CHAPTER 3

Existing System

3.1 Introduction

This chapter is the general background about the existing system directly concerning on ET. It mainly focuses on current process of monitoring tester performance, TSPC. Other processes are explained to support TSPC procedure.

Firstly, what electrical tester is used for is explained. Then, basic parameters that are concerned in this research that are High Frequency Amplitude (LFA) and Overwrite (OVW) are described about their intents, unit measured, test functional description, and testing procedure. Next, TSPC process is elaborately explained. Moreover, the testing procedure for production parts is also illustrated. The secondary standard generation process which is the process that creates TSPC parts and factoring parts is included. Finally, correlation procedure to qualify tester before release tester into production is also taken into account.

3.2 Electrical Tester and Parameters

3.2.1 Electrical Tester

HGA is the main component of hard-disc drive used in computer. It responds how to write data to the disc and read the data back from the disc. Testing on HGA is the important step because it is the screening process that would classify the part as hard-disc drive component that would be shipped to customers. The main component of HGA is slider that is transformed from wafer. Wafer is usually tested by static test. Testing on HGA is the first station that concerns on dynamic test before composing to hard-disc drive.

At this stage, HGA is placed on the flexure that is designed to fly on the media or disc. It would be worked when the media is rotated, and the wind from rotating will push the flexure and Air Bearing Surface (ABS) on slider of HGA to fly above media. As HGA is worked in this manner, there are two tests at this stage that are fly height test and electrical head response test.

Fly height test implemented by Fly tester is used to test the ability in flying of HGA when composed on the flexure. On the other hand, electrical head response is tested by using Electrical Tester (ET). This test concerns on electrical performance of HGA. It measures the response of HGA on the media when the signal is sent to HGA to write on the disc and when the signal from the disc is sent back to HGA.

3.2.2 Parameters

As ET is used to test electrical performance of HGAs, there are many parameters measuring the ability in writing and reading of those HGAs. Each parameter aims to measure the response at different conditions. Different products may require same or different parameters that need to pass the specification, and specifications of different products may not be the same. However, the parameters that are basically needed to be qualified by most products are High Frequency Amplitude (HFA), Low Frequency Amplitude (LFA), Overwrite (OVW), Off-Track Capability (OTC), Off-Track Capability Error Floor (OTC_EFL) and Pulse width at 50% height (PW_50). HFA, LFA, OTC, and OVW are classified as continuous parameter while OTC_EFL and PW_50 are classified as discrete parameters. This research is focused only on continuous parameters that Vail is selected as product to be studied. Parameters that are in specification of Vail are LFA and OVW which are continuous parameters. Each of these parameters is next explained on test intent, test functional description, and unit measured.

3.2.2.1 High Frequency Amplitude (HFA) and Low Frequency Amplitude (LFA)

Amplitude is defined as the average peak-to-peak read signal measured over one revolution at the specified frequency and disc radius. The measurement unit of amplitude is micro volts peak to peak (μVpp). HFA and LFA measurements are collected around the track for both a specified high frequency and a specified low frequency. These basic parametric tests make many full-revolution amplitude measurements of the peak envelope of each signal polarity. Each read operation is proceeded by a full revolution write cycle of the signal to be measured, with the intent to magnetically or thermally stress the transducer prior to each read. Low amplitude results in difficulty in separating between signal and noise and difficulty for Pre-Amp to amplify the signal.

The brief algorithms or the test sequences of testing HFA and LFA are:

1. DC erase
2. Write appropriate frequency (high or low depended on tested parameters)
3. Measure the read-back signal amplitude
4. Repeat step 1-3 by the specified number of cycles
5. Compute the statistical mean of readings

(Source: Seagate document on test parameters)

Measured amplitude values are affected by the sensitivity of the read transducer, the abruptness of recorded transitions in the media, spatial filtering (flying height and read gap thickness), and time domain filtering (from test filters, amplifier bandwidth as driven by the read transducer, read transducer bandwidth).

