SALLY BUCHANAN

The Stanford Library Flood Restoration Project

The restoration project for approximately 50,000 volumes damaged in a flood at the Stanford University Libraries is described, beginning with the placing of the damaged books (which had been previously frozen in a nearby freezer facility) in a vacuum chamber for drying and their subsequent repair by a special project staff. The article describes the various tests conducted in the vacuum chamber on how best to dry the books.

On November 4, 1978, a ruptured water main flooded the basement stacks of the Stanford University Meyer Library. In an earlier article in this journal Philip D. Leighton described the accident, the initial actions by the university to rescue the damaged books, the prompt freezing of the wet books in a nearby freezer facility, and the decision to dry the books in a vacuum chamber at the Lockheed Missiles & Space Company in Sunnyvale, California.[1] While discussions with Lockheed engineers were under way, the library employed the author to supervise the planning and daily operations for a subsequent flood restoration project.

Preliminary Organization

While we waited to hear from Lockheed about cost and availability of the vacuum chamber, a great deal of preliminary organization took place.

Three weeks following the flood, we wanted to make sure mildew was not spreading in the book stack ranges closest to the inundated area. The two levels of stacks hold 400,000 books, 50,000 of which were affected. It was important to know if fumigation of the stacks would be required. Volunteers from the student body and the Stanford Library Associates conducted a two-day check of 20,000 volumes closest to the flood area. They found only 200 books that had been missed in the original flood cleanup and no indication of mildew infestation.

After some discussion, the Stanford Libraries decided not to weed any of the 50,000 damaged books before drying. The library had deliberately selected these particular books in the past decade as part of an organized collection development program. There was a high likelihood we would want to retain everything, and it would be too difficult to locate in the freezer the few books we might weed. If the projected costs at Lockheed seemed too high, we could attempt to weed in an intermediate step between freezer and shelving in the vacuum chamber. This extra step was not finally necessary.

The next problem to consider was where to house the returning books after they had dried. There was a chance they might develop mildew because Lockheed could not fumigate them due to strict air pollution control standards. (The venting of such massive amounts of chemicals as would be required was not safe.)

Serious consideration was given to returning the books to the Meyer Library basement where we would cage off an area to house them. This would solve the difficult problem of shelving. The Restoration Office at the Library of Congress advised strongly against this move, however, because of the possibility of mildew. We certainly did not want to introduce mildew, if it developed,

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into the clean stack area. Also, the stack area had no suitable work space for general cleaning and repairing of books.

The problem of a facility and shelving proved to be one of the most challenging to solve. Several site alternatives were considered and rejected due to the cost of labor to move books in and out, lack of shelving, lack of space, or disruption to library users.

Finally, we decided upon the empty library of a local junior high school (Terman), which had recently closed. The school district was happy to rent the school library, 2,400 square feet, including shelving for 10,000 books. There were also two storage rooms, 1,600 square feet, to use for empty boxes and the books we could not shelve immediately. There was plenty of space for a work area, sorting area, and development of a high humidity room. Although the site was off-campus, it was close enough to make transportation fairly easy. The building was already wired to the police and fire departments for security.

The shelving problem was solved when a local lumber yard offered to build free-standing bookcases at cost. With 120 shelf units and the available shelving in the library, we could house 35,000 books. The remaining 15,000 would go into storage boxes, unstacked, with tops open to encourage air circulation. We found this caused no problems; books acclimated quickly when shelved, and no mildew developed.

We also made contingency plans in case mildew developed at Terman in the dried flood books. The University of California, Berkeley, has a traveling fumigation chamber we could rent if necessary. This precaution fortunately was not needed.

A fresh supply of book cartons was ordered to replace damaged or deteriorated ones. These would be used at the vacuum chamber to pack the dry books for their trip to the project site. We eventually replaced 300 boxes.

