision-making process. The adhesives are ranked to determine which will undergo extensive R&D and pilot-scale testing.

If a suitable replacement adhesive is not found for a particular product, Nashua may consider dropping that product line based on C/B analyses. If the incremental cost of searching for or using a particular waterbased adhesive does not appear to be cost-effective or technically feasible (*i.e.*, if the customer would not benefit from the conversion), Nashua may consider dropping that product line, especially if it is a low volume product.

4.3 Formulation of Solvent-based and Waterbased Adhesives

Nashua formulates its solvent-based adhesives on-site. Before conversion efforts began, the company used six solvent-based and four waterbased adhesive formulations. It currently uses only two solvent formulations which constitute less than ten percent of its product volume. When conversion is complete, Nashua expects to have eight to ten solvent-free waterbased acrylic formulations. The adhesive technology effects of Nashua's conversion to waterbased adhesives are discussed here.

To formulate a solvent-based adhesive, Nashua takes baled natural rubber and mills it into strands a few inches (centimeters) in length. The milled rubber is then added with resins and additives into a mixing tank. Prior to their addition, the resins are heated in an oven to between 140° and 160°F for approximately two to eight hours. The purpose of heating is to reduce the naturally high viscosity of the resins for better mixing. The final ingredient is the carrier

(toluene), which Nashua stores in USTs outside the facility. Toluene is the final ingredient added because of the explosion potential caused by static electricity that can be generated when stirring the solvent.

Nashua is not currently formulating its own waterbased adhesives. These adhesives are purchased as pre-mixed emulsions and stored in glass-fiber tanks until use. These tanks are located inside the facility and provide constant/intermittent agitation to reduce the amount of settling solids. The pre-mixed adhesives include most of the ingredients that Nashua will use in its waterbased formulations, although some materials are generally added to the emulsion before being sent to the coating head. Nashua may add fillers or tackifying agents to the adhesives in a holding tank located next to the coating room. The amount and type of additives are product-specific.

Nashua's waterbased adhesive formulations include a concentration of less than 0.5 percent ammonia (NH_3). The purpose of this ammonia is to keep the adhesive slightly basic (pH of approximately 8.0 to 9.0), which Nashua has determined to be the best for its coating operations. Nashua engineers stated that most adhesive coaters in the industry operate their waterbased adhesives either slightly acidic or slightly basic depending on each facilities' substrate characteristics.

One of the major problems with waterbased adhesives at Nashua is maintaining consistent waterbased coating viscosities. Waterbased coating viscosity varies with temperature and humidity and is constantly monitored in the storage tanks. Ingredients may be added periodically for viscosity adjustment. Nashua strives to maintain coating viscosities of waterbased adhesives between 500 and 2,000 centipoise, although for any waterbased adhesive application, the coating viscosity will vary considerably depending on the coating method used. Solvent-based adhesives tend to be somewhat higher in viscosity.

Nashua uses a heat exchanger located at each coating head pumping station to help ensure constant coating viscosity. This heat exchanger is not used for every waterbased adhesive and its temperature varies between waterbased formulations. Viscosity control is one of the primary reasons that waterbased adhesives are more difficult to coat than solvent-based adhesives. On rare occasions, entire batches of waterbased adhesive have been rejected and sent to waste tanks or recycled back to storage tanks where the viscosity can be adjusted and monitored. Solvent-based adhesives do not experience such wide variations in viscosity. Through trial and error,

Nashua determined that its solvent-based adhesives coat best at a temperature of approximately 90°F, which is the normal ambient temperature in the plant year-round.

Nashua indicated that the solids content of its previous solvent-based and current waterbased adhesives vary over the same range. Solids content of its solvent-based adhesives range from 30 to 70 percent while that of waterbased adhesives range from 30 to 60 percent. For this reason, coating thicknesses and weights have not varied considerably between the two types of adhesives. Coating thicknesses range from one to three thousandths of an inch and coating weights range from 11 to 17 pounds of adhesive per ream of paper. For both adhesive types, the actual coating thickness is product and adhesive specific.

4.4 Costs of Alternative Waterbased Adhesives

In general, the cost of Nashua's waterbased adhesives is approximately the same (within ten percent) as the cost of formulating its solvent-based adhesives. Nashua estimated that the costs for its solvent-based adhesives range from $1 to $4 per pound of wet adhesive (*i.e.*, mixed adhesive, which is ready to apply to a substrate). This cost varies with the price of oil and is higher for some specialty types of adhesives. Although the average cost of waterbased adhesives also ranges from $1 to $4 per wet pound, some formulations are more expensive than solvent-based, resulting in increased costs to customers. This increase in costs has not changed Nashua's profit margin.

Nashua stated that the largest contributing cost in its end-product is the raw paper used to manufacture its label stock. Paper costs range from $0.50 to $0.75 per pound depending on grade and specification. The cost of the adhesives is a distant second or third largest expense behind energy. Raw paper costs have increased minimally due to the change in paper type.

4.5 Cleaning Agents

The final raw material issue at Nashua concerns the cleaning agents used to remove adhesive from storage tanks, adhesive filters, coating equipment, and spills. Nashua personnel indicated that cleaning requirements have increased as a result of converting from solvent-based to waterbased adhesives. This is due to the chemical properties of acrylic adhesives. Once an

acrylic adhesive has dried (*i.e.*, the water has evaporated) it forms a hard, polymer layer. Solvents can penetrate this layer, and Nashua currently uses toluene and TCA to clean equipment. Nashua is attempting to replace its traditional cleaning solvents with less volatile (and hazardous) substances. Nashua engineers indicated that waterbased acrylic adhesives can be cleaned with a mixture of soap, water, and low volatility solvents (*e.g.*, mineral spirits) when wet; however, more frequent and labor-intensive cleaning activities such as scraping and peeling will be required to clean dried adhesive residue. Nashua expects that with increased experience, the cleaning duties should become less cumbersome.

Storage tank cleaning has become somewhat less problematic with the addition of glass-fiber lined storage tanks for waterbased adhesives. These glass-fiber tanks are cleaned with high-pressure water and scraping tools approximately once every six months. In contrast, the stainless steel storage tanks used for solvent-based adhesives require virtually no cleaning, since toluene provides continuous cleaning during the mixing stage. Cleaning of other waterbased coating equipment (*i.e.*, coating heads, drip trays, etc.) is performed using water spray and scraping. The solvent-based coating equipment rarely requires cleaning but TCA or toluene is used to clean the equipment when necessary. Nashua uses PVC piping for waterbased adhesive transfer which, instead of routine cleaning, is replaced when clogged with adhesive. Some pipe replacement was required after three years of use.

Nashua indicated that its largest daily cleaning problem is the metal filters used to filter adhesive when transferring from mixing tank to coating head. Currently, these filters are removed from the lines every three to four hours for cleaning in a toluene bath with a scrub brush. Since Nashua is phasing out its use of toluene, a new method for cleaning the filters will need to be developed. Nashua has yet to find an equally effective replacement for toluene cleaning of waterbased adhesive filters.

Nashua uses a TCA drip while coating solvent-based adhesives to remove adhesive from the paper's edges during coating. This prevents "oozing" of adhesive during roll wind-up by removing one-quarter to one-half inch of adhesive from both edges of the paper. This "oozing" can potentially cause major handling problems. Nashua is currently using a "wiping blade" setup to remove waterbased adhesive from the edge of the paper. This is a more labor-intensive method than the TCA drip. Nashua personnel hope to find a more effective solventless method of removing adhesive from the edges of the product.

