MEMOREX TIMES

3680 Special Issue

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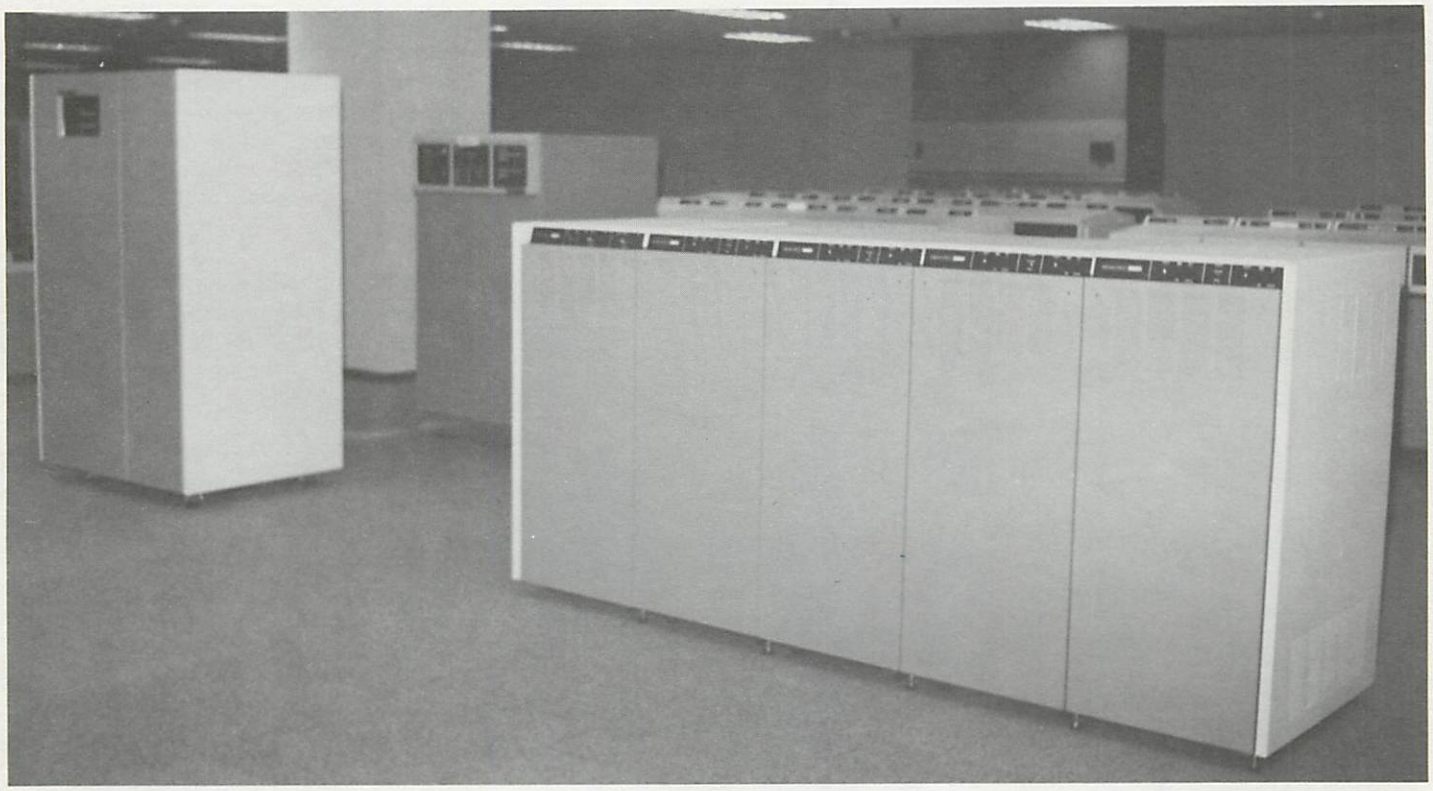


At the customer's location, the 3680 subsystem has achieved the major beta test milestone. The subsystem has been turned over for some time now for use by the customer. The customer is using it 16 hours per day for production applications, and is very pleased with the performance, and reliability of the equipment.

On Schedule, On Target

The new Memorex 3680 is now in Beta Site testing, where all reports indicate it is doing superbly. In fact, installation was achieved in less time than projected at the customer site, a major financial institution in the southwest.

This summer, when volume shipments of the 3680 begin, it will be the first thin-film 3380 PCM disc drive in volume shipments. Delivery of the technologically advanced, reliable, production-ready system is scheduled to begin in the third quarter of this year.

To provide a complete update on the status of the 3680, we interviewed the key members of the team responsible for manufacturing, quality assurance, engineering, program management, recording head technology, and marketing. They are unanimous in their enthusiasm for the performance and marketability of the 3680. This special issue of MEMOREX TIMES provides an in-depth report based on these interviews.

". . . Although gaining an early lead gives a significant advantage in the competitive plug-compatible market, being first is not as important as being best. And we intend to be the best . . ."