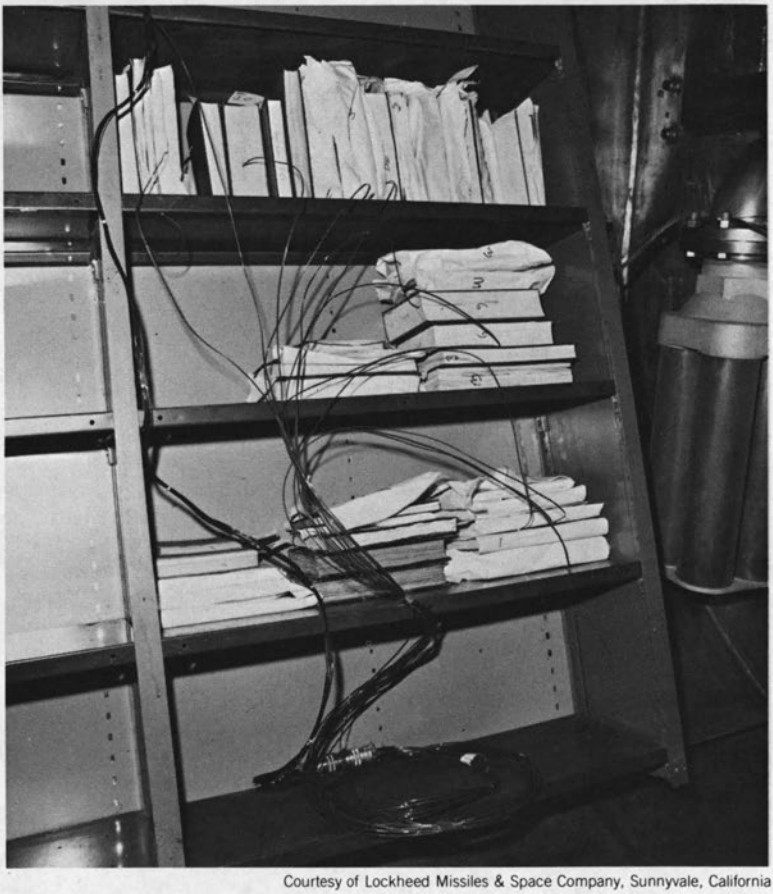
Following the excellent advice in the report *Museum Under Water*,[2] we turned our attention to renting freezer trucks to bring the books the ten miles from the freezer in San Jose to Lockheed in Sunnyvale. In our area, large freezer trucks are at a premium, rented for months at a time to haul produce. Large trucks were unobtainable for daily rental, so small, twenty-foot trucks were reserved. However, after breakdowns on the first day we used them, we decided the distance between the freezer and Lockheed was short enough to warrant the use of enclosed twenty-foot freight trucks.

In practice, the plan worked well, with little thawing occurring in the books in the three hours from the freezer to pulling the vacuum. (After considering and budgeting several alternatives for shipping books from Lockheed to the Terman project site, we found that a local mover was least expensive. This firm's staff could load boxes, drive to Terman, and unload the boxes for less than the truck rental and labor costs if we were to do it ourselves.)

The labor force needed to move such large numbers of books from the freezer to the vacuum chamber and again to the temporary storage facility seemed impossible to assemble. We were working under several restrictions. For security and insurance reasons, Lockheed was anxious that workers be Stanford employees. From our standpoint, we wanted people who would handle the frozen and then dried and fragile books with care. The solution seemed to be to ask Stanford library staff to sign up to help at Lockheed, and we sought permission of department chiefs to use their staff. For public service staff, this meant supplying funds to employ temporary help to fill in for the volunteers. Sign-up sheets were sent to departments asking for date and time preferences.

We set up two shifts, one to unload dry books, another to load the chamber with frozen ones. We decided upon twenty people a shift and two truck drivers a day. The number twenty seemed reasonable to move 5,000 books in three hours or less with ten people unpacking books and ten loading shelves. More than twenty would cause too much congestion within the chamber. Car pools were organized when necessary. A map was drawn up detailing the difficult route to Lockheed.

Lockheed offered forklifts and their own operators to make our labor force available for book handling. The Modern Ice and Cold Storage Company also provided labor and equipment to move frozen cartons out of storage on pallets into the trucks. We re-



Courtesy of Lockheed Missiles & Space Company, Sunnyvale, California

Pretest in vacuum chamber illustrating shelving and wrapping experiments.

cruited truck drivers from among the staff.

