PART III

A Look at the PCB Equipment Buying Process

by John T. Fisher

Capturing the elusive goal of reliability in the purchase contract.

This is the final article in a three-part series that examines the PCB equipment buying process. The first article presented an overview of the process of equipment buying. The second addressed selecting a supplier. This article will explore the difficult task of incorporating reliability into new equipment purchases.

RELIABILITY AS A PURCHASE CRITERION

The current industry emphasis on PCB equipment reliability is a rather recent phenomenon that seems to be inevitable in the natural progression of high-tech manufacturing. When the PCB industry began, product output was the first priority; product quality was pursued as competition intensified. Industry members then began to emphasize the manufacturing process in an effort to cut costs to gain a competitive edge. Initial cost-cutting efforts were devoted to reducing head count, modifying utilities use, accelerating the manufacturing process, and developing equipment with higher production yield, all of which are measurable variables.

The next consideration in reducing manufacturing costs — increasing factory equipment reliability — was more subtle, and no industry standards existed to govern this activity.

Equipment reliability has only recently become a criterion in the PCB equipment purchase contract. IBM was one of the industry leaders in this area, formally announcing its plans to increase the reliability of its purchased equipment at the Spring 1989 Nepcon show in Anaheim, CA.

Since that time, reliability as a purchase criterion has become a major industry topic. Users and suppliers have engaged in much more dialogue on this subject, and data for evaluating equipment reliability has become an increasingly prevalent industry concern. Many articles have been written on this issue, which is also being addressed at many industry conferences.

Design considerations

1) Will adequate design reviews be planned and completed prior to build? Will there be:
   a) a 50% review
   b) a 75% review
   c) a 100% review
   d) a review of detailed drawings
   e) a review of all changes?
2) Does the supplier use a CAD or CATIA design system?
3) Are all customer prints and specifications maintained and up to date?
4) Does engineering generate working drawings from customer specifications?
5) Are all manuals, calibrations, procedures, training materials, and software updated to include the latest design changes?
6) Do working drawings contain all necessary tolerances or testing requirements needed to meet your specifications?
7) Are all drawings provided to every department involved in the job?
8) Is a system established to track any changes prior to completion and replace all back-level prints?
9) Are all involved personnel immediately informed of any changes and periodically updated on the status of the overall project?
10) Through initial design meetings or quotes, has the supplier offered suggestions or design changes that will:
   a) increase reliability
   b) simplify the design
   c) improve manufacturability
   d) reduce the cost?
11) Are the following aspects considered in the design of the equipment:
   a) design for maintainability
   b) design components as field replacement units (FRUs)

At the September 1990 Institute for Interconnecting and Packaging Electronic Circuits (IPC) conference in New Orleans, LA, several speakers helped focus the PCB industry's attention on the matter of equipment reliability. A 1989 Institute of Electronic and Electrical Engineers (IEEE) conference featured a seminar devoted to this issue. The objective of these conferences was to allow leaders of high-tech companies to inform industry members of the new emphasis and to begin an industry-wide effort to define and clarify this topic.

DEFINITION OF EQUIPMENT RELIABILITY

The major problem impeding the efforts to include reliability as a

Design considerations (continued)

c) built-in diagnostics
d) expert systems for troubleshooting?

12) **Does the supplier support in-house acceptance testing prior to shipment?**
13) **Does the supplier propose prototype build prior to construction of multiple units, if possible?**
14) **Is a guarantee or warranty supplied with the equipment upon completion?**
15) **Has the supplier demonstrated, through initial meetings and design reviews, a thorough understanding of the scope of the project and the expected end result?**
16) **Can the supplier provide historical data on MTBF and MTTR for the equipment?**
17) **Does the supplier have experience building this type of equipment?**
18) **Can the supplier provide a list of customers, including names and phone numbers, who currently use similar equipment?**
19) **Does the supplier have a methodology and control system in place to feed future engineering changes and design improvements to the installed equipment base?**

purchase criterion for PCB equipment is lack of an industry-standard definition. Equipment reliability, a term that has always been part of the jargon of this industry, has typically been discussed during the negotiation phase of the equipment buying process. Such discussions, however, have often been severely limited due to the lack of a specific, scientific definition of equipment reliability. In the past, the term was frequently used as a synonym for quality, but as industry members' awareness has increased, it has become apparent that the terms have different meanings. Quality refers to a tool's conformance to specification, which results in the output of a particular product. Reliability, on the other hand, entails quality as well as machine up time and down time, thereby incorporating a time function