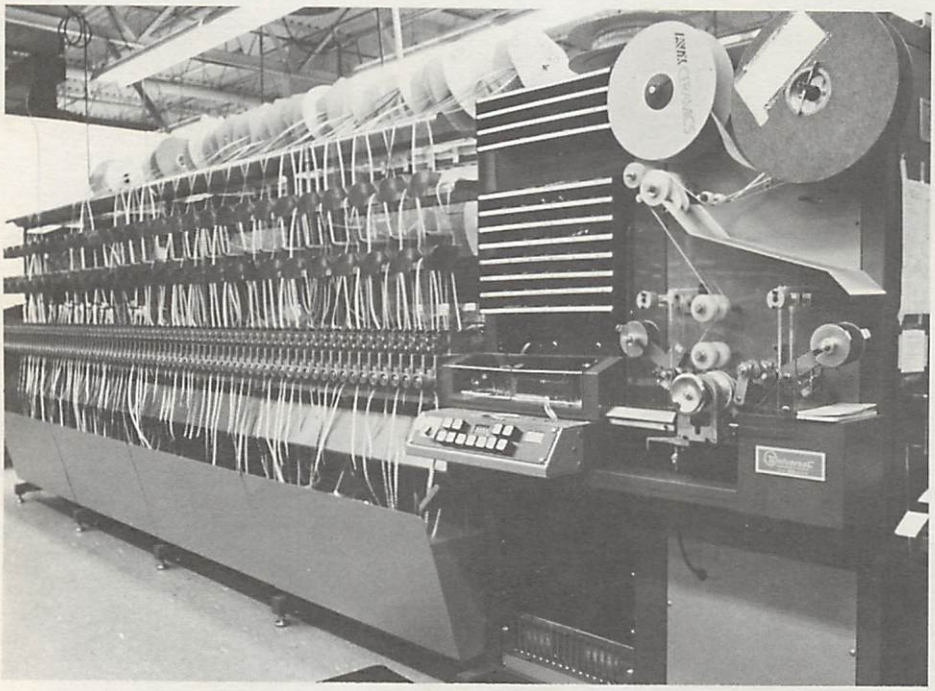
Geoff Seabrook, Manager, Storage Equipment Marketing.

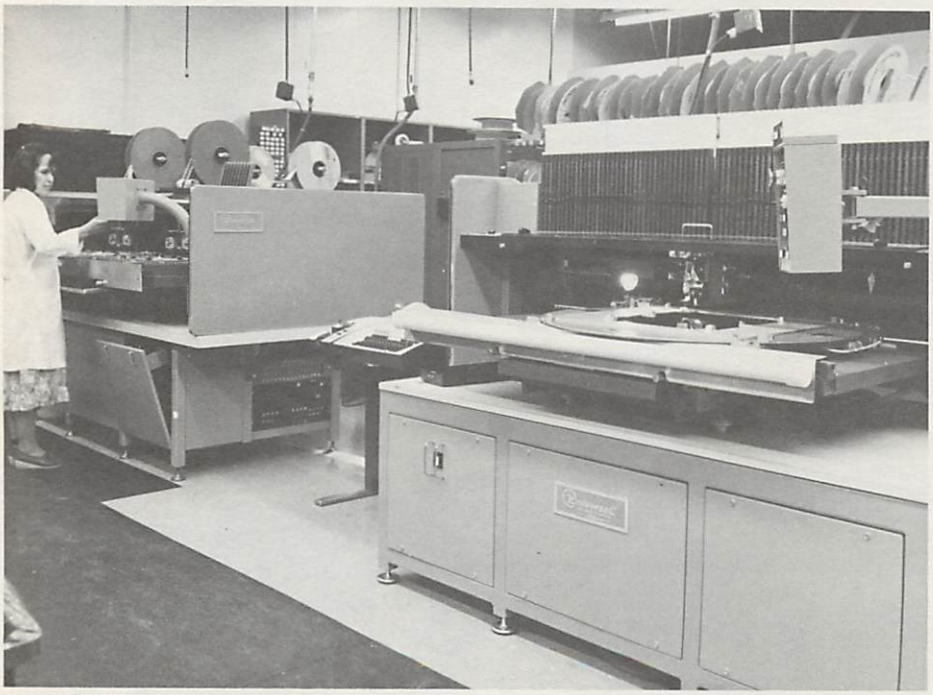
New Manufacturing Facilities Speed 3680 Production

A major capital investment to new manufacturing facilities, coupled with extensive training programs for employees directly involved in manufacturing, highlight the Memorex commitment to its revolutionary 3680 line of thin-film head storage products.

Already this renewed sense of commitment has resulted in on-time deliveries of the first 3680 system to a Beta Test site, in March, and of the first production models to product verification testing, in June.

"The capital committed for the next year to this division for new tools, test equipment and facility changes will equal what the whole company was investing just four years ago."
Jeff Bryant, vice president and general manager, Large Disc Drive Division.





(Top) Receiving many reels of standard PCB components, a single reel is produced by this computerized sequencer machine. The machine is programmed to arrange the components, in a specific logical order, for use on the automatic insertion equipment. (Bottom) These automatic insertion machines are programmed to place components on the blank PC boards.

"It's not in the lab anymore," says Jeff Bryant, vice president and general manager of the Large Disc Drive Division. "The production run has really started."

The ongoing process of ramping up to full production levels involves an unprecedented investment of funds and effort. "The capital committed for the next year to this division for new tools, test equipment and facility changes will equal what the whole company was investing just four years ago," says Bryant.

"We're updating the entire factory to the state-of-the-art," he says. "This involves taking a unique approach to materials handling, using some assembly techniques borrowed from other industries."