As the planning became more involved, a work flow chart was devised to aid in the step-by-step operation. This helped pinpoint potential trouble spots or possible problems we had not considered.

In our preliminary organization, we prepared a detailed budget that included all the alternatives we had considered for facilities, shelving, moving, and labor costs. The budget, for ease of handling, was divided into three phases: the "Emergency" phase, the "Lockheed" phase and the "Terman" phase.

The "Emergency" phase included costs from the initial cleanup, those associated with boxing, the final delivery of books to the freezer, and the costs of replacement and repair of damaged nonbook items such as book carts, carpet, sump pumps, etc.

The "Lockheed" phase included all the projected expenses involved in moving books from the freezer through Lockheed to the Terman site.

The third, or "Terman," phase included all costs for staff salaries, repair, cleaning and replacement of books, equipment, materials, labor, rental of site, telephone, etc. Finally, as part of our preplanning, we designed a checksheet to be used for each book. Every book was to be checked and routed to a destination.

The checksheets were color coded. A green stripe indicated that with minor cleaning and repair the book could be returned immediately to the library. A blue

code indicated that rebinding was necessary. A red stripe meant the book must be held for further repair or replacement. Each checksheet included space for author, title, call number, date, destination, and directions. As books were returned, the checksheets were pulled and kept as a record. Guidelines were developed to help the staff judge the condition of a book to decide how to color code the checksheets.

During this time, as questions about the welfare of the books occurred to us, we consulted Peter Waters, head of the restoration laboratory at the Library of Congress. He suggested a number of critical points (which had come up in previous freeze-dry experiments) to check with the Lockheed engineers. Concerns included pulling or releasing the vacuum so quickly that it might damage paper; heater temperatures; fumigation to prevent mildew; and shelving methods. Waters also agreed to come to California at the end of the first dried load to help evaluate the condition of the books.

On January 5, 1979, Lockheed called to say its facilities would be available to help us. The company also generously offered to absorb the cost of the project as a contribution to Stanford. A pretest to check various shelving methods was established for January 23.[3] We were finally ready to begin.

The "Lockheed" Phase

To prepare for the pretest we selected ninety-six discarded books to fulfill our criteria. We would test four methods of "housing" for the vacuum-drying: milk crates, cardboard cartons, and two shelving methods. We needed both coated and uncoated book paper; books wrapped in freezer paper, partially wrapped, and unwrapped; and both wet and damp books. All these conditions would be found in the flood books. In previous freeze-drying at General Electric[4] and McDonnell Douglas Corporation,[5] milk crates and cardboard boxes had housed the books during the drying process. Both Lockheed and Stanford wondered if books would dry faster unwrapped and placed individually on heated shelving. However, we were not sure which of two shelving positions—books upright with spines to the heated shelf back or books stacked flat on a heated shelf bottom—would be better. Consequently, we tested twenty-four books in each of the four positions, with two in each possible category. For example, in the milk crates, we had the following arrangement:

	Wrapped
Coated paper	2 wet, 2 damp
Uncoated paper	2 wet, 2 damp
	Partially Wrapped
Coated paper	2 wet, 2 damp
Uncoated paper	2 wet, 2 damp
	Unwrapped
Coated paper	2 wet, 2 damp
Uncoated paper	2 wet, 2 damp

Two books in each category gave us a chance to compare results. Each housing method contained the same arrangement of books. The books themselves were chosen haphazardly, weighed dry, then wet, and then dry. Weight difference was recorded and moisture content noted. This was done to see if there was a significant difference among housing methods as far as drying was concerned. There were folio-sized volumes, as well as "tinies." Percentage of change was checked and recorded.

The books shelved both upright and flat were on a shelf unit tilted backwards 20° to keep the spines tight against the heated shelf back. The crates and boxes were placed on upright shelves heated on the bottom. Several hundred pounds of ice were placed on heated shelves to simulate 5,000 frozen books. The vacuum was pulled to 10^{-7} torr.

