Pre-reflow inspection using 3D Laser Technology

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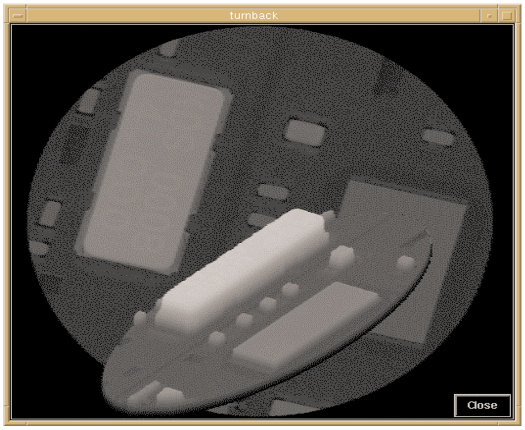


In-line component inspection in a high volume-manufacturing environment can be very challenging. AOI systems can be used to improve quality and reduce defects but frequently result in production constraints due to excessive false failures. There is now an alternative to traditional camera based 2D AOI systems, the GSI Lumonics SVS 8200 uses a patented 3D scanning laser to generate synthetic images, as the system is not sensitive to colour or brightness variations it can greatly reduce the number of false failures.

Ericsson Mobile Communications are a high volume manufacturer of Mobile handsets who have invested heavily in Automatic inspection in recent years. Until recently Ericsson UK have used traditional 2D AOI in each line carrying out pre reflow component inspection. They have also used GSI Lumonics SVS8200 3D inspection systems after the screen printers to carry out 100% paste inspection. 3D-paste inspection was introduced to prevent boards with insufficient or excess paste volume being assembled, typically a cause of more than 50% of end of line surface mount defects. Boards which have insufficient or excess volume of paste are extracted from the line by a buffer unit, the boards are cleaned and re-printed, a much more cost-effective way of dealing with the inevitable print defects. The GSI Lumonics SVS 8200 in line 3D solder paste inspection systems has proved to be very reliable and simple to use. There are no algorithms to adjust and very little engineering time is needed to keep the systems optimised.
The GSI Lumonics system proved to be so successful at this stage of the production process, that the decision was made to trial the newly developed component software for pre-reflow component inspection.

Ericsson had previously made the decision to place the AOI pre-reflow primarily because of the cost and ease of repair at this position in the line. The further the boards move along the process the more costly and difficult the repair procedure is, in some instances it can be cheaper to scrap the whole assembly rather than attempt to repair it. Additionally ICT is becoming more difficult as pin counts increase, component size decreases and component density increases. A further benefit of introducing AOI at this point is the system can be used for placement monitoring and process improvement. Corrections to placement machines can be made from the data obtained from the inspection systems, problems such as bent nozzles, poor board supports etc can be easily identified and corrected, something which is not easily done when the inspection is carried out post reflow. Data provided by 2D AOI manufacturers also suggests that the false call rate should be lower at this point in the line.

Having experienced the complexity of the AOI systems, Ericsson decided that in the future they would like to use only one AOI vendor. This would reduce the amount of training required for the engineers and operators; it would also reduce the quantity of spares stocked and give greater flexibility for future line re-configuration. The inspection system needed to be capable of keeping up with the cycle time of the line, had to be capable of inspecting a wide range of parts. False accept and reject rates had to be very low and engineering intervention (algorithm tuning, image training etc) had to be minimal. The system had to be easy to use and information about the process easily extracted in simple terms so that corrective action could be taken.

Ericsson use a wide range of standard parts, 0402's, Micro BGA, tantalum capacitors and some odd form parts such as connectors, springs, battery's switches etc. The most common faults experienced were misplaced springs and connectors, unfortunately large number of false calls from the 2D AOI systems masked the genuine faults.

For an AOI system to be a useful addition to a production line it has to be capable of to accommodating all the process variation you would normally see, e.g. PCB vendor change, solder mask change and part vendor change. 2D systems can struggle to cope with such a wide variation, the majority rely on complicated algorithms which could be several pages long to try and overcome this problem. When a slightly different part is introduced most systems need some sort of algorithm adjustment.

Constant algorithm adjustments can also have the negative effect of widening the range of what can be accepted as good by the system, inspecting a bare pasted board can be quite revealing after a system has been in use for some time and many algorithm changes have been made. False calls and false accepts can be quite time consuming to rectify particularly if there are multiple systems, and programs are not transferable from system to system. Although careful algorithm tuning can help minimise the problems experienced it can appear to be a never-ending time consuming task.