Normally, most HGAs can read well at low frequency rather then at high frequency. However, the good HGAs should be worked efficiently at both high frequency and low frequency. The amplitudes measured have to be approximately the same between these two. The ability in reading at high frequency defined as HFA should be at least 80% of ability in reading at low frequency or LFA. However, if HFA is much more than LFA, resonance might be taken place. The relationships of HFA and LFA can be determined by resolution that is the ratio of HFA to LFA at the specified radius. The ideal resolution is 1 that means amplitude measured at high frequency is equal to amplitude at low frequency.

Since now the material or wafer has been improved resulting in greater efficiency of HGAs, the variations of the HGAs at different frequencies become less. Hence, resolution is less concerned. Most products are assigned the specification only on either HFA or LFA. The customer requirement is the amplitude that more than the minimum requirement that shows ability in reading back from the disc. In the other words, HGAs have to achieve an amplitude value that surpasses the lower threshold specification.

3.2.2.2 Overwrite (OVW)

Overwrite (OVW) is a basic on-track parametric test that quantifies the amount of attenuation in decibel (dB) that the fundamental of a reference single frequency signal experiences as a result of being overwritten by a new frequency, at the exact same position. This test performs in an attempt to provide margin against developing hard errors in disc drives when writing new information in media that contains old information patterns. Overwrite capability is dependent on conceivable HGA and media characteristics such as write transducer dimension, media characteristics, write current versus number of turns, relative media velocity, and write transducer magnetic.

The OVW test response is very sensitive to the test frequencies used. OVW results can be affected by HGA read-back transducer sensitivity changes or instabilities triggered by overwrite operation. Furthermore, OVW test values are also affected by the magnetic condition of the media prior to writing the reference frequency and can be further altered by non-linear read-back responses from magnetoresistive transducers.

The brief algorithms or the test sequences of testing OVW are:

1. DC erase
2. Write low frequency
3. Measure and record the low frequency amplitude of the read-back signal (V1)
4. Write high frequency
5. Measure and record the low frequency (residual or remnant) amplitude of the read-back signal (V2)
6. Overwrite (OVW) is computed as OVW (dB) = 20 * log (V2/V1)
7. Repeat step 1-6 by the specified number of cycles
8. Compute the statistical mean of readings
9. The results of the test are compared to the pass-fail specification data

(Source: Seagate document on test parameters)

OVW aims to test the over-writing ability of HGA on the disc as defined by how well bits are erased. OVW is defined as the ratio in dB of the low frequency amplitude signal to the low frequency amplitude residual signal after a high frequency overwrites, without an intervening DC erase, at the specified radius. Most products require OVW to be less than maximum specification.

3.3 TSPC Process

The major aim of performing TSPC is to monitor and control tester performance to operated reliably in statistical control. Testers that have performance out of control cannot be used to measure any production parts. The assignable causes that cause tester to be out of control usually are from the testing system such as media and hardware. However, causes may come from the procedure in performing TSPC. For example, TSPC parts, standard parts with known reference readings, used to run on tester and plotted its readings on control charts might be damaged causing reference value change.

Testing operation is the last process in the production before shipping to the customers, especially, testing on ET that test the ability of HGAs in writing to the disc and reading back from the disc after Fly tester that is used to test the ability of HGAs in flying. Therefore, TSPC on ET is important because testing on ET is the final decision before the products are shipped to the customers.

TSPC is implemented by TTO who is directly responsible for performing TSPC in cleanroom. TTO is the ET operator who is qualified by trainer. Thirty percent of their time is dedicated to TSPC task on testers not only ET but also Fly tester. Each TTO from totally 105 TTOs has to run TSPC on 3-4 testers per day. They can run at any testers in the production. For example, they can run TSPC on 2 ETs and 2 Fly testers or 1 ET and 3 Fly testers. Performing on different testers, not only in a group of testers, increases flexibility to the TTOs so that they can switch to each other or work instead of absent person.

TSPC for ET will be run at least once a day on a tester, in routine and when there is a hardware or media change or calibration. In routine, every tester has to run once a day at any time in a day. Moreover, TTO has to run TSPC when there is events as following occurred on ET.

