
Omni Automated Systems Case Study

Bob Waters, a field sales engineer for the Custom Systems Division of Omni Automated Systems, had just learned from his friend Steven Anderson, the purchasing agent for Gentech Office Equipment Company, that Gentech had decided to purchase a robotic test cell from one of Omni's competitors. The test cell was for Gentech's new printed circuit board (PCB) soldering line. The Gentech account was the third robotic work cell sale that Waters had lost over the past two months and the eighth overall. Waters had felt confident that Omni had the inside track on this bid due to Omni's past business relations with Gentech, Waters good personal relations with Gentech's personnel, and Omni's superior product offering. He had been working on this sale for over a year and knew that the loss of this sale would severely impact his chances of future robotic work cell sales to Gentech, as that firm continued to automate its PCB manufacturing operations.

Water's boss, Doug Barnum (Omni regional sales manager), was concerned about Water's lack of success at selling this new product line. Since its introduction, accounts that Waters worked on have yielded only two sales, a 20 percent success ratio. Other Omni salespeople, however were experiencing at least 50 percent success ratio on their major accounts. During this period, Waters continued to have good success at selling Omni's other product lines. Because both Waters and his boss were certain that Gentech personnel were fair in their decision, they decided to conduct a review of his call reports to see if a flaw in his sales strategy and approach may have led to the loss of the Gentech sale.

Background Information

Omni has provided state of the art electronic assembly equipment to electronics manufacturers for more than 40 years. It maintained a competitive advantage over its competitors by continually bringing innovative products and technologies to the marketplace. It was one of the first firms to apply robotics to electronics assembly and was also one of the first firms to offer assembly machines for surface-mount device application. In addition to its acknowledged technological strengths, the firm was also well known for its product quality and reliability. It manufactured a broad line of assembly equipment, from simple component insertion machines to complex robotic work cells. Omni captured a 30 percent market share in 2005 on more than \$1.5 billion in sales. Its corporate headquarters were located in San Jose, California, and it had regional sales offices throughout the United States, Europe, and Japan.

The application of robotics to electronics assembly was first introduced in the mid 1990s. Prior to this time, robotics was primarily applied to heavy industrial and automobile assembly applications. Omni built upon the research and development of robotics like Adept and Unimation and system houses such as Chad Industries and Robotic Automation to introduce its first robotic work cells. Although Omni did not conduct

research in the development of robots, it did devote considerable resources toward finding new applications for this emerging technology.

Bob Waters joined Omni in 2000, after an eight-year career at one of Omni's primary competitors, Universal Assembly (UA) Corporation. Waters normally achieved sales in the top 10 percent of Omni's sales force. He was personable, energetic and well liked and respected by his colleagues and management. Upon arriving at Omni, he was assigned the highly competitive but very lucrative Silicon Valley sales territory and was quickly successful in landing several major contracts.

Gentech Office Equipment Company manufactured a variety of office equipment, from copier/duplicators and facsimile machines, to personal computers and word processors. Gentech was a recognized world leader in the office equipment industry, with sales in 2005 in excess of \$4.2 billion. Gentech had manufacturing operations in several locations around the world, but its San Jose plant was its primary PCB assembly facility.

In recent years, Gentech had experienced significant market share and profit margin erosion due to intense foreign competition. Benchmarks revealed that Gentech had fallen behind the industry in utilizing advanced electronics design and manufacturing techniques. As a result, Gentech initiated a major program to modernize and automate its manufacturing facilities. This program would cost between \$45 and \$60 million and would be conducted over a five-year period.

The new soldering line recently ordered by Gentech from Ace Electronics would automate one of its soldering process lines and would cost approximately \$3 million. Gentech's current soldering line requires the boards to go through four separate stages before the soldering is complete. At each of these stages the boards must be manually loaded and unloaded. This resulted in a high number of damaged boards due to improper handling and inconsistent solder joint quality due to variation in the solution temperature and chemical balances. The new soldering line would virtually eliminate material handling and would add a computerized process control system which would monitor each stage of the process. The robotic test cell would be placed at the end of the soldering line to move boards from the soldering line to the Bitmico PCB testers and to drive the test machines. This would be Gentech's first attempt at robot automation. Gentech had contracted with Moore & Associates, a consulting firm to help draw up plans on how the new soldering line and robotic test cell would be integrated into its existing assembly line. The robotic test cell would cost approximately \$750,000.