This is something few AOI manufactures mention in their sales information, very low false call rates are often quoted, little is said of false accept rates or the technical level of the person required to obtain those results and the amount to time required to keep the system running at those levels.

GSI Lumonics 3D inspection

Component inspection has always been possible on the SVS 8100 and 8200 systems, recent hardware changes and significant software improvements now make 3D component inspection a simple to use, unique and very effective option.

Variations in board or part colour have little affect on the inspection; this removes one of the biggest hurdles the 2D systems have to overcome. Program portability is a problem to many 2D systems; minute changes in lighting and camera calibration have a large affect on the inspection result. Some 2D systems may require substantial changes to databases or new algorithms creating, in effect having to re-write the same program for each machine or re-write all your programs after camera change or adjustment. This is not a problem with a 3D system, part size will not vary from system to system and there are no lighting parameters to adjust.

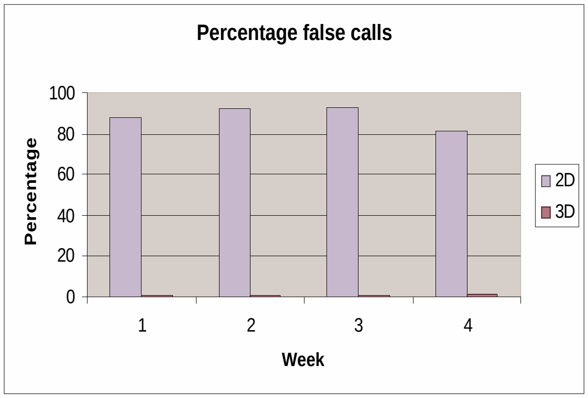
The SVS8200 uses the same 3D-scanning laser that is used in the company's very successful patented 3D-laser paste inspection system. The only difference between a solder paste system and component system is additional software which includes the component algorithms, a programmable Z resolution and enhanced image processing capability's, 2D and 3D data are analysed simultaneously.

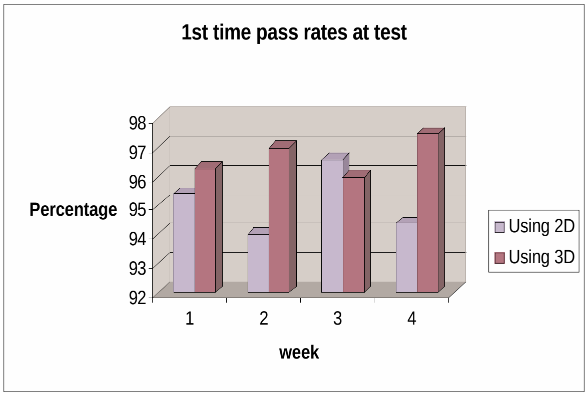
Using the same software has meant existing users of the paste inspection system can generate CPI (Component Placement Inspection) programs within hours of installing the software, new users can be trained in a few of days.

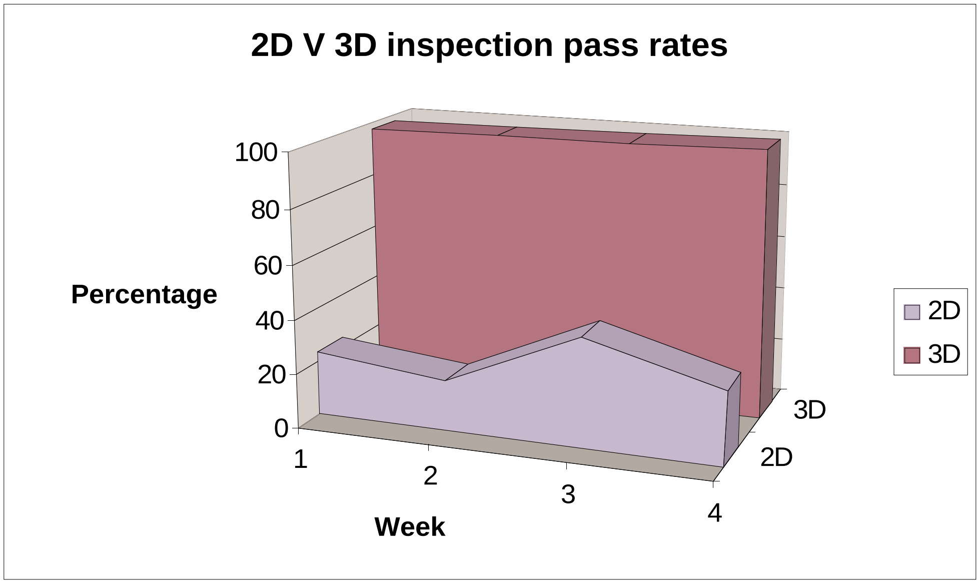
Programming the system is very simple; a standard parts library is included in the software. A simple placement file is all that is needed to program the machine; any new parts are easily created. In most cases it's as simple as drawing a box around the part (Figure 4), the self generating algorithms search the scene in both 3D and 2D, the part is found and the algorithm parameter table is completed automatically (figure 5). With odd shaped parts it may be necessary to make some small adjustments but the software is so simple there are only 12 parameters that can be edited (figure 5) most of these parameters are on/off.