- Calibrate and re-calibrate
  - Factor
  - PreAmp boards
  - Read channel
  - Attenuate
  - Resistance
- Change
  - PreAmp boards
  - Read/Write Control boards
  - SN/OW boards
  - Read channel boards
  - TSDM boards
  - PP/PW boards
  - Differential boards
  - EWR control boards
  - Synthesizer boards
  - Disc

To perform TSPC, testers must be arranged in group that each group consists of up to 18 testers in a vicinity location. The group name must represent the product name and also be assigned uniquely. The purpose of arranging testers in group is to provide the testers same reference when comparing among different testers in a group. In order to provide the same reference, a same set of TSPC parts is used in the TSPC process to run across all testers in the group. By using the same parts run across all testers in a group, the difference among testers in a same group can be obvious, and the changes in TSPC parts can be easily noticed. Moreover, the number of TSPC parts used in performing TSPC in the cleanroom is minimised so that the cost of generating these parts and cost of Integrated Arm Technology (IAT) arms, that are used to hold the part protecting from touching the parts, can be reduced.

Both factoring part and TSPC part are obtained from secondary standard generation process that would be explained in Section 3.5. The average of reading values from secondary standard generation process is used as a reference value for each standard part on specified controlling parameter. That means each standard part has its own reference values for all controlling parameters. This reference value is used when determining delta, difference between reference and reading on a particular tester, in TSPC process.

Testers can be released to the production to test the HGAs if only the result of TSPC shows pass. If any testers failed in TSPC, it must be shutdown and fixed by TTO or technician depending on problems occurred.

To perform TSPC, TTO has to take TSPC parts from secondary standard generation process. Three parts of up-HGAs (tab-up) and three parts of down-HGAs (tab-down) that are qualified to be repeatable parts by standard generation process are necessary. These parts will be used in performing TSPC until the part gets damage, desported, or proved that it is the cause of SPC out of control. As a result, those parts can be used for a week or more. When the new TSPC part is used, it has to be checked to the standard group via software whether that part has its reference value (or X-bar) or not. If not, TTO has to inform zone engineer or TSPC center to get its reference or new TSPC part.

In addition, if there are some new testers in the group, those testers, qualified its new release or conversion process by correlation procedure explained in Section 3.6, is added by *add group* command. Before TSPC operation, the tester has to be confirmed if it prompts to run TSPC or not. Technician has to fix it before performing TSPC in case it has a problem.

Every time before performing TSPC, TSPC parts have to be inspected by visual, and media or disc has to be checked for a scratch. If there are no scratch found, disc will be cleaned up by using 2 or 3 HGAs from production to be run on the tester. On the other hand, if the scratch appeared, it will be turned to use another surface or replaced with the new one. Every time the disc has used the new surface or the new disc, *disc factoring* is needed to determine *calibration factor* or *factor* that will be compensated media variation which varies surface to surface. Disc factoring with bronze standards will make that surface give the reading which correlates to standard reading (gold value). Factor will be calculated by tester software. It requires at least 3 good data to be averaged out, normally more than 5-7 standard factoring parts are applied each tab for factoring. In this number, some that are potential problem parts will be classified as desported by software operation and not used in calculating the factor value. Different parameters have their own factors. Calculating the factors has two ways depending on parameters.

For LFA parameter, factor can be determined by dividing operation.

$$Factor = Raw\ data\ /\ Assigned\ value$$

For OVW parameter, factor can be determined by subtracting operation.

$$Factor = Raw\ data - Assigned\ value$$

Where

- Raw data is the actual reading value that can be read from tester
- Assigned value is the reference value that got from the secondary standard generation process

After the calibration factor, which is the multiplicative or additive correlation factor of a test system, is calculated, the minimum and maximum factor limits should be calculated. If factors are out of control on those limits, those factors will be desported by parameter. Then the mean factor of the qualified part will be used as calibration factor. After desported factor by parameter, each parameter should not be less than 3 parts. If it less than 3 parts, the calibration factor should be re-run on the same surface and re-calculate, or it can be re-run by adding new factoring parts. The standard parts that are desported more than 5 times consecutively will be marked as damaged and be removed from the factoring process next time.

$$Maximum\ factor\ limit = Mean\ factor + tolerance$$
$$Minimum\ factor\ limit = Mean\ factor - tolerance$$

Where

- Tolerance is 5 percent from mean factor for LFA parameters that are using dividing operation

- Tolerance is 0.5 for OVW parameters that are using subtracting operation
- Mean factor is the average of calculated factors of at least 3 qualified parts, that are not desported

After the calibration factor is obtained, it will be applied in testing operation. It is applied to all readings that are testing on the same surface of media as following formula.