Bob Waters and Steve Anderson had become fairly close friends over the past several years. Their children went to the same school, and they lived only a few blocks apart. Their families occasionally got together for social outings, and once or twice a month they would play a round of golf together. Although they were personal friends, Anderson made it a rule to keep business and pleasure strictly separate. Rarely did they talk about business except when Waters made calls on Gentech.

Waters considered Gentech to be an extremely important account and attempted to contact the firm at least once a month. Gentech was one of Waters' first major sales when he joined Omni. Its annual purchases occasionally totaled as much as \$800,000. Furthermore, due to the size of its manufacturing operations, it was a prime candidate for future major purchases from Omni.

Water's Call Reports

Waters reconstructed his activities for the period he had been working on the Gentech sale by reviewing his call reports.

February 4, 2006

Received a call from Anderson. He said that Gentech was about to initiate a bidding process to procure a robot system that was to be a part of Gentech's new soldering line. Anderson asked if Omni had a product that would satisfy Gentech's needs. Told Anderson that Omni could custom build any robotic work cell that he might need. Arranged to visit him the following day.

February 5, 2006

Called on Anderson. Discussed with him the overall requirements of the work cell and the bidding process to be used. The robotic test cell was to be part of Gentech's new soldering line that was purchased from Ace Electronics. The line was to be installed in February of 2007. The test cell had to be delivered and operational within one week of the installation of the soldering line. An operational mockup of the test cell had to be demonstrable at the vendor site 30 days before delivery for initial acceptance testing.

Anderson said that a new bidding process was being instituted this year. Unlike previous capital acquisitions, where vendors were heavily involved in negotiating equipment specifications and cost, product requirements would be drawn up by Gentech personnel, and the supplier would provide a sealed bid at a final presentation. Preliminary bids and product proposals would be used to narrow the number of vendors submitting final bids down to four or five. The final selection would be made jointly by the Purchasing, Manufacturing, and Test Engineering organizations. Anderson would represent Purchasing; Jim Thompson, manager of manufacturing operations would represent Manufacturing; and Carl Jefferson, a senior engineer, would represent Test Engineering. Kevin Reilly; vice president of northern California operations, would also participate in the decision.

Anderson furthermore said that detailed specification for the test cell would not be made available for the preliminary bid phase; these specs would be given only to those vendors selected to submit final bids. Proposals and preliminary bids were to be generated based on preliminary specs available through the Moore consultant. Anderson gave me the name of the Moore consultant and also gave me the name of an Ace engineer for the details on the soldering line and a Bitmico engineer for details on the testers.

Returned to the office and reviewed the situation with the boss (Doug Barnum). Discussed the importance of getting this initial sale in order to have the best shot at Gentech's future robotic automation needs. Surmised that Gentech had instituted this new bidding process in an attempt to get more aggressive pricing from the vendors. Concluded that pricing would therefore be the primary factor in selecting a vendor. Discussed the pricing strategies that we might use and those that might be used by our competition. The boss told me to keep him apprised of the situation and let him know if there was any way he could help. Took home a competitive analysis of the robot industry that was prepared by our marketing group.

February 6, 2006

Called Kevin Reilly at Gentech to try to set up an appointment to meet him. Was told by his secretary that "Mr. Reilly does not interact directly with sales people" and that Anderson should be contacted for all sales-related issues. Tried to explain to her that I needed only a few minutes of his time, but she said that there were no exceptions to the rule.

Wrote the Moore consultant in Los Angeles for the test cell spec. Reviewed specification on the robots that we use in our work cells and specifications on work cells that we had done in the past. Forwarded a recommendation letter from Albany Computers for the robotic insertion cell I sold the company last year for its assembly line.