CHAPTER 5
EQUIPMENT ISSUES INVOLVED IN THE PROCESS CONVERSION

5.1 General

Nashua personnel indicated that nearly every aspect of its label stock manufacturing process had been affected by the conversion to waterbased adhesives. However, all of these changes have proven feasible and have been implemented over time. Nashua believed that any problem arising from the conversion could be solved with a concerted effort in R&D, engineering, and redesign. Since Nashua has been gradually converting its process for about seven years, it has been able to spread its efforts out over a much longer time frame than is normally available to plants attempting to meet permitting deadlines.

This chapter details the process equipment changes that were accomplished for the conversion. The following list contains the equipment and machinery which required modification during the conversion.

- Storage tanks
- Mixing and holding tanks
- Resin heating oven
- Adhesive filters
- Piping
- Pumps and motors
- Heat exchangers
- Coating head and related equipment
- Drying/curing ovens
- Carbon adsorber

Section 5.2 discusses specific equipment changes and equipment performance requirements. Section 5.3 presents maintenance issues related to the conversion. Finally, Section 5.4 outlines the costs and vendor selection process associated with implementing the changes.

5.2 Process Design Modifications and Equipment Trials

During the conversion to waterbased adhesives, much of the equipment and machinery used in the adhesive coated product manufacturing process had to be replaced, added, retrofitted, or decommissioned. These modifications and equipment trials are addressed in this section.

5.2.1 Storage Tanks

Nashua currently uses USTs located outside the facility to store toluene for solvent-based adhesives. These underground tanks reduce the fire and explosion hazards of toluene and rarely require cleaning or maintenance. Other raw materials for its solvent-based adhesives are stored in boxes or drums inside the facility until use.

For waterbased adhesive storage, Nashua has installed glass-fiber lined tanks inside the plant near the mixing rooms. Since Nashua has been gradually converting to waterbased adhesives, replacement tanks have been added as necessary to meet the increased waterbased capacity. Their location is more convenient than the USTs for cleanup (performed approximately twice per year) and maintenance. Nashua decided that using the original stainless steel USTs would not be feasible for waterbased acrylic adhesives due to the cleaning frequency and difficulty in removing acrylic from the steel walls.

Since the solids in waterbased adhesives tend to settle and stick to the interior walls of the tanks, two blades (one located near the top, and the other near the bottom) are included to provide continuous/intermittent agitation. This agitation is required to stabilize the emulsion and thus maintain a coatable viscosity for the waterbased adhesives. However, over-agitation of waterbased adhesives may result in foaming either in the tank or at the coating head. Agitation is not required for solvent-based adhesives since they are formulated on-site using just-in-time manufacturing methods.

Continuous viscosity measurement is required when preparing and coating waterbased adhesives. Nashua uses a viscometer located next to the storage tanks, where an operator keeps a log of waterbased adhesives' viscosity. If the viscosity varies outside an acceptable range for an application, the chemists are immediately notified. Viscosity-altering chemicals may be added as necessary. This monitoring was not required when mixing solvent-based adhesives.

Finally, a new glass-fiber waste storage tank has been purchased, which is larger than any of Nashua's waterbased adhesive storage tanks. This tank stores waste or rejected adhesive until ready for transport to the local publicly-owned treatment works (POTW).

5.2.2 Mixing and Holding Tanks

Nashua uses stainless steel mixing tanks to formulate its solvent-based adhesives. Waterbased adhesives are held in tanks located beside the coating room. Nashua pumps the premixed waterbased adhesives from its storage tanks to the holding tanks where an operator may add some materials to slightly alter the adhesives' properties or coating weight. As with storage tanks, these holding tanks have been replaced on an as-needed basis over the last seven years. In addition, most of the pumps, valves, and pipes were changed by Nashua personnel while the tanks were installed by outside support. Also, the mixing and holding tank rooms will no longer require explosion-proof walls when conversion to waterbased adhesives is complete.

5.2.3 Resin Heating Oven

The oven Nashua uses to heat resins for solvent-based adhesives will no longer be needed when conversion to waterbased adhesives is complete. However, this oven will be kept on-site should Nashua have a future need for it.

5.2.4 Adhesive Filters

Nashua currently uses similar stainless steel canister filters to filter both its solvent-based and waterbased adhesives. The company will continue to use these filters when conversion is complete. The major difference between adhesive filters is that the mesh or screen size is slightly larger for waterbased adhesives. This is due to the emulsion state of the waterbased adhesives which have slightly larger particle sizes.

5.2.5 Piping

Nashua uses stainless steel pipes for piping solvent-based adhesives. These are in the process of being replaced with PVC pipes for the waterbased adhesives. The primary reasons for using PVC are low cost and ease of replacement. PVC piping is considerably cheaper than stainless steel and, as with tanks, has been replaced on an as-needed basis. Also, the PVC piping will not be cleaned when clogged, but will be replaced as necessary. This replacement has been accomplished in-house. PVC pipes have not been used for solvent-based adhesives due to the explosion potential of toluene.

5.2.6 Pumps and Motors

Nashua's pumping requirements for solvent-based and waterbased adhesives differ significantly. Nashua uses a simple high-shearing (agitation) vane pump with solvent-based adhesives. For its waterbased adhesives, Nashua experimented with a lobe pump and an air (diaphragm) pump, and determined that the air pump worked better. Air pumps are low-shearing pumps because the adhesive is not agitated by pump blades such as those used in vane pumps. However, maintenance personnel stated that the air pumps require extensive maintenance. Acrylic adhesives tend to stick in the pump valves causing them to be taken off-line for a four-hour cleaning approximately every three to four months. As with tanks and pipes, Nashua has purchased replacement pumps on an as-needed basis.

Pump motors required replacement due to the different air coupling mechanisms of the new air pumps. Nashua personnel did note that there was no increase in motor capacity or energy required for the waterbased conversion. A bonus for Nashua is that the new motors do not need to be explosion-proof. Explosion-proof motors were required to run solvent-based adhesives to provide protection of the volatile toluene used in the mixture. Nashua's waterbased adhesives contain no solvents and thus have no explosion potential.

5.2.7 Heat Exchangers

An additional piece of equipment that Nashua sometimes uses for waterbased adhesives is a heat exchanger located at the supply pump to the coating head. This heat exchanger is used when necessary to ensure a consistent coating viscosity (via temperature control). Viscosity is a primary control variable of Nashua's waterbased adhesives and requires constant monitoring to ensure proper coating thicknesses and uniformity. Nashua's heat exchangers are of the plate-frame type and are primarily used for cooling rather than heating purposes. Solvent-based adhesives do not require a heat exchanger.

5.2.8 Coating Head and Related Equipment

One of the major modifications for Nashua's conversion involved the redesign of the coating head and related equipment on Line 1. For solvent-based adhesives, Nashua used various coating methods including direct gravure and direct reverse gravure. However, in order to coat waterbased adhesives, Nashua altered its coating head to include a reverse rolling mechanism for adhesive metering. Figure 5-1 illustrates the waterbased coating head used at Nashua. The metering roll is used to pick up adhesive from the trough and transfer it to the application (reverse) roll. This reverse roll application is used to even out the waterbased adhesive before it contacts the paper substrate. This type of coating is termed three roll reverse gravure or offset gravure.