The software identifies the top of the part and then measures down towards the board, a slice is then taken at that point and the area of the part measured, board warpage, colour of components or board have little affect.
Parts are judged on area, XY and theta position, misplaced parts, wrong size parts, tombstone, parts on side, upside down SOT's and diodes are all easily identified. Additional algorithms check polarity in both 2D and 3D, leaded devices can be checked by looking at the knees or feet in the paste, corner algorithms and side algorithms are used for BGA's/ large parts and odd shaped parts.

3D component inspection was introduced slowly at Ericsson, initial offline tests were carried out, and once confidence had been gained the system was positioned in line after the 2D system. The 3D system made considerably fewer false calls than the 2D system. Ericsson were able to remove one operator from the line because they did not need to review the false calls on every board. Initially it was thought a rework station would be needed but with the low number of false calls currently less than 10 PPMO it was found not to be needed. False accept rates have been found to be close to Zero.







Operators are alerted when a fault is detected by an audible alarm, the machine holds the board inside and the operator reviews the fault, once reviewed the board is ejected from the machine and the fault rectified, problems are fixed as they occur. If the same fault is seen 2 or 3 times the operator can easily seem something is wrong with the process, the defect source identifier helps pinpoint which machine, feeder and head are causing problem (Figure 9). Faults are rectified without building numerous incorrect boards and creating rework backlogs, had the fault been detected by a post reflow AOI potentially 40 or 50 boards would require rework, detecting the fault so quickly reduces cost.

An SPC package showing scatter charts for selectable samples shows position and spread of part placement (Figure 7), the data can be used to improve the placement process directly, on screen calculations of CPK are available as well as other SPC tools.

The big surprise from our trials was the stability of the inspection, the system ran for 3 or 4 weeks 24/7 with little engineering intervention. All board and part variations were handled by the system easily.

The Patented 3D-scanner technology has been around for some time now and has proved to be extremely reliable and robust, there are no moving parts and it requires no routine maintenance or part replacement. The system is somewhat simpler to use than some of the camera based systems that have to rely on complicated lighting, multiple cameras or multiple processors to try and get around the shortcomings of using a 2D sensor.

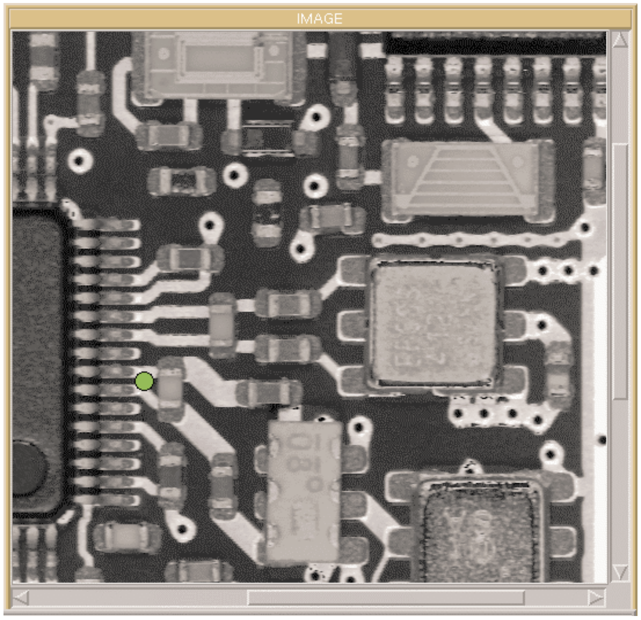
The cycle time for the system to inspect 4 mobile phones is around 25 seconds, inspection time is only governed by area, and not component density or counts as some systems are. The system can inspect practically any part down to 0201's; a higher resolution (12 micron) scanner is also available for the system.