March 4, 2006

Received specs from Moore. Looked them over with Paul Johnson (Omni's systems design engineer) and discussed possible hardware configurations that could be used in the test cell. Asked him to put together a tentative system for Gentech. Gave him the names of the Ace and Bitmico contacts in case he needed additional information on the soldering line of the testers. Called Thompson at Gentech and made an appointment to meet him for lunch next week.

March 8, 2006

Visited Anderson before meeting with Thompson. Found out that eight other firms would be making proposals along with Omni. Asked him how Omni's chances looked for getting invited for the final bidding stage. He said that as long as our bid wasn't way out of line we should have no problem getting past the preliminary bid stage. Showed him Johnson's preliminary proposal for the test cell. He was impressed by the technology and sophistication of the system. Went over the features of the robots that we use in our work cells, stressing the accuracy and speed of the robot and the direct-drive technology used which allows high torque to be generated at relatively low motor speeds. Left him a stack of literature, a copy of Johnson's proposal, and the Albany Computer's testimonial letter.

Met with Thompson and his assistant, Roberts, for lunch. Discussed their situation in the factory and the acquisition of the soldering line and test cell. Thompson and Roberts seemed to be somewhat skeptical about the robotic test cell and the technology upon

which it was based. They said that they had read about robots in various trade journals and seen some of them on television, but had never had a chance to see one in person. Told them about all the robotic work cells that Omni had built and offered to show them one of the robots at our facility. Tentatively scheduled their visit for next week. After lunch I reviewed Johnson's proposal with Thompson and Roberts. They both seemed concerned about reliability and system downtime. I pointed out some of the backups and redundancies built into the system which increase system reliability, and our past track record for high reliability. I also pointed out that due to the proximity of Omni relative to our competitors, Omni was clearly in the best position to provide prompt emergency service in the unlikely event that they had a system failure. They agreed. Left them with copies of the same literature I had left with Anderson.

March 19, 2006

Picked up Thompson and Roberts for our plant visit. Dropped by Anderson's office to see if he wanted to come along. He said he had a meeting later on that day and couldn't. On the way over to the plant we talked about a variety of things, including how well the Warriors basketball team was doing this year. Thompson seemed to have a real interest in basketball so I invited him out to tomorrow night's game. Asked Roberts if he wanted to come along but he said he had plans for tomorrow night. Made arrangements to pick up Thompson at his house.

Once we got to the plant, I showed Thompson and Roberts a robot that was similar to the one that Johnson had proposed for their test call. Ran a demonstration program which made the robot insert various sized components into a PCB and transfer it to different workstations. Thompson and Roberts were very impressed. Showed them how to use the teach pendant and how easy it was to program the robot. Ended our visit by showing them around the facility.

March 20, 2006

Picked up Thompson at his place. Took him out to a nice restaurant on the wharf before the game. During dinner, I reemphasized the servicing advantages of going with Omni. Asked him what he thought Omni's chances were in landing the deal. He said that he really didn't know yet and that choosing a vendor was the least of his worries. He was taking a lot of heat from the union because the new soldering line and the robotic test cell was going to displace 12 employees. I told him how other companies were dealing with the problem and assured him that things would work out. The Warriors won the game 110 to 109.

March 27, 2006

Visited Anderson. Found out that there were problems with the specs. He wasn't sure what the nature of the problem was but he knew that completion of the spec was behind schedule. Arranged a meeting with him, Thompson, Jefferson, and my boss, Doug Barnum, for early next month. Suggested that Reilly be invited also, but Anderson thought he wouldn't attend.

Went to see Thompson. Asked him about the problem with the specs. He said that there was some controversy over who should be responsible for generating the specs, Manufacturing or Test Engineering. He said that no matter which way it went, "Manufacturing would get its needs addressed." Suggested to him that clearly Manufacturing should control the specs since it will be responsible for operating the equipment. He smiled and left to attend to other business.

Ran into the foreman on the assembly floor. He seemed to be pretty unhappy about all the changes that were being made to the assembly line. He complained about the fact that he "had just spent six months getting things running smoothly and now they were going to change things all over again." I sympathized with his position but reminded him how much more efficiently his operations were going to run after the new soldering line and test cell were installed. He agreed that in the long run his operations would probably be better off.