In order to coat waterbased adhesives faster, Nashua changed the type of coating rollers it used. Traditional steel rollers were not the best suited for waterbased application. Nashua uses a combination of steel and rubber rollers to apply its waterbased adhesives. In addition to the coating head configuration change, Nashua changed the gravure coating head density. Since waterbased adhesives have higher surface tension and thus do not wet the paper substrate as well as solvent-based adhesives, a smaller gravure density was designed to provide more coating points on the substrate. Specific details of coating head configuration and gravure density are considered proprietary by Nashua Corporation and therefore are not discussed here. Nashua engineers did indicate that waterbased coatings could have been coated with its solvent-based

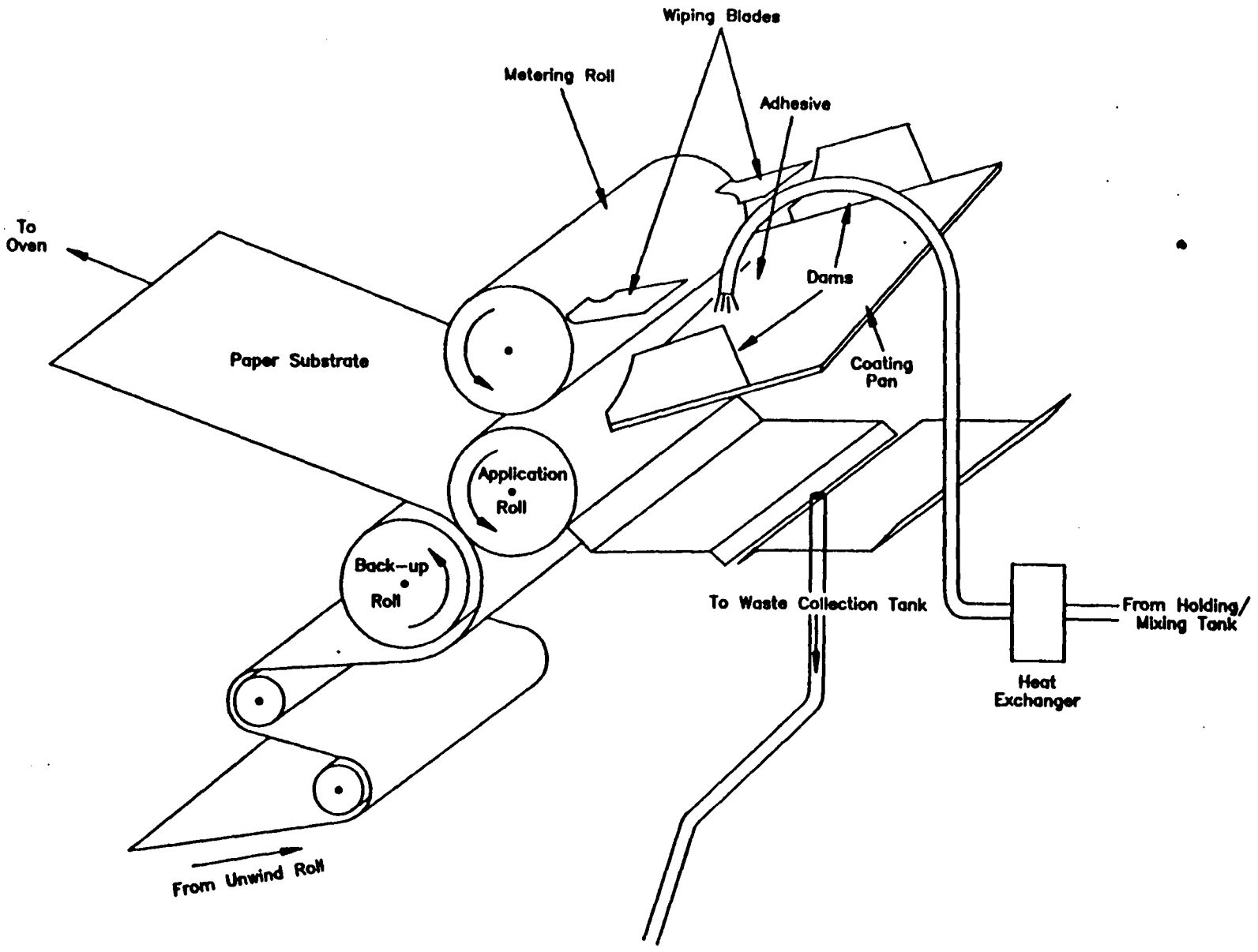

Figure 5-1. Adhesive application equipment.

coating heads at a much slower speed. To increase line speed, the coating head was changed to include rubber rollers and the gravure density was increased.

In the recent past, Nashua had used only one coating head system on Line 1. This caused switchover delays of approximately eight hours to convert from a solvent-based to a waterbased coating head. To combat this problem, Nashua redesigned its Line 1 coating machine to have two easily interchangeable coating heads (since Line 3 is dedicated to waterbased product, no changes were made to it). This reduced changeover downtime from eight hours to one to two hours. The coating head can be changed in approximately fifteen minutes, however, to change the supply and flush the adhesive dispensing equipment, another hour or so is required.

Nashua has found that the coating process is less robust (*i.e.*, requires more maintenance and downtime) for waterbased adhesives. Increased cleaning requirements and more frequent machine adjustments for coating thickness and smoothness are required for waterbased adhesives. Line operators stated that the most often adjusted coating parameters are nip gap size (*i.e.*, distance between application roll and reverse roll) and reverse roll speed. These are also important control elements in solvent-based coating, however, the frequency of required adjustments is greater for waterbased coating. Nashua has also experienced foaming with waterbased adhesives due to their emulsion state. Excessive agitation can cause waterbased formulations to foam, creating additional coating problems.

In addition to changing the coating head, other related equipment required retrofit or replacement. Traditionally, Nashua has used a TCA drip to remove excess adhesive from the paper's edges to prevent runout of the adhesive during windup. However, Nashua plans to phase out TCA and is currently using a stationary wiper blade on either end of the coating head to wipe the adhesive from the paper's edges and return it to the adhesive reservoir. Nashua personnel indicate that this is a short-term solution and alternative methods are currently under consideration.

Nashua also has made available a smoothing bar for its waterbased adhesives, although it is not always used for every application. The purpose of this smoothing bar is to provide a smooth, even coat of adhesive across the entire paper length. The bar is located immediately after the coating head and is not required for solvent-based adhesives.

Nashua believes that its current waterbased coating heads have reached their maximum production volume capacity (*i.e.*, they cannot generate product any faster). The company is

currently looking to replace the Line 3 coating head with a new, higher-volume head. Nashua would not disclose the design of the new coating head.

5.2.9 Drying/Curing Ovens

The final major modification for the Nashua involved the drying/curing ovens. Solvent-based adhesives require an oven temperature configuration in which the temperature in the initial zone is relatively low and gradually increases in subsequent zones. At the final zone, the temperature is at its highest to evaporate any remaining solvent in the adhesive. At Nashua, this solvent-based temperature profile involves oven temperatures of approximately 100°F at the low end and 200°F at the high end. This configuration is necessary because solvent-based adhesives may dry improperly if introduced to high temperatures during the initial curing stages, and excessive solvent removal may lead to explosion hazards.