Process considerate ions

1) Is the job or material identified through the entire process?
2) Does the routing or material tag include information on set-ups, operating procedures, and construction as well as raw materials used in construction?
3) Are routing sheets used to track job status?
4) Are all major specifications or tolerances included in the paperwork?
5) Are all gauges and pieces of measuring equipment periodically calibrated and tagged to indicate recent calibration?
6) Are standards or gauges readily available to operating personnel?
7) Are gauge or calibration standards stored properly to avoid incidental damage?
8) Are master records, traceable to National Bureau of Standards records, kept on all gauges?
9) Are audits performed by in-house or independent groups to ensure compliance to calibration requirements?
10) Do operators check work frequently to ensure compliance to specifications?
11) Are tight-tolerance machines available, and are they frequently calibrated to ensure accuracy?
12) Are process chemicals sampled on a regular basis to fulfill process requirements?

Process considerations (continued)

13) Are temperature, pressure, and flow controlled to ensure consistency?
14) Are special racks, containers, or nests used to protect parts or sub assemblies from damage during processing?
15) Are operators qualified to perform process tests or measurements?
16) Are in-house crafting operations, performed by certified operators?
17) Are nondestructive teats performed on weldments?
18) Are all test results and measurements recorded at the operation, and are raw records kept of these data such that they are traceable to the final product?
19) Are equipment capability records maintained, and is there special equipment designated for tight-tolerance work?
20) Are final inspection procedures adequate to ensure conformance to the customer's specifications?

that is not included in the definition of quality.

Users can typically determine the quality of a machine shortly after it is delivered, installed and debugged. However, they cannot determine reliability y until they collect daily machine performance data over a long period of operation. A machine's true reliability cannot be determined until the end of its life cycle. This theoretical, academic definition of equipment reliability does not address the more complex aspect of the issue. The real problem arises when attempting to formulate an operational definition. There is probably little industry resistance to accepting the academic definition of equipment reliability; the uncertainties lie in the ambiguous area of specific hands-on operating conditions. The operational definition of reliability will continue to evolve, and the industry will not achieve a thorough understanding of this factor until a scientific equation is developed.

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The following are examples of problems that arise when attempting to derive a fair and accurate equation

Component considerations

1) Are raw material lots certified by the supplier or inspected upon delivery to the equipment supplier? Are audits completed and if so, by whom?
2) Are periodic independent tests performed on raw material lots?
3) Are all raw material lots identified by lot number and traceable through the manufacturing process?
4) Are quality control specifications established, published, and fulfilled for all raw material lots?
5) Are nonconforming raw material lots tagged and stored separately to avoid inadvertent use? Are they returned to the supplier?
6) Are all component parts inspected before being shipped to the assembly area?
7) Are all component parts stored and protected from corrosion prior to assembly?
8) Are components or subassemblies such as hydraulic or pneumatic cylinders, tested before assembly?

for assessing machine reliability:

- A supplier's replacement part took five minutes to replace, but arranging this replacement consumed three hours and 10 minutes of ramp-down and -up time. Events such as this raise the question of whether ramp-down and -up time should be included in the reliability equation. In this case, the conveyor line had stopped and product was not exiting the plant. It is therefore apparent that the ratio of down to up time is a major factor in the operational definition of tool reliability.
- The lack of a second or third spare part in the parts room can also bring a piece of machinery to a halt, and it may take a great deal of time to get the necessary part shipped in. The industry must determine where this down time fits into the reliability equation of an operational definition. Regardless of the fact that it is not the supplier's fault, down time must be accounted for in some manner.
- The industry must determine whether retest or requalification time following machine down time is to be considered up or down time.
- Wait time that occurs when neighboring equipment is down, in addition to employee breaks and lunches, must be included in the reliability equation.
- The industry must determine where to include the time needed to add extraneous test equipment to assist in finding a broken part.

These considerations are clearly not yet defined in the PCB industry, and this brief list includes just a few of the many problems that exist in devis-

Facilities considerations

1) Is equipment well maintained, and are maintenance records kept on each piece of equipment?
2) Are housekeeping practices sufficient to provide an adequate working environment for assembly of precision equipment?
3) Is adequate lighting, space, storage, and work area provided to permit quality work?
4) Are the necessary tools and supplies readily available?
5) Does the final inspection area have the proper gauges and instruments for preshipment testing?
6) Are precision measurement machines and equipment housed in a controlled environment?
7) Are there facilities for failure analysis?

ing an accurate and workable operational definition of equipment reliability. The industry will experience some difficulty in including reliability as purchase criterion for factory equipment until a standardized interpretation is achieved.

