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Final Report

IN–PLANT DEMONSTRATION OF ENERGY OPTIMIZATION IN BECK DYEING OF CARPET

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Prepared for

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ATLANTA, GEORGIA 30332

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IN-PLANT DEMONSTRATION OF ENERGY OPTIMIZATION IN BECK DYEING OF CARPET

Final Report

Part III, Phase III Extension of
DOE Contract No. DE-A205-76CS4008

Modification No. M005

Prepared By

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I. SUMMARY

Several energy-conservative technologies have been successfully combined and transferred to a commercial carpet finishing plant to optimize beck dyeing. The technology of "bump-and-run", in which the dyebath temperature was allowed to drift for the last 85% of the hold time instead of being maintained by active steam sparging, reduced the energy consumption by 38% with negligible capital investment required. Merging of dyebath reuse with bump-and-run only marginally increased the energy consumption (to 39%), but substantially lowered the plant's finishing costs further by directly recycling dyes, auxiliary chemicals, and water. Final optimization, which merged a technique whereby the carpet was pulled directly from the hot bath with bump-and-run and dyebath reuse, further improved the economics by drastically reducing water/sewer requirements by 90% and eliminating the holding tank/pumping assembly as a reuse requirement.

Combined energy/materials savings achieved by the full optimization totaled 2.3 cents per pound of goods, with an estimated return of raw capital investment of 6.6 months for application to 8 of the plant's 14 becks with the holding tank/pumping system approach. By combining the hot pull technique with the other modifications, which depends on receiving adequate rinsing in the wet out box already being utilized by the plant before drying, the return period on capital investment is negligible. In the latter case, greater than \$400,000 in savings can be realized by the plant in the first year of implementation of the modifications on the 8 becks.

From a carpet industry viewpoint, the demonstrated modifications have a direct energy conservation potential of 2.4×10^5 barrels of oil equivalent per year assuming the technology is directly transferable to similar atmospheric dyeing processes, e.g., beck dyeing of nylon and polyester fabrics, the potential to the entire textile industry is 2.6×10^6 BOE/year. Indirect energy conservation potential of a undetermined quantity is also inherent in the optimized process via reduced dye, auxiliary chemical and water requirements. Finally, the successful merging of the hot pull technique with the other modifications dictated a water/sewer conservation potential of 2.7×10^9 gallons per year for carpets and 2.3×10^{10} gallons per year including the allied fabric industry.

Economically, total potential savings for the carpet industry on reuse incorporation was $\$1.2 \times 10^7$/year, based on the 2.3¢/lb. savings figure. When the allied fabric industry was included, the national potential was raised to $\$1.0 \times 10^8$/year. These figures includes cost savings due to materials recycled (water, auxiliary chemicals and dyes) as well as energy conservation.

Salem Carpet Co. has expanded bump-and-run over the plant's entire nylon beck production, and is evaluating the process modification on its carrierless polyester production. Studies are also underway to evaluate the rinsing efficiency of the wet-out box for plant incorporation of the hot pull technique, and alternate engineering/economic plans are being derived to incorporate dyebath reuse by the holding tank/pumping system approach if necessary.

II. INTRODUCTION

Data collected in Phase I of DOE Contract Number DE-AS05-76CS40081 revealed that 240 million pounds of nylon and 165 million pounds of polyester are dyed in carpet form on atmospheric dyebecks[1]. An average of approximately 13,000 BTU/pound of goods of steam energy is consumed during a typical carpet beck dyeing cycle, or 9.1×10^5 barrels of oil equivalent (BOE) consumption per year. Atmospheric becks are heated by direct steam injection. Undissipated steam and hot water vapor are removed in bulk during the hold cycles at the boil by an exhaust system. The system, consisting of a stack, damper, and fan is required to prevent steam from escaping into the work area during the hold cycle. Radiation/convection losses from the uninsulated, high surface area machines add to the stack losses to further increase energy consumption and lower efficiency. Many installations familiar to the investigators have inadequate, unmaintained (and thus inefficient) or no heat exchangers applied to hot water drains, and therefore considerable energy is also wasted in the form of hot process water. Pollution treatment costs, water costs, unexhausted chemical costs, and the energy inherent in supplying these services and materials are also considerable due to the conventional practice of draining hot dyebaths to the sewer after each dyeing cycle.

Nylon carpet dyeing processes are particularly narrowly defined from a chemical viewpoint. Quite often long color lines are derived from the same three dyes, with a yellow, a red, and a blue colorant usually included in the formulation. Both Nylon 6 and Nylon 66 fiber types are utilized. Although both acid and disperse dye classes are employed to color nylon carpet, acid dyes are most widely used due to their superior light fastness properties.

The dyebath auxiliary chemicals in nylon acid dyeing, consisting of leveling agent, pH control agent, defoamer, and sequesterant are not appreciably substantive to the fiber, and can thus be reused without hindering the dyeing behavior.

In summary, the nylon carpet dyeing process was an ideal candidate for adapting energy-conserving process modifications. Optimization of the beck dyeing process in the reported demonstration included the modifications of bump-and-run, dyebath reuse, and hot pull. The demonstration project was conducted at the Chickamauga, Georgia, finishing plant of Salem Carpet Company.

The concept of bump-and-run evolved from earlier interests in dyeing nylon carpet at low hold temperatures ($\sim 140^{\circ}F$). To exhaust the dye onto the fiber at this low a temperature, however, additional new chemicals had to be added to the dyebath to "open up" the polymeric structure. Unfortunately, cost/benefit analyses revealed that in at least one of the low-temperature processes being investigated by industry, the added chemical costs more than offset the energy savings realized by dropping the hold temperature from the boil.[2] In addition, the $140^{\circ}F$ temperature was not sufficiently above the wet glass transition temperature of the nylon to fully develop the "bloom", or bulk, of the carpet, giving a poorer surface coverage and hand. For the same reason, coverage of yarn streaks caused by fiber nonuniformities was also a weakness of dyeing at $140^{\circ}F$.

The concept of bump-and-run, first expoused by Mr. John J. Toon of Piedmont Chemical Company, avoids several of the drawbacks associated with $140^{\circ}F$ processes. Phase I had shown that approximately 49% of the total energy consumed in beck dyeings was lost to the atmosphere via the stack, with the bulk lost at the boil (Figure 1). Radiation/convection losses were small by comparison, amounting to only 2% of the energy consumed. In the process of

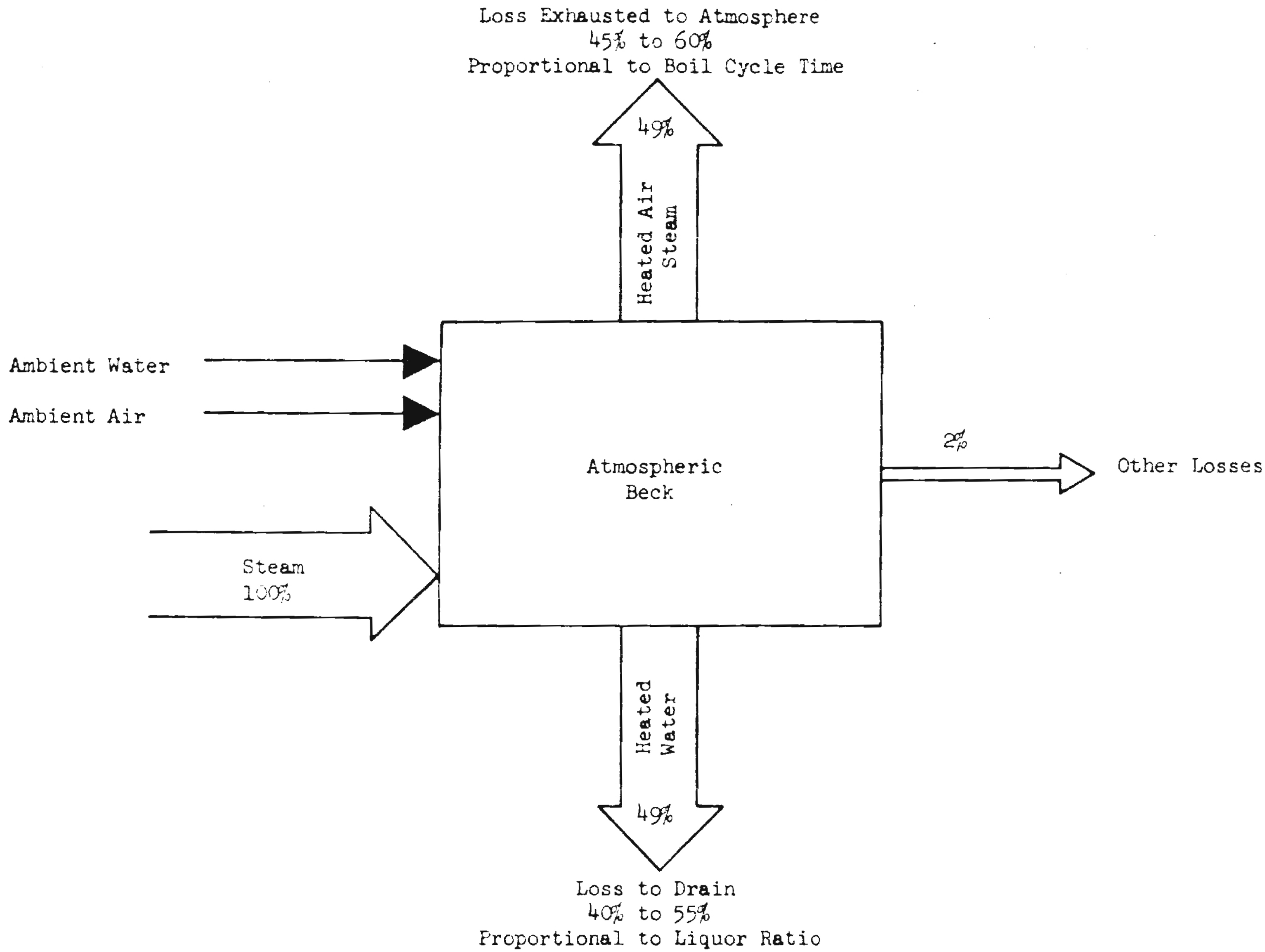


FIGURE 1. ATMOSPHERIC BECK FLOWS

bump-and-run, the stack loss at the boil is minimized while utilizing the low radiation/convection loss as an advantage. The dyebath is brought ("bumped") to the boil in the usual manner, and maintained at the boil for five minutes to level-out the dye. Steam injection is then terminated, the stack fan is cut off and the damper is closed (by controls at the beck), and the beck doors (or curtains) are closed. In effect, the beck is converted into a closed kettle during the remaining 25 minutes of the conventional 30 minute hold cycle with the temperature allowed to drift during the time period (the "run" portion of the modification). Little temperature is lost during the drift period, with experience dictating an approximate drop of $20^{\circ}F$ from the boil. The remainder of the cycle is the same as with conventional processes. As an added benefit, the <u>same chemicals</u> as utilized in the conventional process are adaptable to the bump-and-run modification.

Based on its energy savings potential, ease of adaptation, use of conventional chemicals and bloom characteristics, bump-and-run was selected as the initial process modification to quantify in the plant demonstration. Following ten conventional runs monitored to generate baseline data, ten runs were conducted and monitored with the incorporation of bump-and-run as the only variable.

The next modification, termed dyebath reuse, was designed to reduce the 49% of the energy that is traditionally released to the sewer in the form of hot water (Figure 1) that is not affected by bump-and-run. In the conventional beck dyeing process, the hot bath is discharged to the drain when the correct shade is obtained. If the dyebath is examined before and after the dyeing cycle, two major changes have occurred. First, most of the dye has been removed from the bath by the carpet, and second, the bath is hot rather than cold. In acid dyeing of nylon, the auxiliary chemicals added to the bath are still present in the same condition as they were at the start of the dyeing cycle. When the dyebath is discharged to the drain, large quantities of energy, water and useful chemicals are thus lost. In the procedure demonstrated in the reported project, the spent dyebath was analyzed for the remaining dye, the bath was reconstituted to the desired strength and reused for subsequent dyeings. The energy, water and chemical savings were quantified.

A number of technical problems required solution in pilot-scale research before dyebath reuse could be broadly applied in commercial batch dyeing[1]. First, an analytical system had to be developed to simply, accurately, and economically determine the concentration of dyes remaining in the bath. The analytical techniques had to be compatible with existing dyehouse personnel, space, time, and equipment constraints. Second, dyeings had to be started at elevated temperatures (150^{o}-170^{o}F). The increased rate of dye adsorption from the bath at these temperatures had the potential of leading to spotting and poor levelness in the recycle dyeings. Third, materials handling procedures had to be worked out to give scouring, dyeing, and rinsing cycles compatible with current plant operating procedures. Fourth, evaluation procedures were required to insure that dyeings in recycled baths were equivalent in quality to conventionally dyed-products.

The first key to reusing dyebaths was to develop a simple, but accurate, analysis procedure. The very strong absorption of dyes in the visible region of the spectrum provides the simplest and most precise method for determination of dye concentration. The absorbance, A, of a dye solution can be related to the concentration by the modified Lambert-Beer equation:

$$A = \log I_o/I = Kc$$

where $\underline{I_o}$ is the intensity of the visible radiation falling on the sample, $\underline{I}$ is the intensity of the radiation transmitted by the sample, $\underline{K}$ is a constant including the path length of radiation through the sample and a constant related to the absorptivity of the sample at a given wavelength, and $\underline{c}$ is the concentration of the absorbing species. In mixtures of absorbing species, the total absorbance at any wavelength is the sum of the absorbances of each species and is given by:

$$A_\lambda = K_1c_1 + K_2c_2 + K_3c_3 \cdots + K_nc_n$$

The additive characteristic of light absorption by dyes was important in the analysis of dye mixtures of the type found in spent dyebaths. For such dye mixtures, the absorbance can be measured at a number of wavelengths and the concentration of the dyes determined by simultaneous solution of a set of linear equations of the type shown above. The wavelengths selected for the analysis are generally those for which one of the dyes gives a maximum in absorbance.

Use of the Lambert-Beer relationship requires, of course, determination of the $\underline{K}$ values for each dye at every wavelength used in the analysis. The $\underline{K}$ values were determined by preparing various parts-per-million (ppm) standard solutions of the dyes and measuring the absorbances of the standard solutions on a UV-visible spectrophotometer. The $\underline{K}$ values were obtained from a least-squares fit of the absorbance versus concentration data by a linear equation of the form:

$$A = Kc + B$$

For all dyes used in this work, $\underline{B}$ was essentially zero and regression coefficients indicated that the equation gave an excellent fit of the data. Most of the analyses in the plant demonstration were conducted in this manner.

The final modification, termed hot pull, was investigated as the crowning achievement in the beck optimization. After bump-and-run and dyebath reuse had been merged, the hot pull technique was incorporated to assess the elimination of the requirement for holding tanks and pumping systems. Basically, the modification called for simply pulling the hot carpet directly out of the spent dyebath, leaving the water in the beck and eliminating the drop to the holding tank. To facilitate the hot pull, the plant personnel were supplied with gloves for handling the carpet and beginning the exit over the beck reel. Since bump-and-run was included in the final series, the dyebath had cooled to between 180°-190°F by cycle end, which further facilitated the hot pull technique as long as gloves were used. Final rinsing of the carpet was accomplished in the wet-out box positioned before the entrance to the continuous plant dryer. Each plant prewets the carpet after straightening and before drying to insure uniform side-to-side and end-to-end moisture uniformity. Such uniformity is critical to avoid streaks and other dyeing imperfections caused when the carpet is thermally "shocked" upon entering the 350°-450°F dryer, initiating dye migration.

The analysis scheme had to be altered to accomodate the hot pull. Salem Carpets, due to problems in yarn lot control from the tufting plant, employs a heavy, water-removable tint on all of its greige carpets. In the preceeding sequence combining bump-and-run and dyebath reuse, the dyebath had been pumped to the holding tank and the dyed carpet had been after-rinsed in the beck in the usual fashion. The incoming carpet had been entered into and prerinsed under ambient conditions in the bath left from the previous run, and the rinse bath then dropped. The prerinse did not penalize the energy and material consumption while providing two benefits: 1) the carpet was wet-out, lowering fresh water requirements in replenishing the incoming dyebath from the holding tank, and 2) the prerinse removed the bulk of the tint from the carpet. The latter was especially important, as the analysis as described above was based on a spectrophotometric determination of the dye concentration in the visible region, and any colored impurities such as the tint would have had a detrimental effect on the accuracy of the dye determination. During the pilot scale research, it was discovered that the acid dyes were extractable into octanol, whereas the tints were not. Extraction of the dyebath sample with octanol therefore allowed an analysis layer that contained the dye, but was free of the tint. The prerinse requirement was thus eliminated, and the hot pull technique became feasible.

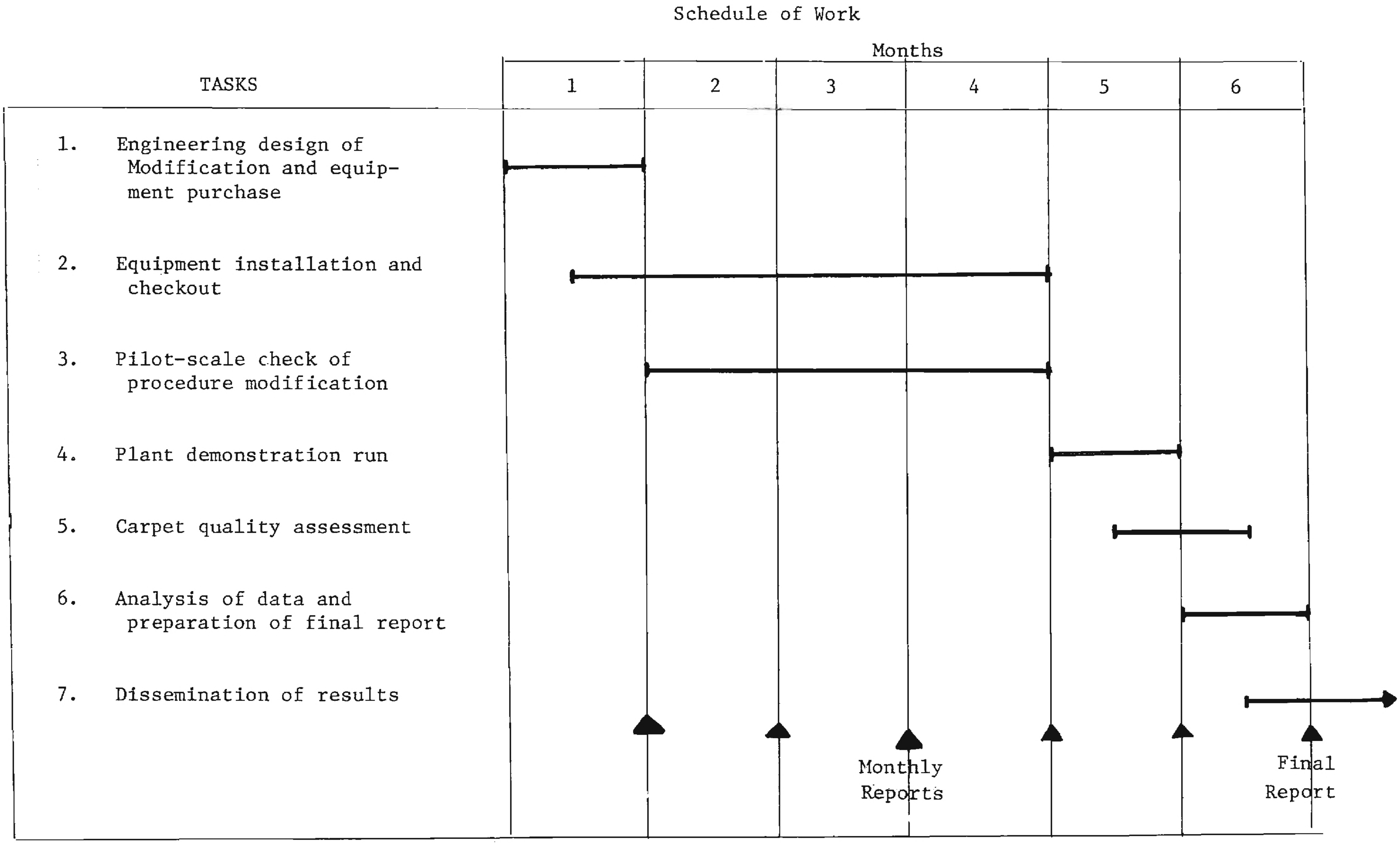
Accurate analysis for dyebath components other than dyes (auxiliary chemicals) was not required. The dyebath additives controlled the dyebath environment and were not used up or removed during the dyeing cycle. The exception was ammonia, which was partially steamed out of the dyebath during the hold cycle. These components were added to the reused baths in direct proportion to the quantity of make-up water required between dyeings, with the exception of ammonia which was added in larger percentages. Since the volume of fresh water added to each dyebath was held constant during each reuse sequence, the auxiliary replenishment was fixed for each cycle.

The uniformity of the reuse-dyed carpet was assessed by selecting representative samples from the dyed goods and determining the color (tristimulus values) on a ACS 400 Color Computer System. The difference in color between each specimen and the average color values of all the samples dyed to that shade was determined using the CIE L* a* b* and FMC II color difference formulas. In the latter system one MacAdam Unit of color difference is defined as the minimum perceptible difference in color. Off-shade dyeings could therefore be readily identified by variations in color difference from the average color values. In addition to instrumental measurements, samples dyed by the reuse procedure were examined visually by the plant dyers and quality control personnel to further assess the color uniformity and color reproducibility.

The industrial partner in the demonstration was Salem Carpets of Chickamauga, Georgia. Salem is a large carpet manufacturing firm ($100 MM annual sales) with a well established reputation for innovation in carpet processing. The overall goal of the reported project was to evaluate and optimize the energy/material consumption of the beck dyeing process over a 50-cycle plant sequence. The compilation of the different technologies incorporated in the internal dyeing sequences within the 50 cycles actually conducted is located in Appendix 1. Approximately 41 tons of carpet were dyed during the demonstration, with 33 tons dyed by modified processes. Complete energy, material and time consumptions were obtained on both the conventional and modified processes. From the data, a detailed cost/benefit analysis was performed to arrive at recommendations to Salem for plant expansion of the technology.

The project consisted of seven (7) major tasks. The tasks and the project work schedule are shown in Figure 2.

Figure 2. TASKS AND WORK SCHEDULE



III. EXPERIMENTAL RESULTS AND DISCUSSION

A. Equipment, Chemicals and Goods

The lists of analytical, computer and engineering equipment required for the project, along with the necessary ordering information, are contained in Appendix 2. Dyes and auxiliaries were purchased from a number of vendors as part of Salem's usual material supply procurement. The greige carpets were randomly selected from Salem's production of the "Jaunty", or closely-related styles. Fiber type varied randomly from Nylon 6 to Nylon 66, with the bulk of the carpet dyed during the project consisting of the former.

B. Engineering Design and Modification

Conducting the in-plant demonstration required modifications to Salem Carpet's dyeing plant facility. The purchase and intallation of capital equipment and the modifications to existing equipment were made by Salem Carpets with the recommendations of the Georgia Tech researchers. The design drawings that were submitted to Salem Carpets are shown in Figures 4 through 9 of this report, while the recommended equipment list is contained in Appendix 2. The equipment and systems as used during the in-plant demonstration are discussed below.