Asked him how the Omni component insertion machines were performing. He told me that one of the machines was down and had been waiting for parts for two days now. Called the people at the service center to find out what was taking so long to service his machine. Was told that the parts were on back order and that they wouldn't be available for at least another day. Apprised them of the situation and suggested that they borrow the parts from another machine that was down in the field. Was assured by them that his machine would be repaired before the end of the day. Relayed the information to the foreman who was grateful for the favor.

April 3, 2006

Barnum made an excellent presentation to Jefferson, Thompson, Roberts, and Anderson on the company and the product line. He reviewed the company's financial status, its position in the market place, our major account customers, and our reputation for quality and service. He also went into quite a bit of detail on the product line, and in particular the robotic work cells. Few questions were asked during the presentation, although Roberts did raise a concern about spares availability for the robot system. Assured him that Gentech's problem with the insertion machine was an isolated case and that spares were always readily available for the robot systems. Distributed to everyone a leather folder with the Omni logo on it and an Omni pen and pencil set. Introduced myself to Jefferson, who, according to Anderson, was probably still upset about having to share responsibility for generating the specs with Thompson. Thompson was supposed to develop Manufacturing's requirements while Jefferson was supposed to define the detailed technical requirements for the system.

April 22, 2006

Checked in with Anderson to see how things were going. He said that both Engineering and Manufacturing had stopped working on the specs until after the preliminary bids were in. This would give them time to understand what their real requirements were and give them an opportunity to look over the preliminary bids.

Spent the afternoon with Thompson discussing the tradeoffs between payload requirements and the impact that it has on cycle time and the maximum velocity that can be achieved by the robot arm. Carefully reviewed with him the impact this decision could have on the throughput of the assembly line and the types of boards that the line could handle. Left him with some additional literature describing the latest developments in robot controllers.

Visited the foreman on the assembly floor. Found him watching an operator load components in the insertion machine for another assembly pass on the boards. He complained that the machines should be more flexible and support any size component in each of the feeds instead of restricting each one to only certain sizes of components. I told him that upgrades to provide that capability were available for the newer machines but weren't available for that particular machine. Explained to him that upgrade kits were usually developed only for the more recent model year machines.

May 28, 2006

Worked with Johnson in developing our tentative bid. Suggested to him that price, reliability, and throughput, in that order, should be the key factors in developing this proposal. After several hours of discussions, we finally agreed on a system. I included variable-speed conveyors, 20-board capacity buffer/loader, 6-axis direct-drive Adept robot, and a 68020-based robot controller with teach pendant. The controller would include 20 GB of hard disk, 128 MB of memory, five external ports, and the standard software development environment. It would also include a one-year warranty and an optional service contract which would entitle Gentech to hardware maintenance and all software upgrades. I felt that based on the preliminary specs from Moore, the robot we selected gave Gentech a perfect compromise between payload capacity and minimum cycle time. Discussed pricing of the system with Barnum and decided to offer only a moderate discount for the preliminary bid state and then a much more aggressive discount for the final bid. The bid would go in at \$718,500. The service contract would be offered at 10 percent of list price, or \$75,000 per year.

June 25, 2006

Checked with Anderson to see how our bid looked. He smiled and told me that all the bids weren't in yet and that a decision would be made sometime in early August. Arranged to play a round of golf with him next weekend.

August 5, 2006

Received a letter from Gentech inviting Omni to bid on the final specifications. Visited Anderson later that day to see if I could gather more information on the bid. Found out that the other firms invited to bid were IAS, Robotic Automation, and UA Corporation. When questioned about our preliminary bid, Anderson suggested that our bid appeared high. Assured him that once we had the final specs we would give them the best price-performance combination available. Asked about the other aspects of our bid, and he told me that the best person to talk to would be Jefferson. Went to look for Jefferson, but he had already left for the day.