Ericsson's experience shows that this unique approach to pre-reflow inspection has been very successful, the system met all of Ericsson's requirements and GSI Lumonics are now the chosen supplier for both Solder paste and pre-reflow inspection at this particular Ericsson UK site.

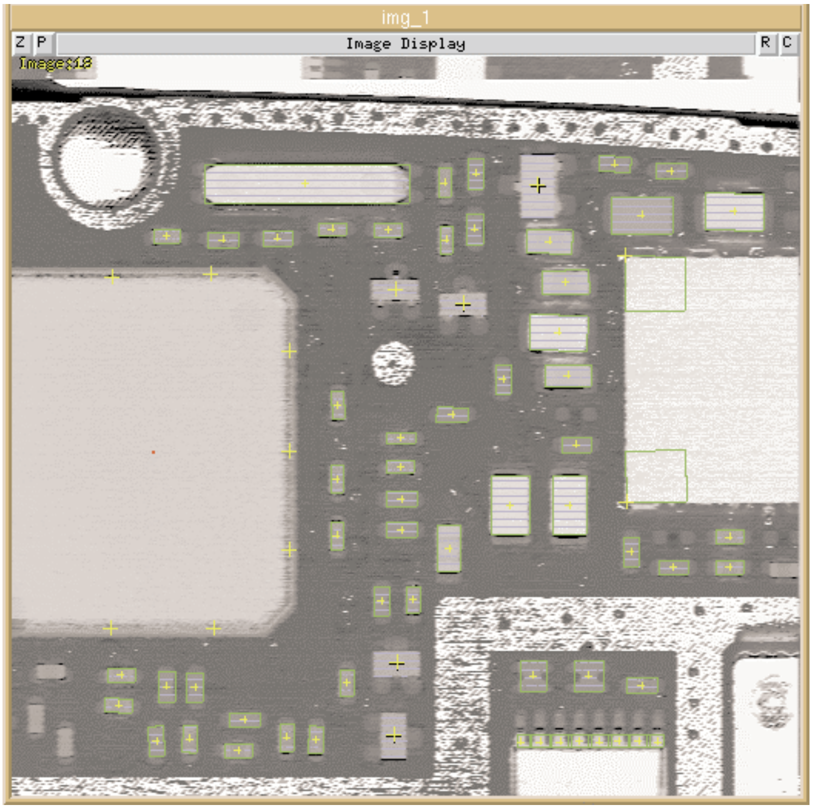
Interest has been show from other Ericsson sites and contract manufacturers. Recently another top 5 mobile phone manufacturer chose the SVS for inline pre-reflow inspection resulting in multiple orders. We are confident that the recent advances will provide the industry with solution it has been waiting for.

A simple to use, reliable, robust inspection system that doesn't use valuable engineering resources to keep running because of false fails and more importantly false accepts.

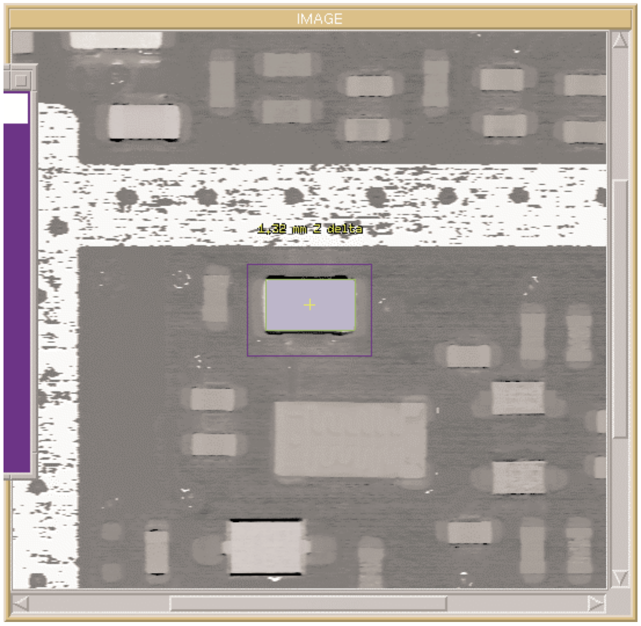
(Figure 1) A Example 3D image, the image is actually a hight map and clearly shows the parts placed on the board, the whiter something is the taller it is.