1. Atmospheric Dye Beck

The atmospheric dye beck used for the in-plant demonstration is shown schematically in Figure 3. The stainless steel beck is typical of the atmospheric becks used by the carpet industry for batch dyeing. A stainless steel sheet with one-inch holes punched on approximately four-inch-centers is used to separate the front of the beck from the rest of the beck where carpet is located. Sparged steam, water, dyes, and auxiliary chemicals

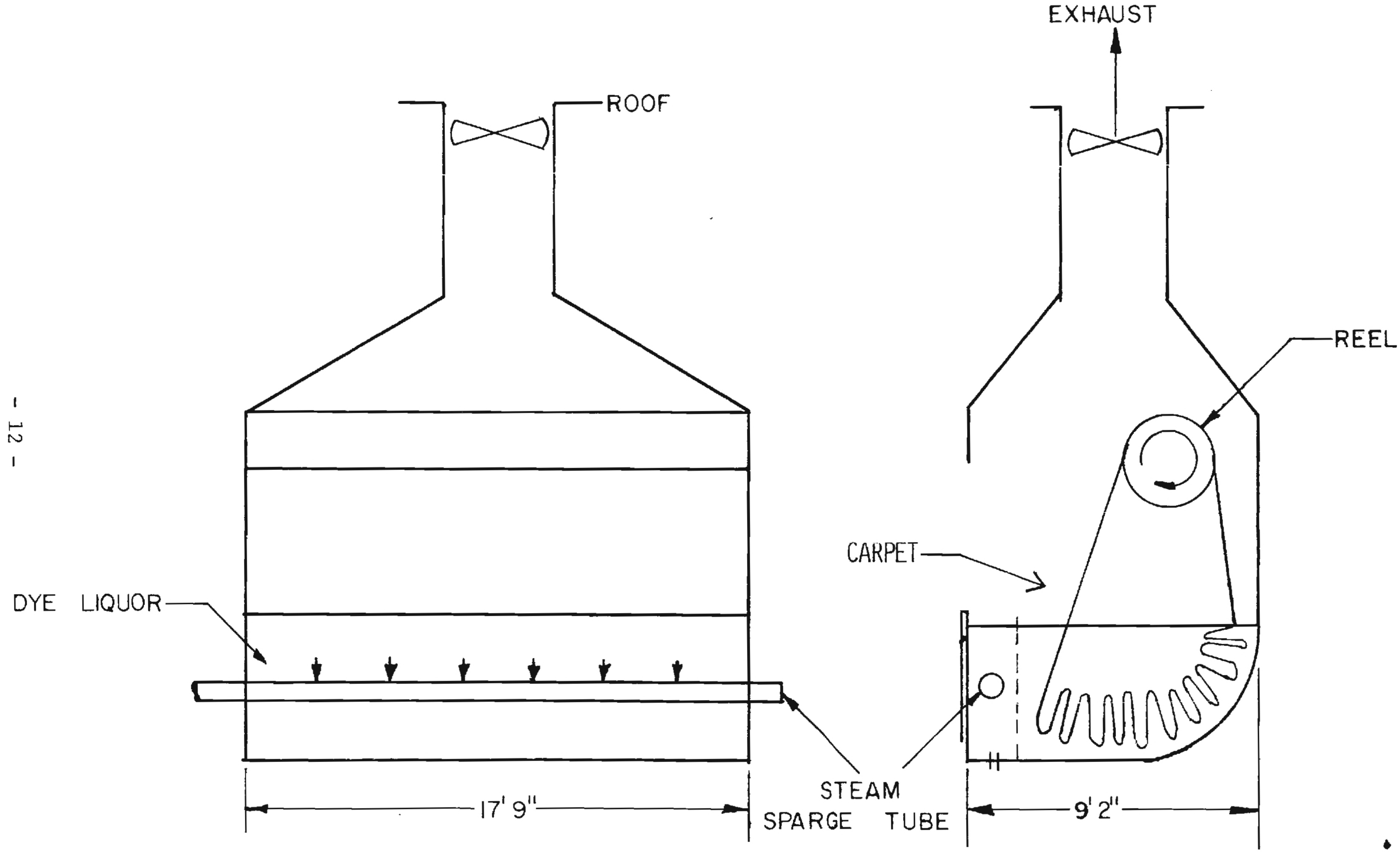


FIGURE 3. SCHEMATIC OF ATMOSPHERIC DYE BECK

are introduced into the beck in the front region.

Several modifications were made to the beck before the reuse runs were conducted. In the conventional process as operated by the carpet manufacturer, the dyes, auxiliary chemicals, etc. entered the beck at the center of the front region. A two-inch DIA, stainless-steel pipe with 1/8-inch holes spaced 6-inches apart was added so that the materials could be introduced uniformily across the front of the beck.

An overflow system shown in Figure 4 was added to the beck to provide the capability of closely regulating the quantity of dye liquor reused each cycle. The overflow system can be used to reduce the dye liquor volume to some predetermined value either before pumping to the holding tank or after returning to the beck.

A sight glass was attached to the side of the atmosphere beck as shown in Figure 5. The sight glass was calibrated to the nearest 500 gallons and was used to make various volumetric measurements needed during the demonstration run.

A spray bar was mounted across the front of the beck as shown in Figure 6 so that the hot carpet being removed from the dye beck during "hot pulls" could optionally be sprayed with cold water. The spray bar was a one-inch, black-iron pipe with 1/8-inch holes spaced three inches apart. The spring bar was found not to be needed in the hot pull process.

A strainer was fabricated to prevent large pieces of lint and strings from entering the drain pump that pumped dye liquor to the holding tank. The drain pipe between the pump and the beck was connected to the left side of the beck near the bottom of the beck and in the front region as shown in Figure 7. An enclosure around the entrance to the drain pipe served as the strainer. An 18-gauge, stainless-steel sheet with 1/16-inch holes to give a 70% open surface was used to form two sides of the enclosure. The left

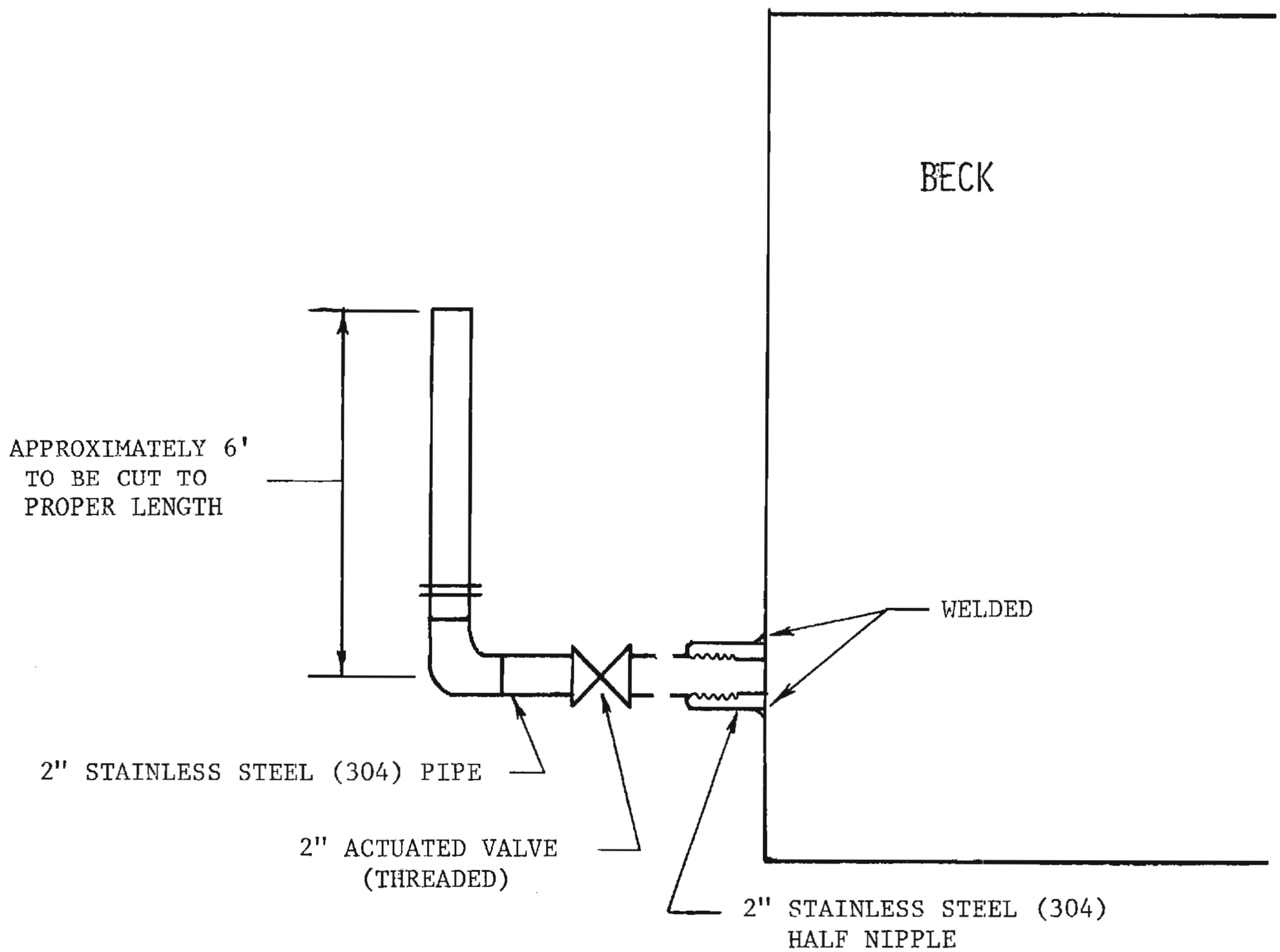


Figure 4.

OVERFLOW SYSTEM

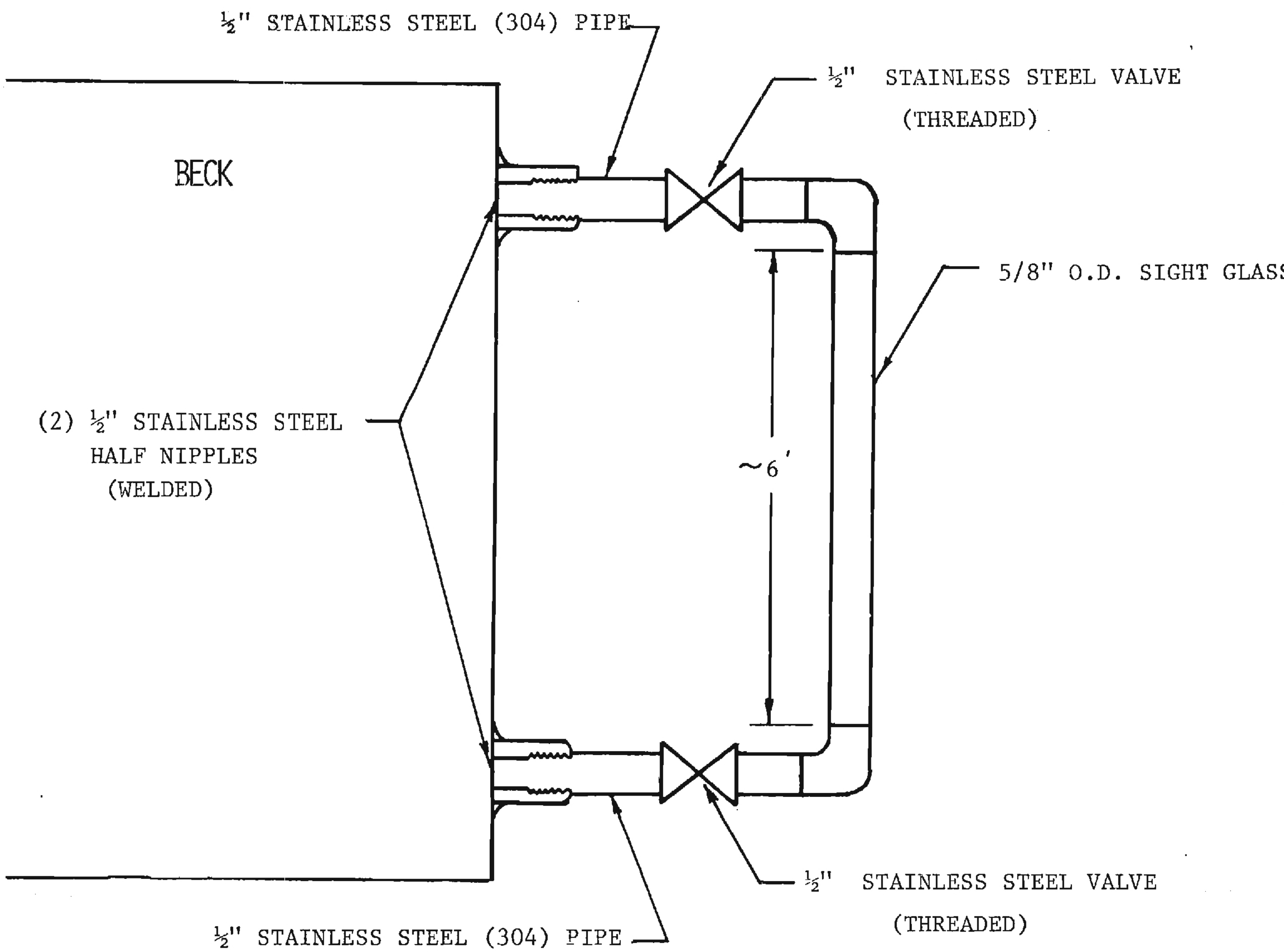


Figure 5.

SIGHT GLASS

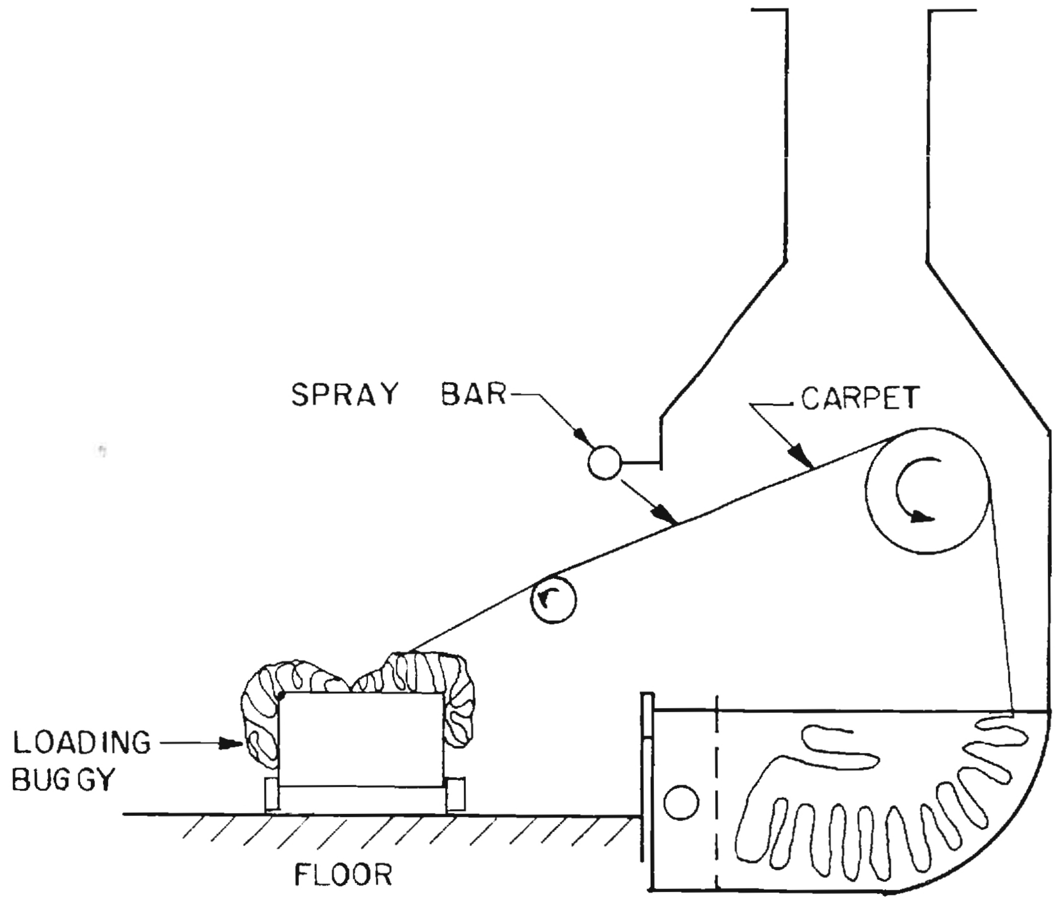


FIGURE 6. SPRAY BAR USED FOR "HOT PULLS"

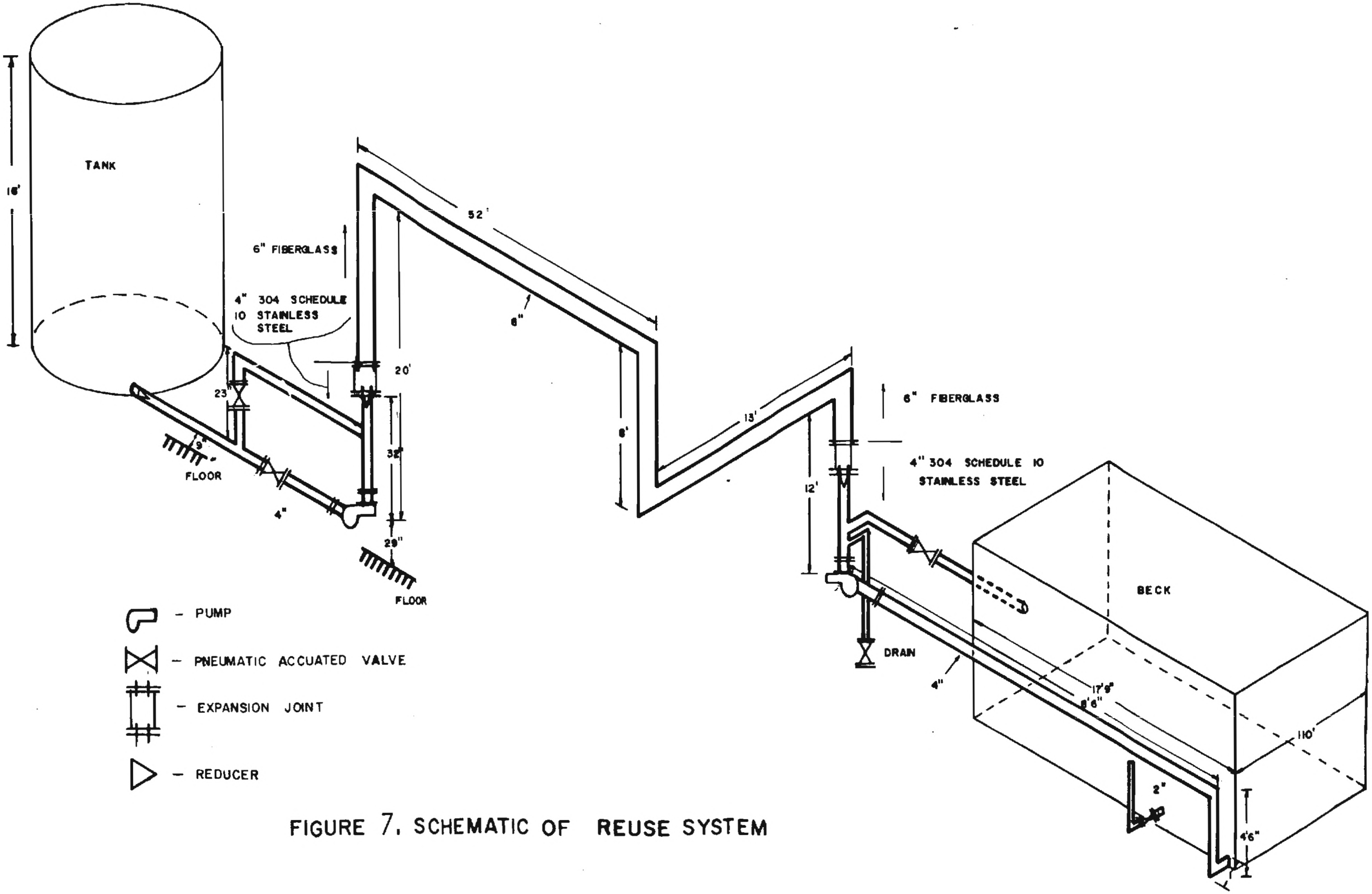


FIGURE 7. SCHEMATIC OF REUSE SYSTEM

side, front, and bottom of the beck served as the other sides of the enclosure. The stainless-steel sheet extended from the bottom of the beck to the overflow level in the beck. The holes in the stainless-steel sheet allowed the dye liquor to flow into the pipe, but at the same time kept most of the lint and strings out of the reuse system.

2. Reuse System

The reuse system is shown schematically in Figure 7. The system consisted of an uninsulated, 6000-gallon, double-wall, stainless-steel cylindrical holding tank and a pumping/plumbing system. Since the construction materials could potentially cause problems in analyzing the dyebath, the materials for the reuse system were carefully selected. Most of the components of the system were made of either 304 stainless steel or fiber glass. Several synthetic materials for the plumbing (PVC, C-PVC, polyethylene, teflon-lined) were considered, but were rejected because of either cost or low strength at the dyebath temperature. Six fiberglass pipes and fittings (2.0 mil lines) were used over most of the distance between the beck and holding tank. Expansion joints were used to isolate the fiberglas piping from the rest of the reuse system because fiberglass has very poor vibrational characteristics. Four-inch, schedule-10,304-stainless-steel pipe and fittings were used to connect the tank and beck to the pumps.

The two-inch valves in the reuse system were Figure 1660, pneumatic-actuated (PA25) Jamesbury ball valves with 316-stainless-steel body and seats. The four-inch valves were Figure 7577-1212359, pneumatic-actuated (PA50) Jamesbury butterfly valves with 316-stainless-steel body and disk and ethylene/propylene seats. The pump motor and valves were wired so that they could be controlled by two manual switches. One switch actuated the pump and valves necessary to pump the dye liquor from the beck to the holding tank. The other switch activated the pump and valves needed to return the bath to the beck.

Two Gorman-Rupp, 14-A4B gray-iron centrifugal pumps with teflon packing were utilized to pump the dye liquor to the holding tank and to return it to the beck. The trash pumps designed with open impellers capable of handling liquids containing entrained solids were used because the dye liquor contained excessive lint and string removed from the carpet during dyeing agitation. Since the time available for emptying and filling the beck was limited to less than ten minutes, the pumps were specified with the capability of delivering 500 gpm against a thirty-foot head. Stainless-steel pumps were desirable since dye liquor is corrosive; however, due to the extremely high cost of stainless-steel pumps, gray-iron pumps were used instead. No problems with dyebath analysis were caused by the gray-iron pumps. The pumps were driven by 10HP-1750 RPM, three-phase, 220 volt motors.