For LFA parameters that are using dividing operation,

$$Calibrated\ data = Raw\ data / Factor$$

For OVW parameters that are using subtracting operation,

$$Calibrated\ data = Raw\ data - Factor$$

Where

- Calibrated data is the value that will be used as a reading value of the parts tested on that surface of media on specified parameter

In performing factoring process, after we place 5-7 factoring parts to run on the tester, software will automatically calculate the factors by parameter. The reading values of tested HGAs are the values that already applied factor. This reading value will be used as a testing value of the test operation. In addition, the desported part is automatically shown on the screen as well.

After the disc and TSPC parts are verified, TSPC number, which represents the product, tester group, tab, and head serial number of TSPC parts, must be assigned. The software will automatically not allow for the access if TTO keys the wrong number. TSPC number is composed of 10 digits as shown below.

X	X	X	X	X	X	X	X	X	X
1	2	3	4	5	6	7	8	9	10

X1, X2	= Product (V0 = Vail)
X3	= Group name (Zone)
X4	= Tab (U = up, D = down)
X5-X9	= Head number of parts
X10	= Zero (0)

When the number of those three parts are already keyed in, TTO has to carefully handle TSPC part one-by-one to load into the tester. As soon as the first part is already loaded, TTO has to run it and up load data. When finished the first part, the second part will be run next in the same way. This operation is done until those three parts are all run in a tab. After that, NTSPC program will calculate the delta of each TSPC part by using the following formulas based on factor applied on each parameter.

For LFA, delta is calculated as percent difference.

$$Delta = [(Reading - Reference) / Reference] * 100\%$$

For OVW, delta is determined as difference value.

$$Delta = Reading - Reference$$

Final delta of each parameter that is the average delta of these three parts is obtained. However, the delta that is desported or is not in the acceptance range calculated from R-control chart is excluded from calculating the final delta. Moreover, if desported parts are more than one out of three, the final delta is not qualified and reported as *Bad* data, and new set of parts has to be run. Additionally, if any one of TSPC parts has been desported or degraded consecutively at same parameter more than 5 consecutive runs, TTO has to change that desported part with the new one. Figure 3.1 shows the determination of final delta to be plotted on the TSPC graph.

When the qualified final delta is obtained, it is plotted on X-bar chart as TSPC charts that center line is set to be zero, meant no difference between reading and reference, as shown in Figure 1.1. For the control limits and sigma, they are controlled by TSPC center.