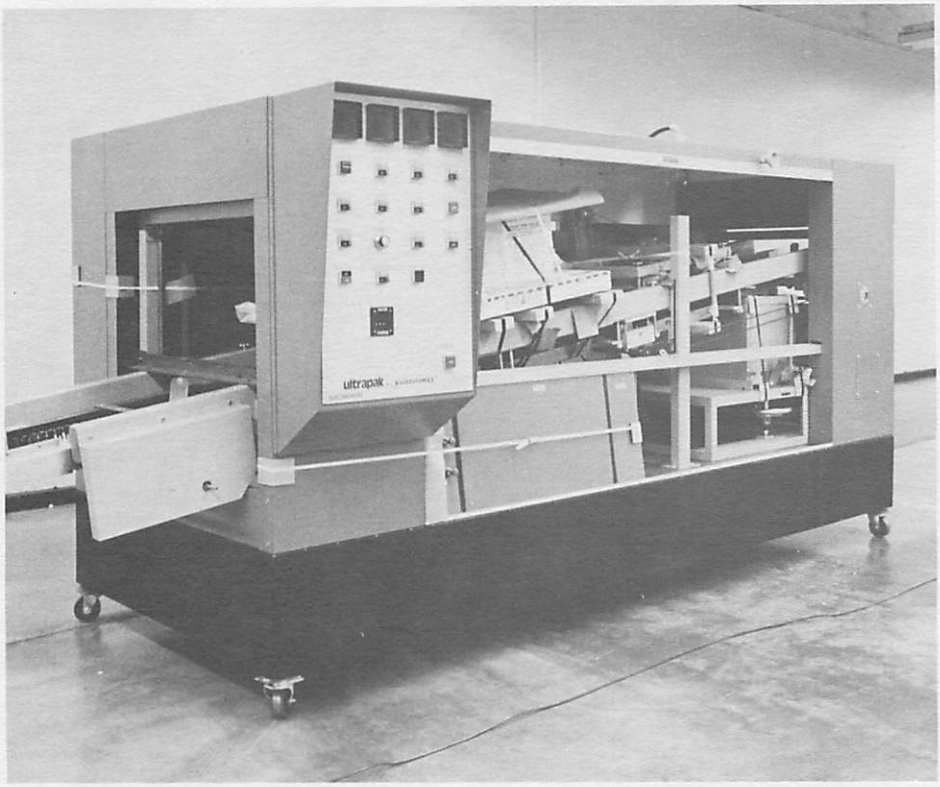
As part of this new approach, precision robotics will be used for the first time to assemble disc stacks, so that platters will not be touched by human hands during assembly. The goal here is to ensure highest quality production by keeping discs as clean as possible and by eliminating variability in the assembly process.

36,000 Feet of Clean Space Added

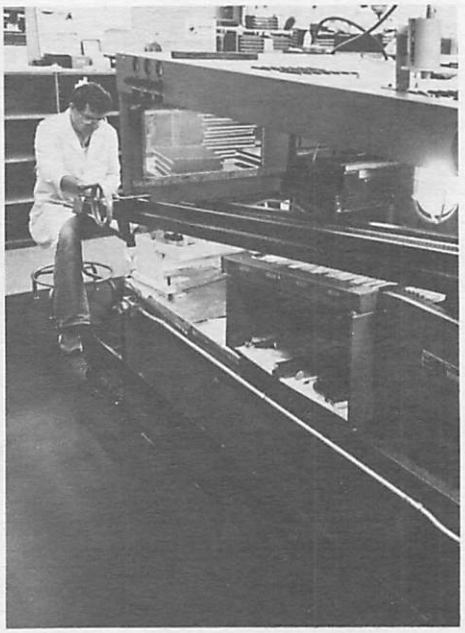
Probably the largest and most obvious facilities change, however, involves the introduction of roughly 36,000 square feet of additional, cleanroom space. This new area of controlled environment—with precise temperature and humidity regulation and air filtration—will equal nearly one-sixth of the entire factory floorspace. The contaminants in these cleanrooms are controlled more stringently than the standard hospital operating room.

Equally important will be the changes brought about by installation of new test equipment in the manufacturing area and establishment of new testing protocols. This equipment ranges from individual testers for power supplies and cables to an automated manufacturing data collection system that makes possible on-line monitoring of test results and production status.

For such innovations to prove successful, the workers involved with them will have to be among the most highly trained in the industry. Several new training courses are thus being instituted, aimed at extending the capabilities of workers at every level in the Large Disc Drive Division.



Capital expenditures have been made on this new Ultrapak Wavesolder system. At our Memorex location in Santa Clara, the two new pieces of equipment are currently being installed.



As the PCB passes through the wave-solder system liquid solder connects the components to the board. Each board is visually inspected before it is sent through the cleaning and drying system.

Statistical Process Control

"We're adopting scientific methods for problem solving in manufacturing, including statistical process control," says Bryant. "That means teaching statistical techniques to the rank and file. It's a novel approach, but the classes are full of eager students. A work force trained to be more analytical will be better able to improve yields by looking at the production data and solving problems that arise."

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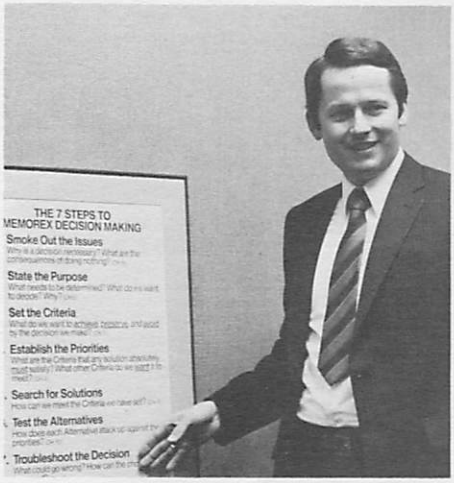


The seven steps of decision making, developed by John D. Arnold, author of "The Art of Decision Making" has been adopted by several Memorex organizations. *Bob Behlman, Manager of Manufacturing, emphasizes the importance of this concept at the weekly staff meeting.*

Memorex sub-assembly plant in Nogales, Mexico utilizes new equipment in their wave soldering system.

In addition, workers are being "cross-trained," so they will be able to handle a broader range of responsibilities in a functionally reorganized plant. Every manager in the division must also attend a special training course on management techniques. Enhanced training not only prepares employees to perform more effectively in their specific jobs, Bryant says, "it gets people involved and gives them a sense of ownership in the business."