Waterbased adhesives exhibit the opposite response. They are exposed to high temperatures (approximately 250°F) in the initial zone(s) of the drying oven to evaporate the water as quickly as possible and cure the adhesive. The temperature is then reduced during subsequent zones until it approaches 55°F at the oven exit. Heat exchangers are used to supply the cool air during final oven zones for waterbased adhesives. Nashua engineers stated that the oven temperatures are set permanently for drying/curing of all its waterbased formulations. Operators are not required to change these settings when coating different adhesives. Nashua also indicated that its oven energy requirements have not increased during the conversion. Although the temperature profiles have changed, the overall energy requirements have remained approximately the same.

Nashua's ovens employ a roller system to keep the coated web moving through the oven. The ovens for Lines 1 and 2 are heated by forced steam generated from an on-site boiler. The same oven on Line 1 is used to dry/cure both waterbased and solvent-based adhesive coatings. Line 3 is heated by natural gas burners within the drying line. The steam or natural gas heats the air in the oven to a maximum of approximately 250°F. Each oven is approximately 200 feet long and has up to five temperature zones. Within each zone, the temperature can be controlled independently of the other zones in the oven. When coating waterbased adhesives, all the ovens use an air recirculation system. Only a portion of the air passing over the coated web is vented

to the atmosphere, while the remainder is again passed over the web. This lowers the energy requirements, especially for the on-site boiler during the winter months. Nashua engineers noted that the energy cost on a dollars per BTU basis is approximately the same for steam and direct-fired ovens.

Total air flow through the ovens remains approximately the same as before conversion, although some reconfiguration has occurred to accommodate temperature differences. Air flow per temperature zone was changed, but exact air flow per zone is considered proprietary information by Nashua. Typically, solvent-based products begin with a high airflow in the initial zone to evaporate the large amount of solvent and keep the solvent concentration below the LEL. The air flow drops during subsequent oven zones. Waterbased products experience the opposite treatment to solvent-based products; low air flows are predominant in the initial oven zones while higher air flows are typical in the last oven zone.

A significant drying problem associated with waterbased adhesives is curling. At Nashua, these adhesives are subjected to high temperatures in the early stages of drying which not only evaporate water from the adhesive, but also evaporate the natural water content of the paper substrate. In simple terms, dry paper tends to curl. Curling can lead to major laminating problems. Since the face stock used for lamination has its natural water content intact, over-dry adhesive-coated paper tends to draw water from the face stock, resulting in curling. For the waterbased adhesives, Nashua strives to keep a final water content after drying of about two to three percent. Even with this water content in the adhesive, the paper tends to curl. Nashua has diminished this problem somewhat with the addition of a water misting system located at the exit of the drying oven. Upon exiting the oven, the cured coating and paper are sprayed with an even water mist to replenish the natural water content of the paper. Nashua sets the final oven zone temperature at approximately 55°F because the paper exhibits the best water absorption properties at that temperature.

Curl is much less of a problem with solvent-based adhesives since high temperatures are not introduced until the final drying stages, thus reducing the residence time for the water in the paper to evaporate. Also, toluene has a low flash point (40°F) and high vapor pressure (20 mmHg abs); therefore, the oven temperatures are not quite as high for the solvent-based adhesives, allowing the paper's natural water content to remain in the paper.

Nashua personnel indicated that Line 1 oven capacity was not an issue in the conversion to waterbased adhesives. The company's original ovens had enough capacity to run waterbased adhesives at approximately the same line speeds as its solvent-based counterparts. The addition of infrared (IR) heaters to some oven zones has increased drying capability. These IR heaters provide additional heating capacity by pre-heating the adhesive-coated paper using less energy than would otherwise be required by the oven. This allows a lower residence time in the oven, which is important for faster line speeds in waterbased formulations. Nashua uses one to five IR heater(s) per set of ovens. Since Line 3 ovens have been configured to run waterbased adhesives, no changes were necessary in its configuration.

Most of the oven changes were accomplished using in-house knowledge except for IR heater installment. These heaters were installed by the vendor but are maintained in-house.

A benefit of converting to waterborne adhesives has been the reduced fire and explosion hazards in the ovens caused by the solvent-based adhesives. Prior to conversion, Nashua used monitors to constantly record the LEL of solvent present in the ovens. These monitors will be removed when conversion is completed. Also, by removing the explosion hazard, Nashua will not have to continually measure dilution air flow in the ovens and may reduce air dilution costs.

Nashua has plans to fit new ovens on its Line 3 coating machine. These ovens will replace the current ovens, which are approximately 25 years old. Nashua is doing this to help accomplish its goal of enabling Line 3 to apply both release and adhesive coats and also laminate coated paper. Nashua personnel specifically stated that the new ovens are not a result of process changeover, rather, they are simply upgrading to state-of-the-art ovens.

5.2.10 Carbon Adsorber

When using solvent-based adhesives on Line 1, Nashua sends the oven exhaust to a carbon adsorption system located on the roof of the facility. With the conversion to waterbased adhesives, Nashua will no longer need this solvent recovery system. They already have made plans to sell the adsorption system for approximately $50,000; however, it will cost approximately this much to remove the system and dispose of the fouled charcoal. Removal of this system will reduce operational costs including charcoal replacement, steam production for

stripping the charcoal of its organics, and a recovery system to extract the organics from the steam.

5.3 Maintenance and Operational Issues

Nashua's conversion to waterbased adhesives has involved various equipment maintenance issues. Maintenance has increased in some instances and decreased in others depending on the type of equipment. Overall, however, Nashua personnel indicate that maintenance requirements have balanced and remain approximately the same as they were before conversion. They also expect that some of the new problems will disappear with time as they gain experience in the coating with waterbased adhesives. This section briefly discusses the maintenance issues involved with each equipment item pertinent to the conversion process.

Nashua indicated that while maintenance activities associated with storage, mixing, and holding tanks have changed, there has been no net increase in maintenance in this area. New maintenance activities include more frequent cleaning and some increased clogging. These requirements absorb maintenance capacity previously associated with solvent-based adhesives, including monitoring for leaks and accessing USTs for repair.

Maintenance requirements for the new PVC piping have remained the same or are somewhat lower than for the stainless steel pipes used for solvent-based adhesives. Clogging problems are readily solved by replacing the inexpensive PVC pipes with new ones.

Pump maintenance has increased due to the tendency of waterbased acrylic adhesives to stick in the pump valves. This results in taking the pumps off-line for approximately four hours every three to four months for cleaning.

The heat exchangers are relatively low maintenance items. They require only periodic preventative maintenance to clean or repair.

Nashua expects no change in maintenance for the coating head and related equipment. In fact, since creating the dual coating head for Line 1, maintenance problems associated with switching the coating head have been eliminated. Although the waterbased coating head has more parts (*e.g.*, metering roll, and smoothing bar), maintenance has not been a major deterrent to changeover.

Maintenance requirements for the drying/curing ovens have evolved during the conversion. Maintenance costs for the LEL meters have dropped since solvent-based use has diminished, however, the IR heaters for waterbased adhesives require periodic maintenance. Nashua expects that some additional maintenance may be required in the future if the drying of waterbased adhesives begins to affect the interior of the ovens via solids entrapment.

The conversion has reduced maintenance on the carbon adsorber. Under full-time solvent-based operation, the carbon adsorber required maintenance approximately five to ten times per year. This level has been reduced as the percentage of solvent-based adhesive use has declined. Since the adsorber will no longer be used at the Nashua facility after complete conversion, this maintenance requirement will be eliminated.