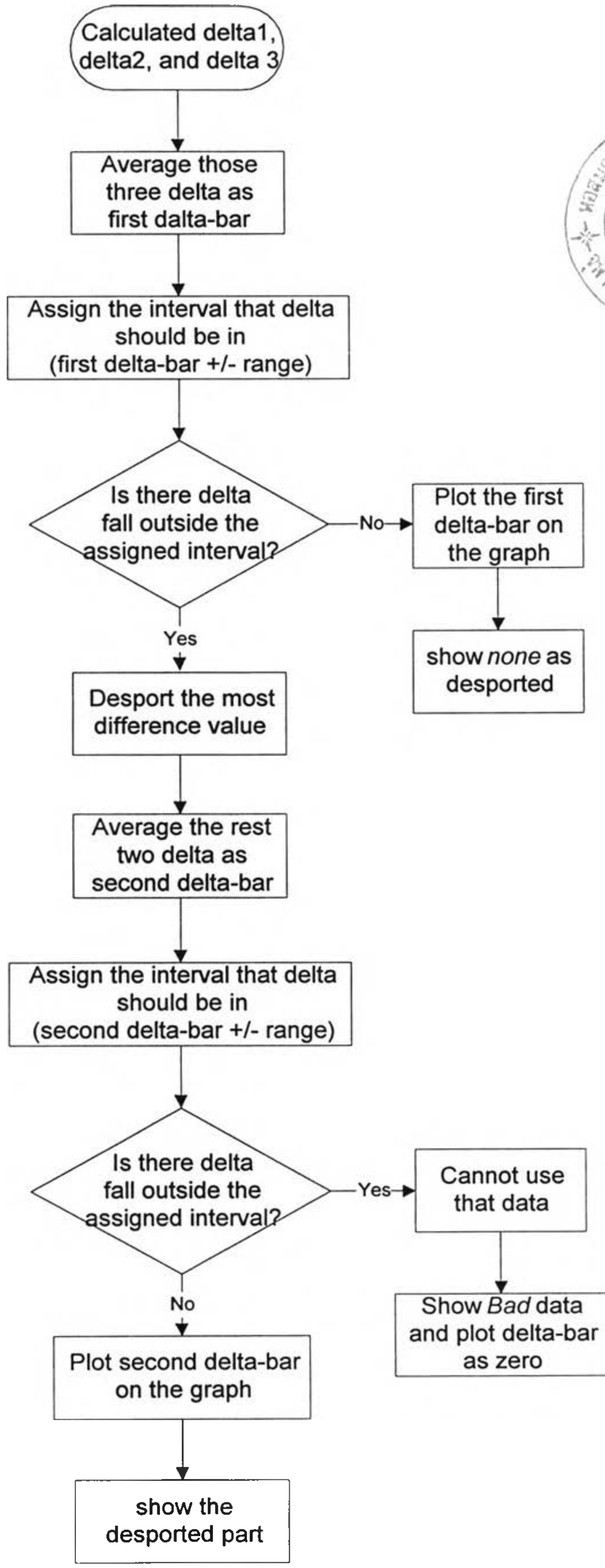

Figure 3.1: The flow diagram of calculating the final delta

(Source: Seagate document on TSPC work instruction)

TSPC will be run along time line on X-bar control chart. Then, the control limits can be established. Sigma is calculated from pooled standard deviation of all parts in each product.

$$
\begin{aligned}
+3\ \text{SIGMA} &= \bar{\bar{X}} + 3\ \text{SIGMA} \\
+2\ \text{SIGMA} &= \bar{\bar{X}} + 2\ \text{SIGMA} \\
+1\ \text{SIGMA} &= \bar{\bar{X}} + 1\ \text{SIGMA} \\
\text{CL} &= \bar{\bar{X}} \\
-1\ \text{SIGMA} &= \bar{\bar{X}} - 1\ \text{SIGMA} \\
-2\ \text{SIGMA} &= \bar{\bar{X}} - 2\ \text{SIGMA} \\
-3\ \text{SIGMA} &= \bar{\bar{X}} - 3\ \text{SIGMA}
\end{aligned}
$$

The out of control conditions can be defined as following:

→ Condition "A" means for last point beyond +/- 3 sigma
→ Condition "B" means for 2 of 3 points in a row beyond +/- 2 sigma
→ Condition "C" means for 4 of 5 points in a row beyond +/- 1 sigma
→ Condition "D" means for 9 points in a row in single positive or negative side

The control limits are set as 3-sigma. Only "*Condition A*" will be focused in the first stage while the other conditions are just warning. If the final delta is defined as "*Condition A*", the root causes have to be found out and then corrective action will be taken to fix those problems.