3. <u>Dyebath Temperature Control Device and Controller Modification</u>

The temperature controller used in the Salem Plant was a Foxboro Model 43C-H. The controller, referred to as a clock in the plant, uses pneumatic systems to obtain proportional control of steam flow to the beck, and indicates the cycle condition, rise, hold, or end of cycle by means of 7W, 110V/electric lamps (Figure 8). A modification was made to the controller involved with testing to allow for a short five minute hold period at the

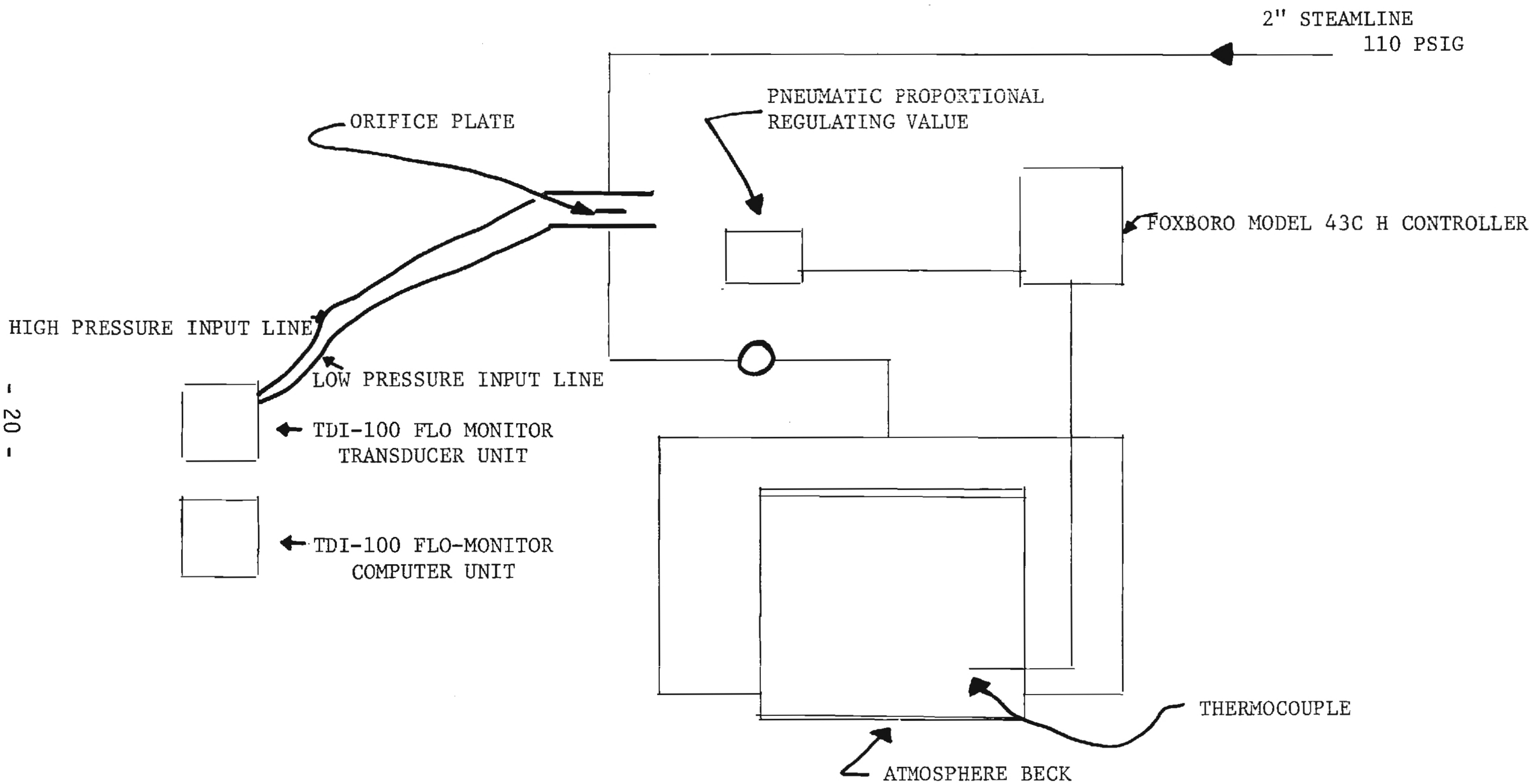


Figure 8. Dyebath Temperature Control Device and Steam Monitoring System

boil followed by a twenty five minute drift with the steam turned off prior to illuminating the end of cycle lamp, i.e., to adapt bump-and-run to the process.

The modification consisted of installation of an automatic reset timer, Omron STP-MYH-AH, and mounting base, Omron 8PF, on the wall adjacent to the controller. The circuitry simply involved breaking the wire to the end of cycle lamp and using this to energize the timer motor. The secondary timer was preset to the length of drift period up to sixty minutes. At the end of the drift period, a normally open contact on the timer was closed to illuminate the end of cycle lamp. The controller attendant performed his or her normal duties upon seeing the end of cycle light such as calling for fabric sample for shade matching. The modification avoided manual setting of the controller timer twice during each cycle, a handicap for the operator.

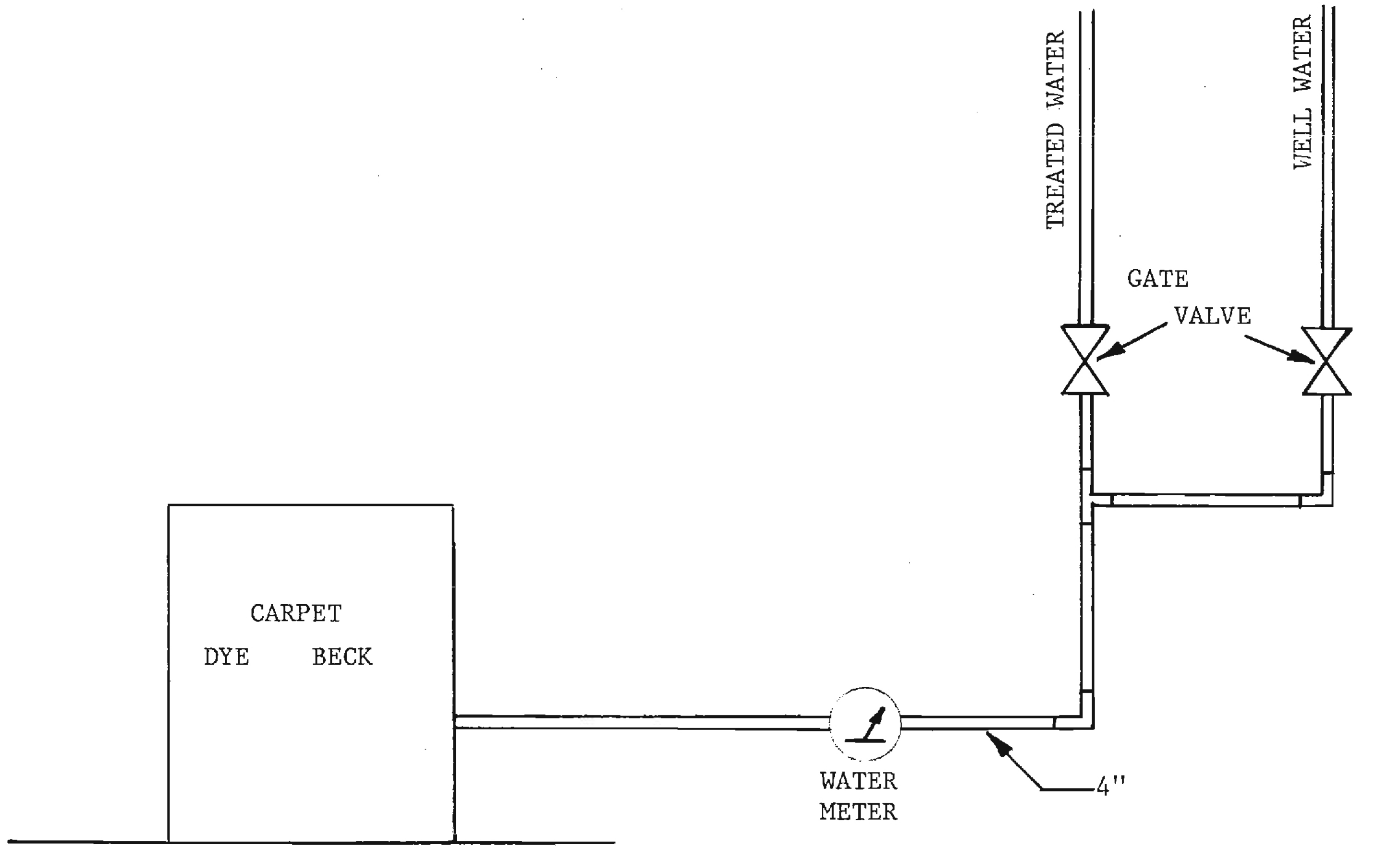
The hold period timer on the controller was settable for up to sixty minutes, and for bump-and-run was set at five minutes. At the end of the hold period as the secondary timer was energized, a second contact on the secondary timer was utilized to illuminate a neon lamp located on the timer in order that the controller attendant would recognize the drift condition, rather than assume that some malfunction had occurred. By setting the secondary timer to zero, all normal controller functions were returned to normal and the presence of the secondary timer was essentially transparent to the controller attendant. Disruption of normal plant procedure was thus avoided, facilitating personnel acceptance of bump-and-run.

4. <u>Steam Monitoring System</u>

The steam flow measurements were made using TDI-100 and TDI-150 Flow Monitors to measure the pressure drop across an orifice plate inserted into the steam line. A schematic of the steam-monitoring system is included in Figure 8. The TDI-100 and TID-150 Flow Monitors have two components: a transducer unit and a computer unit. The transducer measures the pressure drop across the orifice plate, converts the pressure drop into an electrical signal and sends the electrical signal to the computer unit. The computer unit computes the flow rate from the transducer signal and integrates the flow rate over time to give total flow. Both flow rate and total flow can be continuously read with the TDI instruments.

5. <u>Water Meter</u>

A schematic diagram of the location and orientation of the water meter is shown in Figure 9. The water meter selected for the reuse tests was a Brooks Propeller Meter Model 3312-03A31AA, which is designed to measure flow through a four-inch line. However, the four-inch Brooks water meter failed before the reuse tests were begun. The failure was caused by the large volume of lint contained in the chlorine-treated water used for many of the conventional dyeings at Salem Carpets. The cross-sectional area of the meter through which the water and lint passed was not large enough to allow the lint to pass freely. As a result, the turbine inside the meter was dislodged from its position in the line and lost. After two failures of the four-inch meter, the decision was made to test a larger water meter and to use only well water in the remaining runs, eliminating the lint. A six-inch, Kent turbine meter was installed, and was used throughout the reuse runs without any operational problems.



NOTE: WATER METER MUST BE
MOUNTED HORIZONTALLY

Figure 9. LOCATION & ORIENTATION OF WATER METER

C. Computer Interface and Programs

1. Computer Interface

The input/output interface between the Bausch and Lomb Spectronic 100 spectrophotometer and Hewlett-Packard 9815A desktop computer used for dyebath analysis at the Salem Carpets demonstration had to be constructed at Georgia Tech. The following describes the digital input/output signals for the two instruments being interfaced, and describes the interface in terms of its operation and servicing.

The Bausch and Lomb Spectronic 100 has a standard forty-four terminal double-sided printed circuit board connector on its back plane which delivers complemented BCD (binary coded decimal) output of the three low-order digits, and a fourth high-order line which switches between logic 0 and logic 1. These are parallel outputs. The output logic levels are RTL (resistor-transistor logic) compatible in terms of voltage. The three low-order digits use the definition that logic 1 is greater than or equal to 0.8 vdc and logic 0 is less than or equal to 0.4 vdc. The fourth high-order line uses the definition that logic 1 is less than or equal to 0.4 vdc and logic 0 is greater than or equal to 0.8 vdc.

The Hewlett-Packard 9815A has a BCD input/output option which permits parallel reception of ten data digits at TTL (transistor-transistor logic levels), which are that logic 0 is less than or equal to 0.4 vdc and logic 1 is greater than or equal 2.4 vdc. The input lines are used to acquire the three low-order digits and the fourth high-order bit in standard parallel BCD code. The data input is through twisted wire cable. All unused digits are held at logic 0, using a common ground (0 vdc) potential. The number of input data digits and format of these digits is controlled by internal programming of the HP 9815A, described in the "BCD Interface Manual".

The interface designed and constructed at Georgia Tech provides logic level conversion and complements the data from the B & L Spectronic 100 to provide standard BCD encoding. The design criteria were to have a high input impedance for low current demand from the RTL circuitry, to provide an adjustable threshold for the logical 0 to logical 1 transition to permit varying this setting for optimun noise immunity, and to provide a copy of the BCD output on a LED (light emitting diode) display using a BCD to seven segment TTL decoder to show that level conversion and BCD encoding were being accomplished successfully. The interface is powered by an independent 5 volt, 1 amp regulated power supply with short circuit and over-temperature protection.

The schematic diagram for one data bit is shown in Figure 10. A total of thirteen of these circuit elements are required to provide three four-bit, low-order digits and the fourth high-order bit. The differential comparator is one-fourth of a LM 339 integrated circuit. Maximum input current is on the order of five microamps. The output of the LM 339 is an open collector using the 5.8 KΩ pull-up resistor tied to the +5 vdc supply line to set standard TTL output. Operational amplifier gain of one-hundred is set by the input and feedback resistors to give rise and fall times for TTL circuitry.

Figure 11 is the power supply schematic diagram. The LM 309K is a To-3 package integrated circuit five-volt regulator with thermal overload protection and current limitation. A one-amp fuse is located in the +5 line at the inter-

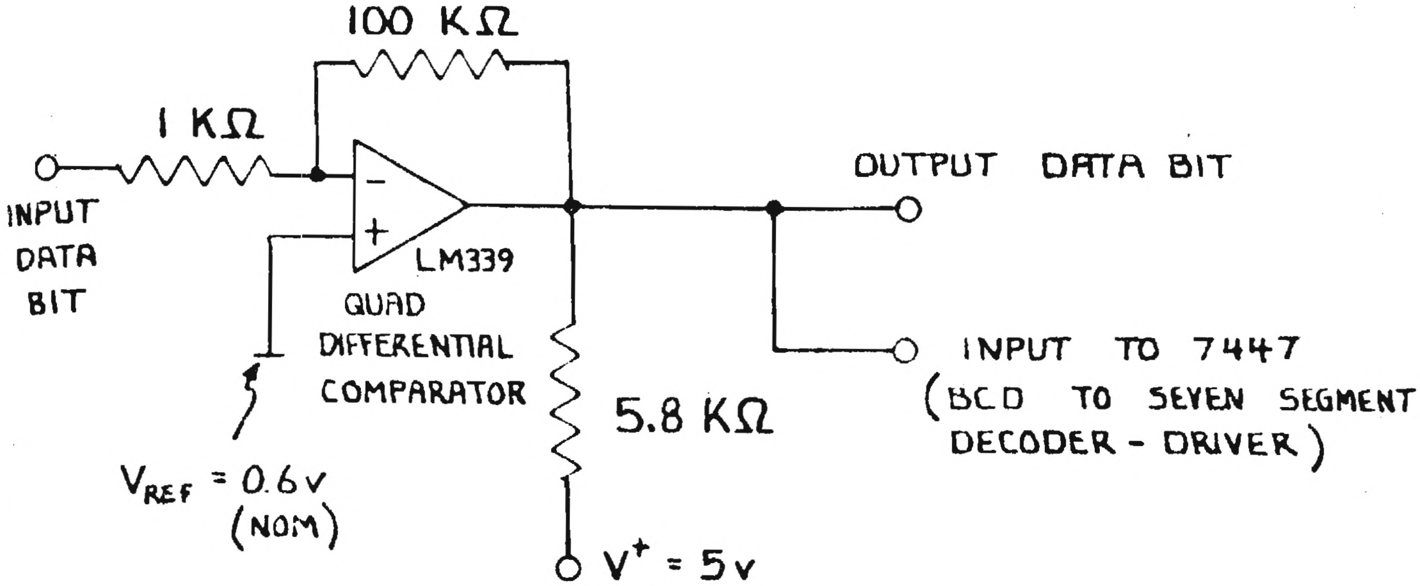
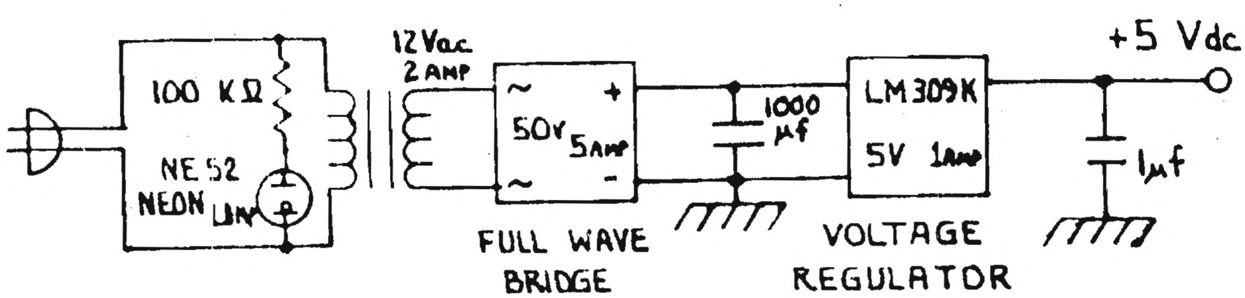


Figure 10. Single Bit Level Conversion Schematic (Total Required = 13)



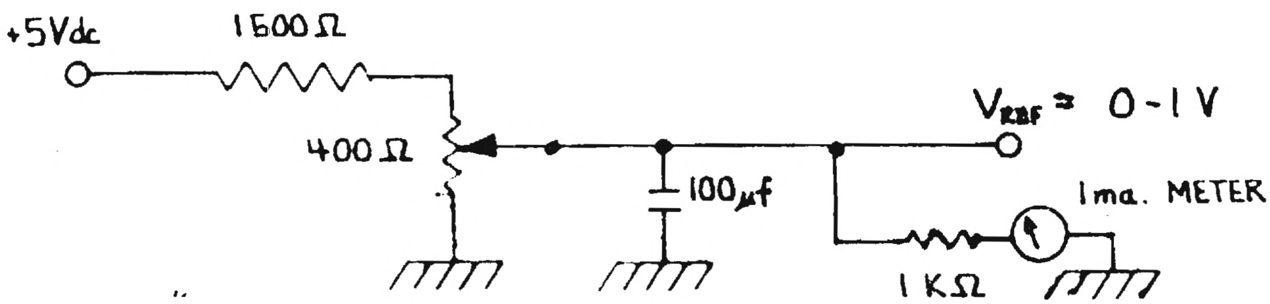


Figure 11. Five Volt Regulated Power and Reference Voltage Supply

face circuitry for additional protection. The reference voltage for the LM 339 translators is derived from the regulated supply as shown.

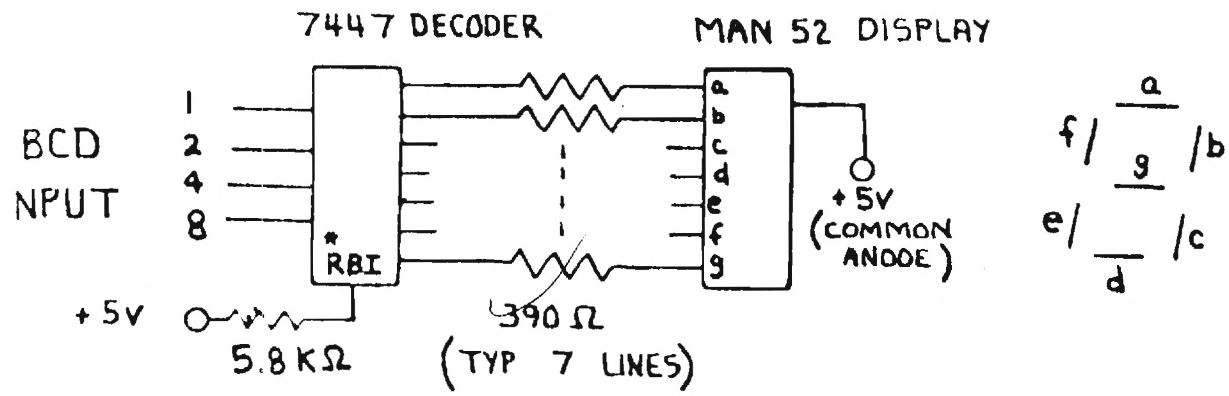
Figure 12 illustrates schematically the drive for one interface display digit. The MAN 52 seven segment LED display is a dual inline package with a common anode configuration. The 390Ω resistors limit the diode current to 10-15 milliamperes through the open collector transistors on the 7447 TTL decoder/driver.

Figure 13 gives the pin-out for the LM 339, 7447 and MAN 52. Each is a dual inline package with fourteen or sixteen pins. Within the interface, each chip is mounted in a socket for easy replacement should a failure occur.

2. Programs

The programs written for the Hewlett-Packard 9815A desktop programmable calculator/computer are designed to provide a conversational mode of interface between the dyer and the dyebath analysis equations and data. All the stored programs and base data are stored on magnetic tape, available to the H-P 9815A through its built-in tape drive which functions under program control. External data are available through the BCD input/output interface to the Bausch and Lomb Spectronic 100 spectrophotometer constructed at Georgia Tech and described in the previous section.

The conversational interactive interface with the dyer is effected by printing alphanumeric questions to the dyer on the built-in tape printer and soliciting responses through the keyboard, such as entering the numeral one (1) for yes or two (2) for no. This accomplishes general program selection and identifies the particular options within each program which the dyer is interested in following.



NOTE: On the fourth high-order bit, only the 1 input is used, the RBI (Ripple Blanking Input) is tied to ground, and only Segments B and C which form the numeric character 1 are wired.

Figure 12. Display Schematic

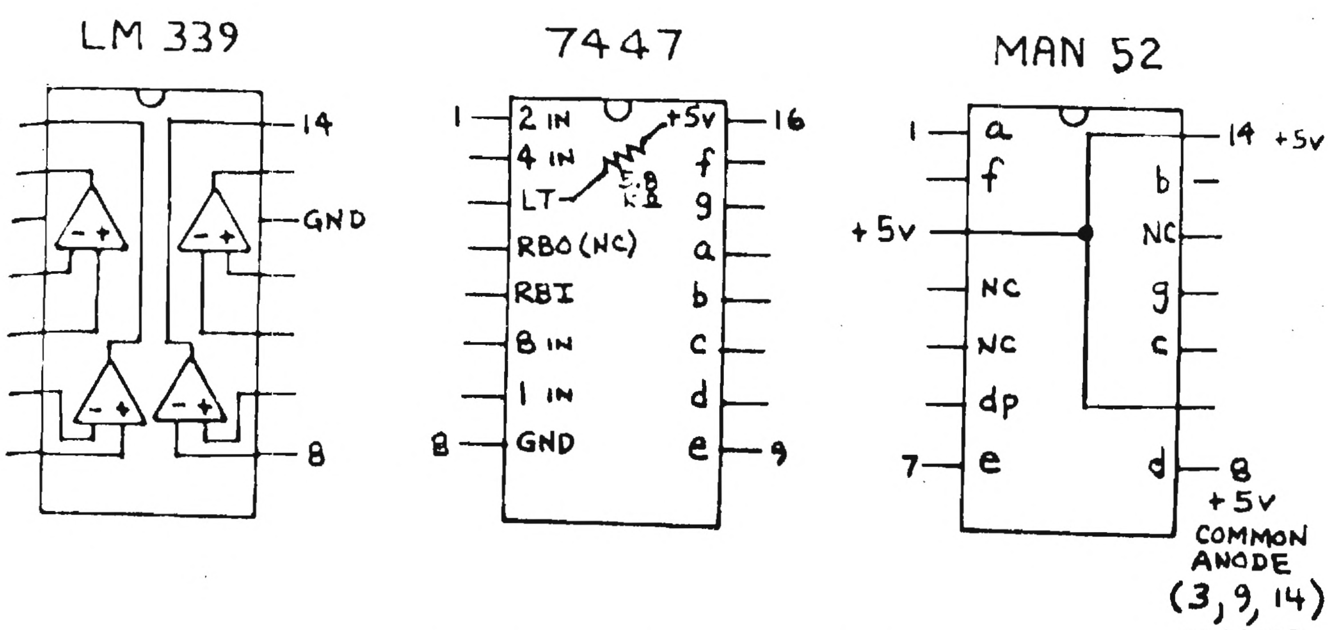


Figure 13. Pin-out of Integrated Circuits

The programs cover dyebath reuse analysis and general utility routines to provide for factors such as recipe changes and new dye lot strength calculations. The tape drive identifies programs or data by file numbers. Thus the various programs and data are referenced by sequential numbers beginning with zero. The first program or program zero is a monitor program calling the appropriate files for the major program functions. The calculator/computer has a special auto-start feature at the time of cut-on which loads and begins execution of program zero. The following description of program content tracks the logical program flow in the major program functions defined for dyebath reuse.