5.4 Vendor Selection and Costs of Modifications

Nashua used several methods to locate and install new equipment during the conversion to waterbased adhesives. The particular path chosen varied depending on the equipment sought. Nashua also verified equipment costs using several different routes. This section examines Nashua's process for finding equipment for conversion and investigating capital and installation costs of this equipment.

5.4.1 Storage Tanks

In choosing new tanks, Nashua consulted an outside agent that it uses on a continual basis for purchasing much of its auxiliary (*i.e.*, non-process) equipment. This agent deals with many tank vendors and was entrusted to choose the best (and most cost-effective) tanks for Nashua's application. Nashua indicated that the agent receives a small fee (percentage of the purchase price) as part of the agreement.

Nashua's internal group of maintenance and engineering personnel installed auxiliary components (*e.g.*, pipes, pumps, valves, and switches) before the tanks were installed. However, actual tank installation was performed by the tank vendor. The new tanks required four to eight hours of installation time each, depending on size. The tanks range in size from 700 to 15,000

gallons and range in cost from $5 per gallon for small tanks ($3,500) to $1.33 per gallon for large tanks ($20,000). Installation costs run two to three times the purchase cost of each tank.

Nashua stated that a total of ten storage tanks have been installed as capacity for waterbased adhesives has grown. Nashua noted that annual incremental costs for continuous mixing of waterbased adhesives are minimal. Cleaning costs for storage tanks will increase. Solvent-based storage tanks rarely required cleaning, but waterbased tanks will require cleaning approximately twice per year. Cleaning involves two one-man shifts (16 man-hours) and generates $600 in wastewater disposal costs. The wastewater is stored in waste tanks on-site until being transferred to the local POTW.

5.4.2 Mixing and Holding Tanks

The rooms which house mixing and holding tanks have undergone a complete retrofit with equipment compatible with waterbased formulations. After complete conversion, these rooms will no longer need to be explosion proof due to the removal of solvent materials. Nashua estimated that the necessary retrofit was accomplished in approximately one day per room, by internal labor, and cost approximately $5,000. The scrap steel was sold for a minimal return of $2 per 100 pounds.

Nashua used the same purchasing agent for retrofitted holding tanks as for storage tanks. The tanks range in size from 700 to 3,000 gallons and range in cost from $3,500 for small tanks to $15,000 for large tanks. Installation costs run two to three times the purchase cost of each tank. Annual costs for operating the new holding tanks should remain the same as for solvent-based materials.

5.4.3 Resin Heating Oven

The only cost difference associated with the resin heating oven may be reduced energy requirements due to the phasing out of in-house formulated solvent-based adhesives. Quantification of these savings, as well as savings in reduced maintenance and operator labor, was not possible. Nashua personnel believe that these costs are minimal.

5.4.4 Adhesive Filters

Nashua has purchased some new stainless steel filters for its waterbased adhesives; however, these have been purchased over the last eight years on an as-needed basis. For this reason, the total capital cost for filters has been dispersed over a number of years. Some of these filters were already in use because of the waterbased capacity of Line 3. Nashua uses approximately 10 to 15 stainless steel filters which cost about $2,000 each and are purchased from two vendors.

5.4.5 Piping

When retrofit of its mixing and holding tank rooms is complete, Nashua will have replaced all its stainless steel pipes with relatively inexpensive PVC piping. The stainless steel piping has been replaced with PVC as waterbased capacity has grown or when older pipes were clogged or worn out. PVC piping costs approximately $0.50 per foot and is purchased at a local supply house. New pipes are installed by Nashua personnel.

5.4.6 Pumps and Motors

Pump and motor replacement has been accomplished by trial and error at Nashua. Pump vendors were contacted with pump specifications and trials of air and lobe pumps were performed to determine which was best suited for Nashua's application. Changeout of pumps involved replacement of the pump and connection to a new motor. The replacement and hookup of these pumps was accomplished with in-house personnel.

Currently, Nashua is using an air pump which costs approximately $500 to $2,000. The vane pumps that Nashua used for solvent-based adhesives have been replaced with waterbased compatible pumps as waterbased coating capacity has grown. Testing and trial runs of new pumps have been conducted during the last seven years as old pumps have required replacement. The energy costs for the motors have remained approximately the same. Maintenance of the air pumps has increased relative to the vane pumps used for solvent-based adhesives; however, some of these pumps are replaced rather than repaired due to economic feasibility.

5.4.7 Heat Exchangers

The heat exchangers used to maintain constant coating viscosity were purchased through the same agent Nashua uses to purchase storage and holding tanks. The purchase cost of one of these heat exchangers was under $5,000 with an additional $2,000 to $3,000 for installation. The additional energy costs associated with operating these heat exchangers was unknown. Maintenance of the heat exchangers is minimal and therefore maintenance costs are not quantified.

5.4.8 Coating Head and Related Equipment

Nashua personnel stated that in the past they have designed and modified the coating heads for waterbased adhesives in-house at a cost of approximately $200,000. However, Nashua is currently contacting vendors about new waterbased coating head designs. Nashua is talking to various coating head vendors who specialize in coating waterbased adhesives and discussing specific needs. Nashua intends to increase its line speeds in the near future; the factor limiting line speed is the coating head (oven capacity is currently not a limitation at Nashua). From experience, Nashua expects a newly designed coating head purchased from an outside vendor to cost in the range of $300,000 to $600,000. Annual maintenance and operational costs for the new coating heads are not expected to change.

5.4.9 Drying/Curing Ovens

Nashua did not increase its oven capacity to incorporate waterbased adhesives. Its oven length was adequate to operate at approximately the same line speeds as solvent-based materials with changes in zone configuration and temperatures only. The only capital costs Nashua incurred were the result of adding one to five IR heaters to its ovens to increase drying/curing speeds. These IR heaters cost approximately $10,000 each with an additional $10,000 for installation. The highest expense associated with IR heaters is the control panel, which cost $40,000 each. Since up to three or four IR heaters can be operated by one control panel, Nashua needed several panels for its IR heaters.

Nashua expects its energy requirements to remain approximately the same for drying waterbased adhesives as it is for solvent-based adhesives. The only increased energy requirement may result from the use of IR heaters, however, Nashua believes that the energy required to operate this equipment is much less than that required to heat the oven air to higher temperatures. Nashua expects that maintenance costs for its LEL meters should diminish as solvent-based adhesives are replaced. However, future maintenance costs may increase should Nashua experience acrylic buildup from use of waterbased adhesives.

Nashua's new state-of-the-art oven that will be installed on Line 3 will cost approximately $1,000,000. This figure is given only as a reference for new oven costs (since the ovens are not a requirement for conversion) and is not relevant to costs associated with Nashua's changeover process. In fact, no capital costs for Nashua's current oven were incurred as a result of the changeover (for the purposes of this report, IR heaters are treated as a separate expense from ovens).

5.4.10 Carbon Adsorber

Nashua expects maintenance and operation costs for its carbon adsorption system to be eliminated when conversion is complete. This system is slated for removal, saving approximately $75,000 every five years in carbon replacement costs and approximately $60,000 per year in electrical energy costs. Steam production and maintenance costs will also disappear. Nashua will sell the recovery system equipment for a modest price of $50,000 when the conversion is complete. This is approximately the cost of system removal and fouled carbon disposal.

CHAPTER 6
ADHESIVE PRODUCT PERFORMANCE REQUIREMENTS

6.1 Adhesive Performance Criteria

Although Nashua produces label products aimed at the commodity sector of the adhesive market, product performance requirements are still critical to its product lines' success. There are two factors which must be considered to determine if an adhesive formulation will perform its function correctly: the adhesive performance levels required in the application and the environmental conditions to which the adhesive will be subjected.