Neither the supplier nor the user can comfortably negotiate equipment reliability without an adequate equation and standardized language for examining this issue. In addition, these parties must recognize a fair trade-off in the purchase contract. The user must be able to interpret a

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supplier's offer of 300 hours mean time before failure (MTBF) for $300,000, or 400 hours MTBF for $1,000,000. Due to lack of understanding of the implications of reliability, it is difficult to determine the benefit of such a trade-off. Users and suppliers must experience a learning curve to gain this knowledge.

Users in the PCB industry have begun to negotiate contracts requesting increased reliability in new machine purchases. The key is to incor-

Special considerations

1) Are facilities available to design and build special packaging for proper shipment?
2) Is final packaging adequate to prevent any damage during shipment?
3) Are storage facilities adequate for components or units completed prior to shipment to avoid damage or corrosion?
4) Dose the supplier encourage on-site review of the manufacturing process and discussion with the individuals responsible for completing the project?
5) Are all criteria In place for outside vendors to the supplier, particularly those operations such as heat treatment, plating, and finishing operations?
6) Do contractad outside services receive complete copies of drawings and specifications for the project, and do they provide certification for their portion of the work?
7) Does the supplier recommend periodic rebuild, and how long does it take?
8) Does the supplier provide maintenance training, including classroom, instruction, training manuals, specialized training equipment, and a training package?

porate the MTBF and mean time to repair (MTTR) into the purchase contract. (The first article in this series, which appeared in the December 1990 issue of ***PC FAB*** presented an initial examination of equipment reliability as a purchase criterion.) The MTBF and MTTR data, introduced during the initial quote requests, are continuously addressed throughout the purchase negotiations. Warranties and penalties for failure to deliver the MTBF and MTTR rates specified in the contract are also incorporated.

Users and suppliers have not collected MTBF and MTTR data accurately in the past; however, they do have a general understanding of what constitutes a reasonable request. The

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fact that MTBF and MTTR are now being included in equipment purchase contracts has caused users and suppliers to examine these factors more carefully. Data collection of these mean times will eventually become commonplace.

The increased emphasis on MTBF and MTTR will necessitate that users and suppliers share data and openly discuss new design parameters. Long-term relationships between these parties can also enhance the flow of data necessary for achieving a greater understanding of the operational definition of reliability. Users and suppliers must form closer partnerships if the reliability variables are to be accurately defined and a language derived to facilitate further development in this area.

The tables presented in this article contain some ideas and considerations that can help the supplier and user incorporate equipment reliability into the purchase contract.

THE IMPLICATIONS OF AN INCREASE IN THE RELIABILITY OF EQUIPMENT

A plant's revenue is significantly increased when overall plant reliability is increased 5% and capital costs do not skyrocket. Even a small increase in production yield can create a large amount of revenue. Users who work to achieve equipment reliability will gain a significant competitive edge in the PCB industry. Suppliers who offer the highest levels of reliability and work with users to increase these goals will be in greater demand than those who are slower to comprehend the importance of this issue.

In addition, suppliers and users will have to make significant changes if increased equipment reliability is to be viable. They will have to attend conferences that help define the terms of reliability and work together to find a fair equation for determining this factor. The burden is equal for both parties. Suppliers must, by their own volition, strive to increase their machinery's reliability y, and users must not be reluctant to request an increase in tool reliability y. Such a request should be considered analogous to a prospective automobile buyer asking for six-ply radials instead of two-ply tires.

Equipment reliability must be incorporated early in the purchase cycle at the quote request level in a consistent manner for small and large purchases. The drive for increased reliability must become a corporate lifestyle.

CONCLUSION

Equipment reliability must be incorporated early in the purchase cycle at the quote request level in a consistent manner for small and large purchases. The drive for increased reliability must become a corporate lifestyle. Inconsistency concerning this issue will increase the amount of time it takes users and suppliers to achieve an industry standard. The word is out that equipment reliability as a purchase criterion is here to stay. With users and suppliers sharing the responsibility for defining the term, the industry will achieve a standard for scientifically measuring this variable. •

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