Vertical Integration for Maximum Control

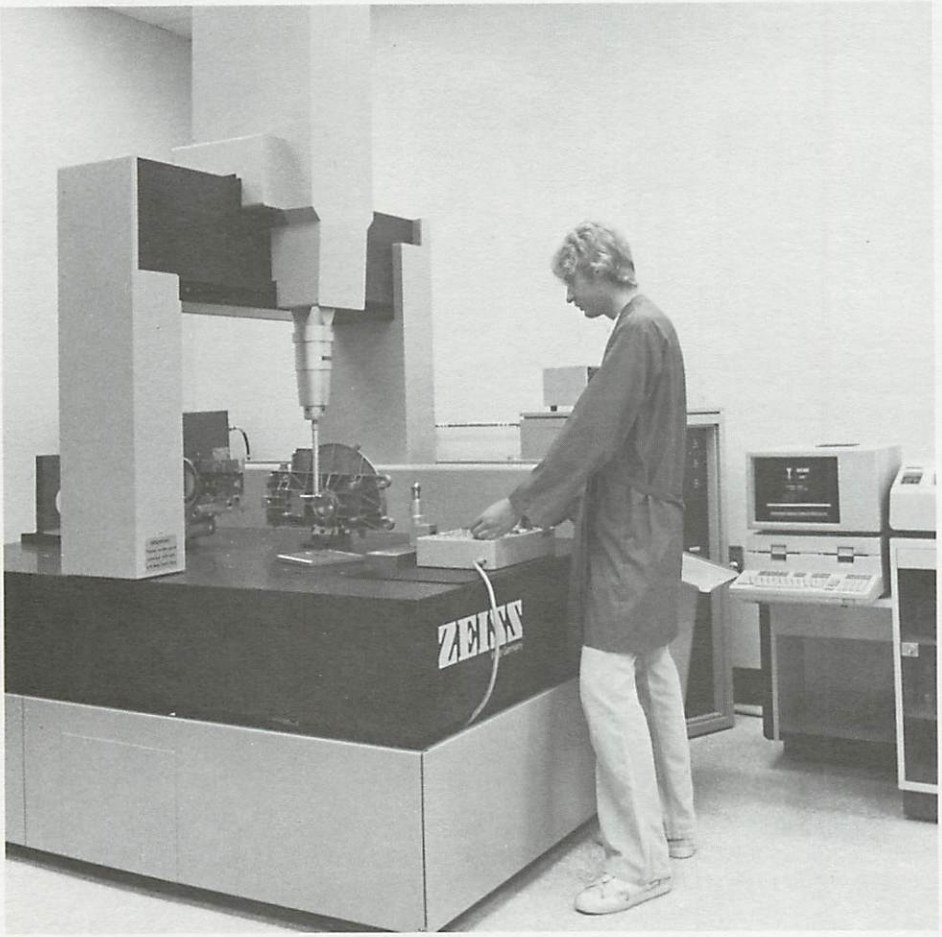
Finally, Memorex's commitment to manufacturing excellence is evident in what Bryant calls "our vertical integration of technology." Essentially, this means keeping direct control over the manufacture of critical components in the 3680 product, rather than purchasing them from other companies.

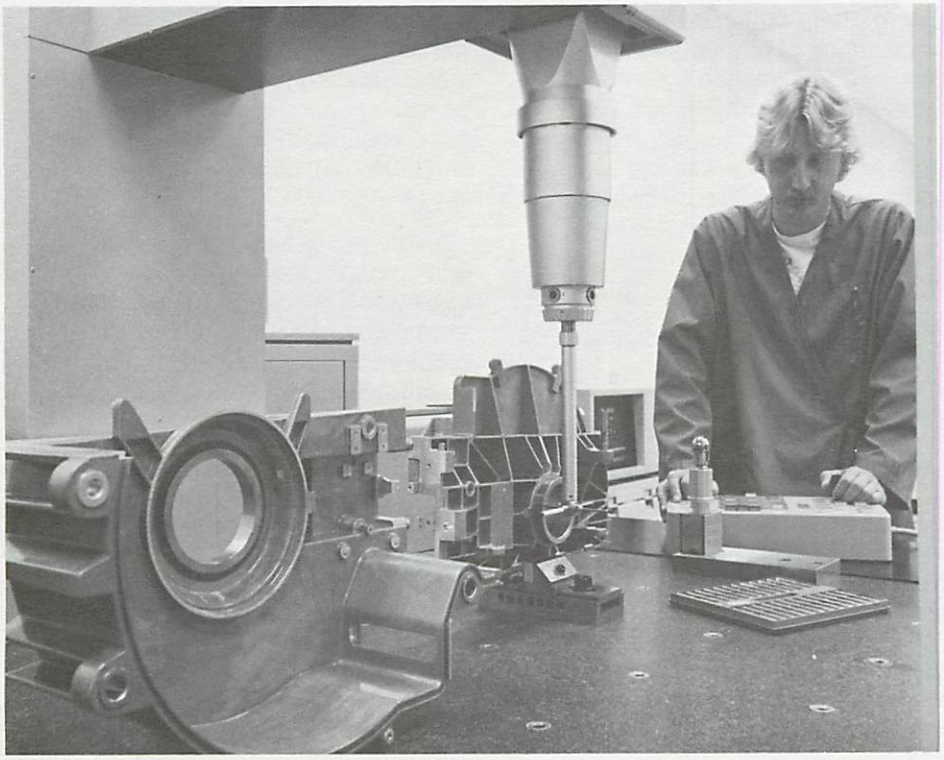
This strategy involves two distinct elements. First, some components, like printed circuit boards, head-arm assemblies and cables, are being manufactured in remote "feeder plants" owned and operated by Memorex. Two such plants supplying parts for 3680 are in Mexico, where they have established an excellent record for defect-free workmanship.

Second, two joint ventures have been established with Control Data Corporation to share the risk and expense in two particularly capital-intensive areas. One venture, Disk Media, Inc. (DMI), will manufacture the advanced recording media for use with the thin-film heads.

"One of the most significant decisions has been to do all the critical parts of the 3680 ourselves," says Bryant. "That's our assurance of being able to meet our production commitments. We understand this technology. It's *ours.*"

Stringent, Innovative Four-step Testing Strategy Assures Quality in 3680





The mechanical precision of every critical part of the 3680 HDA is checked. This state-of-the art precision measurement system is accurate to as precise as 60 microns.