There are three important adhesive properties by which adhesive performance may be judged: tack, peel adhesion, and creep while experiencing shearing forces. Tack is defined by the American Society of Testing and Materials (ASTM) as the property of a material which enables it to form a bond of measurable strength immediately on contact with another surface. Tack is quantified by measuring the force necessary to break such a bond. Peel adhesion is the force required to break the bond between the adherend and adherent (the backing for the adhesive) after a specified dwell time. It is quantified by measuring the force required to remove an adhesive and its backing from a specified adherend surface at a specified rate of peel. Creep results when the cohesive strength of the adhesive is not sufficient to withstand a shearing force. When the adhesive experiences creep, the end result is that the adherent moves in relative position to the adherend.

There are seven important environmental constraints on the performance of adhesives. These constraints are temperature, humidity, solvent exposure, exposure to corrosive agents, ultraviolet light exposure, exposure to air pollutants, and adherend surface conditions. Each adhesive formulation will respond to these environmental influences differently. Exposure to these environmental factors is strongly dependent on the end use of the product. For example, bumper stickers for automobiles are exposed to extreme temperatures and humidity, as well as air pollutants. Labels for frozen foods (which Nashua manufactures) are exposed to very low temperatures.

The surface condition of the adherend for which the adhesive-coated product is intended plays a strong role in resultant adhesive bond strength. If the surface condition is very rough,

the adhesive may not develop enough surface contact with the adherend to form a strong adhesive bond. If the adherend surface is too smooth, weak chemical interactions between the adhesive and the adherend may compromise the strength of the adhesive bond. Dirt, loose paint, or other surface contaminants can compromise adhesive bond strength dramatically.

6.2 Nashua Performance Criteria

For Nashua's niche in the marketplace, the two most important environmental exposures are temperature and surface condition of the adherend. Since each adhesive formulation generally has limited environmental conditions in which it functions well, Nashua has designed its entire adhesive product line to cover a broad range of temperatures and surface conditions. Nashua's product lines attempt to cover application temperatures from -30° to 150°F, on surfaces ranging from corrugated cardboard to smooth plastics. This range of applications can be envisioned as a two dimensional box, as depicted in Figure 6-1.

Nashua was able to cover the spectrum depicted in Figure 6-1 by using solvent-based adhesives. In its move to waterbased adhesives, it has been necessary for them to retain coverage of this spectrum of applications, or risk losing market segments. For the most part, Nashua has had success finding waterbased adhesive formulations which met or exceeded the spectrum of applications of the solvent-based adhesive formulations they replaced.

Nashua described a recent successful waterbased adhesive replacement of a solvent-based adhesive. Nashua has one client who formerly purchased two label products manufactured with solvent-based adhesives. One product was used by the client for room temperature applications, while the other was used at low temperatures. The room temperature solvent-based adhesive cost Nashua approximately $1.00 per pound of wet adhesive. The low temperature solvent-based adhesive cost Nashua approximately $1.50 per pound of wet adhesive. Nashua was able to obtain a waterbased adhesive which, at a cost of approximately $1.15 a pound, performs in both the room temperature and low temperature environments.

Nashua has found that some inherent qualities possessed by waterbased adhesives are superior to solvent-based adhesives for some of Nashua's end-product applications. For instance, the tack of waterbased adhesives is generally somewhat lower than for solvent-based adhesives. For the application of some labels, lower tack can be beneficial. If a label is improperly placed,

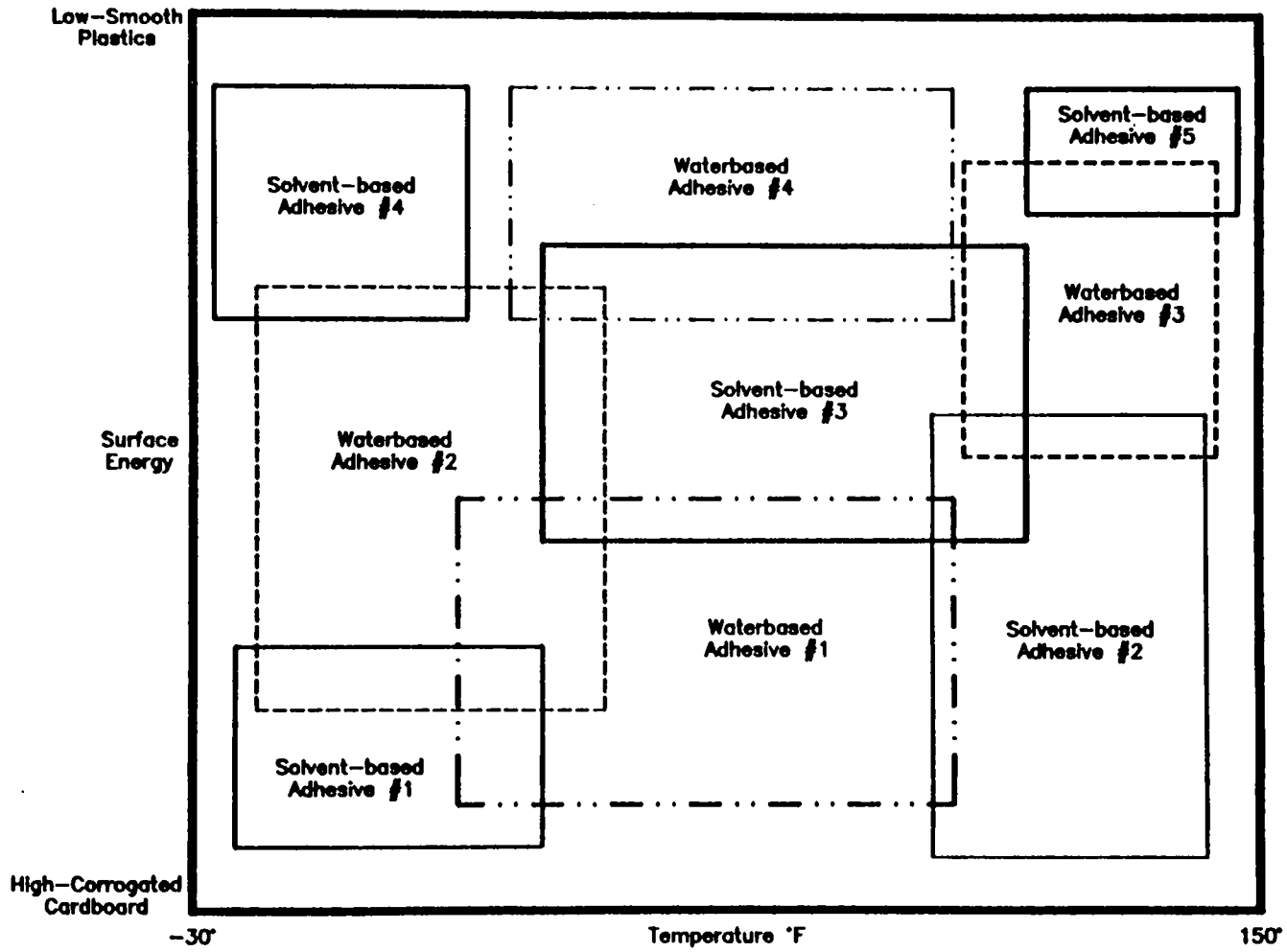

Figure 6-1. Example application range of adhesive-coated products.

it can be removed and reapplied without destroying the label. This property leads to additional applications for waterbased adhesives, including removable/reusable labels. Nashua has found that final adhesive bond strength is generally greater with waterbased formulations, so permanent bonding can be stronger than with solvent-based adhesives.