The monitor program contains the access directions to the nine principle programs stored on tape. Two basic programs of this group contain the dyebath reuse calculation procedure, taking advantage of some 160 files to extract data for the particular reuse run under analysis. The remaining programs serve to generate, modify, remove, or list contents of the data files, thereby supporting the basic reuse function.

The programs and the data file structure were generated independently at Georgia Tech, representing a total revision of software for dyebath reuse. The application of these programs to dyebath reuse at Salem Carpets served as their first application in an industrial environment. Among the features incorporated in the revised software were improved clarity of instructions to the operator, a simpler format, and increased capacity for style/shade, dye and auxiliary information.

Basically, the unit of information storage under this system is a tape cartridge. Each tape cartridge contains all the programs for reuse work and space for up to six dyes, six auxiliaries, and forty style/shade combinations. Thus ten tapes, for example, can hold a library for four hundred style/shade combinations. Typically, they would be separated according to type of fiber and dyeing procedure. Each style/shade combination on a tape may use one or more of the dyes and auxiliaries, which allows shades using dyes and chemicals from the common group to coexist on one tape.

The reuse program solicits and stores the volume of the reuse bath and the weight of fabric in the next run. It then requests input of the style number and shade number. After loading the style/shade data file, the program directs the operator to set the spectrophotometer to the correct wavelength for an absorbance measurement, to zero the spectrophotometer, and to load the sample. When this has been completed, the absorbance measurement is taken automatically. This sequence of steps is repeated as many times as there are dyes in the formula. The number of dyes and optimum wavelengths for the measurements are stored in this file, sufficient data is available to solve $\underline{n}$ equations for the $\underline{n}$ unknowns, i.e., the concentrations of the $\underline{n}$ dyes in the bath.

The program which solves the $\underline{n} \times \underline{n}$ matrix uses a simple Gauss-Jordan elimination technique. At its completion, the concentrations of reuse dyes are reported to the operator. This step normally serves no useful function, but occasionally a standard solution of known concentration may be tested to confirm that the system has correctly performed absorbance measurement and concentration calculation functions.

The final program of the reuse series was designed to detail the dye and auxiliary quantities for reconstitution of the reuse dyebath to the proper level for the next dyeing. The quantity of dye in the bath for each of the several species which may be present is calculated by multiplying the concentration value from the analysis in units of mass per unit volume times the volume of the dyebath. This number, the mass of dye present, is substracted from the total mass of dye needed, which in turn is found by multiplying the dye formula quantity in units of dye mass needed per unit weight of fabric times the weight of fabric.

Dyebath reuse program listings for the HP-9815A desktop computer are contained in Appendix 3. Entries by file step are detailed.

D. <u>Conventional Salem Process</u>

The conventional Salem Carpets process as practiced in November of 1979 is detailed in Appendix 4. The process was typical of that used in most carpet operations with the exception of the ammonia addition. By keeping the pH on the basic side during the initial phase of the cycle with the ammonia, the fixation of the acid dyes was slowed, allowing better leveling. As the cycle proceeded, the ammonia was largely steamed out of the bath, resulting in a gradual decrease in the pH and fixation of the dye.

A total of ten (10) conventional runs were conducted in the monitored dyebeck to generate baseline data. The consumption data by shade is detailed in Appendices 5-8. for the conventional sequence. Cost factors for the energy and materials are detailed in Table 1, and are applicable to all of the dyeings conducted. The average consumption data for conducting the ten runs by the original Salem process are tabulated in Table 2. Color differences between the samples and the average color values for the individual shades are detailed in Appendix 9. Both <u>D</u> and <u>F</u> light sources of the ACS Color Computer System were utilized.

Table 1. Cost Factors

ENERGY			AUXILIARIES						DYES		
($/1000 LBS STEAM)	($/$10^6$ BTU)	WATER/SEWER (¢/1000 GAL)	LEVEL. (¢/LB)	SEQUEST. (¢/LB)	DEFOAM. (¢/LB)	AMMONIA (¢/LB)	MSP (¢/LB)	ACETIC (¢/LB)	YELLOW ($/LB)	RED ($/LB)	BLUE ($/LB)
3.12	3.00	45	59	27	36	7	32	16	8.47	7.25	15.00

Table 2. Average Consumption Data for Dyeing Sequences

SEQUENCE	TOTAL RUNS (#)	LOAD (LBS)	STEAM CONSUMPTION HEAT-UP (LBS)	STEAM CONSUMPTION TOTAL (LBS)	ENERGY PER WEIGHT OF CARPET HEAT-UP (BTU/LB)	ENERGY PER WEIGHT OF CARPET TOTAL (BTU/LB)	WATER/ SEWER (GAL)	AUXILIARIES (LBS)	TIME (MIN)	ADDS (#)
Conventional	10	1667	5384	9620	3711	6636	9149	105	268	0.7
Bump-and-Run	10	1677	3784	6252	2595	4287	8442	100	269	0.8
First Bump-and-Run/ Dyebath Reuse	11	1717	1810[a]	4277[a]	1212[a]	2865[a]	5581	46	357	1.4
Second Bump-and-Run/ Dyebath Reuse	13	1700	3071	6238	2077	4220	5313	43	341	1.0
Bump-and-Run/ Dyebath Reuse/ Hot Pull	6	1558	2653	5969	1958	4406	888	316	316	1.2

[a] TDI malfunctioned, and energy data was invalidated.

E. Bump-and-Run Sequences

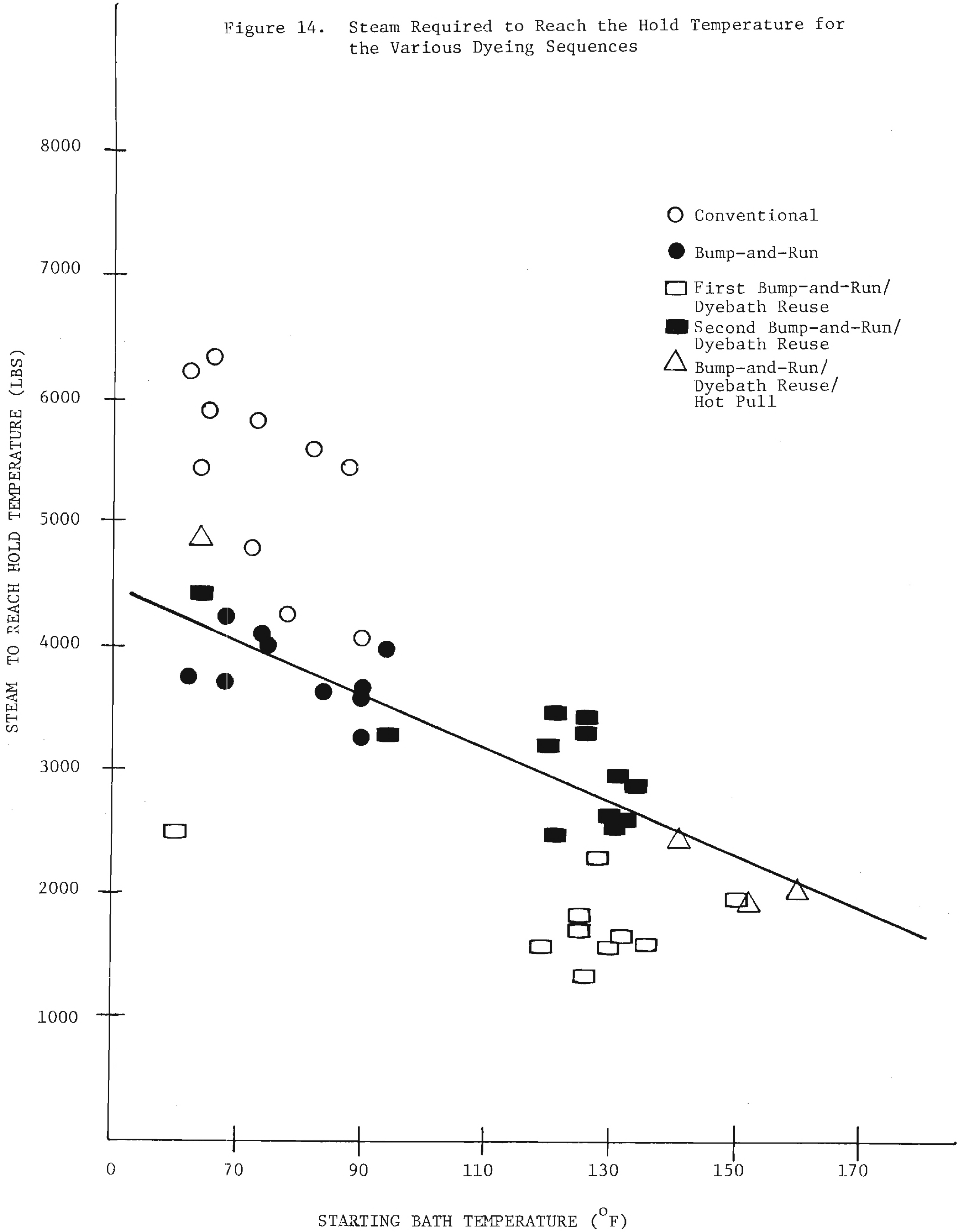
A total of ten (10) cycles were conducted by the process termed bump-and-run (see Appendix 10 for the process description). The consumption data for the sequence is contained in Appendices 5-8, with the average consumption located in Table 2. Color differences were obtained where possible, and are recorded in Appendix 9. The color differences for the bump-and-run sequence compared favorably with those of the conventional sequence.

F. Combined Bump-and-Run/Dyebath Reuse Sequences

Two separate sequences were conducted with bump-and-run and dyebath reuse combined. The first sequence incorporated eleven (11) cycles, while the second sequence incorporated thirteen (13) cycles. The procedure is detailed in Appendix 11. Consumption data for the two sequences are detailed in Appendices 5-8, with the average consumption located in Table 2. Color difference data between the dyed samples and the average color values are shown in Appendix 9. Again, favorable comparisons in shade matching were obtained.

As the steam flow data were being collected for Project Runs 21-31, the investigators realized that the data was abnormally low based on theoretical calculations. A new TDI system had been incorporated beginning with the sequence that had not been tested before the demonstration. As evidence that the total steam data for the sequence was faulty, the steam required for the initial "bump" for the conducted cycles versus starting bath temperature is plotted in Figure 14. As seen from the plot, the first bump-and-run/dyebath reuse sequence does not correlate with the other entries of the plot, being shifted lower than the other modified sequences. Another

Figure 14. Steam Required to Reach the Hold Temperature for the Various Dyeing Sequences



TDI was used for the following sequence, and reasonable data were obtained. Due to the TDI problem with Project Runs 12-31, and since a second parallel sequence was conducted under proper measurement conditions (Project Runs 32-44), the steam data for the initial bump-and run/dyebath reuse sequence was ignored in deriving percentage savings and in the cost/benefit analysis.

G. <u>Bump-and-Run/Dyebath Reuse/Hot Pull Sequence</u>

Although the return on investment (ROI) estimates for incorporation of dyebath reuse are attractive (less than one year), any outlay for capital equipment (holding tanks, pumps, pipes, etc.) is undesirable if it can be avoided. By pulling the carpet directly from the hot dyebath and leaving the exhausted liquid in the beck, the necessity of a holding tank/pumping system was eliminated. Technical feasibility of the hot pull process depended on receiving adequate rinsing at some other point in the plant. The wet-out box situated before the entrance of the drying oven offered sufficient rinsing of the carpet without affecting crock fastness. Since the wet-out of the carpet before drying was standard operating procedure at Salem, the dyeing process was not penalized in water consumption for the final rinse, reducing water/sewer requirements.

A total of six (6) cycles were conducted in a fully-optimized procedure (Appendix 12). Consumption data for the sequence is detailed in Appendices 5-8, and the average consumption data is contained in Table 2. Color difference data are shown in Appendix 9 for Project Runs 45-50. By adding the auxiliary chemicals and dyes before entering the carpet in the hot ($\sim 180^{\circ}F$) bath, better level on the initial strike was obtained. The pumping system was utilized to circulate the dyebath in the beck for several minutes before adding carpet to insure a completely-homogeneous dyebath. The color differences were acceptable using the fully-optimized process.

H. Carpet Quality

As detailed in the preceeding sections, color correlation of carpets dyed with the modified procedures was acceptable.

In Table 2, the average number of adds increased on reuse incorporation, which in turn perturbed the energy and time consumptions upward. For example, from Appendices 5 and 6, an add in a bump-and-run/dyebath reuse sequence carried a penalty of 1000-1800 pounds of steam and 1-2 hours of process time. Discussions with the plant dyers and dyeing lab director revealed that Salem Carpets averages 1.2 - 1.5 dye adds per cycle. In other words, the average add ratio of 0.7 and 0.8, respectively, for the conventional and bump-and-run sequences were unusually low for the plant. The dyers agreed that the 1.2 adds per cycle average over the three sequences incorporating dyebath reuse was in line with the plant experience. As a result, a figure of 1.2 adds per cycle was assumed for the subsequent cost/benefit analysis.

The number of redyes are also an important criteria of product quality. The conventionally-dyed carpets required one redye. Correspondingly, no more than one redye per sequence was required for the process-modified sequences. Bump-and-run and dyebath reuse did not increase the number of redyes normally encountered by the plant .

One observation made was that redyes occured in bunches across the plant, with some shifts encountering few redyes while others suffered numerous redyes on the 14 becks. Possible causes were unconventional yarn lots and improper preparation of dye concentrates in the drug room. For example, dye formulations were on hand for nylon yarn from two different manufacturers. Due to the differences in the yarn properties, the two formulations were quite varied. During the demonstration, yarn lots from a third manufacturer entered production for which no dye/auxiliary formulation had been devised. The dyers were therefore forced to choose between the available two formulations, neither of which had been designed for the third manufacturer's yarn. Such lack of control led, of course, to an increase in the add rate as well as in the number of redyes.

IV. SAVINGS AND COST/BENEFIT ANALYSIS

A. Percentage Savings in Consumption

Table 2 reports the average consumption data for energy, materials (except dyes) and time, as well as the average number of adds, from Appendices 5 - 8. Since the shade order was different in the various dyeing sequences, no average correlation of dye consumption by sequence could be ascertained. Therefore the percentage dyes saved per cycle was derived by dividing the dyes recycled for each bath by the total dye required for the shade. The latter consisted of the sum of the recycled dye, make-up dye, and dyes entered via adds:

$$\begin{array}{c}\text{\% dye savings}\\ \text{per cycle}\end{array} = \frac{\text{mass of recycled dyes}}{\text{total mass of dye entered}} \times 100$$

The sequence averages were obtained by:

$$\begin{array}{c}\text{\% dye savings}\\ \text{per sequence}\end{array} = \frac{\text{average mass of recycled dyes}}{\text{average total mass of dye entered}} \times 100$$

The percentage savings for the energy and materials are detailed in Table 3.

Table 3. Percentage Savings for Modified Dyeing Processes Over the Conventional Procedure

SEQUENCE	STEAM CONSUMPTION HEAT-UP (%)	STEAM CONSUMPTION TOTAL (%)	WATER/SEWER (%)	AUXILIARIES (%)	DYES YELLOW (%)	DYES RED (%)	DYES BLUE (%)	ADDS (#)
Bump-and-Run	30	35	-	-	-	-	-	0.8
First Bump-and-Run/ Dyebath Reuse	-[a]	-[a]	39	56	5.0	5.5	6.3	1.4
Second Bump-and-Run/ Dyebath Reuse	43	35	42	59	5.1	6.5	7.4	1.0
Bump-and-Run/ Dyebath Reuse/ Hot Pull	49	38	90	59	0.9	1.1	0.4	1.2

[a]TDI malfunctioned, and energy data was invalidated

B. Cost Savings for Modified Sequences

Model cycles for energy consumption for the various dyeing sequences were derived from Appendix 5 by averaging the heat-up, add, and level-out comsumptions for the runs conducted in the sequences. The add consumption averages were all multiplied by 1.2, the production add factor for Salem Carpets, to give a total steam consumption for the model cycle (Table 4). Using the data in Tables 1, 2 and 4 and Appendices 13-15, combined cost savings per pound of carpet in comparison to the conventional process were derived for the various input parameters (Table 5). For simple incorporation of bump-and-run, 0.78¢/lb was gained from the energy reduction. By the nature of bump-and-run, energy is the only parameter reduced on process modification.

The first sequence incorporating dyebath reuse was included by using the same steam cost savings figure as the second reuse sequence. The assumption was necessary due to the failure of the TDI unit discussed earlier in this report. Water/sewer, auxiliary, and dye cost savings were, of course, directly applicable from the first reuse sequence data as these parameters were independent of the energy measurements (Appendices 14-15). The bump-and-run/dyebath reuse sequences that involved use of the holding tank average 2.3¢/lb of carpet in savings. As in the earlier plant demonstration on pantyhose, the greatest contributions to the cost savings were the recycled auxiliaries and energy (average of 51% and 36%, respectively, for the two sequences). The contribution by water/sewer savings were small (average of 5%) due to the low price of water purchase and treatment in the U.S. With increasing pressure from EPA regulations, such as

Table 4. Model Cycles for Energy Consumption Based on Appendix 5.

SEQUENCE	STEAM CONSUMPTION HEAT-UP (LBS)	1.2 ADDS (LBS)	LEVEL-OUT (LBS)	TOTAL (LBS)	SAVINGS (%)
CONVENTIONAL	5384	2864	2566	10814	-
BUMP-AND-RUN	3784	1273	1620	6677	38
SECOND BUMP-AND-RUN/ DYEBATH REUSE	3071	2048	1459	6578	39
BUMP-AND-RUN/ DYEBATH REUSE/ HOT PULL	2653	2153	1223	6029	44

TABLE 5. Combined Cost Savings for Process Modifications

SEQUENCE	TOTAL RUNS (#)	COST SAVINGS/UNIT WEIGHT STEAM (¢/LB)	WATER/SEWER (¢/LB)	AUXILIARIES (¢/LB)	DYES (¢/LB)	TOTAL (¢/LB)	CONTRIBUTION TO COST SAVINGS STEAM (%)	WATER/SEWER (%)	AUXILIARIES (%)	DYES (%)
BUMP-AND-RUN	10	0.78	-	-	-	0.78	100	-	-	-
FIRST BUMP-AND-RUN/ DYEBATH REUSE	11	0.81[a]	0.10	1.16	0.33	2.40	34	4	48	14
SECOND BUMP-AND-RUN/ DYEBATH REUSE	13	0.81	0.11	1.16	0.09	2.17	37	5	53	5
BUMP-AND-RUN/ DYEBATH REUSE/ HOT PULL	6	0.81	0.22	1.12	0.01	2.16	38	10	52	0

[a] Since the TDI malfunction invalidated the steam flow data on the first dyebath reuse runs, the average for the second reuse sequence steam cost savings was also used for the first sequence.

the recently published effluent guidelines for carpet finishing plants proposing incorporation of multimedia filtration in addition to the best practicable control technology currently available[3], the cost for treatment of the waste will become more expensive, increasing savings on reuse incorporation. Regardless of economics, the EPA goals of zero discharge by 1985 will certainly increase the attractiveness of dyebath reuse. Dyes were also a relatively minor part of the cost savings due to the high exhaustion, but any dye savings are important in the face of rising costs (Table 1) and in reducing hard-to-remove color in the plant effluent.

In the final sequence, the hot pull technique was combined with bump-and-run and dyebath reuse. The reduction in water/sewer requirements was striking, conserving an average of 8261 gal/cycle over the conventional sequence (a reduction of 90%) and 5447 gal/cycle over the average of the first two reuse sequences (Table 2). As seen in Table 5, the additional reduction in water roughly doubled the cost/weight savings contributed by water/sewer for the final sequence.

The average cycle loads from Column 3 of Table 2 were themselves averaged to give a plant average of 1664 lbs/cycle. The plant average load was used in conjunction with Column 7 of Table 5 to generate the overall cost savings per cycle on incorporation of the various process modifications (Table 6). Although lower than the other sequences since conserved energy was the only added value, the $12.98 /cycle cost savings with bump-and-run were significant in that the simple, easy to incorporate modification requires hardly any capital investment. To alleviate setting the steam controller twice instead of once as in the conventional process, installation of the Omron auxiliary timer is recommended at a cost of $30 per controller. This is the only investment suggested for implementation of bump-and-run. As an

Table 6. Savings Per Average Cycle Load (1664 lbs)

Sequence	Savings ($/Cycle)	
Bump-and-Run	12.98	
First Bump-and-Run/ Dyebath Reuse	39.94	
Second Bump-and-Run/ Dyebath Reuse	36.11	Average: $37.33 Cycle
Bump-and-Run/ Dyebath Reuse/ Hot Pull	35.94	

added bonus, first-quality goods were obtained in the demonstration with bump-and-run by using the plant's standard auxiliary chemicals and dyes.

The three sequences incorporating dyebath reuse averaged \$37.33/cycle (Table 6). The deviation from the mean was small for the individual sequences, including the final sequence incorporating the hot pull technique. The average figure was therefore used in the subsequent cost/benefit analysis.

C. Cost Benefit Analysis for Salem Carpets

1. Incorporation of Bump-and-Run

The participating plant operates 14 production becks. Conservatively, 57% of the plant production (8 becks) can be adapted to the bump-and-run process. If this is the only modification adapted, the annual savings will be:

$$8 \text{ becks} \times 4.0 \frac{\text{cycles}}{\text{beck-day}} \times \frac{7 \text{ days}}{\text{week}} \times 50 \frac{\text{weeks}}{\text{year}} \times \frac{\$12.98}{\text{cycle}} = \$145{,}013/\text{year}$$

The 4.0 cycles per beck-day is based on the plant operation of 24 hours per day, with an average of 310 minutes per cycle derived from Column 10, Table 2. The plant normally operates 7 days per week for nearly the entire year, or 50 weeks. Using the savings figure of \$12.98/cycle from Table 6, the annual plant savings are an impressive \$145,013 on incorporation of bump-and-run alone. The only suggested modification for the implementation of bump-and-run (installation of the \$30 Omron auxiliary timer on each steam controller) would require only a \$240 investment for conversion of eight controllers. The return on investment (ROI) would therefore be almost instantaneous, resulting in considerable profit for the plant during the first year.