That evening I reviewed the specs and the price lists of our competitors. IAS is a small entrepreneurial company with approximately 15 installations nationwide. Felt that IAS probably could offer Gentech a better price but lacked the experience and stability that Gentech would want from a vendor. Robotic Automation has more experience in robotic applications but it has no other products in the electronic assembly market and its experience in these applications is limited.

Although UA offers the same types of robots in its work cells, it doesn't manufacture its own conveyors and board loaders. It could therefore not offer the same level of customization in its work cells nor be as price competitive as Omni could. UA could offer more capabilities in its robot controller than any of the other companies, but these additional capabilities would come at a considerable additional cost to Gentech. Gentech would need these additional capabilities only if it found itself in the unlikely situation of needing to reprogram the robot to perform significantly more complex functions than are currently planned for the test cell.

August 6, 2006

Spent the afternoon with Jefferson. Noticed that copies of the literature that I had left with Anderson and Thompson were sitting on Jefferson's desk. Asked him how our proposal looked. He said the proposal looked fine at this point but reminded me that the final specs were still under development. Reviewed with him various features of the robot and robot controller that were proposed for the test cell. He didn't seem as concerned about the controller's capabilities as much as Omni's commitment toward continuing to upgrade and improve the product once it was purchased. He said that the Manufacturing people were concerned about the product becoming obsolete once new technologies were introduced. I assured him that Omni was committed toward continuing to improve and enhance its products and cited numerous examples of how the products in the field were continuing to be improved. Also reminded that software upgrades and enhancements for the controller would be "free" under the maintenance contract. Took note of some technical documentation that he wanted and told him I'd drop it off later that evening.

September 2, 2006

Met with Anderson. Found out that responsibility for developing the specifications had been given to Jefferson. Jefferson would now be responsible for incorporating both Manufacturing's requirements and Engineering's requirements into the final specs. He said the change was made in the hopes that giving responsibility for the specs to one organization would help resolve some of the problems they had in coordinating the task. Anderson also confessed that neither group had been able to make much progress on the specs due to a lack of criteria upon which the specs could be developed. This problem became apparent when they tried to merge Manufacturing's and Engineering's requirements and found that many of the requirements conflicted. Upon further investigation, it was discovered that the two organizations had developed their requirements based upon different criteria. Furthermore, after reviewing the preliminary bids, it became obvious that each vendor had also made different assumptions about the

criteria in developing their specifications. Jefferson therefore had contacted the Moore consultant and requested assistance in developing appropriate criteria. Jefferson was due back at the end of the week.

I knew that this would give me an opportunity to influence the specs and ensure that they contained certain features standard in our robots and conveyors. Having these features in the specs would give Omni a clear advantage in the bidding. Made a note to see Jefferson early next week.

September 16, 2006

Spent the morning with Jefferson discussing the benefits of the Omni system. Made sure to place special emphasis on features standard in our robots and conveyors that increase the mean time between failure and reduce the likelihood of component failure. Felt confident that he recognized the Omni advantages. Left him with some highly technical literature which described these features.

Went to visit the foreman on the assembly floor and found him talking to one of the software engineers that Gentech had recently hired to work on its process control system. Asked him if he thought he might also be doing some work on robotic test cell and he said that it was a possibility. Told him about the extensive programming environment that came with our controllers and the fact that the system could be programmed off-line without disrupting production. He mentioned that he had heard from a friend last year about all of the bugs in the Omni programming environment and wondered if they had been fixed yet. I smiled and assured him that those problems were long since past and that we now had an extensive quality assurance program in place. Also told him about the many horror stories I had heard about the programming environments in the UA and IAS systems and that my understanding was that some of those problems were still not fixed.

September 30, 2006

Met with Jefferson at his request. He had been reading a trade journal about the state of the art in robot systems and had noticed that Omni was rarely mentioned in the article as a leader in the field. He said that he was concerned about selecting a vendor that would maintain a state-of-the-art product since future robotic installations would most likely involve the same vendor. I told him about some of our pending product announcements and the types of advanced research that we were involved in. I also reminded him that although we might not lead the robotics industry as a whole, we did lead the industry in the field of robotics applied to electronics assembly, the field that Gentech should be most concerned about. He agreed and seemed satisfied that Omni could meet all of its future requirements.