While Nashua has had success replacing most of its solvent-based adhesives with waterbased adhesives, duplicating the performance of every product has not yet been possible. Nashua personnel believe that it may have to cease production of one product for which a suitable waterbased adhesive alternative has not been found. Nashua personnel are not particularly concerned about the loss of this product, as it represents a small portion of their production volume (approximately ten percent of current sales).

In general, Nashua has found that the end product manufactured with waterbased adhesives can be more robust for Nashua's applications than that manufactured with solvent-based adhesives. While the end product may be superior with waterbased adhesives, the process of coating those adhesives is much more cumbersome. Nashua personnel are convinced that the increases in end product quality justify the more troublesome production process associated with waterbased adhesives.

6.3 Ensuring Quality

Since the conversion to waterbased adhesives began, Nashua has been improving its methods of ensuring the quality of its products. Until the late 1980s, when Nashua used primarily solvent-based adhesives, the company employed a Quality Control (QC) method of ensuring product quality. With this method, Nashua often tested a wet adhesive in its laboratory before its use in production. Nashua's current on-site laboratory has assumed more of a Quality Assurance (QA) function. Nashua's waterbased adhesives are, for the most part, already formulated when they arrive from the adhesive manufacturer. Nashua takes samples from the adhesive supply to determine if the adhesives perform according to the manufacturer's claims and within Nashua's limits. This is accomplished by applying the adhesive to a substrate in the laboratory on a bench scale coater and testing various adhesive parameters, such as peel adhesion and tack. A sample of adhesive is run through an infrared spectrometer, which is capable of determining if the adhesive has the correct chemical structure. This is an important test, because

in the past, Nashua has received bulk shipments which were discovered to be the wrong adhesive. According to Nashua personnel, Nashua's revised methods of laboratory QA have been highly successful in ensuring adhesive quality.

With the shift towards QA, Nashua has enabled its laboratory to become more involved with research and development of waterbased adhesives. Nashua stays abreast of new developments in waterbased coating technology and is continually searching for potential product improvements. Nashua is also conducting research that would allow the facility to formulate its own adhesives in the future. According to Nashua personnel, when solvent-based adhesives were prevalent at Nashua, the laboratory was viewed as an added expense in the business. Nashua now considers its laboratory an important tool in the continuing success of its waterbased adhesive-coated products.

CHAPTER 7
PROCESS EMISSIONS AND WASTE STREAMS

7.1 General

Nashua personnel have stated that the primary purpose of the company's conversion to waterbased adhesives was to ensure compliance with future federal and state regulations. The conversion has caused changes in Nashua's waste streams and other emissions. This chapter discusses environmental issues related to the conversion.

7.2 Changes in Waste Stream Generation and Emissions

Most of Nashua's waste streams and emissions are expected to decline to negligible levels when conversion to waterbased adhesives is completed, replacement of current cleaning solvents (*i.e.*, toluene and TCA) is effected, and elimination of the solvent-diluted silicone release coat is achieved. Wastewater discharges are the only waste stream expected to increase. Process air emissions from the solvent-based adhesives through the oven on Line 1 will be completely eliminated in this conversion process. Non-process air emissions such as cleaning and fugitive leaks from toluene and TCA storage and handling are also expected to be eliminated. This section discusses the quantifiable impact of conversion on air emissions, hazardous waste generation, wastewater discharges, and solid waste.

7.2.1 Air Emissions

To quantify the air emissions differential at Nashua, stack and fugitive emissions of toluene and TCA were compared from pre-conversion to expected levels after conversion. Nashua strives to leave less than one percent solvent in its final coated product; however, this amount will be neglected for the following crude analysis of Nashua's annual toluene emissions. Before conversion, Nashua estimated its stack and fugitive emissions of toluene at 1,500,000 pounds per year after control. After conversion, Nashua expects that toluene emissions will be zero from the adhesive coating process and minimal from cleanup operations. (Toluene

used in cleanup operations will be replaced as soon as a viable alternative is found.) Before conversion, stack and fugitive TCA emissions were approximately 60,000 pounds per year. After conversion (when TCA cleaning requirements are reduced), Nashua expects that TCA air emissions will be negligible. Some TCA may be used as a final wipe on the coating head after cleaning until a suitable replacement is found.

The less than 0.5 percent concentration of ammonia present in waterbased adhesives has caused increased concern because of the Occupational Safety and Health Administration (OSHA) regulations concerning worker exposure to ammonia. Testing and personnel monitoring will be continued to ensure worker safety.

Nashua personnel stated that the particulate material (PM-10) emissions from their boiler operations should remain about the same after conversion. Demand on its boiler output should not change significantly. However, personnel indicated that if PM-10 emissions became a problem, control equipment may be added.

7.2.2 Hazardous Waste

Before conversion, Nashua recovered toluene emissions from the oven via a carbon adsorber. This recovered toluene was then sent to an incineration company who used the solvent for fuel blending. Nashua estimated that it sent 30 55-gallon drums per month to the incinerator before conversion. After conversion, it expects to send about one 55-gallon drum of toluene waste monthly to the incinerator, if no replacement is found.

TCA hazardous waste shipments should remain about the same after conversion as before, approximately one to two 55-gallon drums per month. The reason for this is that before conversion Nashua recycled approximately 90 percent of the TCA they used for cleaning purposes. Due to the reduction in TCA usage, Nashua will no longer recycle TCA and all spent TCA will be disposed.

7.2.3 Wastewater

Nashua's wastewater disposal methods have changed as a result of the conversion. Nashua generates wastewater from cleaning operations and waste waterbased adhesive.

Originally, only Line 3 operations (which have always been waterbased) resulted in process wastewater. Solvent-rich effluent from Lines 1 and 2 were collected via a drainage system and stored in waste tanks until shipment off-site as hazardous waste. Wastewater shipments have increased as Nashua has brought more waterbased products on-line. Nashua officials were unable to quantify wastewater discharge differences before and after conversion although they stated that the amount generated has increased.

Nashua engineers stated that officials at the local POTW are very receptive to its wastewater because it has a high in biological oxygen demand (BOD) and provides excellent organics to break down sewage from other city wastes. However, in the future, Nashua expects that the POTW will not as readily accept its high-BOD wastewater as stricter environmental regulations lower the amount of organics that can be released to the sewer. Nashua personnel noted that a minuscule amount of organics will always be present in its waste adhesive resulting from the concentration of broken down chains of acrylate polymers produced during polymerization of the waterbased acrylic formulation.

7.2.4 Solid Waste

Nashua engineers indicated that they do not expect the amount of solid waste to increase due to the conversion. Most of the company's solid waste consists of waste coated paper which is currently not recyclable. Nashua's total hazardous waste shipment volume has been reduced, since the paper originally coated with solvent was sent off-site as hazardous waste, but as a result of the conversion, can now be landfilled. Other wastes, like solid waste generated during cleaning operations (*e.g.*, brushes, rags) can be landfilled when contaminated with waterbased adhesives, whereas solvent-based adhesive cleaning waste must be disposed of as hazardous waste.