2. Incorporation of Bump-and-Run/Dyebath Reuse

Merging of dyebath reuse with bump-and-run considerably improves the cost savings per cycle but also requires more capital investment. Assuming that a conservative 57% (8 becks) of production can be converted to the combined process, the yearly savings using the facts detailed earlier are:

$$8 \text{ becks} \times 4.0 \frac{\text{cycles}}{\text{beck-day}} \times 7 \frac{\text{days}}{\text{weeks}} \times 50 \frac{\text{weeks}}{\text{year}}$$

$$\times \frac{\$37.33}{\text{cycle}} = \$418{,}096/\text{year}$$

The plant scheduling is such that two machines can be operated from a single holding tank, and therefore four insultated tank systems would be required to adapt dyebath reuse to the eight becks. Based on Appendix 2 and vendor information, Table 7 was derived as an estimate of the costs required to outfit the becks for the combined process. Based on the annual savings derived above and the estimated cost of implementation, and neglecting any tax benefits, the return on raw capital investment is:

$$\text{ROI} = \frac{\$231{,}580 \text{ cost}}{\$418{,}096 \text{ savings/year}} \times 12 \frac{\text{months}}{\text{year}} = 6.6 \text{ months}$$

The 6.6 month ROI is well within the acceptable paybeck period of 1-2 years followed by most members of the industry.

Using the hot pull technique in conjunction with bump-and-run and dyebath reuse, the $418,096 savings in the first year would be nearly all profit as the only expenses would be the $10,000 for the analysis system and $240 for the auxiliary timers. Some modification of the wet-out box situated before the dryer may be required to facilitate better rinsing of the hot-pulled carpets.

TABLE 7. Projected Cost of Incorporating Bump-and-Run/Dyebath Reuse to Eight Production Becks

PROCESS EQUIPMENT	TOTAL COST ($)
Holding Tank Assembly, 4, 10,000-gallon capacity each, fiberglass reinforced construction	
$15,000 x 4 =	$60,000
Pumps, 8, grey iron with teflon packing	
$1100 x 8 =	$ 8,800
Pump Motors, 8, 10 HP-750 RPM	
$270 x 8 =	$ 2,160
Pump Accessories (couplings, sheaves, belts, etc)	
$550 x 4 =	$ 2,200
Piping, Fiberglass and Stainless	
$3000 x 4 =	$12,000
Elbows, Tees, Flanges, Valves etc.	
$15,000 x 4 =	$60,000
Strainer System, 4	
$300 x 4 =	$ 1,200
Sight Glass, 4	
$300 x 4 =	$ 1,200
Auxiliary Timer, 8	
$30 x 8 =	$ 240
SUBTOTAL	$147,800

TABLE 7 (cont'd.)

<u>INSTALLATION COST</u>	
Taken as 50% of equipment subtotal:	$73,780
<u>ANALYTICAL SYSTEM</u>	
Including spectrophotometer, computer, interface, accessories, and disposable items for one-year operation	$10,000
TOTAL ESTIMATED COST OF IMPLEMENTATION:	$231,580

Crockfastness is the quality control factor in question. However, of the carpets pulled hot in the final dyeing sequence of the project, all passed Salem's quality control standards. All of the carpets in the sequence were also heavily tinted, which adequately tested the accuracy of the octanol extraction system for the analysis.

The thought and training required to alter the plant's usual procedure to the hot pull technique is therefore justified in company profits, as well as in drastically reduced water/sewer requirements. Even if the capital investment in holding tanks and pumping systems is made, the 6.6 month ROI still makes the demonstrated modifications extremely attractive for implementation.

D. Projected National Energy Conservation Potential

The total reduction in pounds of steam per cycle for the fully optimized process (bump-and-run/dyebath reuse/hot pull) was 4785 (Column 4, Table 4). The average cycle load was 1664 pounds of carpet (Column 7, Table 5). Using a conversion factor of 1150 BTU/lb of steam, the energy savings per pound of goods were quantified as:

$$\frac{4785 \text{ lbs. steam} \times 1150 \frac{\text{BTU}}{\text{lb}}}{1664 \text{ lbs of carpet}} = 3307 \frac{\text{BTU}}{\text{lb}} \text{ savings}$$

A recent government publication placed the fourth quarter/1978 through third quarter/1979 carpet production at 1.42 billion pounds of nylon and 0.19 billion pounds of polyester (Table 8).[4] A second publication has placed beck production of nylon carpets at 25%,[5] up from 20% estimated in the project proposal, and reflecting the trend back to becks in recent years with the market upsurge of solid shades. The proposal estimate of 90% of the polyester carpets dyed on becks remains valid in 1980. Using the "most recent" yearly data[4] and

TABLE 8. Most Recent Full-Year Carpet Production Data

Quarter	Nylon Staple (lbs x 10^{-3})	Nylon Filament (lbs x 10^{-3})	Polyester (lbs x 10^{-3})
Q4-1978	159,968	183,473	46,969
Q1-1979	161,232	172,126	45,022
Q2-1979	171,852	191,929	47,295
Q3-1979	197,880	185,523	46,969
TOTALS:	690,932	733,051	186,255
	1,423,983		

[a] Source: Government Pulications, Current Industry Reports, Carpets and Rugs, Pub. Nos. MQ-22Q (78 and 79)-5, U.S. Dept. of Commerce, Washington, D.C.

assuming the savings per pound would be the same for polyester carpet as for nylon carpet, the direct natural energy conservation potential is calculated as:

$$\left\{\left[1.42 \times 10^9 \ \frac{\text{lbs nylon}}{\text{year}} \times 0.25 \text{ beck factor}\right] + \left[0.19 \times 10^9 \ \frac{\text{lbs polyester}}{\text{year}} \times 0.90 \text{ beck factor}\right]\right\} \times 3.307 \times 10^3 \text{ BTU savings/lb}$$

$$= 1.42 \times 10^{12} \text{ BTU/year}$$

Using the standard conversion factor of 5.8×10^6 BTU/BOE, the BTU energy conservation potential translates to 2.4×10^5 BOE/year. **Based on 4.1×10^7** BOE/year consumed in wet processing [1], application of the technology strictly to beck dyeing of nylon and polyester carpets would result in a 0.6% reduction in the energy requirements of the wet processing segment of the textile industry (0.001 quads).

The technology has the technical potential of being implemented in all beck dyeing of nylon and polyester carpet as calculated above. Realistically, however, a gradual implementation of the technology is expected, with a 50% penetration into the available market estimated by 1990.[6]

Projections based on 1973 annual production and equipment-in-place data have placed the total poundage of nylon and polyester fiber dyed in batch atmospheric equipment at 4.5×10^9 pounds [1,6]. This figure includes not only the 0.425×10^9 pounds of carpet that is beck dyed, but also all fabric materials dyed atmospherically by similar time/temperature profiles and equipment, e.g., beck dyeing of cotton/polyester blends, paddle machine dyeing of men's nylon socks, etc. Assuming that the technology as developed is directly transferable to all forms of atmospheric batch dyeing of fabrics containing nylon and polyester fibers, which is valid based on the similarities of the fabric systems to the carpet beck, the overall direct energy conservation potential demonstrated by the project is calculated as:

$$4.5 \times 10^9 \frac{\text{lbs}}{\text{year}} \times 3.307 \times 10^3 \frac{\text{BTU savings}}{\text{lb}}$$

$$= 1.5 \times 10^{13} \frac{\text{BTU}}{\text{year}} \quad 2.6 \times 10^6 \frac{\text{BOE}}{\text{year}}$$

The expanded volume raises the potential energy savings to 6.3% of the annual energy consumed in wet processing (0.015 quads). As with the pure carpet calculation, however, a market penetration of 50% by 1990 is realistic considering the conservation attitude of the industry toward process modifications.

E. Projected Industry Economic Potential

The modified processes averaged 2.3¢/lb of carpet economic savings (Column 6, Table 5). Using the carpet production figures derived in Section IV-D, the maximum potential economic savings to only the carpet section of the textile industry is:

$$2.3 \times 10^{-2} \frac{\text{\$ savings}}{\text{lb}} \times 0.53 \times 10^9 \frac{\text{lbs carpet beck dyed}}{\text{year}}$$

$$= 1.2 \times 10^7 \ \text{\$ savings/year}$$

Translating the technology to the total poundage of nylon and polyester fiber dyed annually in batch atmospheric equipment (4.5×10^9 pounds [1,6]) gives an expanded maximum potential economic savings to the textile industry of:

$$2.3 \times 10^{-2} \frac{\text{\$ savings}}{\text{lb}} \times 4.5 \times 10^9 \frac{\text{lbs fiber atmospherically dyed}}{\text{year}}$$

$$= 1.0 \times 10^8 \ \text{\$ savings/year}$$

As in Section IV-D, these calculations should be tempered with the expectation that the technology will be gradually implemented, with a 50% penetration into the available market estimated by 1990.[6]

F. Indirect Energy Savings

Although the focus of the report has been on direct energy savings to the plant, considerable indirect national energy savings are also inherent in implementation of the demonstrated modifications. The drastic reduction in auxiliary chemicals, which are usually petrochemical based and/or require considerable fossil fuel input for synthesis, would have a measurable impact on national energy consumption if realized industry-wide. The same argument can be applied to the recycled dyes. In addition, treatment of make-up water and effluent requires energy in the form of synthesized chemicals such as chlorine and in electrical pump energy. The reduction of water/sewer requirements, if matched industry-wide, would thus also have an impact on national energy consumption. The data required to quantify the indirect energy savings on reuse incorporation (cost per unit weight of synthesizing auxiliary chemicals, dyes and chlorine, pump energy requirements in aeration ponds, etc.) were not available to the authors.

V. CONCLUSIONS

The in-plant demonstration of carpet dyebeck optimization met or surpassed all of the project's goals and objectives. From Column 4 of Table 4, the merging of dyebath reuse and hot pull with bump-and-run reduced the steam consumption by 2.9 pounds of steam/pound of carpet. Using the conversion factor of 1150 BTU/pound of saturated steam, 3307 BTU/pound of carpet was conserved. Since 0.36×10^9 pounds of nylon and 0.17×10^9 pounds of polyester are dyed annually on the beck, [4] utilization of the optimized cycle strictly in carpet production would yield a direct national savings of 1.42×10^{12} BTU of energy per year (2.4×10^5 barrels of oil equivalent per year, 0.001 quad). When all nylon and polyester fibers dyed on similar atmospheric equipment is included in the annual poundage, the potential energy savings is raised to 1.5×10^{13} BTU/year (2.6×10^6 BOE/year, 0.015 quads).

The reduction in auxiliary chemical, dye, and water/sewer requirements also dictated substantial <u>indirect</u> energy savings from a national viewpoint, as well as contributing to the economic attractiveness of the demonstrated modifications (Appendices 6-8 and Tables 5-6). From a pollution reduction viewpoint, the modifications were also extremely efficient. From Appendix 13, dyebath reuse alone reduced the water requirements by 2.3 gallons/pound of carpet. Based on the above national production figures for carpet beck usage, the demonstrated water/sewer conservation potential is 1.2×10^8 gallons/year. By utilizing the hot pull technique, the demonstrated potential jumps to 2.7×10^9 gallons/year. Using the nylon/polyester full production figure of 4.5×10^9 lbs/year, the water/sewer conservation potential rises to 1.0 x 10^{10} gallons/year and 2.3 x 10^{10} gallons/year, respectively, for the holding tank and hot pull approaches. Such reductions in treatable water volume embrace the attractiveness and economics of combining the dyebath reuse/hot pull process with effluent separation or clean-up technology (hyperfiltration, chlorination, ozonolysis, carbon adsorption, etc.) to further the goal of reaching a "closed-loop" batch dyeing process.

Since the demonstration terminated, Salem Carpets has incorporated bump-and-run in all of its nylon production, and is experimenting with the technique on its beck-dyed carrierless polyester production. A study of the rinsing effectiveness of the wet-out box prior to the dryer is also underway, and any appropriate modifications will be defined for incorporation of the hot pull technique. Engineering studies are being conducted on the optimum holding tank/pumping installation in case the management decision is reached to use this approach instead of the hot pull technique. Dyebath reuse will be incorporated once bump-and-run is optimized across the plant and the proper engineering modifications are made.

VI. DISSEMINATION OF INFORMATION

The investigators have already begun to disseminate the results of the project to the remainder of the industry. A list of presentations that have been made or are scheduled to be made to date is shown in Appendix 16. Written publications in the industry's trade journals is also planned upon DOE approval of this report, as well as further oral presentations when opportunities arise. Trade organizations such as the Carpet and Rug Institute (CRI), the American Textile Manufacturer's Institute (ATMI), the American Association of Textile Chemists and Colorists (AATCC) and the various state associations will also be heavily utilized to publicize the results and cost/benefit analysis of the demonstration. Finally, the Textile Sector of the Georgia Industrial Energy Extension Service, funded by DOE through the Georgia Office of Energy Resources and directed by the School of Textile Engineering at Georgia Tech, will be used to disseminate the information and encourage implementation by individual plant contacts.

VII. BIBLIOGRAPHY

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2. F. L. Cook and R. L. Moore, Unpublished Results, Industrial Energy Extension Service Report, Georgia Institute of Technology, 1979.

3. Anonymous, "Proposed Effluent Guidelines: Rulemaking for the Textile Mills Point Source Category",Joint Brochure, U.S./-EPA and Office of Water and Waste Management, Washington, D.C., Winter, 1979.

4. Government Publications, *Current Industry Report/Carpet and Rug*, Pub. Nos. MQ-22Q - (78 and 79) - 5, U.S. Dept. of Commerce, Washington, D.C.

5. R. Weber and H. Hoise, *Carpet and Rug Industry*, (4), 20 (1979).

6. W. C. Tincher, DOE Projection Evaluation Sheet for Project Entitled "Energy Conservation in the Textile Industry, Phase III: In-Plant Demonstration of Energy Utilization in Beck Dyeing of Carpet", February 12, 1979.

A P P E N D I C E S

APPENDIX 1

Dyeing Sequences Conducted by Various Processes

Project Run (#)	Run in Sequence (#)	Technology Used	Shade Name
1	1	Conventional	Thistle
2	2	"	Thistle
3	3	"	Auburn
4	4	"	Auburn
5	5	"	Bamboo
6	6	"	Bamboo
7	7	"	Bamboo
8	8	"	Bamboo
9	9	"	Chamois
10	10	"	Chamois
11	1	Bump-and-Run	Sauterne
12	2	"	Pecan
13	3	"	Pecan
14	4	"	Sauterne
15	5	"	Sauterne
16	6	"	Watercress
17	7	"	Camel
18	8	"	Camel
19	9	"	Camel
20	10	"	London Fog

APPENDIX 1 (cont'd.)

Project Run (#)	Run in Sequence (#)	Technology Used	Shade Name
21	1	Bump-and-Run/Dyebath Reuse	Rice
22	2	"	Skycraper Blue
23	3	"	Thistle
24	4	"	Thistle
25	5	"	Thistle
26	6	"	Thistle
27	7	"	Buckeye
28	8	"	Buckeye
29	9	"	Buckeye
30	10	"	Buckeye
31	11	"	Buckeye
32	1	Bump-and-Run/Dyebath Reuse	Polar White
33	2	"	Polar White
34	3	"	Polar White
35	4	"	Rice
36	5	"	Bran
37	6	"	Bran
38	7	"	Bran
39	8	"	Bran
40	9	"	Bran
41	10	"	Thistle
42	11	"	Thistle
43	12	"	Thistle
44	13	"	Thistle
45	1	Bump-and-Run/Dyebath Reuse/Hot Pull	Bone
46	2	"	Bone
47	3	"	Bone
48	4	"	Muffin
49	5	"	Muffin
50	6	"	Temple Gold

Appendix 2. Engineering and Analysis Equipment Required by the Project

Item No.	Item Description	Estimated Cost ($)	Quantity	Estimated Total Cost ($)	Potential Vendor
	WATER METER				
1	Water Meter Brooks Propellor Meter Model 3312-04A31AA For 4" Water Line		1	775.00	Stallings, Inc. 4220 Pleasantdale Road Chamblee, Georgia Phone (404)-448-7084
2	STEAM MONITORING SYSTEM ACCESSORIES				
2A	OrificePlate (Stainless Steel Tab Type) with Concentric Bore. 300 lb. Steel Weld Neck Flanges with Pressure Taps and Pressure Pick-up Parts For Steam @ 125 psig. Orifice Plate is to be sized for 2" Steam Line (schedule 40, I.D.) Pipe Carrying 125 psig Steam With Flow Rate Ranging From 0 to 6500 lbs/hr.	300/ea.	1	300.00	J.W. Sweet Co. P.O. Box 6395 Columbia, S.C. 29260 Phone: (803)-754-7492
2B	1/8" Quick Connects (Male)	2.00/ea	4	8.00	

APPENDIX 2 (cont'd.)

Item		Estimated Cost ($)	Quantity	Estimated Total Cost ($)	Potential Vendor
No.	Description				
2C	½" Blackiron Pipe (150 psi)	0.26/ft	25ft	6.50	Obtain Locally
2D	½" Full Port Valve (Gate or Ball) (150 psi)	9.43/ea.	4	37.72	"
2E	½" Blackiron 90° Elbow (150 psi)	0.10/ea.	4	0.40	"
2F	½" Blackiron TEG (150 psi)	0.26/ea.	4	1.04	"

APPENDIX 2 (cont'd.)

Item No.	Item Description	Estimated Cost ($)	Quantity	Estimated Total Cost ($)	Potential Vendor
3.	FIBERGLASS PIPING AND FITTING				
3A	6" Pipe with 20 mil liner	8.48/ft	98 ft	831.04	Ameron - Bonstrand Products 2508 Canal Ave. Atlanta, GA 30341 Phone (404)-457-6685 Contact: John Patric
3B	6" 90° Elbow	72.98/ea	4	291.92	
3C	6" Filament wound flange	42.82/ea	8	342.56	
4.	304 STAINLESS STEEL PIPING AND FITTINGS				Southwest Stainless of Georgia 6290 I-85 Access Road Norcross, GA Phone (404)-449-7965 Contact: Dick George
PIPE					
4A	2" 304 Stainless Steel Pipe, Schedule 40	6.11/ft	20 ft	12.22	or
					Stainless Distribution and Supply Norcross, GA Phone (404)-449-7720 Contact: Richard Bennett
4B	4" 304 Stainless Steel Pipe Schedule 40	20.25/ft	32 ft	648.00	
4C	5" 304 Stainless Steel Pipe Schedule 40	25.00/ft	4 ft	100.00	

2225.74

APPENDIX 2 (cont'd.)

Item		Estimated Cost ($)	Quantity	Estimated Total Cost ($)	Potential Vendor
No.	Description				
4D	6" 304 Stainless Steel Pipe Schedule 40	30.00/ft	2 ft	60.00	"
4E	8" 304 Stainless Steel Pipe Schedule 40	45.50/ft	10 ft	455.00	"
90^{o} ELBOWS					
4F	2" 304 Stainless Steel 90^{o} Elbow Schedule 40	14.22/ea	2	28.44	"
4G	4" 304 Stainless Steel 90^{o} Elbow Schedule	67.20/ea	3	201.60	"
4H	8" 304 Stainless Steel Elbow Schedule 40	302.50/ea	1	302.50	"
TEES					
4I	4" 304 Stainless Steel Tee Schedule 40	127.80/ea	5	639.00	"

1686.54

APPENDIX 2 (cont'd.)

Item No.	Item Description	Estimated Cost ($)	Quantity	Estimated Total Cost ($)	Potential Vendor
4J	5" 304 Stainless Steel Tee Schedule 40	190.00/ea	1	190.00	"
4K	8" 304 Stainless Steel Tee Schedule 40	439.80/ea	1	439.80	"
	<u>FLANGES</u>				
4L	2" 304 Stainless Steel Flange Schedule 40	40.00/ea	6	240.00	"
4M	4" 304 Stainless Steel Flange Schedule 40	67.20/ea	21	1411.20	"
4N	3½" 304 Stainless Steel Flange Schedule 40	60.50/ea	1	60.50	"
4O	5" 304 Stainless Steel Flange Schedule 40	80.00/ea	5	400.00	"
4P	6" 304 Stainless Steel Flange Schedule 40	96.25/ea	2	192.50	"
4Q	8" 304 Stainless Steel Flange Schedule 40	143.00/ea	4	572.00	"

3506.00

Item No.	Item Description	Estimated Cost ($)	Quantity	Estimated Total Cost ($)	Potential Vendor
	<u>HALF NIPPLES</u>				
4R	½" Half Nipple 304 Stainless Steel Schedule 40 (½" X 3")	1.50/ea	2	3.00	"
4S	2" Half Nipple 304 Stainless Steel Schedule 40 (2" X 4")	5.50/ea	1	5.50	"
	<u>REDUCERS</u>				
	304 Stainless Steel (Schedule 40)				
4T	8 X 6	139.75/ea	1	139.75	"
4U	6 X 5	115.05/ea	1	115.05	"
4V	8 X 4	186.00/ea	2	372.00	"
4W	6 X 4	64.20	2	128.40	"
4X	5 X 3	128.70	1	128.70	"
4Y	3 X 2	22.04	1	22.04	"
4Z	4 X 2	38.45	3	115.35	"
4AA	4 X 3½	50.00	1	50.00	"

1079.79

APPENDIX 2 (cont'd.)

Item No.	Item Description	Estimated Cost ($)	Quantity	Estimated Total Cost ($)	Potential Vendor
5	PUMPS AND ACCESSORIES				
5A	Gorman-Rupp 14-A4B Gray Iron Centrifugal Pump with Teflon Packing (212° MAX)	1071.00/ea	2	2142.00	Daigh Equipment Co. 1860 Scobb Industrial Blvd. S.E. Smyrna, GA Phone (404)-432-8836 Contact: Bill Waits
5B	10HP-1750 RPM 3 Phase Drip Motor 220 Volts	270.00/ea	2	540.00	"
5C	Coupling	82.80/ea	1	82.80	"
5D	Base Plate and Coupling guard	149.40/ea	1	149.40	"
5E	Sheaves, Belts, Bearing, etc.	300.00 TOTAL	1	300.00	"

3214.20

Item No.	Item Description	Estimated Cost ($)	Quantity	Estimated Total Cost ($)	Potential Vendor
6.	<u>SIGHT GLASS</u>				
6A	Penbenthy Model No. 70A, 316 Stainless Steel ½" Pipe Size 5/8" Glass Value Set 70A, 316 Stainless Steel	220.00/ Set	1	220.00	Streater Sales, Inc. 2090 Tucker Industrial Road Tucker, GA Phone (404)-939-4544 Contact: Nelson Gore
6B	6' length of Pressure glass with red line	25.20	1	25.20	"
6C	6' Bronze Guard Rods	8.64/ ea	4	34.56	"
6D	½" Stainless Steel (304) Pipe Schedule 40	0.50/ft	2	1.00	same as 4
				280.76	

Item No.	Item Description	Estimated Cost ($)	Quantity	Estimated Total Cost ($)	Potential Vendor
7.	VALVES				
	ITT Grinnell Corporation Valves				Simco Supply Co. Inc. 665 8th St. N.W. Atlanta, GA Phone (404)-875-9371 Contact: Bill Blankmier
7A	2" Figure 1660 Bar Stock ball valve; 316 Stainless Steel Body and Trim; RCS. PA 25 Actuaton for 80 psi available air supply intergal nema 4, 4 way solenoid with speed control	439.92/ea	2	879.84	ITT Grinnell Corp. P. O. Box 4719 645 Northside Dr. N.W. Atlanta, GA 30302 Phone (404)-524-6201
7B	Same as 7A with 70" Extended Stem	∿500.00/ea	1	500.00	"

1379.84

APPENDIX 2 (cont'd.)