"The secret of success is maintaining a consistent discipline."
Clayton Mills, quality assurance manager.

Increased customer demand for reliability along with the inherently greater complexity of thin-film technology have created a need for even more stringent testing and product verification in the next generation of disc drives. In response, Memorex has adopted a new quality assurance strategy that will maintain the highest standards of product integrity in the 3680.

The strategy has four main components, involving tests at each critical stage of product development, from design to installation. "The market demands this sort of commitment," says Cleayton J. Mills, quality assurance manager, Large Disc Drive Division.

The first step in this disciplined approach is design verification testing (DVT), in which quality assurance professionals work with product designers and manufacturing process planners to identify potential problem areas before full-scale production begins. Previously, this procedure was carried out on individual units. In the 3680 program, full strings were subjected to DVT testing.

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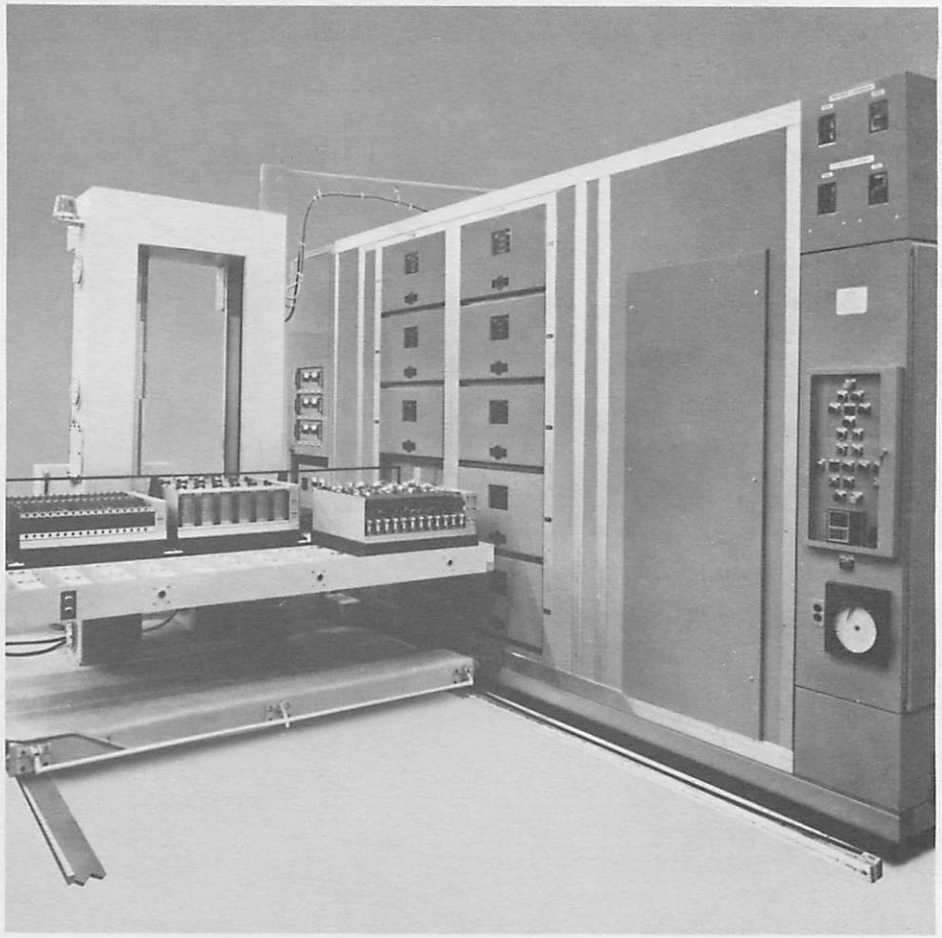
Individual integrated circuits and assembled printed circuit boards are "burned in" at high temperatures. This testing ensures that components will hold-up even under unusual stress situations.



New "burn-in" equipment, as shown above, has been designed specifically for Memorex. Known as the Production Burn-In Facility for PCB's, this new equipment will be installed mid summer 1983.

Next comes production verification testing (PVT), which involves examination of products that come off a product qualified and process certified manufacturing line. First, each step of the manufacturing process must be certified to see that it performs as required. Then each component produced is verified against the product specifications. Once the line is qualified, completed products are sent to PVT. The first 3680's were delivered to PVT on June 1.