The chamber at Lockheed is a beautiful piece of machinery. The stainless steel interior is eighteen feet by eighteen feet by thirty-six feet. It has several portholes for viewing, an impressive instrument panel, and an immaculate assemblage of pumps underneath. To one side hangs a cryogenic panel cooled to −320°F. by liquid nitrogen. The books were arranged, thermocouplers inserted to record temperatures, and the massive door shut and locked.

After fifty-five hours the vacuum was released slowly to avoid condensation of moisture on the books. We carefully inspected each book and found eight books still not dry. These eight all had coated paper and were either wrapped or partially

wrapped. Three were in cardboard boxes, two in milk crates, two standing upright. The books housed on a shelf, stacked flat, were all dry. But the books housed upright on a shelf looked best. There was the least amount of paper cockling and cover warping. We did discover that we would need to shelve books firmly, for support. A large book dried next to a small one would warp out at the unsupported edges.

Using an Aqua-Boy, an instrument that indicates moisture content of paper, we checked the paper on all test books. Most recorded less than 2 percent moisture content (the lowest the instrument records). For book paper 5 to 7 percent is considered best.[6] The paper felt extremely dry and fragile. The bindings were tight and broke if the books were "forced" open. It was obvious that acclimating in a humidity environment of 50–60 percent would certainly be necessary. Therefore, we made arrangements for humidifiers and fans for the Terman site. And, in fact, we found that in four to six weeks at 50–60 percent r.h. the book paper regained enough moisture to register from 5–6 percent, and bindings opened readily again.

After discussing the pretest results, Lockheed and Stanford decided to dry the books upright, unwrapped, spines to heated metal shelf backs, shelves tilted 20°, books arranged by size when possible, because they were less distorted in this method than in the other three. There was no *significant* difference in drying in the pretest between housing methods. The initial difference appeared to be in having books wrapped or unwrapped. Wrapped books definitely dried much more slowly. However, during the drying of our regular loads, we noticed time and again that books stacked flat on shelves in a horizontal pile did not dry well. The three or four middle books in the stack always failed to dry in one cycle.

Lockheed started building and installing enough shelving to house 5,000 books. Special heater strips were mounted on the backs of all shelves. A large folio shelf was built to accommodate the several dozen large volumes in each load. Lockheed estimated an official starting date of February 5, 1979. We decided each load would take approximately four days to dry. The plan was to dry one load a week for eight weeks. But Lockheed discovered a schedule conflict that would necessitate two loads a week, if the books could be dried that fast. This meant rearranging all volunteers, trucks, and movers to a four-week schedule if drying time could be shortened.

On February 5, 1979, the first group of volunteers met at Lockheed where security was very tight—everyone signed in and out with badges assigned to each person. Before we started, a session was held to train volunteers in book handling, give shelving instructions, and assign work teams. The shelves in the chamber were arranged in four long ranges with two aisles. Everyone wore old clothes, soft-soled shoes to avoid marking the chamber floor, and gloves to protect hands from frozen books.

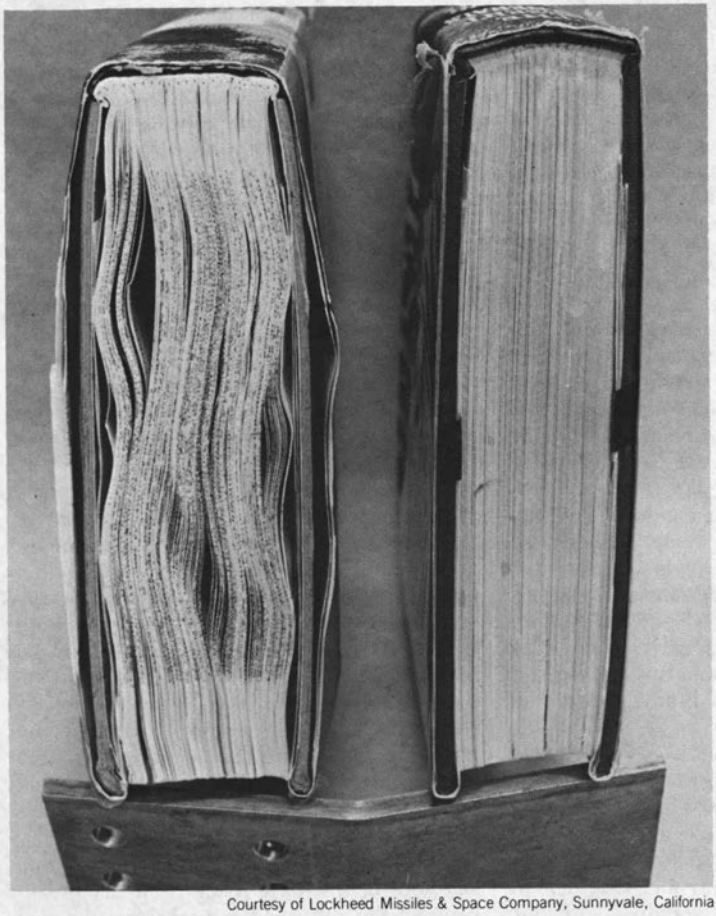
People worked in teams of two or three. One person unpacked the frozen volumes, and another carried them into the chamber and placed them on the shelves. In the chamber other volunteers arranged books by size. Volumes too tall to stand upright were laid flat on shelves. Folios went on special shelving.