Item		Estimated Cost ($)	Quantity	Estimated Total Cost ($)	Potential Vendor
No.	Description				
7C	4" Figure 7577-1212359 Butterfly Valve; CI Body 316 Stainless Steel Disk, EPT (Ethylene propylene) Seat, with RCS PA50 Actuator; integral nema 4 - 4 way solenoid valve with speed control	487.00/ ea	4	1948.00	"

1948.00

APPENDIX 2 (cont'd.)

Item		Estimated Cost ($)	Quantity	Estimated Total Cost ($)	Potential Vendor
No.	Description				
	<u>STRAINER SYSTEM</u>				
8.	316 Stainless Steel Wire Strainer	300.00	1	300.00	Same as 6A

9. Computer Requirements

No.	Description	Cat. No.	Manufacturer	Price ($)	Quantity	Total Price ($)
9A	9815A Desk top Computer	9815A	Hewlett-Packard	2,900/ea	1	$ 2,900.00
	Factory Installed Options					
9B	2008 Total Program Steps	001	"	500/opt	1	500.00
9C	2 I/O Channels	002	"	200/opt	1	200.00
9D	6 Additional Data Cartridges	003	"	54/set	2	108.00
9E	BCD Interface	98133A	"	600/opt	1	600.00
9F	Carrying Case	98145A	"	35/ea	1	35.00
9G	Printer Paper	9270 - 0479	"	21.60/6 roll pkg	2	43.20
	Maintenance Agreement covering 9815A, options 001 and 002, and 98133A	--	"	246/yr	1	246.00

[1]Vendor: Hewlett-Packard Corporation
P. O. Box 105005
450 Interstate North Parkway
Atlanta, Georgia 30348
(404)955-1500

10. <u>Computer-Spectrophotometer Interface</u>

No.	Description	Cat. No.	Manufacturer	Price ($)	Quantity	Total Price ($)
10	Logic Interface between B&L Spectronic 100 and HP9815A[1]	--	Built at Georgia Tech	500/ea	1	$ 500.00

11. Spectrophotometer and Accessories

No.	Description	Cat. No.	Manufac-turer	Price ($)	Quantity	Total Price ($)
11A	B&L Spectronic 100 Spectrophotometer with 14-377-267 multiple Sample Compartment	14-385-200	Fisher	2553.13	1	$ 2,533.13
11B	Instructional Manual	14-385-204	"	4.81	2	9.63
11C	Blue Phototube	14-385-232	"	16.84	1	16.84
11D	Red Phototube	14-385-233	"	16.84	1	16.84
11E	Tungsten Lamp	14-377-290	"	16.36	2	32.75
11F	Spectrophotometer Cells	14-385-904D	"	68.91	4	275.63
						$ 2,884.82

[1]Vendor: Fisher Scientific
2775 Pacific Dr.
Norcross, GA
(404) 449-5050

12. Miscellaneous OS&E Items

No.	Description	Cat. No.	Manufac-turer	Price ($)	Quantity	Total Price ($)
12A	30ml Syringes	14-823-10E	Fisher	8.50/ea	3	$ 25.50
12B	Kimwipes	6-666A	"	31.80/ea	1	31.80
12C	100ml pipets	13-650U	"	4.96/ea	2	9.92
12D	50ml pipets	13-650S	"	3.50/ea	2	7.00
12E	25ml pipets	13-650P	"	2.74/ea	2	5.48
12F	5ml pipets	13-650F	"	1.76/ea	2	3.52
12G	Pipet bulbs	13-681-51	"	11.75/ea	2	22.50
12H	250ml beakers	2-555-20A	"	14.88/12	12	14.88
12I	Test tubes	14-932A	"	7.68/24	24	7.68
12J	Test tube holders	14-781-16	"	3.30/ea	2	6.60
12K	Acetone	ΔA-17	"	43.20/cs	1	43.20
12L	Liquinox Liquid Detergent	4-322-15A	"	3.50/qt	2	7.00
					TOTAL:	$ 185.08

[1]Vendor: Fisher Scientific
2775 Pacific Dr.
Norcross, GA
(404) 449-5050

13. Syringe Filter Accessories

No.	Description	Cat. No.	Manufac- turer	Price ($)	Quantity	Total Price ($)
13A	Prefilters, 100/pkg	AP2501000	Millipore	7.20/pkg	3	$ 21.60
13B	Water Filters	HAWP01300	"	18.90/pkg	3	56.70
13C	Swinny Filter Attach- ment, 13mm	XX3001200	"	22.40/ea	2	44.80
13D	Swinny Replacement Parts					
	O-ring, Teflon, 5/pkg	XX3001201	"	13.20/pkg	1	13.20
	Gasket, Teflon, 10/pkg	XX3001202	"	24.10/pkg	1	24.10
	SS Filter Screen	XX3001210	"	6.60/ea	1	6.60
	Wrench Set	XX3001204	"	6.60/ea	1	6.60

[1]Vendor: Millipore Corporation
Ashby Road
Bedford, Massachusetts 01730
(617)275-9200

APPENDIX 3.

Program Listings for Dyebath Reuse

Program 0

```
0000 CLEAR
0001 CLRA÷J
0002 #REGS
0003 2
0004 0
0005 1
0006 #REGS
0007 9
0008 0
0009 #REGS
0010 4
0011 0
0012 0
0013 ENTER↑
0014 4
0015 3
0016 +≑-
0017 LOAD
0018 GOSUB   0400
0020 FIX     1
0022 CFG     1
0023 CFG     2
0024 CFG     3
0025 CFG     4
0026 CFG     5
0027 CFG     6
0028 CFG     7
0029 CFG     8
0030 3
0031 5
0032 0
0033 0
0034 .
0035 0
0036 PRINT
0037 SPACE
0038 STOP
0039 STO     R088
0041 PRNTα
0043 PRINT
0044
0045 G
0046 A
0047 L
0048 S
0049 .
0050 ENDα
0051 SPACE
0052 CLEAR
0053 PRNTα
0055 G
0056 I
0057 V
0058 E
0059
0060 W
0061 E
0062 I
0063 G
0064 H
0065 T
0066 LINE
0067 O
0068 F
0069
0070 F
0071 A
0072 B
0073 R
0074 I
0075 C
0076
0077 (
0078 L
0079 B
0080 S
0081 )
0082 LINE
0083 T
0084 H
0085 E
0086 N
0087
0088 P
0089 R
0090 E
0091 S
0092 S
0093
0094 <
0095 R
0096 U
0097 N
0098 >
0099 ENDα
0100 SPACE
0101 SPACE
0102 SPACE
0103 SPACE
0104 FIX     1
0106 STOP
0107 STO     R088
0109 PRINT
0110 CLEAR
0111 4
0112 0
0113 0
0114 ENTER↑
0115 0
0116 +≑-
0117 LOAD
0118 GOTO    0400
0120 LBL
---- L
0122 PRNTα
0124 L
0125 I
0126 B
0127 R
0128 A
0129 R
0130 Y
0131
0132 S
0133 E
0134 A
0135 R
0136 C
0137 H
0138 LINE
0139 F
0140 A
0141 I
0142 L
0143 E
0144 D
0145
0146 T
0147 O
0148
0149 F
0150 I
0151 N
0152 D
0153 LINE
```

Program 0

```
0154 T
0155 H
0156 I
0157 S
0158
0159 S
0160 T
0161 Y
0162 L
0163 E
0164 /
0165 S
0166 H
0167 A
0168 D
0169 E
0170 *
0171 *
0172
0173 R
0174 E
0175 S
0176 T
0177 A
0178 R
0179 T
0180
0181 *
0182 *
0183 ENDα
0184 GOTO     0000
0186 LBL
---- M
0188 CLEAR
0189 RCL      A
0190 STO      R089
0192 1
0193 +
0194 +÷-
0195 LOAD
0196 RCL      R000
0198 SPACE
0199 FIX      0
0201 PRNTα
0203 PRINT
0204 .
0205 D
0206 Y
0207 E
0208
0209 M
0210 I
0211 X
0212 ENDα
0213 SPACE
0214 SPACE
0215 STO      G
0216 1
0217 STO      B
0218 4
0219 2
0220 STO+     B
0221 STO+     G
0222 FOR      B÷G
0223 RCL I    B
0225 PRNTα
0227 *
0228 *
0229
0230 C
0231 R
0232 A
0233 N
0234 K
0235
0236 T
0237 O
0238
0239 PRINT
0240 *
0241 *
0242 LINE
0243 1
0244 )
0245
0246 P
0247 U
0248 L
0249 L
0250
0251 K
0252 N
0253 O
0254 B
0255
0256 O
0257 U
0258 T
0259 2
0260 )
0261
0262 Z
0263 E
0264 R
0265 O
0266 LINE
0267 3
0268 )
0269
0270 P
0271 U
0272 S
0273 H
0274
0275 K
0276 N
0277 O
0278 B
0279
0280 I
0281 N
0282
0283 4
0284 )
0285
0286 P
0287 R
0288 E
0289 S
0290 S
0291
0292 <
0293 R
0294 U
0295 N
0296 >
0297 ENDα
0298 SPACE
0299 SPACE
0300 SPACE
0301 SPACE
0302 GOSUB    L04
0304 RCL      R000
0306 1
0307 +
0308 RCL      B
0309 4
0310 2
0311 -
0312 *
```

Program 0

```
0313 STO      J
0314 ROLL↓
0315 STO+  I  J
0317 NEXT     B
0318 FIX      0
0320 CLEAR
0321 2
0322 LD&GO
0323 LBL
---- A
0325 CLEAR
0326 3
0327 LD&GO
0328 LBL
---- B
0330 CLEAR
0331 4
0332 LD&GO
0333 LBL
---- C
0335 CLEAR
0336 5
0337 LD&GO
0338 LBL
---- D
0340 CLEAR
0341 6
0342 LD&GO
0343 LBL
---- E
0345 CLEAR
0346 7
0347 LD&GO
0348 LBL
---- F
0350 CLEAR
0351 8
0352 LD&GO
0353 LBL
---- G
0355 CLEAR
0356 9
0357 LD&GO
0358 LBL
---- 04
0360 STOP
0361 CALL    4A
0363 +
0364 RETURN
0365 LBL
---- H
0367 CLEAR
0368 4
0369 6
0370 +÷-
0371 LD&GO
0372 LBL
---- I
0374 CLEAR
0375 4
0376 7
0377 +÷-
0378 LD&GO
0379 END
```

APPENDIX 3. (cont'd.)

Program Listings for Dyebath Reuse

Program 1

```
0000 PRNTα
0002 D
0003 Y
0004 E
0005 B
0006 A
0007 T
0008 H
0009 LINE
0010 R
0011 E
0012 C
0013 O
0014 N
0015 S
0016 T
0017 I
0018 T
0019 U
0020 T
0021 I
0022 O
0023 N
0024 LINE
0025 Q
0026 U
0027 A
0028 N
0029 T
0030 I
0031 T
0032 I
0033 E
0034 S
0035
0036 F
0037 O
0038 R
0039 LINE
0040 N
0041 E
0042 W
0043
0044 S
0045 H
0046 A
0047 D
0048 E
0049 LINE
0050 LINE
0051 ENDα
0052 5
0053 0
0054 0
0055 ENTER↑
0056 RCL      R089
0058 9
0059 1
0060 +
0061 LOAD
0062 GOSUB    0500
0064 3
0065 .
0066 7
0067 8
0068 5
0069 3
0070 RCL      R088
0072 *
0073 STO      E
0074 1
0075 STO      B
0076 RCL      R000
0078 STO      G
0079 FOR      B+G
0080 RCL I    B
0082 +÷-
0083 STO I    B
0085 RCL      E
0086 STO* I   B
0088 5
0089 4
0090 RCL      B
0091 +
0092 STO      J
0093 RCL I    J
0095 RCL      R086
0097 *
0098 STO      H
0099 STO+ I   B
0101 4
0102 8
0103 RCL      B
0104 +
0105 STO      J
0106 CLEAR
0107 1
0108 0
0109 RCL I    J
0111 LOAD
0112 RCL      R010
0114 EEX
0115 2
0116 ÷
0117 STO* I   D
0119 EEX
0120 3
0121 STO÷ I   B
0123 CFG      4
0124 LBL
---- 01
0126 CLEAR
0127 RCL I    J
0129 FIX      0
0131 4
0132 0
0133 +
0134 LOAD
0135 SPACE
0136 GOSUB    0086
0138 SPACE
0139 RCL I    B
0141 IF -
0142 GOSUB    L04
0144 RCL I    B
0146 4
0147 5
0148 4
0149 ÷
0150 IF SFG   4
0151 GOTO     0163
0153 ENTER↑
0154 INT
0155 -
```

APPENDIX 3. (cont'd.)

Program 1

```
0156 LSTX
0157 X⇌Y
0158 4
0159 5
0160 4
0161 ÷
0162 X⇌Y
0163 PRNT¢
0165 A
0166 D
0167 D
0168
0169 PRINT
0170
0171 L
0172 B
0173 S
0174 END¢
0175 IF SFG 4
0176 GOTO    0189
0178 X⇌Y
0179 PRNT¢
0181 +
0182
0183 PRINT
0184
0185 G
0186 M
0187 S
0188 END¢
0189 SPACE
0190 IF SFG 4
0191 RETURN
0192 NEXT    B
0193 SPACE
0194 SPACE
0195 PRNT¢
0197 *
0198 *
0199 A
0200 U
0201 X
0202 I
0203 L
0204 I
0205 A
0206 R
0207 I
0208 E
0209 S
0210 *
0211 *
0212 END¢
0213 SPACE
0214 1
0215 STO     B
0216 6
0217 7
0218 STO     J
0219 LBL
---- 02
0221 RCL I   J
0223 IF 0
0224 GOTO    L03
0226 STO     R001
0228 RCL     R086
0230 STO*    R001
0232 EEX
0233 3
0234 STO÷    R001
0236 6
0237 STO-    J
0238 SFG     4
0239 GOSUB   L01
0241 7
0242 STO+    J
0243 GOTO    L02
0245 LBL
---- 03
0247 CLEAR
0248 5
0249 1
0250 +⇌-
0251 LOAD
0252 GOSUB   0000
0254 SPACE
0255 SPACE
0256 PRNT¢
0258
0259 *
0260 *
0261 *
0262 *
0263 *
0264 *
0265 *
0266 *
0267 *
0268 *
0269 *
0270 *
0271 *
0272 END¢
0273 SPACE
0274 SPACE
0275 SPACE
0276 SPACE
0277 SPACE
0278 CLEAR
0279 LD&GO
0280 LBL
---- 04
0282 PRNT¢
0284 *
0285 *
0286 *
0287 *
0288 W
0289 A
0290 R
0291 N
0292 I
0293 N
0294 G
0295 *
0296 *
0297 *
0298 *
0299 LINE
0300 -
0301
0302 V
0303 A
0304 L
0305 U
0306 E
0307 S
0308
0309 M
0310 E
0311 A
0312 N
0313 LINE
0314
0315 E
0316 X
0317 C
0318 E
0319 S
0320 S
```

APPENDIX 3. (cont'd.)

Program 1

```
0321
0322 D
0323 Y
0324 E
0325 END↓
0326 ENTER↑
0327 ENTER↑
0328 RCL      H
0329 X≠Y
0330 -
0331 ÷
0332 EEX
0333 2
0334 *
0335 +≠-
0336 FIX      1
0338 PRNT≠
0340
0341 =
0342 PRINT
0343
0344 %
0345 END↓
0346 ROLL↓
0347 SPACE
0348 SPACE
0349 RETURN
0350 END
```

APPENDIX 3. (cont'd.)

Program Listings for Dyebath Reuse

Program 2

```
0000 RCL     R000
0002 PRNT⏎
0004
0005 S
0006 O
0007 L
0008 V
0009 E
0010
0011 N
0012 *
0013 N
0014
0015 =
0016
0017 PRINT
0018
0019
0020 END⏎
0021 SPACE
0022 CFG     1
0023 GOTO    L01
0025 LBL
---- 00
0027 SFG     1
0028 LBL
---- 01
0030 1
0031 STO     A
0032 +÷-
0033 STO     D
0034 RCL     R000
0036 STO     F
0037 STO     G
0038 FOR     A→F
0039 RCL     A
0040 STO     B
0041 STO     H
0042 FOR     B→G
0043 1
0044 RCL     R000
0046 +
0047 STO     C
0048 RCL     B
0049 RCL     A
0050 GOSUB   A
0052 STO     E
0053 FOR     C→HD
0054 RCL     B
0055 RCL     C
0056 GOSUB   A
0058 RCL     E
0059 STO÷ I  J
0061 NEXT    C
0062 NEXT    B
0063 RCL     A
0064 RCL     R000
0066 IF X=Y
0067 GOTO    C
0069 RCL     A
0070 1
0071 +
0072 STO     B
0073 FOR     B→G
0074 1
0075 RCL     R000
0077 +
0078 STO     C
0079 FOR     C→HD
0080 RCL     A
0081 RCL     C
0082 GOSUB   A
0084 STO     E
0085 RCL     B
0086 RCL     C
0087 GOSUB   A
0089 RCL     E
0090 STO- I  J
0092 NEXT    C
0093 NEXT    B
0094 LBL
---- C
0096 NEXT    A
0097 2
0098 STO     A
0099 RCL     R000
0101 STO     F
0102 FOR     A→F
0103 1
0104 STO     B
0105 RCL     A
0106 1
0107 STO     D
0108 -
0109 STO     G
0110 FOR     B→G
0111 RCL     A
0112 RCL     B
0113 GOSUB   A
0115 STO     E
0116 RCL     J
0117 STO     I
0118 1
0119 RCL     R000
0121 +
0122 STO     J
0123 RCL     A
0124 -
0125 RCL     J
0126 RCL     B
0127 -
0128 GOSUB   A
0130 STO I   1
0132 RCL     E
0133 STO I   J
0135 NEXT    B
0136 NEXT    A
0137 1
0138 STO     A
0139 RCL     R000
0141 2
0142 ÷
0143 INT
0144 STO     F
0145 FOR     A→F
0146 RCL     A
0147 1
0148 RCL     R000
0150 +
0151 GOSUB   A
0153 STO     E
0154 RCL     J
0155 STO     I
0156 RCL     A
0157 +÷-
0158 1
0159 RCL     R000
0161 +
0162 +
0163 LSTX
0164 GOSUB   A
0166 STO I   I
0168 RCL     E
0169 STO I   J
0171 NEXT    A
0172 IF CFG  1
0173 GOTO    L00
```

Program 2

```
0175 1
0176 STO     A
0177 RCL     R000
0179 STO     F
0180 1
0181 ÷
0182 STO     I
0183 FOR     A÷F
0184 RCL     A
0185 FIX     0
0187 PRNTα
0189 C
0190 O
0191 N
0192 C
0193 .
0194
0195 PRINT
0196
0197 =
0198 ENDα
0199 RCL     A
0200 RCL     I
0201 GOSUB   A
0203 FIX     1
0205 PRNTα
0207 PRINT
0208
0209 (
0210 M
0211 G
0212 /
0213 L
0214 )
0215 LINE
0216 ENDα
0217 SPACE
0218 STO I   A
0220 NEXT    A
0221 CLEAR
0222 1
0223 LD&GO
0224 LBL
---- A
```

```
0226 X≑Y
0227 1
0228 -
0229 RCL     R000
0231 1
0232 ÷
0233 *
0234 +
0235 STO     J
0236 RCL I   J
0238 RETURN
0239 END
```

Program Listings for Dyebath Reuse

Program -0

```
0000 LBL
---- 90
0002 9
0003 0
0004 #REGS
0005 FIX      0
0007 CLEAR
0008 PRNT∝
0010 G
0011 I
0012 V
0013 E
0014
0015 S
0016 T
0017 Y
0018 L
0019 E
0020
0021 #
0022 LINE
0023 P
0024 R
0025 E
0026 S
0027 S
0028
0029 <
0030 E
0031 N
0032 T
0033 E
0034 R
0035 >
0036 LINE
0037 G
0038 I
0039 V
0040 E
0041
0042 S
0043 H
0044 A
0045 D
0046 E
0047
0048 #
0049 LINE
0050 P
0051 R
0052 E
0053 S
0054 S
0055
0056 <
0057 R
0058 U
0059 N
0060 >
0061 LINE
0062 LINE
0063 LINE
0064 LINE
0065 LINE
0066 END∝
0067 STOP
0068 X≑Y
0069 PRNT∝
0071 S
0072 T
0073 Y
0074 L
0075 E
0076
0077 #
0078
0079 =
0080
0081 PRINT
0082 END∝
0083 X≑Y
0084 PRNT∝
0086 S
0087 H
0088 A
0089 D
0090 E
0091
0092 #
0093
0094 =
0095
0096 PRINT
0097 END∝
0098 X≑Y
0099 EEX
0100 4
0101 *
0102 +
0103 STO      R087
0105 CLEAR
0106 1
0107 0
0108 LOAD
0109 CLEAR
0110 LBL
---- 91
0112 STO      A
0113 RCL I    A
0115 IF 0
0116 GOTO     L
0118 RCL      R087
0120 IF X=Y
0121 GOTO     M
0123 LBL
---- N
0125 RCL      A
0126 1
0127 +
0128 4
0129 0
0130 IF X=Y
0131 GOTO     K
0133 ROLL↓
0134 GOTO     L91
0136 LBL
---- 93
0138 PRNT∝
0140 A
0141 L
0142 L
0143
0144 O
0145 F
0146
0147 L
0148 I
0149 B
0150 R
0151 A
0152 R
0153 Y
0154 LINE
0155 S
0156 E
```

Program -0

```
0157 A
0158 R
0159 C
0160 H
0161 E
0162 D
0163
0164 F
0165 O
0166 R
0167
0168 T
0169 H
0170 E
0171 S
0172 T
0173 Y
0174 L
0175 E
0176 /
0177 S
0178 H
0179 A
0180 D
0181 E
0182
0183 S
0184 L
0185 O
0186 T
0187 W
0188 I
0189 T
0190 H
0191 O
0192 U
0193 T
0194
0195 S
0196 U
0197 C
0198 C
0199 E
0200 S
0201 S
0202 LINE
0203 LINE
0204 S
0205 T
0206 A
0207 R
0208 T
0209
0210 O
0211 V
0212 E
0213 R
0214
0215 A
0216 N
0217 E
0218 W
0219 LINE
0220 LINE
0221 ENDα
0222 CLEAR
0223 LD&GO
0224 LBL
---- J
0226 CLEAR
0227 RCL      A
0228 9
0229 1
0230 +
0231 LOAD
0232 SPACE
0233 GOSUB  0000
0235 SPACE
0236 RETURN
0237 END
```

Appendix 4.