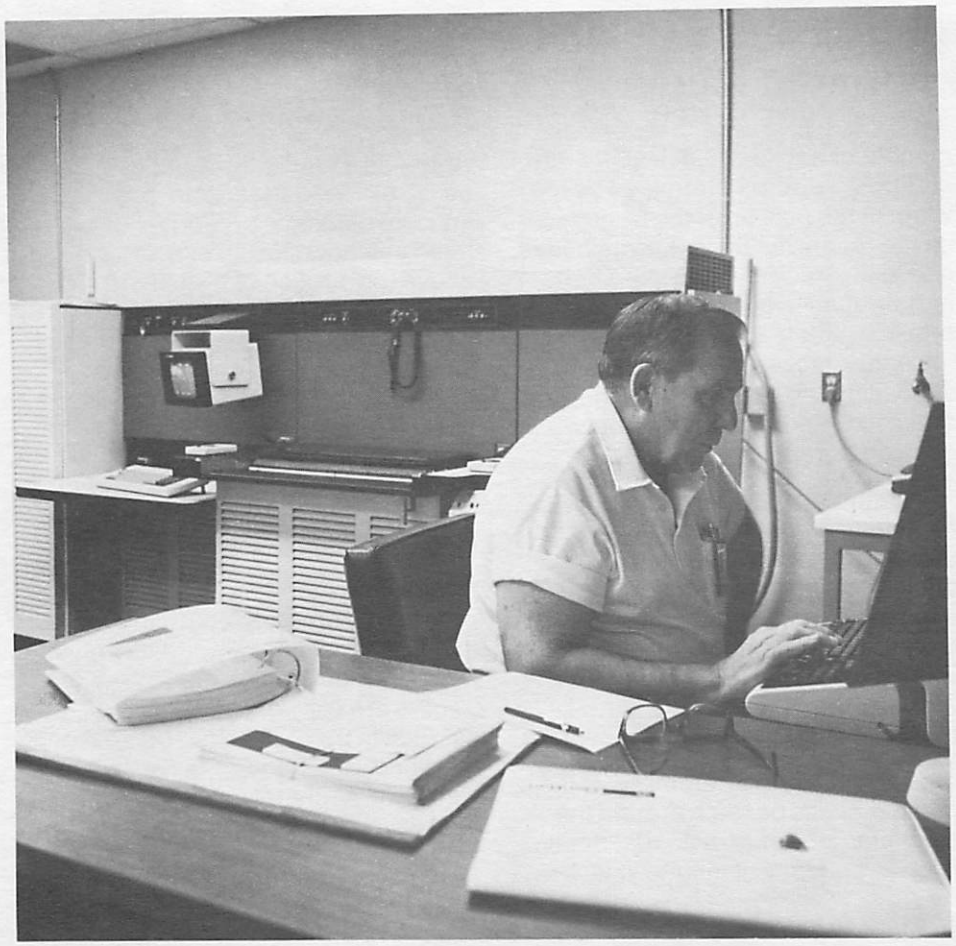
New Test Laboratory

The third stage of the quality assurance strategy is reliability demonstration testing (RDT), to be performed in a new product measurement and analysis (PML) laboratory, now under construction. The purpose of RDT is to verify reliability performance characteristics of a product and also to conduct production audits.

The PML Laboratory, which is scheduled for completion in August, will be located in the middle of the manufacturing area. "Customers will be able to see tangible evidence of our commitment to ongoing reliability and performance of our products," says Mills.

Finally, customer configuration testing (CCT) will apply the Memorex quality assurance strategy directly to a customer's most immediate problems. In CCT, sample configurations will be checked to see that it meets the promised performance criteria before a system is handed over to the buyer.

"The secret of success in a quality assurance program is maintaining a consistent discipline," says Mills, an internationally recognized expert in the field who was recently invited to China to lecture on quality assurance. "The DVT, PVT, RDT, and CCT components of our master strategy bring that discipline to design, manufacturing and ultimately to performance."



The "today" look (above) and the new "tomorrow" look (left) in circuit board test equipment typify some of the capital expenditures being made on the 3680 program. These PCB instruments test each individual component and assembly on every board. It tests all the possible combinations to check the functionality of the board to a very high level of accuracy.

Burn-In Tests: a Memorex First

Several specific, innovative features are also an integral part of the quality assurance strategy. One of these is "burn-in" testing, which subjects individual integrated circuits, then assembled printed circuit boards, and finally completed products to sustained periods of stress at elevated temperatures. The objective of such testing is to identify weak components quickly. Experience has shown that if these weak components can be weeded out early, the failure rate of the product shipped to the customer will be very low.

True Failure Analysis

Another important feature is "true failure analysis"—as opposed to the more conventional "sympton analysis." In other words, once a weak component is found, it is not just replaced. Rather, an analysis is made to find out specifically *why* it failed. "The way to prevent problems is to cut them off at their roots," says Mills. "True failure analysis means addressing a failure not where it's found but where it's caused." It results in savings on equipment and improved control of vendor quality.

Finally, a sophisticated management tool called "statistical process control" has been adopted as a feature of the Q/A program. Basically, this involves analyzing the manufacturing process to find its idiosyncracies, which can cause production to fluctuate. Such variations occur in any complex process, but statistical analysis can help stabilize production.

Memorex's aggressive new approach to quality assurance is ready to pay off, Mills believes. "We were able to install a system at the Beta Test site in less time than had been anticipated, and the equipment has been running superbly. You just have to 'think prevention.'"

Technological Breakthroughs in the 3680: Thin-Film Heads and M Formula Media

Since the introduction of modern disc drives with ferrite heads in 1965, the storage capacity of these subsystems has increased nearly 100-fold and average access time has been cut by more than half. Now, the consensus is that further advances will require fundamentally new technologies—read/write heads miniaturized using techniques developed in the semiconductor industry, and improved disc media that can support a much greater concentration of data.

"Memorex has had to learn a whole new set of technologies to make the new heads," says Jeff Bryant, vice president and general manager of the Large Disc Drive Division. "Ferrite technology is reaching its limits and for the 3680 we decided to use thin-film heads."

The density with which data can be stored magnetically on discs depends on two key parameters. First, the number of tracks per inch along the radius of a disc is determined by the width of the pole tip of the transducer on the read/write head. Ferrite heads had to be precisely machined and hand-wound in a labor-intensive process. "Thin-film" heads, as the name implies, are made by depositing thin layers of material on a silicon wafer substrate, using photolithographic processes.

Not only does this revolutionary technique produce recording heads that are physically smaller, but the fabrication itself can be less expensive, since hundreds of heads are produced simultaneously on each wafer.

Lighter, Faster "Flight"

The second critical parameter is the number of bits per inch around the circumference of a track, determined by the frequency of magnetic flux reversals a read/write head can achieve. This depends, in turn, on the intrinsic magnetic properties of a head and how close it can be "flown" above the surface of a spinning disc. Ferrite technology can produce a circumferential density of only about 9,000 bits per inch. The thin-film head, because of its small size and accurate tolerances, can achieve much higher circumferential densities than older technologies. In the 3680, circumferential density is 15,000 bits per inch.

"When we started our development program, there were only a few thin-film heads in the world and none were in production," says Bryant. "There are still no really viable sources of these heads in the rest of the world, and through our joint venture (Peripheral Components, Inc.) we plan to become a high volume producer."