October 15, 2006

Had lunch with Anderson. Found out that Thompson had been transferred to another organization within Gentech and that Roberts had been promoted to plant superintendent. Anderson wouldn't discuss the circumstances surrounding Thompson's transfer and encouraged me not to bring it up with Jefferson or Roberts. Also discovered that Reilly

had formed a new group called Computer Integrated Manufacturing to be responsible for the various computer systems that manufacturing had acquired. Asked Anderson if he thought this new group would have any say in the selection of the test cell. He said that Jefferson would be representing their interests and that no changes to the selection committee were anticipated. Invited Anderson, Roberts, and Jefferson to the Robots 8 conference that was to be held in Santa Clara at the end of the month. Left exhibit passes at the location of Omni's hospitality suite with Anderson.

October 29, 2006

Met Anderson, Roberts, and Jefferson at our hospitality suite. Introduced them to our vice president of marketing, Dan White, and several other Omni executives. Took them on a tour of our exhibit booth and showed them our work cell demonstrations. Gave them each a ticket to tonight's conference gala dinner and encouraged them to stay for the festivities. Learned from Anderson that the specs would be ready by November 15. Told him that I would come by to pick them up and then excused myself to meet another client.

November 15, 2006

Picked up the final specs from Anderson. He said that the bid presentation for all four suppliers would be held on January 20. We would be given two hours to make our presentation, at the end of which we were to hand in our final bid. Our assigned time slot was from 1 to 3 p.m.

Went back to the office to review the specs. The specs contained some unexpected requirements. Gentech had gone along with our robot and conveyor specifications, but had specified additional board loading capacity and a significant number of additional capabilities in the robot controller. The board loader would be no problem, since we custom build our own; the robot controller however, could be a problem. Asked Johnson to start putting together our final proposal and arranged for him and Barnum to participate in the formal presentation. Called Jefferson and arranged to meet with him after the holidays.

November 29, 2006

Spent the afternoon going over the final specs with Jefferson. Found out that the additional capability in the robot controller was required for a bar coding system that Gentech planned on installing in the future. Discussed various alternatives for providing that capability and sold him on one that could be satisfied by our current controller. Reviewed all other aspects of the specs with him, pointing out Omni benefits and features along the way. He seemed satisfied that Omni could deliver as promised. Stopped by to see Roberts and Anderson, but both were tied up in a meeting for the rest of the day.

December 18, 2006

Sent Anderson, Roberts, and Jefferson each a large holiday box of gourmet foods for the coming New Year. It contained fine cheeses, meats and chocolates.

January 10, 2007

Reviewed our final proposal with Johnson and Barnum. The proposed system contained only minor modifications from the one submitted for the preliminary bid. Decided to include more memory and a larger disk in the controller and modify the board loader specs to conform to those called for in the final specifications. After several hours of discussion, we decided to go in with a bid of \$687,000.

January 21, 2007

The presentation went extremely well. Barnum started with a brief corporate overview, stressing Omni's reputation for innovation, reliability, and service. Johnson followed with a discussion of the technical aspects of our proposed test cell, making sure to point out how each of the requirements in the Gentech specs was satisfied. I summed up the presentation and handed the bid to Reilly. Anderson thanked us for a "superb" presentation and said that we would hear from them by late February.

February 26, 2007

Received a call from Anderson notifying me that Omni had lost the bid. He said that the committee had narrowed the field down to Omni and UA and that UA had just edged us out. He couldn't pinpoint one particular reason for the selection, but did say that cost did not play a large factor in the decision since both companies came in at about the same price. He added that each member of the committee had a different reason for preferring UA, but that all were unanimous in the feeling that UA would better satisfy the company's needs. When asked about the possibility of having a meeting to discuss the issue, he replied that his orders were to tell all vendors that the committee's decision was final and that the matter wasn't open for discussion. He congratulated me on the job I had done representing Omni and said that he hoped this decision wouldn't affect our friendship.