Conventional Salem Process
as of December, 1979

1. Load carpet.
2. Fill the beck with water.
3. Add the auxiliaries, to include:

   leveling agent

   sequesterant

   defoamer

   ammonia

   and run 5-10 minutes.
4. Add dyes and run 5-10 minutes.
5. Add MSP as pH control agent, and run 5 minutes.
6. Rinse to boil at $4^{O}F$/minute.
7. Hold at boil for 30 minutes, and patch.
8. If on shade, proceed to Step 9. If not, make the necessary add and repeat Steps 6-8.
9. Repeat Steps 6 and 7 without patching to insure that level is attained.
10. Drop the dyebath to the drain, fill the beck with rinse water, and run 5 minutes.
11. Pull the carpet, drop the rinse bath, and clean the beck.
12. Return to Step 1.

APPENDIX 5.

Energy Consumption Data for The Dyeing Sequences

SEQUENCE CONVENTIONAL	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	LOAD (LBS)	ADDS (#)	TEMPERATURE/STEAM HEAT-UP TEMP. (°F)	HEAT-UP STEAM (LBS)	ADD 1 TEMP. (°F)	ADD 1 STEAM (LBS)	ADD 2 TEMP. (°F)	ADD 2 STEAM (LBS)	ADD 3 TEMP. (°F)	ADD 3 STEAM (LBS)	LEVEL-OUT TEMP. (°F)	LEVEL-OUT STEAM (LBS)	TOTAL STEAM (LBS)
"	1	1	Thistle	1642	1	72	4782	180	2904	–	–	–	–	172	3073	10759
"	2	2	Thistle	1680	0	82	5590	–	–	–	–	–	–	192	3325	8915
"	3	3	Auburn	1665	1	66	6317	186	2573	–	–	–	–	190	2617	11507
"	4	4	Auburn	1640	0	65	5905	–	–	–	–	–	–	194	2433	8338
"	5	5	Bamboo	1650	1	64	5431	184	2130	–	–	–	–	186	2165	9726
"	6	6	Bamboo	1666	1	78	4253	184	2433	–	–	–	–	192	2696	9382
"	7	7	Bamboo	1700	1	62	6218	194	2045	–	–	–	–	199	2352	10615
"	8	8	Bamboo	1680	1	73	5836	186	2192	–	–	–	–	192	2506	10532
"	9	9	Chamois	1680	1	88	5446	173	2430	–	–	–	–	182	1869	9745
"	10	10	Chamois	1667	0	90	4057	–	–	–	–	–	–	183	2620	6677
			TOTAL:	16670	7	740	53835	1287	16707	–	–	–	–	1882	25656	96196
			AVERAGE:	1667	0.7	74	5384	184	2387	–	–	–	–	188	2566	9620

APPENDIX 5. (cont'd.)

SEQUENCE	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	LOAD (LBS)	ADDS (#)	TEMPERATURE/STEAM										
						HEAT-UP		ADD 1		ADD 2		ADD 3		LEVEL-OUT		TOTAL
BUMP & RUN						TEMP. (°F)	STEAM (LBS)	TEMP. (°F)	STEAM (LBS)	TEMP. (°F)	STEAM (LBS)	TEMP (°F)	STEAM (LBS)	TEMP. (°F)	STEAM (LBS)	STEAM (LBS)
"	11	1	Sauterne	1652	2	62	3733	172	0	157	848	–	–	166	1318	5899
"	12	2	Pecan	1685	2	90	3585	168	1547	168	1907	–	–	176	1793	8832
"	13	3	Pecan	1740	0	94	3981	–	–	–	–	–	–	164	2267	6248
"	14	4	Sauterne	1620	0	75	3987	–	–	–	–	–	–	173	2029	6016
"	15	5	Sauterne	1692	1	68	4225	180	1012	–	–	–	–	176	995	6232
"	16	6	Watercress	1616	0	68	3705	–	–	–	–	–	–	173	1559	5264
"	17	7	Camel	1670	1	74	4103	170	1514	–	–	–	–	174	1595	7212
"	18	8	Camel	1670	0	90	3654	–	–	–	–	–	–	165	1894	5548
"	19	9	Camel	1720	0	90	3245	–	–	–	–	–	–	168	1412	4657
"	20	10	London Fog	1700	2	84	3618	175	883	160	778	–	–	175	1334	6613
			TOTAL:	16765	8	795	37836	865	4956	485	3533	–	–	1710	16196	62521
			AVERAGE:	1677	0.8	80	3784	173	991	162	1178	–	–	171	1620	6252

APPENDIX 5. (cont'd.)

SEQUENCE FIRST BUMP & RUN/ DYEBATH REUSE	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	LOAD (LBS)	ADDS (#)	TEMPERATURE/STEAM HEAT-UP TEMP. (°F)	HEAT-UP STEAM (LBS)	ADD 1 TEMP. (°F)	ADD 1 STEAM (LBS)	ADD 2 TEMP. (°F)	ADD 2 STEAM (LBS)	ADD 3 TEMP. (°F)	ADD 3 STEAM (LBS)	LEVEL-OUT TEMP. (°F)	LEVEL-OUT STEAM (LBS)	TOTAL STEAM (LBS)
"	21	1	Rice	1616	1	60	2499	164	1234	–	–	–	–	190	1062	4795
"	22	2	Skyscraper Blue	1570	2	150	1962	172	1353	182	1612	–	–	181	1080	6007
"	23	3	Thistle	1640	2	136	1591	168	1348	174	730	–	–	179	876	4545
"	24	4	Thistle	1616	3	125	1703	170	986	164	1392	176	983	[a] –	–	5064
"	25	5	Thistle	1640	1	128	2302	178	1328	–	–	–	–	181	883	4513
"	26	6	Thistle	1770	0	132	1642	–	–	–	–	–	–	175	1357	2999
"	27	7	Buckeye	1800	2	130	1585	162	1644	162	96	–	–	168	1000	4325
"	28	8	Buckeye	1786	2	119	1665	157	527	168	1599	–	–	183	990	4781
"	29	9	Buckeye	1920	0	126	1336	–	–	–	–	–	–	143	974	2310
"	30	10	Buckeye	1780	1	125	1816	157	1455	–	–	–	–	171	155	3426
"	31	11	Buckeye	1745	1	[b] –	–	–	–	–	–	–	–	–	–	–
			TOTAL:	18883	15	1231	18101	1328	9875	850	5429	176	983	1571	8377	42765
			AVERAGE:	1717	1.4	123	1810	166	1234	170	1086	176	983	175	931	4277

[a] No level-out cycle for this run, since 3 adds had been made.

[b] For unknown reason, TDI zeroed on this run, and accurate measurements were not obtained.

APPENDIX 5. (cont'd.)

SEQUENCE SECOND BUMP & RUN/ DYEBATH REUSE	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	LOAD (LBS)	ADDS (#)	TEMPERATURE/STEAM HEAT-UP TEMP. (°F)	HEAT-UP STEAM (LBS)	ADD 1 TEMP. (°F)	ADD 1 STEAM (LBS)	ADD 2 TEMP. (°F)	ADD 2 STEAM (LBS)	ADD 3 TEMP. (°F)	ADD 3 STEAM (LBS)	LEVEL-OUT TEAM. (°F)	LEVEL-OUT STEAM (LBS)	TOTAL STEAM (LBS)
"	32	1	Polar White	1666	2	64	4425	160	1610	168	1904	-	-	172	2411	10350
"	33	2	Polar White	1650	1	130	2623	164	2147	-	-	-	-	169	1470	6240
"	34	3	Polar White	1690	3	121	3455	162	2064	162	1998	163	2031	168	1325	10873
"	35	4	Rice	1692	2	120	3182	176	1413	172	1673	-	-	179	1326	7594
"	36	5	Bran	1710	1	94	3281	166	1935	-	-	-	-	174	909	6125
"	37	6	Bran	1720	0	130	2822	-	-	-	-	-	-	171	1640	4462
"	38	7	Bran	1660	0	132	2599	-	-	-	-	-	-	159	1732	4331
"	39	8	Bran	1802	1	131	2537	176	1143	-	-	-	-	175	1281	4961
"	40	9	Bran	1662	0	134	2871	-	-	-	-	-	-	181	1604	4475
"	41	10	Thistle	1790	0	126	3295	-	-	-	-	-	-	179	1787	5082
"	42	11	Thistle	1820	0	126	3419	-	-	-	-	-	-	184	1239	4658
"	43	12	Thistle	1600	1	131	2933	163	1593	-	-	-	-	178	1017	5543
"	44	13	Thistle	1638	2	121	2484	168	1238	170	1448	-	-	175	1228	6398
			TOTAL:	22100	13	1560	39926	1335	13143	672	7023	163	2031	2264	18969	81092
			AVERAGE:	1700	1.0	120	3071	167	1643	168	1756	163	2031	174	1459	6238

APPENDIX 5. (cont'd.)

SEQUENCE BUMP & RUN/ DYEBATH REUSE/ HOT PULL	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	LOAD (LBS)	ADDS (#)	TEMPERATURE/STEAM HEAT-UP TEMP. (°F)	HEAT-UP STEAM (LBS)	ADD 1 TEMP. (°F)	ADD 1 STEAM (LBS)	ADD 2 TEMP. (°F)	ADD 2 STEAM (LBS)	ADD 3 TEMP. (°F)	ADD 3 STEAM (LBS)	LEVEL-OUT TEMP. (°F)	LEVEL-OUT STEAM (LBS)	TOTAL STEAM (LBS)
"	45	1	Bone	1560	0	64	4877	-	-	-	-	-	-	174	1521	6398
"	46	2	Bone	1560	0	149	2422	-	-	-	-	-	-	172	1163	3585
"	47	3	Bone	1550	3	141	2422	174	1448	170	1428	169	1643	180	1147	8088
"	48	4	Muffin	1526	3	152	1925	-	1812	-	2372	-	2345	-	1046	9500
"	49	5	Muffin	1590	0	-	2244	-	-	-	-	-	-	-	1219	3463
"	50	6	Temple Gold	1560	1	160	2028	-	1511	-	-	-	-	-	1242	4781
			TOTAL:	9346	7	666	15918	174	4771	170	3800	169	3988	526	7338	35815
			AVERAGE:	1558	1.2	133	2653	174	1590	170	1900	169	1994	175	1223	5969

APPENDIX 6.

WATER/SEWER AND TIME REQUIREMENTS FOR DYEING SEQUENCES

SEQUENCE CONVENTIONAL	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	ADDS (#)	WATER/ SEWER (GAL)	CYCLE TIME (MIN)
"	1	1	Thistle	1	9985[a]	280
"	2	2	Thistle	0	9945[a]	209
"	3	3	Auburn	1	9985[a]	299
"	4	4	Auburn	0	9925	192
"	5	5	Bamboo	1	9615	383
"	6	6	Bamboo	1	10165	278
"	7	7	Bamboo	1	9965	295
"	8	8	Bamboo	1	6165[b]	293
"	9	9	Chamois	1	6165[b]	265
"	10	10	Chamois	0	9575	189
			TOTAL:	7	91490	2683
			AVERAGE	0.7	9149	268

[a] Water meter malfunctioned, and fill volumes were calculated from the the beck dimensions.

[b] The rinse water from the previous cycle was used as the dyebath water for the next run, as was infrequently done in conventional practice at the plant.

APPENDIX 6. (cont'd.)

SEQUENCE BUMP & RUN	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	ADDS (#)	WATER/ SEWER (GAL)	CYCLE TIME (MIN)
"	11	1	Sauterne	2	9855	280
"	12	2	Pecan	2	10005	385
"	13	3	Pecan	0	6125[b]	224
"	14	4	Sauterne	0	6125[b]	225
"	15	5	Sauterne	1	9615	260
"	16	6	Watercress	0	9775	213
"	17	7	Camel	1	9965	348
"	18	8	Camel	0	10625	202
"	19	9	Camel	0	6125[b]	205
"	20	10	London Fog	2	6205[b]	352
			TOTAL:	8	84420	2694
			AVERAGE:	0.8	8442	269

APPENDIX 6. (cont'd.)

SEQUENCE FIRST BUMP & RUN/ DYEBATH REUSE	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	ADDS (#)	WATER/ SEWER (GAL)	CYCLE TIME (MIN)
"	21	1	Rice	1	7869	400
"	22	2	Skyscraper Blue	2	4919	415
"	23	3	Thistle	2	7856	365
"	24	4	Thistle	3	5447	455
"	25	5	Thistle	1	4745	282
"	26	6	Thistle	0	4605	225
"	27	7	Buckeye	2	6028	450
"	28	8	Buckeye	2	3410	385
"	29	9	Buckeye	0	4786	258
"	30	10	Buckeye	1	5202	373
"	31	11	Buckeye	1	6527	315
			TOTAL:	15	61394	3923
			AVERAGE:	1.4	5581	357

APPENDIX 6. (cont'd.)

SEQUENCE SECOND BUMP & RUN/ DYEBATH REUSE	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	ADDS (#)	WATER/ SEWER (GAL)	CYCLE TIME (MIN)
"	32	1	Polar White	2	8336	445
"	33	2	Polar White	1	4458	315
"	34	3	Polar White	3	7687	595
"	35	4	Rice	2	5156	385
"	36	5	Bran	1	5227	313
"	37	6	Bran	0	3896	240
"	38	7	Bran	0	4966	310
"	39	8	Bran	1	3735	310
"	40	9	Bran	0	3852	245
"	41	10	Thistle	0	3780	267
"	42	11	Thistle	0	4824	277
"	43	12	Thistle	1	8215	309
"	44	13	Thistle	2	4937	420
			TOTAL:	13	69069	4431
			AVERAGE:	1	5313	341

APPENDIX 6. (cont'd.)

SEQUENCE BUMP & RUN/ DYEBATH REUSE/ HOT PULL	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	ADDS (#)	WATER/ SEWER (GAL)	CYCLE TIME (MIN)
"	45	1	Bone	0	3625	280
"	46	2	Bone	0	125	249
"	47	3	Bone	3	345	456
"	48	4	Muffin	3	245	445
"	49	5	Muffin	0	725	225
"	50	6	Temple Gold	1	265	240
			TOTAL:	7	5330	1895
			AVERAGE:	1.2	888	316

APPENDIX 7.

Auxiliary Chemical Consumption Data for Dyeing Sequences

SEQUENCE	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	LOAD (LBS)	ADDS (#)	AUXILIARY CHEMICALS LEVEL. (LBS)	SEQUEST. (LBS)	DEFOAM. (LBS)	AMMONIA (LBS)	MSP (LBS)	ACETIC (LBS)
CONVENTIONAL											
"	1	1	Thistle	1642	1	16	32	4	24	24	0
"	2	2	Thistle	1680	0	17	34	6	26	26	0
"	3	3	Auburn	1665	1	17	34	6	26	26	0
"	4	4	Auburn	1640	0	16	32	11	24	24	0
"	5	5	Bamboo	1650	1	17	34	6	17	17	0
"	6	6	Bamboo	1666	1	17	34	4	26	26	0
"	7	7	Bamboo	1700	1	17	34	6	26	26	0
"	8	8	Bamboo	1680	1	17	34	6	26	26	15
"	9	9	Chamois	1680	1	17	34	6	17	17	0
"	10	10	Chamois	1667	0	17	34	4	26	26	0
			TOTAL:	16670	7	168	336	59	238	238	15
			AVERAGE:	1667	0.7	16.8	33.6	5.9	23.8	23.8	1.5

APPENDIX 7. (cont'd.)

SEQUENCE BUMP & RUN	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	LOAD (LBS)	ADDS (#)	AUXILIARY CHEMICALS LEVEL. (LBS)	SEQUEST. (LBS)	DEFOAM. (LBS)	AMMONIA (LBS)	MSP (LBS)	ACETIC (LBS)
"	11	1	Sulterne	1652	2	17	34	4	26	26	0
"	12	2	Pecan	1685	2	17	34	6	26	26	0
"	13	3	Pecan	1740	0	17	34	6	17	17	0
"	14	4	Saulterne	1620	0	16	32	6	16	16	0
"	15	5	Saulterne	1692	1	17	34	4	26	26	0
"	16	6	Watercress	1616	0	16	32	4	24	24	0
"	17	7	Camel	1670	1	17	34	6	26	26	0
"	18	8	Camel	1670	0	17	34	6	26	26	0
"	19	9	Camel	1720	0	17	34	6	17	17	0
"	20	10	London Fog	1700	2	17	34	6	17	17	0
			TOTAL:	16765	8	168	336	54	221	221	0
			AVERAGE:	1677	0.8	16.8	33.6	5.4	22.1	22.1	0

APPENDIX 7. (cont'd.)

SEQUENCE FIRST BUMP & RUN/ DYEBATH REUSE	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	LOAD (LBS)	ADDS (#)	AUXILIARY CHEMICALS LEVEL. (LBS)	SEQUEST. (LBS)	DEFOAM. (LBS)	AMMONIA (LBS)	MSP (LBS)	ACETIC (LBS)
"	21	1	Rice	1616	1	16	16	4	24	24	0
"	22	2	Skyscraper Blue	1570	2	5.3	5.3	3	12	8	0
"	23	3	Thistle	1640	2	4	4	3	8.5	2	4
"	24	4	Thistle	1616	3	5.3	5.3	2	20[a]	8	0
"	25	5	Thistle	1640	1	6	6	3	20[a]	8	0
"	26	6	Thistle	1770	0	6	6	3	20[a]	9	0
"	27	7	Buckeye	1800	2	6	6	3	20[a]	9	0
"	28	8	Buckeye	1786	2	5	5	2	20[a]	8	0
"	29	9	Buckeye	1920	0	8	8	3	20[a]	12	0
"	30	10	Buckeye	1780	1	6	6	6	20[a]	9	0
"	31	11	Buckeye	1745	1	6	6	6	20[a]	9	0
			TOTAL:	18883	15	73.6	73.6	38	204.5	106	4
			AVERAGE:	1717	1.4	6.7	6.7	3.5	18.6	9.6	0.4

[a] Eight lbs. ammonia added to prerinse bath.

APPENDIX 7. (cont'd.)

SEQUENCE SECOND BUMP & RUN/ DYEBATH REUSE	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	LOAD (LBS)	ADDS (#)	AUXILIARY CHEMICALS LEVEL. (LBS)	SEQUEST. (LBS)	DEFOAM. (LBS)	AMMONIA (LBS)	MSP (LBS)	ACETIC (LBS)
"	32	1	Polar White	1666	2	27[b]	17	6	26	26	0
"	33	2	Polar White	1650	1	0	6	3	12	6	0
"	34	3	Polar White	1690	3	6	6	3	20[a]	8	0
"	35	4	Rice	1692	2	14	6	2	20[a]	8	0
"	36	5	Bran	1710	1	0	6	3	14	9	0
"	37	6	Bran	1720	0	6	6	3	16	9	0
"	38	7	Bran	1660	0	6	6	3	16	8	0
"	39	8	Bran	1802	1	14[b]	4	2	16	5	0
"	40	9	Bran	1662	0	6	6	3	16	8	0
"	41	10	Thistle	1790	0	6	6	6	16	9	0
"	42	11	Thistle	1820	0	5	5	3	16	7	0
"	43	12	Thistle	1600	1	4	4	3	16	6	0
"	44	13	Thistle	1638	2	5	4	3	16	6	0
			TOTAL:	22100	13	99	82	43	220	115	0
			AVERAGE:	1700	1	7.6	6.3	3.3	16.9	8.9	0

[b]Additional leveling agent added because of unlevel dyeing.

APPENDIX 7. (cont'd.)

SEQUENCE BUMP & RUN/ DYEBATH REUSE / HOT PULL	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	LOAD (LBS)	ADDS (#)	AUXILIARY CHEMICALS LEVEL. (LBS)	SEQUEST. (LBS)	DEFOAM. (LBS)	AMMONIA (LBS)	MSP (LBS)	ACETIC (LBS)
"	45	1	Bone	1560	0	16	16	6	24	24	0
"	46	2	Bone	1560	0	4	4	3	16	6	0
"	47	3	Bone	1550	3	4	4	3	16	6	0
"	48	4	Muffin	1526	3	4	4	2	16	6	0
"	49	5	Muffin	1590	0	6	6	3	16	9	0
"	50	6	Temple Gold	1560	1	4	4	3	16	6	0
			TOTAL:	9346	7	38	38	20	104	57	0
			AVERAGE:	1558	1.2	6.3	6.3	3.3	17.3	9.5	0

APPENDIX 8.

Dye Consumption Data and Savings
for Dyeing Sequences

SEQUENCE	PROJECT RUN	RUN IN SEQUENCE	SHADE	LOAD	ADDS	RECYCLED DYES			ADDED DYES			TOTAL DYES			DYE SAVINGS		
				(#)	(#)	YELLOW (g)	RED (g)	BLUE (g)	YELLOW (g)	RED (g)	BLUE (g)	YELLOW (g)	RED (g)	BLUE (g)	YELLOW (%)	RED (%)	BLUE (%)
CONVENTIONAL	(#)	(#)															
"	1	1	Thistle	1642	1	-	-	-	1701	885	274	1701	885	274	-	-	-
"	2	2	Thistle	1680	0	-	-	-	1735	903	281	1735	903	281	-	-	-
"	3	3	Auburn	1665	1	-	-	-	4419	2842	558	4419	2842	558	-	-	-
"	4	4	Auburn	1640	0	-	-	-	4177	2798	538	4177	2798	538	-	-	-
"	5	5	Bamboo	1640	1	-	-	-	324	149	39	324	149	39	-	-	-
"	6	6	Bamboo	1666	1	-	-	-	356	155	40	356	155	40	-	-	-
"	7	7	Bamboo	1700	1	-	-	-	385	168	41	385	168	41	-	-	-
"	8	8	Bamboo	1680	1	-	-	-	334	151	39	334	151	39	-	-	-
"	9	9	Chamois	1680	1	-	-	-	657	250	64	657	250	64	-	-	-
"	10	10	Chamois	1667	0	-	-	-	585	218	58	585	218	58	-	-	-
			TOTAL:	16670	7	-	-	-	14673	8519	1932	14673	8519	1932	-	-	-
			AVERAGE:	1667	0.7	-	-	-	1467	852	193	1467	852	193	-	-	-

APPENDIX 8. (cont'd.)

SEQUENCE BUMP & RUN	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	LOAD (#)	ADDS (#)	RECYCLED DYES YELLOW (g)	RECYCLED DYES RED (g)	RECYCLED DYES BLUE (g)	ADDED DYES YELLOW (g)	ADDED DYES RED (g)	ADDED DYES BLUE (g)	TOTAL DYES YELLOW (g)	TOTAL DYES RED (g)	TOTAL DYES BLUE (g)	DYE SAVINGS YELLOW (%)	DYE SAVINGS RED (%)	DYE SAVINGS BLUE (%)
"	11	1	Sauterne	1642	2	-	-	-	219	55	58	219	55	58	-	-	-
"	12	2	Pecan	1685	2	-	-	-	912	423	163	912	423	163	-	-	-
"	13	3	Pecan	1740	0	-	-	-	853	419	171	853	419	171	-	-	-
"	14	4	Sauterne	1620	0	-	-	-	199	53	57	199	53	57	-	-	-
"	15	5	Sauterne	1692	1	-	-	-	218	56	59	218	56	59	-	-	-
"	16	6	Watercress	1616	0	-	-	-	165	39	60	165	39	60	-	-	-
"	17	7	Camel	1670	1	-	-	-	540	316	85	540	316	85	-	-	-
"	18	8	Camel	1670	0	-	-	-	537	317	85	537	317	85	-	-	-
"	19	9	Camel	1720	0	-	-	-	564	337	96	564	337	96	-	-	-
"	20	10	London Fog	1700	2	-	-	-	300	173	77	300	173	77	-	-	-
			TOTAL:	16765	8	-	-	-	4507	2188	911	4507	2188	911	-	-	-
			AVERAGE:	1677	0.8	-	-	-	450.7	218.8	91.1	450.7	218.8	91.1	-	-	-

APPENDIX 8. (cont'd.)