All the empty boxes were stacked and hauled away by the trucks, to be brought back again to repack dry books. They could not remain at Lockheed because of the fire hazard. Several volunteers took turns removing and stacking empty boxes to one side, out of the way. Aside from the breakdown of the refrigerator trucks that delayed us, the chamber was loaded by twenty people in 2¼ hours.

On this first day we entertained reporters from several television stations as well as newspapers. In their enthusiasm for pictures, they invaded the chamber with cameras, coffee cups, and cigarettes—a problem we had not foreseen!

There was great applause when the door closed officially on the first load. As the vacuum was pulled, the chamber filled with fog and we lost sight of the books. At 10:00 p.m., February 5, Lockheed's liaison staff member Leon Davies called to say all was progressing well. The thermocouplers inserted in various test books were sending out data recorded on a sheet, and the books were starting to dry.

On February 8 Lockheed phoned to say



Courtesy of Lockheed Missiles & Space Company, Sunnyvale, California

Pretest showing result with book cut in half. Half on left was soaked, vacuum-dried, but not yet pressed. In actual drying process, cockling of paper was kept to a minimum by shelving firmly.

the books would be ready to check in twenty-four hours, and Peter Waters arrived in California to be present for the chamber opening.

Exactly four days after pulling the vacuum, the chamber was opened for a final check. The books looked surprisingly good but seemed very dry. Peter Waters suggested reducing drying time and keeping internal temperatures of books to a maximum of 90°F. There were a hundred larger books, stacked flat, which were not dry—particularly those in the middle of the stack. Warping and cockling were held to a minimum. Much dirt was lifted to the paper surface and could be brushed away.

Surprisingly, many books with coated paper, whose pages had blocked, were found to be released by the vacuum process. But bindings were extremely brittle, and paper moisture content did not register on the Aqua-Boy. After much consultation, Lockheed suggested a forty-eight hour drying cycle with six or eight additional hours of warm air circulation but with unheated shelves. Items still not found dry by volunteers were left in the chamber for another cycle. Each book was checked separately to be sure it was dry. This was done by quickly inserting the hand into several of the center sections where drying occurred last. Lockheed also weighed the amount of ice collected from each load. It averaged 1,800 pounds, or approximately one-third pound of water per book.

The results of the initial drying cycle

Courtesy of Lockheed Missiles & Space Company, Sunnyvale, California

Loading the vacuum chamber with frozen books.

were so encouraging, we knew for the first time that we could save most of the books.

February 12 was the first full day at Lockheed, unloading one dry load and loading a frozen one. From now until the conclusion, we would spend two days a week loading and unloading 10,000 books a day. After a training session to caution volunteers about the fragility of books and to give instructions on packing, we began to unload dry books. Some volunteers carried books to others who packed carefully, making sure books would not bounce around inside boxes.