Appendix 1

Note: This document provides a preliminary description of the robotic test cell for Gentech Office Equipment Company. These specifications are based upon information provided by Gentech, Ace Electronics and Bitmico Tester Corporation. All specifications are subject to change.

General Description

Figure 1 shows the general layout of the robotic test cell. The test cell consists of one incoming conveyor and two outgoing conveyors, a robot and three Bitmico 8000 testers. The input conveyor receives the board from the solder wash station of the solder line and regulates the throughput to the robot cell. The robot should be outfitted with a double sided end effector so that board loading and unloading can be accomplished within a minimum cycle time. The robot moves the board from the board loading station to one of the available testers. The robot removes the tested board from the tester with the side of the end effector not holding the board to be tested. After placing the untested board onto the tester, testing of that board is initiated. The tested board is moved to a bidirectional belt for feeding onto one of the two outgoing conveyors. Based on the results of the board test, the board is placed on either the “passed” or “failed” conveyor.

Board Specifications

Boards will range in height from a minimum of 5 inches to a maximum of 24 inches and will range in width from a minimum of 7 inches to a maximum of 30 inches. Maximum warp and twist of the board will be .01 inches per inch of board. A fully assembled board will range between .5 and 5 pounds in weight. The maximum height of any component on the board will be .75 inches. Component bodies will not extend into an area .2 inches wide along each edge of the board. A tooling hole is located in the upper left, lower left and lower right corners of the board. These holes will be .15 inches in from each of these corners and will be .09 inches in diameter. These holes are used to mount the board into the test fixture.

Tester Specifications

The testers are Bitmico 8000 in-circuit testers. They are equipped with an RS-232C port which allows communication with the tester. Testing can be initiated and test status (e.g., test in progress, board failed, board passed, tester idle, test fault) can be polled through this interface. An interrupt signal is generated by the tester when testing is complete. The period of time required to test a board varies depending on board complexity, but typically takes 15-20 seconds. There is a 10 foot vertical clearance envelope around the test bed. Pins for the test fixture are .085 inches in diameter and 1 inch in height. For more details on the tester contact Bitmico customer support.