SEQUENCE FIRST BUMP & RUN/ DYEBATH REUSE	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	LOAD (#)	ADDS (#)	RECYCLED DYES YELLOW (g)	RECYCLED DYES RED (g)	RECYCLED DYES BLUE (g)	ADDED DYES YELLOW (g)	ADDED DYES RED (g)	ADDED DYES BLUE (g)	TOTAL DYES YELLOW (g)	TOTAL DYES RED (g)	TOTAL DYES BLUE (g)	DYE SAVINGS YELLOW (%)	DYE SAVINGS RED (%)	DYE SAVINGS BLUE (%)
"	21	1	Rice	1616	1	0	0	0	176	88	32	176	88	32	0	0	0
"	22	2	Skyscraper Blue	1570	2	10.2	6.7	4.9	106	147	367	116.2	153.7	371.9	8.8	4.4	1.3
"	23	3	Thistle	1640	2	5.3	10.6	50.3	1620	837	239	1625.3	847.6	289.3	0.3	1.3	17.4
"	24	4	Thistle	1616	3	104.5	64.7	26.1	1630	782	248	1734.5	846.7	271.1	6.0	7.6	9.5
"	25	5	Thistle	1640	1	35.2	26.1	9.1	1555	889	262	1590.2	915.1	271.1	2.2	2.9	3.4
"	26	6	Thistle	1770	0	102.2	39.2	11.2	1591	867	266	1693.2	906.2	277.2	6.0	4.3	4.0
"	27	7	Buckeye	1800	2	109.0	64.7	25.0	4150	3772	1394	4259	3836.7	1419	2.6	1.7	1.8
"	28	8	Buckeye	1786	2	320.2	327.0	136.3	3905	3074	1212	4225.2	3401	1348.3	7.6	9.6	10.1
"	29	9	Buckeye	1920	0	278.2	266.8	103.3	4234	3529	1330	4512.2	3795.8	1433.3	6.2	7.0	7.2
"	30	10	Buckeye	1780	1	203.3	182.8	71.5	4008	3531	1272	4211.3	3713.8	1343.5	4.8	4.9	5.3
"	31	11	Buckeye	1745	1	248.7	228.2	87.4	3880	3328	1230	4128.7	3556.2	1317.4	6.0	6.4	6.6
			TOTAL:	18883	15	1416.8	1216.8	525.1	26855	20844	7852	28272	22061	8374	–	–	–
			AVERAGE:	1717	1.4	128.8	110.6	47.7	2441	1895	714	2570	2005	761	5.0[a]	5.5[a]	6.3[a]

AVERAGE DYE SAVINGS: 5.6%

[a]Derived by dividing the average recycled dye weights by the average total dye weights.

APPENDIX 8. (cont'd.)

SEQUENCE SECOND BUMP & RUN/ DYEBATH REUSE	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	LOAD (#)	ADDS (#)	RECYCLED DYES YELLOW (G)	RECYCLED DYES RED (g)	RECYCLED DYES BLUE (g)	ADDED DYES YELLOW (g)	ADDED DYES RED (g)	ADDED DYES BLUE (g)	TOTAL DYES YELLOW (g)	TOTAL DYES RED (g)	TOTAL DYES BLUE (g)	DYE SAVINGS YELLOW (%)	DYE SAVINGS RED (%)	DYE SAVINGS BLUE (%)
"	32	1	Polar White	1666	2	0	0	0	37	12	9	37	12	9	0	0	0
"	33	2	Polar White	1650	1	0	0	0	36	12	6	36	12	6	0	0	0
"	34	3	Polar White	1690	3	0	0	0	54	21	15	54	21	15	0	0	0
"	35	4	Rice	1692	2	0	0	0	184	88	34	184	88	34	0	0	0
"	36	5	Bran	1710	1	2.3	4.5	0	990	305	81	992.3	309.5	81	0.23	1.5	0
"	37	6	Bran	1720	0	27.3	2.7	0	938	318	77	965.3	320.7	77	2.8	.8	0
"	38	7	Bran	1660	0	34.4	23.9	5.3	888	276	69	922.4	299.9	74.3	3.7	8.0	7.1
"	39	8	Bran	1802	1	42.0	7.0	0	878	303	81	921	310	81	0.5	0.2	0
"	40	9	Bran	1662	0	62.3	29.1	8.0	786	256	67	848.3	285.1	75	7.3	10.2	10.7
"	41	10	Thistle	1790	0	100.7	53.2	20.1	1671	897	260	1771.7	950.2	280.1	5.7	5.6	7.2
"	42	11	Thistle	1820	0	107.3	67.6	27.8	1614	869	276	1721.3	936.6	303.8	6.2	7.2	9.2
"	43	12	Thistle	1600	1	83.5	55.6	23.9	1400	782	274	1483.5	837.6	297.9	5.6	6.6	8.0
"	44	13	Thistle	1638	2	128.5	95.4	33.1	1470	769	237	1598.5	864.4	270.1	8.0	11.0	12.3
			TOTAL:	22100	13	588.3	339.0	118.2	10947	4908	1486	11535	5247	1604	-	-	-
			AVERAGE:	1700	1.0	45.3	26.1	9.1	842	378	114	887	404	123	5.1[a]	6.5[a]	7.4[a]

AVERAGE DYE SAVINGS: 6.3%

APPENDIX 8. (cont'd.)

SEQUENCE	PROJECT RUN (#)	RUN IN SEQUENCE (#)	SHADE	LOAD (#)	ADDS (#)	RECYCLED DYES YELLOW (g)	RECYCLED DYES RED (g)	RECYCLED DYES BLUE (g)	ADDED DYES YELLOW (g)	ADDED DYES RED (g)	ADDED DYES BLUE (g)	TOTAL DYES YELLOW (g)	TOTAL DYES RED (g)	TOTAL DYES BLUE (g)	DYE SAVINGS YELLOW (g)	DYE SAVINGS RED (g)	DYE SAVINGS BLUE (g)
BUMP-AND-RUN/ DYEBATH REUSE/ HOT PULL																	
"	45	1	Bone	1560	0	0	0	0	73	14	9	73	14	9	0	0	0
"	46	2	Bone	1560	0	5.5	1.3	0	77	16	10	82.5	17.3	10	6.7	7.5	0
"	47	3	Bone	1550	3	3.0	0.8	0	54	16	10	57.0	16.8	10	5.3	4.8	0
"	48	4	Muffin	1526	3	5.6	1.4	0	241	72	34	246.6	73.4	34	2.3	1.9	0
"	49	5	Muffin	1590	0	6.3	2.3	0.1	233	85	34	239.3	87.3	34.1	2.6	2.6	0.29
"	50	6	Temple Gold	1560	1	10.6	4.5	1.0	2921	720	232	2931.6	724.5	233	0.36	0.62	0.43
			TOTAL:	9346	7	31.0	10.3	1.1	3599	923	329	3630	933	330	-	-	-
			AVERAGE:	1558	1.2	5.2	1.7	0.2	600	154	54.8	605	156	55	0.9	1.1	0.4

AVERAGE DYE SAVINGS: 0.8%

APPENDIX 9.

Color Differences Between Dyed Samples and Average Color Values by Shade

SEQUENCE	SHADE	PROJECT RUN (#)	RUN IN SEQUENCE (#)	CIE L*a*b*				FMC II					
				SOURCE D		SOURCE F		SOURCE D			SOURCE F		
				DL	DE	DL	DE	DC	DL	DE	DC	DL	DE
Bump-and-Run/ Dyebath Reuse	Rice	21	1	-0.52	0.52	-0.52	0.52	0.19	-1.32	1.33	0.17	-1.29	1.30
"	"	35	4	-1.50	1.62	-1.48	1.58	2.40	-3.74	4.44	1.76	-3.62	4.03
Conventional	Thistle	1	1	3.02	3.14	3.05	3.18	3.43	7.25	8.02	2.32	7.21	7.57
"	"	2	2	3.12	3.24	3.15	3.31	2.78	7.53	8.03	1.89	7.51	7.74
Bump-and-Run/ Dyebath Reuse	"	23	3	0.16	0.74	0.17	0.57	1.93	0.44	1.97	1.43	0.45	1.50
"	"	24	4	-0.47	0.51	-0.47	0.50	0.32	-1.08	1.12	0.24	-1.07	1.10
"	"	25	5	-3.18	3.32	-3.21	3.37	2.61	-6.86	7.34	1.82	-6.82	7.06
"	"	26	6	1.12	1.50	1.11	1.30	2.05	2.71	3.39	1.22	2.62	2.89
"	"	41	10	-1.99	2.26	-2.00	2.11	4.24	-4.32	6.05	2.76	-4.29	5.10
"	"	42	11	1.82	1.93	1.80	1.87	0.77	4.35	4.42	0.50	4.22	4.25
"	"	43	12	1.50	1.52	1.47	1.50	1.68	3.58	3.92	1.26	3.41	3.63
"	"	44	13	2.03	2.12	2.00	2.11	3.49	4.81	5.94	2.73	4.63	5.37
Bump-and-Run/ Dyebath Reuse	Buckeye	27	7	-0.79	1.21	-0.83	1.29	1.25	-1.64	2.06	1.01	-1.68	1.97
"	"	28	8	0.05	0.35	0.05	0.35	0.47	0.09	0.48	0.40	0.08	0.41
"	"	29	9	1.30	1.62	1.33	1.70	1.42	2.79	3.13	0.95	2.81	2.96
"	"	30	10	0.54	0.78	0.54	0.68	1.21	1.20	1.70	0.89	1.17	1.48
"	"	31	11	-0.96	1.06	-0.97	1.08	0.28	-1.96	1.98	0.19	-1.95	1.96

APPENDIX 9. (cont'd.)

Color Differences Between Dyed Samples and Average Color Values by Shade

SEQUENCE	SHADE	PROJECT RUN (#)	RUN IN SEQUENCE (#)	CIE L*a*b*				FMC II					
				SOURCE D		SOURCE F		SOURCE D			SOURCE F		
				DL	DE	DL	DE	DC	DL	DE	DC	DL	DE
Bump-and-Run/ Dyebath Reuse	Sauterne	11	1	0.83	0.93	0.81	0.94	1.30	2.13	2.50	1.04	2.08	2.32
"	"	14	4	-0.30	0.46	-0.31	0.47	0.39	-0.74	0.84	0.33	-0.77	0.83
"	"	15	5	0.79	0.79	0.80	0.80	0.27	2.04	2.06	0.22	2.05	2.06
"	Pecan	12	2	0.47	0.52	0.46	0.50	0.95	1.16	1.49	0.66	1.12	1.30
"	"	13	3	-0.45	0.53	-0.44	0.50	1.08	-1.09	1.54	0.74	-1.05	1.29
"	Watercress	16	6	0.49	0.49	0.49	0.49	0.18	1.25	1.26	0.15	1.26	1.27
"	Camel	17	7	-0.55	0.63	-0.53	0.59	1.29	-1.35	1.87	0.99	-1.27	1.61
"	"	18	8	-0.22	0.28	-0.22	0.22	0.61	-0.54	0.81	0.43	-0.52	0.68
"	"	19	9	0.91	1.00	0.89	0.96	2.00	2.26	3.02	1.51	2.17	2.64
"	London Fog	20	10	-0.10	0.11	-0.10	0.11	0.16	-0.26	0.31	0.13	-0.26	0.28

APPENDIX 9. (cont'd.)

Color Differences Between Dyed Samples and Average Color Values by Shade

SEQUENCE	SHADE	PROJECT RUN (#)	RUN IN SEQUENCE (#)	CIE L*a*b*				FMC II					
				SOURCE D		SOURCE F		SOURCE D			SOURCE F		
				DL	DE	DL	DE	DC	DL	DE	DC	DL	DE
Bump-and-Run/ Dyebath Reuse/ Hot Pull	Muffin	48	4	0.58	0.68	0.58	0.68	0.87	1.51	1.71	0.67	1.47	1.61
"	"	49	5	-0.98	1.08	-0.96	1.08	1.39	-2.46	2.83	1.05	-2.38	2.60
"	Temple Gold	50	6	0.47	0.51	0.48	0.53	0.40	1.06	1.14	0.28	1.07	1.11
Bump-and-Run/ Dyebath Reuse	Skyscraper Blue	22	2	0.12	0.19	0.14	0.20	0.52	0.30	0.60	0.46	0.35	0.58
Conventional	Auburn	3	3	-0.49	0.57	-0.50	0.57	0.29	-1.02	1.06	0.26	-1.04	1.07
"	"	4	4	0.53	0.61	0.54	0.61	0.34	1.13	1.18	0.28	1.14	1.18
"	Bamboo	5	5	0.41	1.05	0.37	1.09	2.70	1.02	2.88	2.02	0.89	2.21
"	"	6	6	-1.52	2.09	-1.44	2.04	4.81	-3.72	6.08	3.54	-3.45	4.94
Conventional	"	7	7	1.36	1.40	1.38	1.44	0.21	3.49	3.50	0.13	3.48	3.49
"	"	8	8	1.27	1.65	1.22	1.59	3.97	3.23	5.12	2.93	3.02	4.21
"	Chamois	9	9	0.76	0.85	0.79	0.89	0.17	1.93	1.44	0.14	1.96	1.96
"	"	10	10	0.06	0.27	0.04	0.27	0.67	0.14	0.69	0.50	0.09	0.51

APPENDIX 9. (cont'd.)

Color Differences Between Dyed Samples and Average Color Values by Shade

SEQUENCE	SHADE	PROJECT RUN (#)	RUN IN SEQUENCE (#)	CIE L*a*b*				FMC II					
				SOURCE D		SOURCE F		SOURCE D			SOURCE F		
				DL	DE	DL	DE	DC	DL	DE	DC	DL	DE
Bump-and-Run/ Dyebath Reuse	Polar White	32	1	0.44	1.12	0.50	1.14	2.98	1.14	3.19	2.33	1.30	2.67
"	"	33	2	2.55	2.59	2.60	2.64	1.55	6.60	6.78	1.27	6.67	6.79
"	"	34	3	-2.39	2.75	-2.52	2.97	1.82	-5.59	6.16	1.48	-6.14	6.32
Bump-and-Run/ Dyebath Reuse/ Hot Pull	Bone	45	1	1.74	1.84	1.72	1.79	2.47	4.45	5.09	1.92	4.35	4.75
"	"	46	2	-1.69	2.15	-1.65	2.19	3.50	-4.21	5.47	2.76	-4.06	4.91
"	"	47	3	-0.04	1.04	-0.06	1.08	1.49	-0.05	1.49	1.26	-0.11	1.26
Bump-and-Run/ Dyebath Reuse	Bran	36	5	0.72	0.90	0.73	0.87	1.69	1.76	2.44	1.40	1.74	2.24
"	"	37	6	-1.63	2.23	-1.59	2.01	5.54	-3.82	6.73	4.06	-3.67	5.48
"	"	38	7	-3.18	3.68	-3.12	3.61	6.75	-7.45	10.05	4.82	-7.17	8.64
"	"	39	8	1.96	3.30	1.85	3.33	8.25	4.90	9.60	5.71	4.54	7.30
"	"	40	9	1.23	1.40	1.25	1.39	2.16	3.05	3.74	1.74	3.04	3.51

Appendix 10.

Bump-and-Run Process

1. Load carpet.
2. Fill the beck with water.
3. Add the auxiliaries, to include:

   leveling agent

   sequesterant

   defoamer

   ammonia

   and run 5-10 minutes.
4. Add dyes and run 5-10 minutes.
5. Add MSP as pH control agent, and run 5 minutes.
6. Raise to boil at $4^{o}F$/minute.
7. Hold at boil for 5 minutes, cut off the fan (damper closes automatically), and close the beck door.
8. Drift for 25 minutes, and patch.
9. If on shade, proceed to Step 10. If not, make the necessary add and repeat Steps 6-9.
10. Repeat Steps 6-8 without patching to insure that level is attained.
11. Drop the dyebath to the drain, fill the beck with rinse water, and run 5 minutes.
12. Pull the carpet, drop the rinse bath, and clean the beck.
13. Return to Step 1.

Appendix 11.

Combined Bump-and-Run/Dyebath Reuse Process

1. Load carpet into rinse water left from previous cycle, and run 3 minutes.
2. Drop the rinse bath to the drain.
3. Pump the reused dyebath into the beck from the holding tank.
4. Add the auxiliaries, to include:

   leveling agent

   sequesterant

   defoamer

   ammonia

   and run 5-10 minutes.
5. Add dyes and run 5-10 minutes.
6. Add MSP as pH control agent, and run 5 minutes.
7. Raise to boil at $4^{o}F$/minute.
8. Hold at boil for 5 minutes, cut off the fan (damper closes automatically), and close the beck door.
9. Drift for 25 minutes, and patch.
10. If on shade, proceed to Step 11. If not, make the necessary add and repeat Steps 7-10.
11. Repeat Steps 7-9 without patching to insure that level is attained.
12. After sampling for analysis, pump the exhausted dyebath to the holding tank, fill the beck with rinse water, and run 5 minutes.
13. Pull the carpet from the rinse water, skim loose fiber from the water surface, and clean the lint filter.
14. Return to Step 1.

Appendix 12.

Combined Bump-and-Run/Dyebath
Reuse/Hot Pull Process

1. Add the auxiliaries to the hot dyebath left in the beck from the previous cycle, and run 5 minutes.
2. Add dyes and run 5-10 minutes.
3. Load carpet, run 5-10 minutes.
4. Add MSP, run 5 minutes.
5. Raise to boil at $4^{\circ}F$/minute.
6. Hold at boil for 5 minutes, cut off the fan (damper closes automatically), and close the beck door.
7. Drift for 25 minutes, and patch.
8. If on shade, proceed to Step 9. If not, make the necessary add and repeat Steps 5-8.
9. Repeat Steps 5-7 without patching to insure that level is attained.
10. Pull the carpet from the hot dyebath (180°-$190^{\circ}F$) with the use of protective gloves, and secure a dyebath sample for analysis.
11. Return to Step 1.

APPENDIX 13.

Cost Savings Due to Energy and Water/Sewer Reductions

SEQUENCE	STEAM TOTAL (LBS)	LOAD (LBS)	STEAM PER UNIT WEIGHT (LBS/LB)	COST/ UNIT WEIGHT (¢/LB)	SAVINGS (¢/LB)	WATER/ SEWER (GAL)	WATER PER UNIT WEIGHT (GAL/LB)	COST/ UNIT WEIGHT (¢/LB)	SAVINGS (¢/LB)
CONVENTIONAL	10814	1667	6.49	2.02	–	9149	5.49	0.25	–
BUMP-AND-RUN	6677	1677	3.98	1.24	0.78	8442	5.03	0.23	–
FIRST BUMP-AND-RUN/ DYEBATH REUSE	–[a]	1717	–[a]	–[a]	–[a]	5581	3.25	0.15	0.10
SECOND BUMP-AND-RUN/ DYEBATH REUSE	6578	1700	3.87	1.21	0.81	5313	3.13	0.14	0.11
BUMP-AND-RUN/ DYEBATH REUSE/ HOT PULL	6029	1558	3.87	1.21	0.81	888	0.57	0.03	0.22

[a]TDI malfunctioned, and steam data was invalidated.

APPENDIX 14.

Cost Savings Due to Auxiliary Reductions

SEQUENCE	AVERAGE AUXILIARY MASS LEVEL. (LBS)	SEQUEST. (LBS)	DEFOAM. (LBS)	AMMONIA (LBS)	MSP (LBS)	ACETIC (LBS)	LOAD (LBS)	COST/UNIT WEIGHT LEVEL. (¢/LB)	SEQUEST. (¢/LB)	DEFOAM. (¢/LB)	AMMONIA (¢/LB)	MSP (¢/LB)	ACETIC (¢/LB)	TOTAL (¢/LB)	TOTAL SAVINGS (¢/LB)
CONVENTIONAL	16.8	33.6	5.9	23.8	23.8	1.5	1667	0.59	0.54	0.13	0.10	0.46	0.01	1.83	-
BUMP-AND-RUN	16.8	33.6	5.4	22.1	22.1	0.0	1667	0.59	0.54	0.12	0.09	0.42	0.00	1.76	-
FIRST BUMP-AND-RUN/ DYEBATH REUSE	6.7	6.7	3.5	18.6	9.6	0.4	1717	0.23	0.11	0.07	0.08	0.18	0.00	0.67	1.16
SECOND BUMP-AND-RUN/ DYEBATH REUSE	7.6	6.3	3.3	16.9	8.9	0.0	1700	0.26	0.10	0.07	0.07	0.17	0.00	0.67	1.16
BUMP-AND-RUN/ DYEBATH REUSE/ HOT PULL	6.3	6.3	3.3	17.3	9.5	0.0	1558	0.24	0.11	0.08	0.08	0.20	0.00	0.71	1.12

APPENDIX 15.

Cost Savings Due to Dye Reductions

SEQUENCE	RECYCLED DYES YELLOW (g)	RECYCLED DYES RED (g)	RECYCLED DYES BLUE (g)	LOAD (LBS)	VALUE/UNIT WEIGHT YELLOW (¢/LB)	VALUE/UNIT WEIGHT RED (¢/LB)	VALUE/UNIT WEIGHT BLUE (¢/LB)	VALUE/UNIT WEIGHT TOTAL (¢/LB)
FIRST BUMP-AND-RUN/ DYEBATH REUSE	128.8	110.6	47.7	1717	0.14	0.10	0.09	0.33
SECOND BUMP-AND-RUN/ DYEBATH REUSE	45.3	26.1	9.1	1700	0.05	0.02	0.02	0.09
BUMP-AND-RUN/ DYEBATH REUSE/ HOT PULL	5.2	1.7	0.2	1558	0.01	0.00	0.00	0.01

APPENDIX 16.

Dissemination of Information Efforts
to Date

1. F. L. Cook and M. Moore, "In-Plant Experiences with Dyebath Reuse", Clemson University Wastewater Conference, Hilton Head, S. C., January, 1980.

2. F. L. Cook, "In-Plant Implementation of Dyebath Reuse in Hosiery and Carpet Operations", AATCC South Central Section Meeting, Chattanooga, Tenn., February, 1980

3. W. C. Tincher "In-Plant Optimization of Carpet Beck Dyeing", Invited Seminar, N. C. State University, College of Textiles, January, 1980.

4. W. C. Tincher "In-Plant Optimization of Carpet Beck Dyeing", Joint Georgia Tech/Clemson University Symposium entitled "Energy Conservation in the Textile Industry", Atlanta, GA., February, 1980.