7.3 Waste Disposal Costs and Savings

Nashua expects to decrease its emissions and disposal costs by decreasing permitting requirements, lowering insurance costs, and reducing hazardous waste disposal costs. Future air permit expenses will be reduced after the changeover. Beginning in November of 1993, the State

of Nebraska will begin charging industrial facilities $25 per ton of hazardous emissions. This change is in conjunction with requirements set forth in the CAAA. Nashua will avoid this cost due to their process conversion to waterbased adhesives. The paperwork and man-hours required to develop an operating permit will also be significantly reduced for its coating operations.

Additional savings will result from a reduction in hazardous waste disposal paperwork and associated man-hours. Also, the reduction in volume of hazardous waste generated (especially toluene) by Nashua will result in significant savings. A 55-gallon drum typically costs $25 to $50 per drum to ship off-site and a minimum of $100 to $600 to dispose of, depending on its contents. Assuming a typical shipping and disposal cost of $180 per drum, a total of approximately $62,000 could be saved per year in toluene disposal.

Some of the savings in hazardous waste shipments would be offset by the increased volume and cost of wastewater piped off-site. Nashua stated that sewage disposal costs are much higher in the Omaha area than the cost of city water. Nashua estimated wastewater disposal costs at about $350 per week greater than pre-conversion costs. Assuming a 50 week work year, additional wastewater disposal costs amount to $17,500.

Concern over leaking USTs is another potential environmental problem that is eliminated by the conversion to waterbased adhesives. The conversion to waterbased adhesives will ensure that no potentially expensive underground solvent leaks occur and contaminate groundwater.

Nashua does not expect its solid waste disposal costs to change significantly after the conversion. Some incremental costs may decrease since adhesive-coated solid waste will no longer be considered hazardous and can be landfilled. By decreasing the volume of hazardous waste generated, Nashua has been able to redistribute its waste disposal costs from hazardous to nonhazardous solid and liquid wastes. After Nashua has found new cleaning agents for its waterbased adhesives, the disposal costs of their current cleaning solutions (toluene and TCA) will decline further or be eliminated. Depending on the volatility and hazard of its new cleaning agents, a further reduction of hazardous wastes such as cleaning tool washing and cleaning rags may be possible.

CHAPTER 8
SUMMARY AND CONCLUSIONS

8.1 Characterization of Success/failure of Process Conversion

Nashua's conversion to waterbased adhesives can generally be characterized as highly successful, as the company is very close to achieving its goals of solvent-free operations while maintaining profitability. There are several attributes of Nashua's operations, all previously discussed in this report, which have facilitated conversion to waterbased adhesives:

- Nashua's production lines generally operate in a dedicated mode.
- Nashua manufactures products aimed at commodity market sectors.
- Nashua has allowed a relatively long time (approximately six to seven years) to fully effect the conversion.
- Nashua had significant experience using waterbased adhesive coatings before the conversion began (approximately five years).
- Nashua management planned and initiated the conversion, and have continued to provide their full support.

In Nashua's experience conducting the waterbased conversion, it has also identified numerous impediments to solvent-based adhesive product manufacturing including:

- There will be future regulatory costs of stack and fugitive emissions of solvents.
- There is a potential for solvent leaks or spills and associated costs.
- There are inherent dangers of solvents (*e.g.*, explosivity, combustibility, noxious fumes) and resulting monitoring and precautionary costs.
- Expensive maintenance of its solvent-recovery system is required for solvent-based manufacturing.
- There is a lack of current research into improvement of solvent-based adhesives.

Nashua also noted numerous advantageous qualities possessed by waterbased adhesives:

- Waterbased adhesives are similar in price or cheaper than solvent-based adhesives.
- The performance levels of waterbased adhesives are fully satisfactory for Nashua's products.
- Waterbased adhesives do not contain high levels of hazardous materials (*e.g.*, solvents).
- Research and development into waterbased adhesives is significant and continuing.
- There is potential for expansion into new markets with waterbased adhesive-coated products.

Prior to implementing the conversion to waterbased adhesives, Nashua understood that there would be associated negatives, including:

- There is an increased capital cost of new equipment for waterbased adhesive storage, transfer, and coating application.
- There are associated personnel training costs.
- Finding and testing waterbased adhesive coatings that meet internal and external performance criteria is time-consuming and costly.
- There are potential difficulties in the implementation of the conversion of a product line (*i.e.*, marketing considerations).
- There is the potential for the loss of some product lines and market niches.
- The costs of removal of equipment used for storage, transfer and coating of solvent-based adhesives are significant.

Nashua personnel indicate that the conversion to waterbased adhesives has been successful on several levels. First, Nashua has found waterbased adhesives that can successfully compete with solvent-based adhesives for its applications. Second, Nashua has converted most of its operations already, and has remained profitable during the conversion period. Third, Nashua is removing itself from future hazards and costs associated with solvent-based adhesive use.

Finally, Nashua personnel strongly feel that their company has moved towards a more environmentally sound means of production, above and beyond monetary considerations.

8.2 Technology Transfer Opportunities

While Nashua's conversion to waterbased adhesives has been successful, the keys to the success of the conversion, which were delineated in the first series of bullets in this chapter, apply specifically to Nashua. Other plants and manufacturers may find uses for waterbased adhesives if they have similar operations. Other manufacturing processes, such as batch operations or specialty product manufacturing, might be less amenable to conversion. Conversion opportunities for different companies and plants must be considered individually. However, Nashua's successful conversion certainly demonstrates that waterbased adhesives have market potential.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before compl

1. REPORT NO. EPA-600/R-95-011c	2.	
4. TITLE AND SUBTITLE Solvent-Based to Waterbased Adhesive-Coated Substrate Retrofit, Volume III: Label Manufacturing Case Study: Nashua Corporation		5. REPORT DATE December 1995
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Beth W. McMinn, W. Scott Snow, and Dan T. Bowman		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS TRC Environmental Corporation 6340 Quadrangle Drive, Suite 200 Chapel Hill, North Carolina 27514		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-D2-0181, Task 2/017
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Air Pollution Prevention and Control Division Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED Final; 11/92-6/93
		14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES APPCD project officer is Chester A. Vogel, Mail Drop 61, 919/541-2827. This series includes five volumes.

16. ABSTRACT This volume discusses Nashua Corporation's Omaha facility, a label and label stock manufacturing facility that no longer uses solvent-based adhesives. Information obtained includes issues related to the technical, economic, and environmental barriers and opportunities associated with the use of waterbased adhesives. Specific objectives of the visit were to collect information necessary to characterize Nashua's market profile, manufacturing supplies, manufacturing process profile, environmental issues, and waterbased adhesive coating experience, as well as the limitations of waterbased adhesive coatings. The case study report consists of eight chapters. Chapter 1 gives background information related to Nashua's conversion efforts, including market profile, process description, and a general description of its conversaion efforts. Chapter 2 identifies Nashua's motivations for converting its solvent-based operations to waterbased adhesives. Chapter 3 briefly describes the marketing factors that affected the process conversion. Chapter 4 identifies the various raw material issues, including costs, involved in the process conversion. Chapter 5 details the process equipment issues of the conversion, including specific equipment impacts, costs, vendor selection, and maintenance. Chapter 6 discusses the adhesive product performance requirements. Chapter 8 summaries the conclusions.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Adhesives	Pollution Prevention	13B	11A
Labels	Coatings	Stationary Sources	13D	11C
Solvents		Water-based Adhesives	11K	
Substrates			11D	
Equipment			14G	
Cleaning			13H	

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 62
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)