Appendix 1

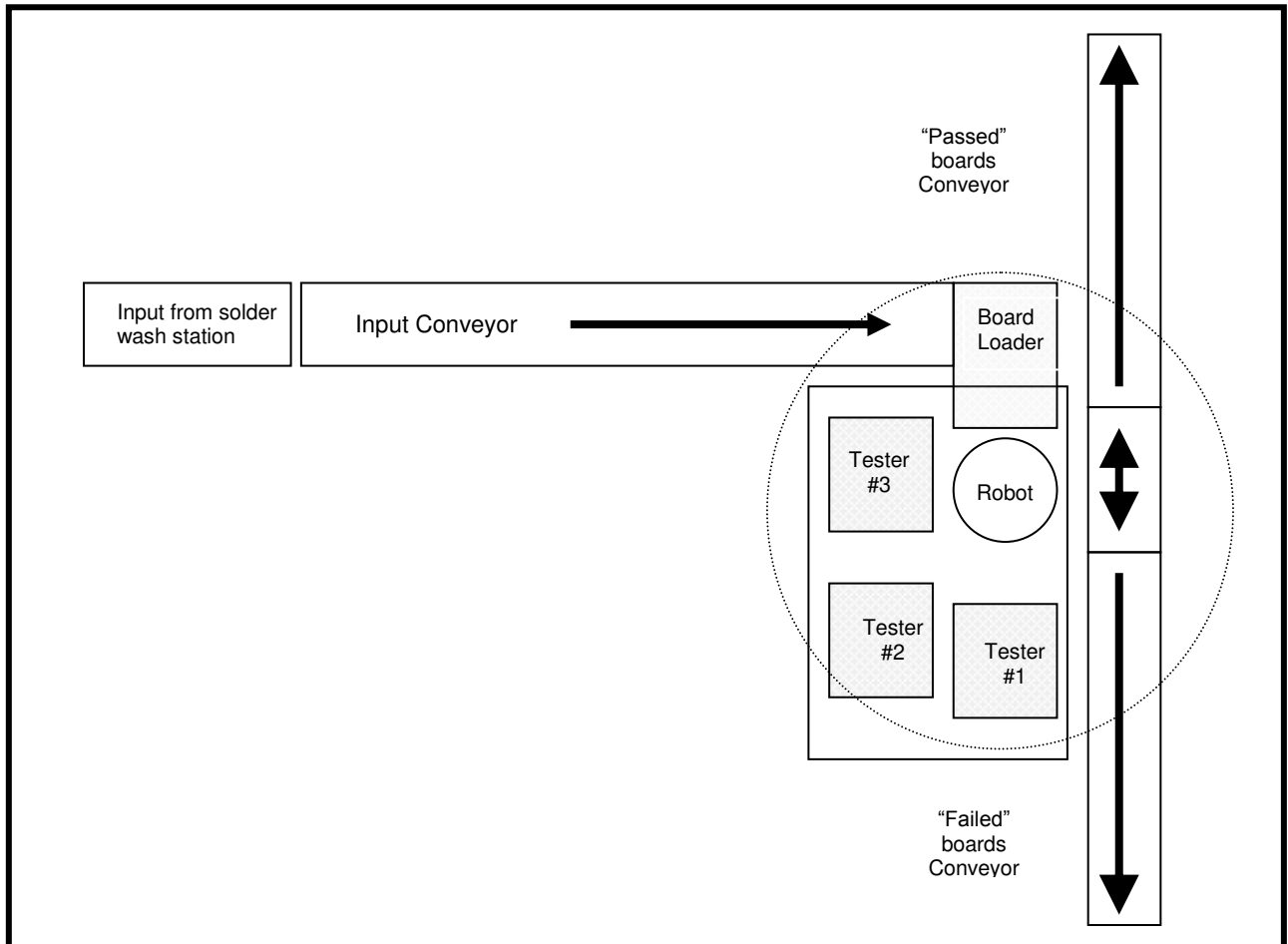


Figure 1

Conveyor Requirements

The output conveyor from the solder wash station is 4 feet in height 2 feet in width and moves at the rate of 15 feet per minute. Boards will be spaced a minimum of 5 feet apart on the conveyor and will be oriented such that the tooling holes are located in the upper left, lower left, and lower right corners of the board. The input conveyor for the test cell should be 30 feet in length and be capable of buffering a minimum of 15 boards.

The output conveyor for the failed boards should be 4 feet in height, 2 feet in width and 50 feet in length. The conveyor should be capable of speeds ranging form 10 to 30 feet per minute. The conveyor will feed a rework area where failed board will be processed.

The output conveyor for the passed boards should be 4 feet in height, 2 feet in width and 55 feet in length. The conveyor should be capable of speeds ranging from 10 to 35 feet per minute. The conveyor will feed a packaging area where boards will be packaged for shipment.

Robot Controller Requirements

The controller is required to coordinate the actions of the robot, the three testers, the input conveyor, the bidirectional belt, and the two output conveyors. In addition to the normal operation of the test cell, the conditions shown in Table 1 should be handled with the specified remedial actions.

Condition	Action
One or more of the testers is inoperative.	Continue testing with the operating testers.
Input buffer is almost full.	Continue testing and issue a warning to the operator.
Input buffer is full.	Stop the robot and signal for the operator.
A tester is not responding.	Continue testing with the other testers and issue a warning to the operator
N consecutive failed boards have been encountered.	Stop the robot and signal for the operator.
Either of the output conveyors has been shut down.	Stop the robot and wait for conveyor(s) to be restarted.

Table 1

The robot should be programmable either through a teach pendant or off-line through the controller’s software environment. Adequate flexibility and functionality should be provided in the system to allow modification or customization of the system in the future.

System Requirements

The overall test cell must have a minimum 2000 hour mean-time-between-failure and a 96% uptime. The work cell noise level should not exceed continuous 80 db.

A safety shield should be included in the design of the test cell. The robot work envelope must not be accessible by the operator without emergency stopping the robot.