The main out of control root causes are from TSPC parts, factoring parts, media or disc, and tester issues. Those can be verified by following the corrective action instruction for TTO in Appendix E. It is responsibility of TTO to find out the root causes and fix the problems occurred from TSPC parts, factoring parts, and disc. If root causes cannot be found, the causes tends to occur from tester issues or hardware that is the responsibility of technician to take corrective action by following tester troubleshooting guide in Appendix F. If it is still out of control, engineer is in charge of finding out those causes. When finished verification of corrective action or troubleshooting, TSPC must be re-run again to confirm status of the tester whether it is away from out of control. If it is still out of control, the tester must be shutdown until the problems are fixed by engineer responsibility. On the other hand, if the retest point is in control, the tester can then be released to the production to operate its normal operation. In case of re-running TSPC to confirm tester's status, TTO has to record the result as "*Retest*" and specify out of control corrective action that TSPC corrective action code is shown in Appendix H.

3.4 Testing Procedure

In spite of running TSPC after calibration or hardware change, TSPC is also performed at least once a day in routine on every tester in cleanroom. It can be performed at any time in a day. It is performed to ensure that tester can operate properly during testing operation.

Since TSPC will be perform during testing operation that HGAs from production will be run, it is directly impacted from testing conditions. Principles used in performing TSPC is similar to the use in normal testing operation such as Electro Static Discharge (ESD) precaution. Thus, this section explains the procedures in testing production parts on electrical testers (Source: Seagate document on testing manual).

ESD Control

In the cleanroom, operators have to be protected from ESD. They must wear site-required ESD-approved cleanroom garments and ESD-approved Nitrilite gloves on both hands at all times. Moreover, they must put on grounding wrist strap and plug the wrist strap cord into the wrist strap grounding receptacle before handling HGAs. Those HGAs can be removed from their trays for HGAs testing only at ESD controlled HGA tester work station.

Tester Power Up and Power Down

Operator turns on the switch on the side of the tester. All circuit breakers on the side of the tester should be in the up position. Then, operator has to press reset button on the side of the tester. Dover motion master box power light is now on and the red Dover reset light is not lit. All equipment should now be on. Tester has to be warmed up for 15 minutes if it was off for a long time or several hours. Operator has to check spindle air pressure and stage air pressure. If equipment or air pressure is not correct, operator has to contact supervisor or technician.

If the tester is not be used, it has to be powered down. The Windows Electric test program is terminated so that disc will be stopped from rotating. After that, operator presses turn off button on the side of the tester.

Disc Changing

In order to check whether the disc is scratched or damaged, it has to be removed from spindle. Before removing the disc, operator has to ensure that disc is not spinning. If the disc is still spinning, it has to be stopped by terminating the Windows Electric test program. Dealing with disc, operator must wear approved gloved and handle disc by out edges and do not touch the test surface. Operator removes spindle screw on the top of the spindle by using the appropriate torque screwdriver for the specific size of disc and then removes clamp. Then, the disc can be removed from spindle. It would be inspected for damage. If the active surface of the disc is good, it will be re-installed on the spindle with the good surface facing down. On the other hand, if the disc has a crash or other damages, the operator should vacuum the tester deck and replace it with a good surface to install it on the spindle. Operator has to note the disc serial number and surface used as well. After that, operator places clamp back on the top of spindle, and turn screw back onto the spindle. When a new disc surface is installed, the disc must be calibrated factor and performed TSPC before production testing can resume.

HGA Handling

HGAs are taken from the trays. Those HGAs will be checked for obvious defects before testing especially on bent springs (gimbals). Parts that are defective gimbals cannot be tested. Furthermore, parts will be checked for Air Bearing Surface (ABS), in charge of HGA's flying, contamination. If the contamination is found, operator has to lightly wipe the ABS with cotton swabs dampened. In addition, when not being tested or handled, HGAs should remain in the proper test block tray. Improper handling or stacking HGA on the top of one another results in HGA's damage.

Selecting Product and Disc

Operator has to select the product on the screen. In the same way, operator can select the disc from a list of available disc files, or he/she can add a new disc if that disc is not available in the list. Before HGA is tested, the operator should ensure that the correct filter, used for filtering signal, is connected to the back of Electronic Write-Read (EWR) box, that generates signal, when the product is firstly setup.

Testing Production HGAs

Before starting testing HGA parts, the nest either left nest for tab up-HGA or right nest for tab down-HGA that would be tested is selected. All statistics on the display such as number of pass and fail parts can be reset. Then, operator enters the number that represents product, zone, tab, and tester number.