Jeff Bryant's weekly staff meeting encompasses many different professional fields. These individuals work together to "Smoke out the issues." Shown above are individuals from Human Resources, Finance, Quality Assurance, Manufacturing, Engineering, Materials, and Thin-Film Head Development.

This video measuring system is used to determine the thin-film head track width from pole to pole on each head contained on individual wafers.

Unmatched Surface Uniformity

For thin-film heads to achieve their potential in the 3680, however, required a second major technological achievement, development of the "M formula" disc coating. This new, advanced-particulate media has stronger and more consistent magnetic properties, which provide the highest signal-to-noise ratio in the industry. The oxide particles are extremely uniform and lend themselves to precise orientation and proper fusion with the epoxy binder.

The resulting disc surface has a smoothness and uniformity that allow closer flying heights and greater data densities. At the same time, it has unsurpassed durability. An M formula surface resists more than 15,000 head loads in a Winchester-type drive—a 50% improvement over industry standards. The difference is even visible under an electron microscope, which shows an M formula surface smoothly covered and a conventionally coated surface pocked with holes.

Because of their superior qualities, M formula discs require improved testing procedures. In the past, imperfections in discs have been identified by storing digital data on them and then reading it back. Locations of imperfections (the "holes" seen under the electron microscope) are listed at the beginning of each track so a computer can avoid storing data there. A new piece of test equipment at Memorex uses analog recording to search for more subtle magnetic anomalies. "We're looking at more minuscule errors," says Bryant, "and have had to sensitize the testing system in order to find them."

Innovation, of course, is a continuous process. Actually, the thin-film head used in the 3680 already represents an improvement over the "first generation" head used in the 3690. The new, "second generation" heads have two layers of windings in the transducer, instead of one, which provide enhanced magnetic properties. Memorex was the first company to announce the use of this advanced head and further development is under way. Research on disc surfaces is also continuing. Bryant says this work will likely lead to the eventual introduction of "thin-film coatings" to complement thin-film heads.

Thin-film head technology requires a whole new testing system—statistical process control analysis. Here a technician uses a wafer probe tester to check the characteristics of a wafer full of thin-film heads.

How Unique Features Were Developed for the 3680

The 3680, whose advanced technology resulted from the most extensive development process in Memorex history, will provide customers several unique features.

". . . Only the 3680 can be expanded by one single-spindle unit at a time. It's a unique product . . ."
Bill Brown, vice president for development engineers.

"We decided very early to package the drive as a single-spindle unit with the smallest possible footprint in a low-profile box, and we've succeeded," says William Brown, vice president for development engineering. "Data processing facilities are all running out of space. The 3680 uses the least floor space in its market and it's the only one low enough (44 inches in height) for operators to see over. Most important, only the 3680 system can be expanded by one single-spindle unit at a time. It's a unique product compared to any of the competition, including IBM."

Unique Self-Diagnostics

To make 3680 systems easier to maintain, an extensive set of new and unique computerized self-diagnostic capabilities have been added all along the string. All units have microprocessors that perform "go–no go"

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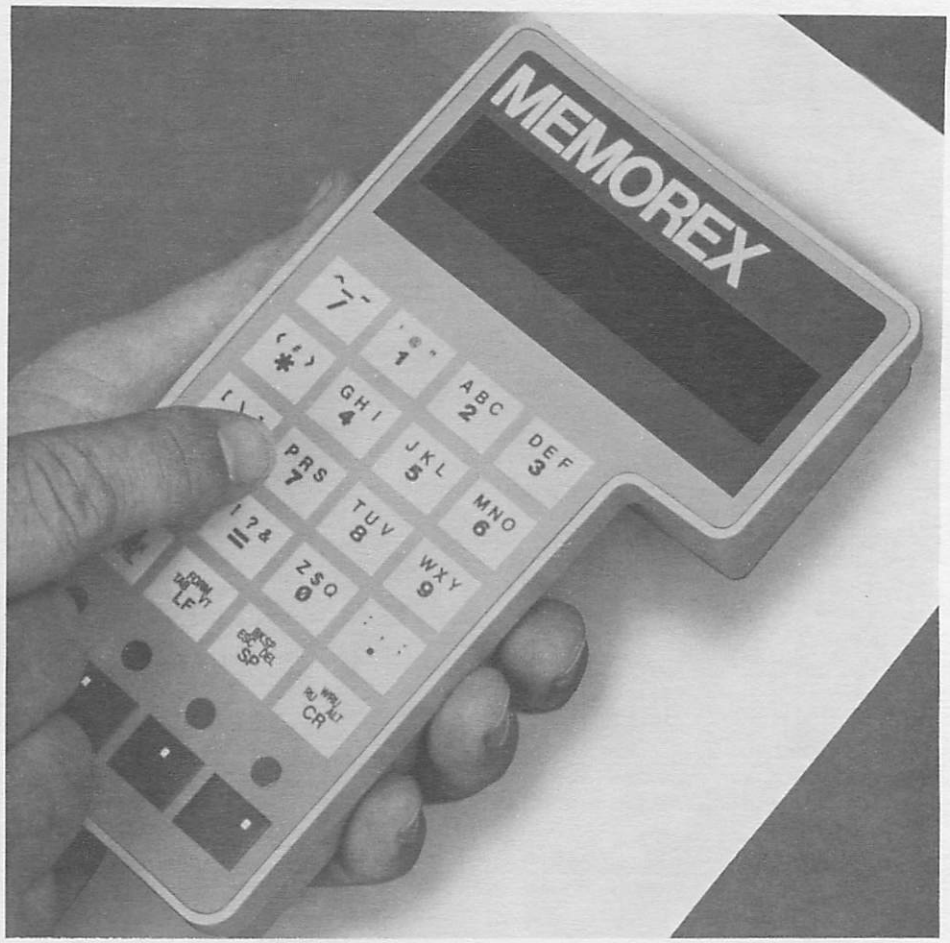
test and other diagnostics automatically at power up time. The string controller also has a diagnostic unit to test the read and write function continuously. And the disc drive itself contains two microprocessors that have diagnostic capabilities.