The professional movers loaded packed boxes efficiently, and all was completed in two hours! Because we had not counted upon such efficiency, we had to wait two hours for frozen books to be delivered. After this day, we planned a continuous effort with frozen books arriving soon after dry ones had left. With times for breaks, we were finished, usually by 2:30 p.m., after starting at 8:30 a.m.

Because there were no microforms or computer tapes in the flooded area, we ran some test items. We soaked microcards, silver halide, diazo and vesicular microfilm, silver halide microfiche, and computer tapes for two hours underwater, froze them for forty-eight hours at −15°F. and vacuum dried them. The microcard was ruined because the card came apart. The film itself showed no ill effect. The computer tape contents were examined, and no errors were found. Even all three microfilms ex-

hibited only minor spotting and no loss of text. It does seem probable that longer exposure to water could ruin the film emulsion.

Phonodiscs and photographs came through the process well. There was no discernible damage to discs supported by their covers during vacuum drying. Some photographs cockled slightly but responded to pressing between sheets of acid-free paper in a book press.

Sixteen-millimeter and 35mm movie film (no nitrate film tested) can be immersed immediately in distilled water and taken to a processing laboratory. If done quickly there should be no loss. Film found in the Meyer basement sat wet for a week with little loss to emulsion. Movie film frozen and vacuum dried in a roll in its cardboard container also recovered well.

The problem of relaying empty boxes was solved when the movers agreed to accept the emptied ones at the end of the day and return them in their truck to be used to pack the next load.

In order to prevent overdry spines on books that went through more than one cycle, on subsequent cycles we shelved them with spines out, away from the heat. This proved to work well.

The "Terman" Phase

The first load of dry books was delivered to the Terman site where the initial shipment of pine bookcases was ready. With the help of Stanford Library Associates volunteers, books were unpacked and shelved for acclimatizing. (The humidity was now at 55 percent.) Each load took approximately two days to shelve, rather loosely, in marked groupings. As the books came from the chamber in no particular order, we did not worry about shelving them in order. Instead, we sorted and placed them in order before returning them to the library.

At this point, staff was interviewed and hired for the book restoration project as previously planned and budgeted. All would start March 8, the projected date of our last load. We needed nine chamber loads to finish as there were more than the estimated 40,000 items, and some items went through more than one cycle. This amounted to about 1 percent per load.

Three full-time and five part-time staff were hired. Eventually, one part-time person was increased to full-time. The full-time staff were given specific areas of responsibility: one in charge of major repair, another of sending books out for rebinding, another of day-to-day checklist operations by the whole staff. One part-time staff member was given responsibility for packing and sending books back to the library and keeping those records. Other part-time staff spent some time searching market alternatives for books that would have to be discarded. We had a form printed listing all the choices they were to consider, such as new or used copies, microforms, branch library copies, copies at nearby U.C. Berkeley, discard, restore, photocopies, etc.

On March 15 the staff was assembled and ready to start, with the exception of two members who would join the staff in April. The first few days were spent in an introductory workshop in repair techniques, recovering pamphlets, and conservation considerations. The staff was instructed in the sorting and checking process and practiced until they were able to judge books. The repair workshop was under the direction of the full-time staff member who had worked in the binding and finishing division of the Stanford libraries.

When the week-long training session was over, the Terman phase of the flood project started in earnest. Books were sorted by loads so we could be sure they had acclimated properly. Shelves were set aside for sorting books by call number to return to the library. Broken sets were held until they were complete. Other shelves were marked for specific repair problems such as recasing, spine repairs, paper repairs, etc. Almost all the pamphlet covers were ruined, so several thousand were set aside for repair. Spine labels and bookplates in general held firm. Many books, whose cases and bindings were sound but badly warped, have been greatly helped by pressing. They are misted lightly with water and placed between absorbent, acid-free paper in small hand presses.

The thirty or forty books that showed signs of mildew were fumigated in a makeshift arrangement, consisting of a plastic garbage can with a snap-on lid. Nylon lines

Courtesy of Lockheed Missiles & Space Company, Sunnyvale, California

A shelf of dried books. Note the warping of some volumes.

were strung across it inside, an inch apart in two lines on several levels. A damp towel was placed in the bottom with a handful of thymol crystals. Books were hung, supported by two lines, the lid snapped on and left for four to five days. This was done in a well-ventilated area with all leather binding checked daily. Leather tends to soften somewhat when exposed to thymol fumes.