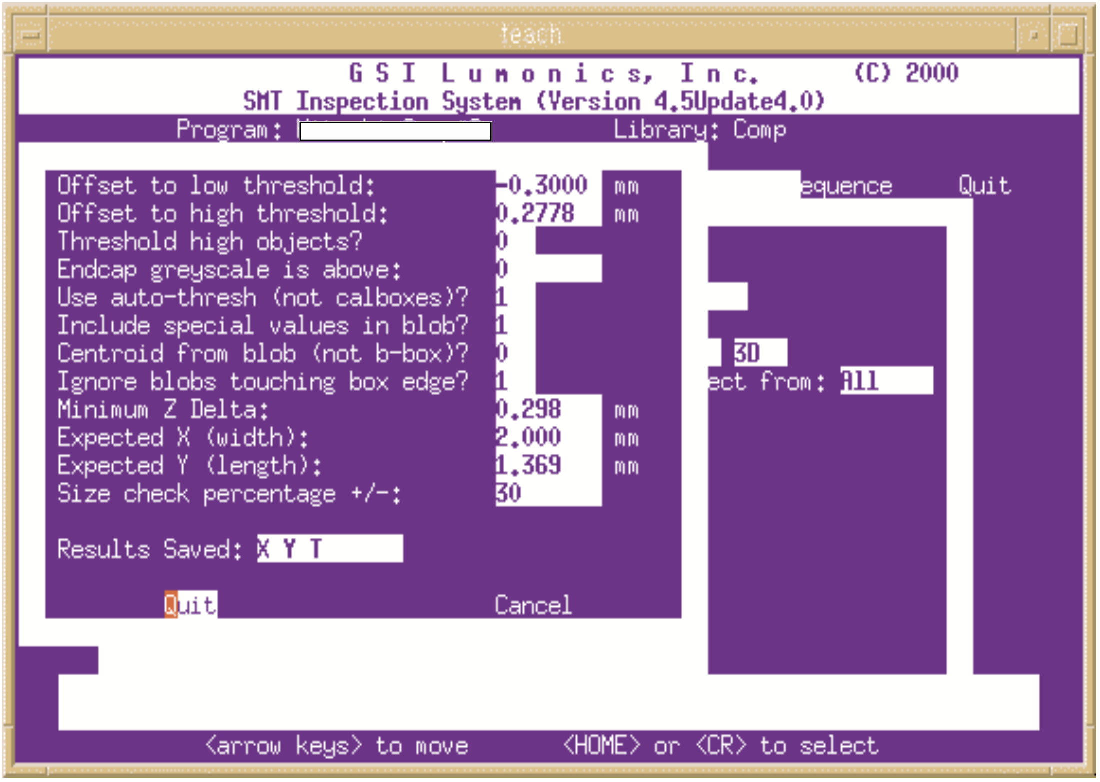
(Figure 2) 2D image of the same scene, notice how difficult identifying the small devices such as chip resistors is when they appear the same greyscale as the board.



(Figure 3) Same 3D-inspection image, different algorithms are used to find different package types.