One of these microprocessors checks the drive logic. The other, called the "Diagnostic Exchange (DX)" printed circuit board, has two functions. First, it measures power supply voltages and the output voltages of all heads, including the servo head. Second, if a fault is located, it provides an exchange function that allows an operator to switch drive logic units between the two actuators in each head disc assembly (HDA).

Tom Idleman, Manager of Advanced Storage Control Unit Engineering, played a key role in the development of MAPS—maximum availability path selection available on the 3680 subsystem.



One of the 3680's unique features is a hand-held portable maintenance terminal (PMT). This terminal is used to monitor performance and diagnose operational problems. "Previously, some units would have a diagnostic panel or interface the size of a suitcase," says Bill Brown, vice president for development engineers.

The importance of the DX board can best be illustrated by an example. Most malfunctions are caused by circuit failures. If one of the two drive logic units in the 3680 becomes inoperable, the information can still be retrieved by switching temporarily over to the remaining drive logic unit. This unit can be used to transfer the data to another disc drive and then can be returned to its normal operation, while a customer engineer fixes the faulty drive logic circuit.

"This arrangement allows the customer engineer to work on the "B" side of a drive while the customer continues using the "A" side," says Brown. "By being able to work on the lowest level resource, and switch actuators using the DX function, we keep all data available and cause minimum inconvenience to the customer."

MAPS Charts New Course in Actuator Access

Another feature of the 3680 that takes unique advantage of the dual actuators is maximum availability path selection (MAPS). In a full string of eight disc drives and two string controller paths, when one string controller path is communicating with an actuator, the other can automatically access any of the 15 non-busy actuators. (Under intelligent dual interface (IDI) on other Memorex models, the same function required use of a time-consuming string switch procedure.) Because IBM disc systems group the actuators into bunches of four, they do not allow simultaneous access to all non-busy actuators in the same group of four.

Once problems have been identified and steps taken to reduce their impact, the customer engineer can take advantage of other 3680 features to hasten repairs. The most important of these is a unique hand-held portable maintenance terminal (PMT) that can plug into the 3888 storage control, a string 3683 controller or a 3680 disc drive. The PMT, which resembles a pocket calculator, is used to monitor performance and diagnose operational problems by interfacing with the diagnostic microprocessors in various units.

Cost-Effective Remote Diagnostics

In addition, the 3888 storage control incorporates an RS-232 interface, which enables the system to communicate via telephone to a remote diagnostic center. It also houses a floppy disc to log error symptom codes. With these capabilities, the user will also be able to run user-friendly diagnostics on the host computer. This multiple diagnostic capability can help pinpoint problems more quickly and tell the customer engineer which field-replaceable unit to take on a service call.

"Previously, some units would have a diagnostic panel or interface for a diagnostic device the size of a suitcase," says Brown. "Our new approach, using the PMT and remote diagnostics is unique—more flexible and more cost-effective."

The Bottom Line: Better Performance and Reliability

Ultimately, the worthiness of a new disc storage subsystem is judged by users who have had a chance to gain considerable experience with it. Their criteria are straightforward: How well does it perform? How reliable is it? The evidence indicates a superior rating based on looking at the advanced physical and functional architecture of the 3680.

"When we began looking at the overall architecture of the 3680 system," recalls Alex E. Malaccorto, 3680 program manager, "we realized that things had to change a lot. We needed to partition work among the various components differently to get better performance. With improved microelectronics, 'intelligent' functions that were once performed only in the storage control unit could now be incorporated into each disc drive."

More Efficient Communications

This change toward putting microprocessors in each unit of a string allows the 3680 system to communicate more efficiently with its host CPU. For example, in response to a "seek" command from the CPU, the storage control unit of an older system would first have had to request the position of the actuator arm from the disc drive and then compute how far the arm should move to find the required data. During this time, some other functions might have been delayed. In the 3680, the computations needed to execute a "seek" command are made in the disc drive itself, while the storage control unit performs other functions.

Overall performance of older systems was also impaired because diagnostic functions could only run on the storage control unit. "Many users would wait until 3 a.m. to run their diagnostics so they wouldn't have to tie up a whole string," says Malaccorto. "Now, with distributed intelligence, we can do this at the drive level. Memorex has developed more advanced capabilities than any of its competitors."

Just how much performance will be improved by such changes in functional architecture has been the subject of considerable analysis. "Performance has to be related to specific jobs," Malaccorto advises. "Using mathematical models for a set of typical benchmarks, we estimate that the 3680 will show 25% to 40% better performance than the IBM 3380, in terms of job throughput." The model chosen is an industry standard model as expressed in "DASD Path and Device Contention Considerations" by S.E. Friesenborg of IBM's Washington Systems Center.

"The Beta Test site configuration is not large enough to judge performance adequately," he says. "There we're focusing on functionality—and the equipment is working beautifully. What will be needed to test performance will be a side-by-side comparison between our system and the 3380. We're confident that the response time of the Memorex 3680 will be substantially shorter at every level of throughput." The performance models must be verified by benchmark tests. Results of these tests are scheduled for release to the field in late July.

Better Reliability

Reliability can be enhanced by physical architecture. The single spindle architecture of the 3680 has been designed to be inherently more reliable. Each storage module is a complete stand-alone unit with its own separate power supply and air filtration system.

Customer Satisfaction

"Equipment performance is much more important now, with systems operating 24 hours a day," Malaccorto concludes. "And reliability is vital. Previously, when a single spindle wasn't working it meant only one application couldn't run. Now, so much data is involved that a whole business might be affected. Fortunately, the performance and reliability goals of the 3680 are right on target."

"Using mathematical models for a set of typical benchmarks, we estimate that the 3680 will show 25% to 40% better performance than the IBM 3380, in terms of job throughput."
Alex Malaccorto, 3680 program manager.

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