Books needed by patrons and not available through interlibrary loan were tracked down when possible. Repairs were made, and they were sent back for use. We were successful in locating about fifty books, 75 percent of the total requested.

One of the hardest hit stack areas was a locked stack where 3,000 items were housed. Many of these were tiny volumes, no more than three inches by five inches. None were rare books, but all were special because of age, binding, size, content, or scarcity. Many of these books were precipitated onto the floor by the force of the water. Most had leather covers and original bindings. The leather swelled with exposure to water, then shrank as the books dried, distorting covers and bindings. We found that exposure to 60 percent humidity for six to eight weeks and pressing them helped. But many covers were lost, and these items, approximately 500, will be recased by our trade bindery. Others, in somewhat better shape, will be placed in handmade book boxes.

Summary

One of the strongest, positive results of the vacuum process is the remarkably fine shape of the book paper. There has been minimal staining and cockling, even in the severely soaked books. Much dirt was lifted to the surface. If the books were shelved firmly and by size in the chamber, cockling and warping were reduced.

If books went to the freezer badly warped and distorted by water, they were dried in that state and tended to be extremely difficult to press or rebind. If, however, wet books could be straightened *gently* and with regard for bindings, they will recover in a much more satisfactory condition. A technique that worked well was to freeze the distorted books; let them thaw slightly, reshape them gently, and then vacuum dry them. We tried this with several dozen books. They held their new shape because of their frozen condition, yet appeared to withstand careful manipulation well. This

technique is good only for books with twisted covers or pages, bent boards or pages. It will not be effective for the swelling of pages in thoroughly soaked books. They must be frozen, dried, and rebound.

Although most books with clay-coated paper recovered after the vacuum process, some did not. One of our difficult problems has been the 200 to 300 books with pages blocked due to clay-coated paper. In some instances, careful flexing of pages and judicious use of a needle probe and bone folder were enough to coax pages apart. Neither cold vapor nor hot steam seemed effective. Rewetting, freezing, and redrying as recommended by Corning also failed to help.[7]

One experiment, which produced some results and which deserves more experimentation, involved rewetting blocked spots and pages, freezing them, and exposing them to the defrost cycle of a microwave oven. However, both animal and plastic glues attract microwaves and melt very fast, so care must be taken not to expose the book more than ten to fifteen seconds at a time. The freezing of the wet spots seemed to be more effective in the microwave oven than just wetting the paper and had the advantage of stabilizing the paper.

As of August 9, 32,000 books had been returned to the library. Approximately 1,500 books are scheduled for rebinding, 1,000 books await repair, and 15,000 still require sorting and checking. By October 1, 1979, approximately 80 percent of the total number of items should be returned to the library. The rest will be held for rebinding and repair. We will lose only 100 to 200 books. We have identified several hundred books whose paper is so brittle they will need to be microfilmed to preserve their content. However, this brittleness is due not to the flood, but to acid paper.

The Stanford University Libraries' budget for all three phases of the flood project is $316,633. Lockheed estimates its actual costs as approximately $40,000. Eastman Kodak donated $2,000 worth of film restoration, the Modern Ice and Cold Storage Company donated approximately $8,000 worth of freezer space and labor, and various other businessmen contributed expertise, food, labor, trucks, and supplies.

It is obvious that the recovery of the Stanford books is due in great part to the fact that their exposure time to water was kept to a minimum. The chemical and biological actions were stopped by quick freezing. The vacuum process successfully dried massive amounts of material quickly and efficiently with no apparent damage resulting from the process itself. Finally, the truly magnificent volunteer effort by Stanford staff, students, and friends provided the care and labor needed to make the project the success it is.

The last book taken from the Lockheed chamber was a copy of Shakespeare's *All's Well That Ends Well*. These words appear in act II, scene 1: "Great floods have flown from simple sources." Looking back on Stanford's "great flood," we realize it has had a much less damaging outcome than could have been foreseen last November.

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