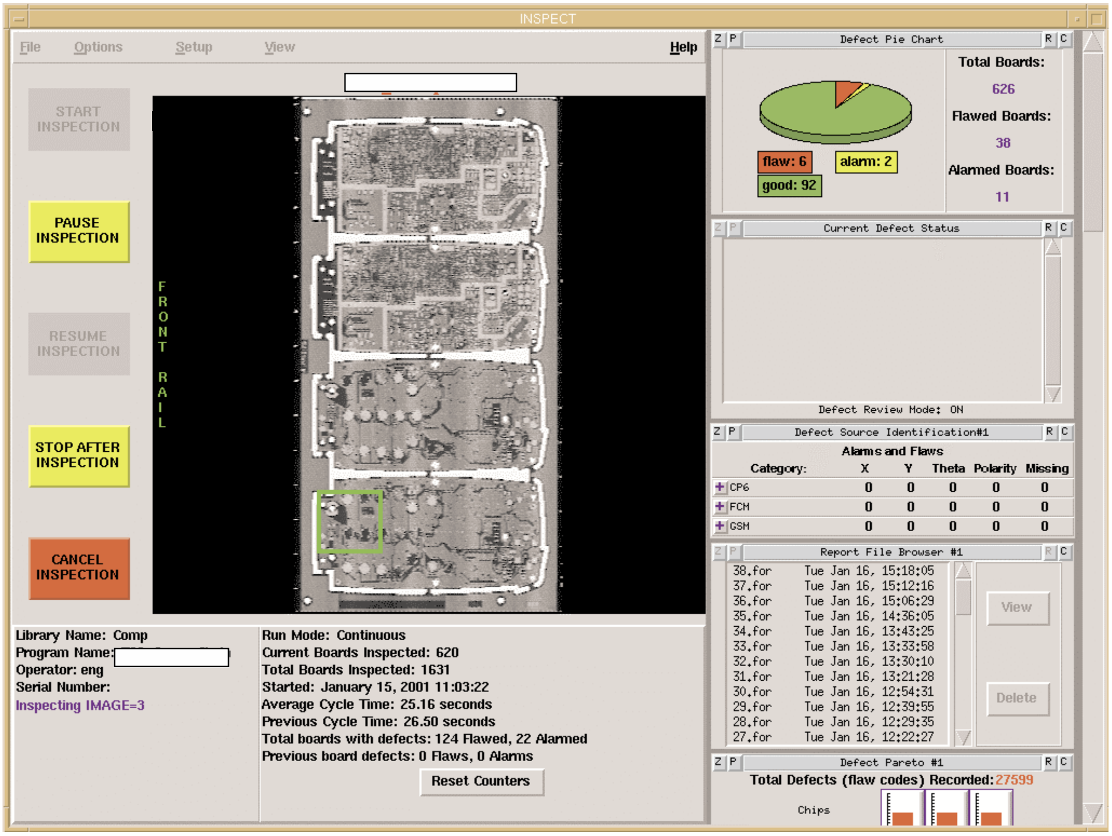


(Figure 4) Algorithm training image, outer blue box shows search area, green box drawn around part, part highlighted blue showing successful algorithm generation.



```
                    G S I   L u m o n i c s,   I n c.      (C) 2000
                 SMT Inspection System (Version 4.5Update4.0)
         Program: [redacted]               Library: Comp

  Offset to low threshold:        -0.3000  mm           equence      Quit
  Offset to high threshold:       0.2778   mm
  Threshold high objects?         0
  Endcap greyscale is above:      0
  Use auto-thresh (not calboxes)? 1
  Include special values in blob? 1
  Centroid from blob (not b-box)? 0                  3D
  Ignore blobs touching box edge? 1              ect from: All
  Minimum Z Delta:                0.298    mm
  Expected X (width):             2.000    mm
  Expected Y (length):            1.369    mm
  Size check percentage +/-:      30

  Results Saved: X Y T

          Quit                    Cancel

          <arrow keys> to move        <HOME> or <CR> to select
```

(Figure 5) Example of algorithm parameters editor.



Total Boards: 626

Flawed Boards: 38

Alarmed Boards: 11

Defect Review Mode: ON

Alarms and Flaws

Category:	X	Y	Theta	Polarity	Missing
CP6	0	0	0	0	0
FCM	0	0	0	0	0
GSM	0	0	0	0	0

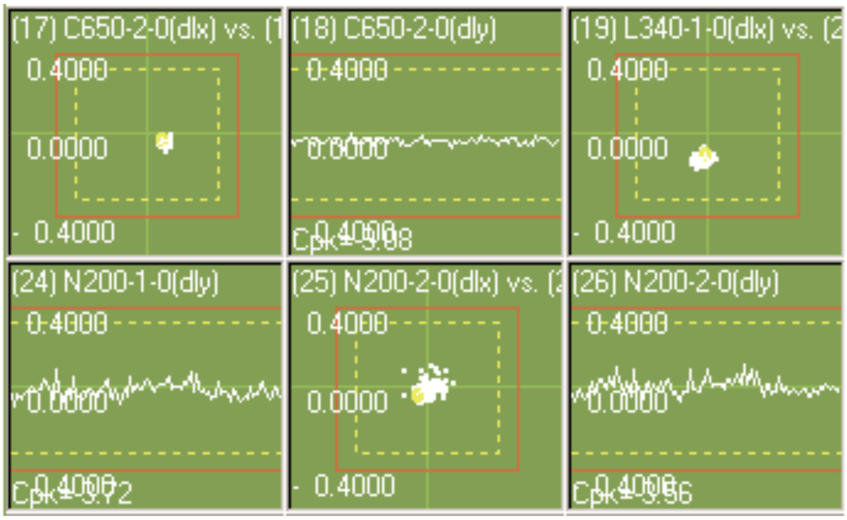
```
38.for      Tue Jan 16, 15:18:05
37.for      Tue Jan 16, 15:12:16
36.for      Tue Jan 16, 15:06:29
35.for      Tue Jan 16, 14:36:05
34.for      Tue Jan 16, 13:43:25
33.for      Tue Jan 16, 13:33:58
32.for      Tue Jan 16, 13:30:10
31.for      Tue Jan 16, 13:21:28
30.for      Tue Jan 16, 12:54:31
29.for      Tue Jan 16, 12:39:55
28.for      Tue Jan 16, 12:29:35
27.for      Tue Jan 16, 12:22:27
```

Total Defects (flaw codes) Recorded: 27599

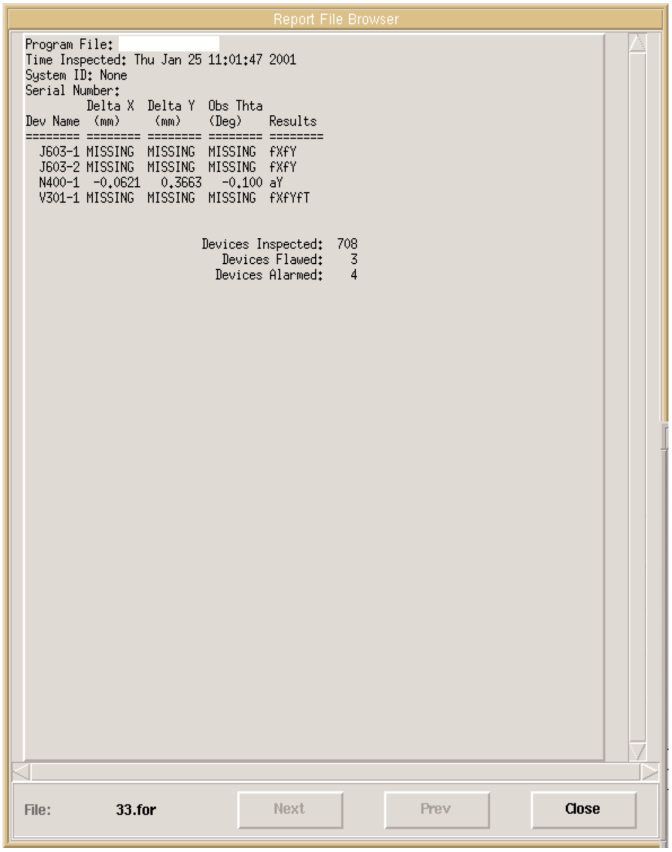
Library Name: Comp
Program Name: [redacted]
Operator: eng
Serial Number:
Inspecting IMAGE=3

Run Mode: Continuous
Current Boards Inspected: 620
Total Boards Inspected: 1631
Started: January 15, 2001 11:03:22
Average Cycle Time: 25.16 seconds
Previous Cycle Time: 26.50 seconds
Total boards with defects: 124 Flawed, 22 Alarmed
Previous board defects: 0 Flaws, 0 Alarms

(Figure 6) Operator interface.



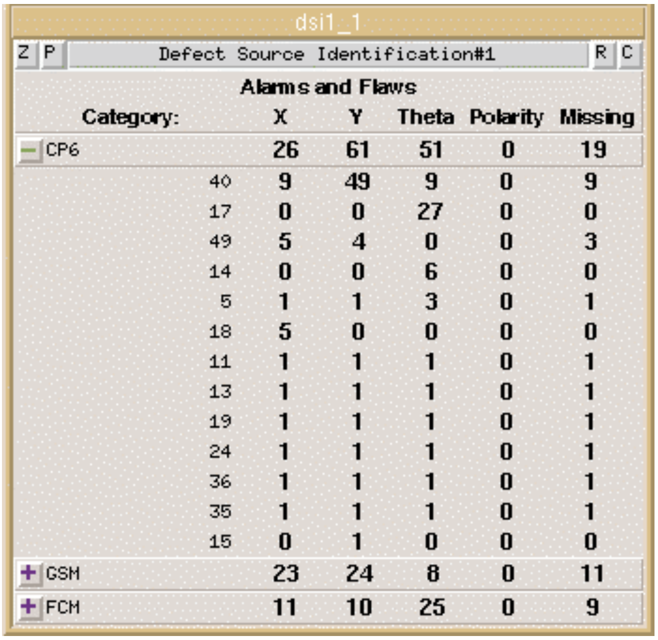
(Figure 7) Sample SPC output.



```
Program File:
Time Inspected: Thu Jan 25 11:01:47 2001
System ID: None
Serial Number:
         Delta X  Delta Y  Obs Thta
Dev Name  (mm)     (mm)    (Deg)    Results
======== ======== ======== ======== ========
  J603-1 MISSING  MISSING  MISSING  fXfY
  J603-2 MISSING  MISSING  MISSING  fXfY
  N400-1  -0.0621   0.3663   -0.100 aY
  V301-1 MISSING  MISSING  MISSING  fXfYfT


                          Devices Inspected:  708
                             Devices Flawed:    3
                            Devices Alarmed:    4
```

File: 33.for

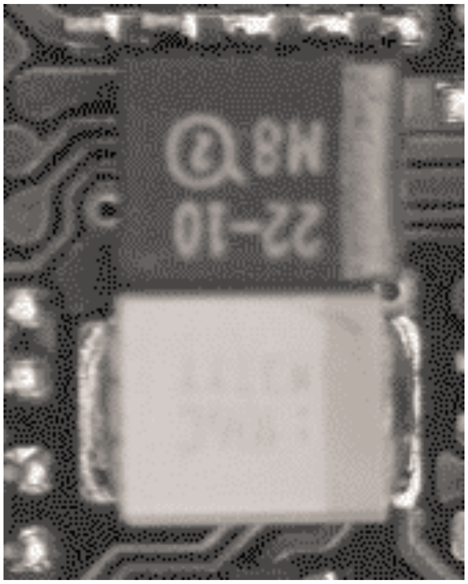
(Figure 8) Sample inspection result file.



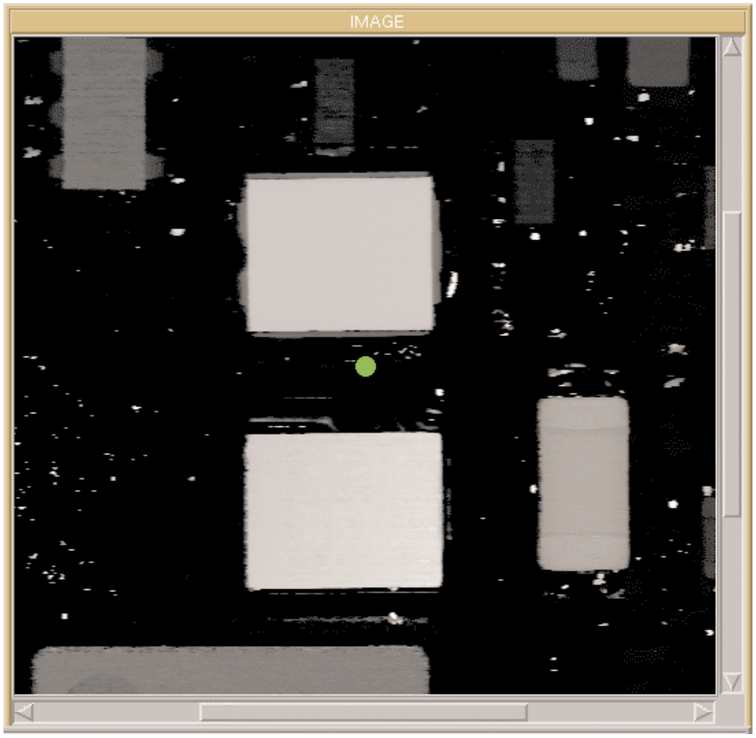
Alarms and Flaws

Category:		X	Y	Theta	Polarity	Missing
− CP6		26	61	51	0	19
	40	9	49	9	0	9
	17	0	0	27	0	0
	49	5	4	0	0	3
	14	0	0	6	0	0
	5	1	1	3	0	1
	18	5	0	0	0	0
	11	1	1	1	0	1
	13	1	1	1	0	1
	19	1	1	1	0	1
	24	1	1	1	0	1
	36	1	1	1	0	1
	35	1	1	1	0	1
	15	0	1	0	0	0
+ GSM		23	24	8	0	11
+ FCM		11	10	25	0	9

(Figure 9) Defect source identifier, allows quick and simple identification of problem machines, feeders heads etc, from the above example we can see feeder 40 on the CP6 is causing the largest number of errors.



(Figure 10)
CCD 2D image of two tantalum capacitors, one yellow one black, a 2d algorithm has to be able to cope with this variation easily as this could be normal production variation, combine this with the background variation caused by changing PCB vendor the range is vast.



(Figure 11)
The same two tantalum capacitors viewed in 3D, the brighter something is the taller it is, we can see the black (bottom) cap is slightly taller than the yellow one. The colour variation has little effect, the part can be seen easliy.