To start testing parts, operator has to enter a part serial number, and then that HGA on Integrated Arm Technology (IAT) will be mounted in the tester receiver. In mounting HGA, operator will pick up IAT arm by edge of wing. He/she cannot touch Flex on Suspension (FOS), circuit association. Operator also visually inspects the IAT arm on the barcode side for foreign material such as scrapped FOS. It would be removed if found. He/she has to ensure that the nest loading area is clean. After that, IAT arm is loaded on the nest, inserting front edge first over the front alignment pin, and then gently lower the IAT arm into the position over back alignment pin. After that, it would be push down on the middle to ensure proper seating. If the IAT arm is not seated properly, it can be unclamped and reload again. Operator cannot place IAT arms on PC board or anywhere else except IAT tray.

When the test is finished, HGA on IAT arm is removed from the receiver and placed in Pass or Fail tray. The failed part has to be properly labeled all failures. Good parts can be staged to the next operation when testing of that lot is completed. Operator has to make sure that the tray is covered before leaving clean area. The operator must notify supervisor if three or more parts consecutively fail in one lot.

In performing TSPC, it can be implemented in the same way. The difference is that TSPC parts are not put in the production pass/fail try, but are kept for further use.

3.5 Secondary Standard Generation Process

As referring to Chapter.2, the measured value obtained from National Institute of Standards and Technology (NIST) is the accepted standard for measured quantities through international agreements. This standard will be transferred to measuring instruments that are used in production work by calibration. The process of transferring NIST standards to the company's measuring instruments is accomplished by means of a hierarchical system of transfers as Figure 2.1.

Firstly, the company will establish a primary standard called "*Silver Standard*" of each measured quantity that is directly calibrated to the "*Gold Standard*" of NIST. Then, the silver standard will be used to calibrate "*Bronze standards*" which will be further used to calibrate "*Second Bronze Standard or Second Standard*" used in the production. Figure 3.2 shows the typical hierarchy of calibrations within a company.

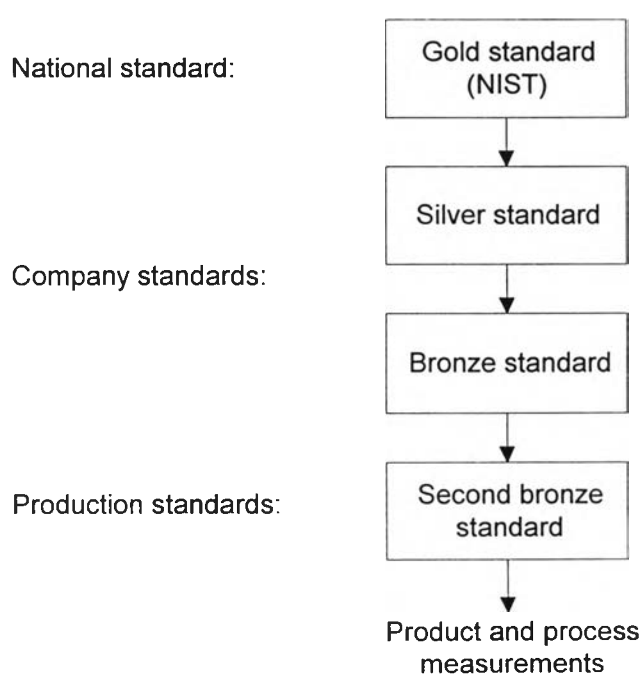

Figure 3.2: Hierarchy of standard generation process

Second standards are used as production standards. They are used as factoring parts, correlation parts, and TSPC parts. Since those parts are concerned in this report, the generation process of these second standards is discussed.

Secondary standard generation process is started with collecting 35 pairs of HGA's candidates from production. The tester selected for this generation process is unconditionally released tester after performing correlation procedure that are explained in Section 3.6. This tester will be setup according to requirements of the specified product that is matched up with what bronze standards were generated at Seagate Cooperate Standard Lab (SCSL). Then, the tester will be calibrated with at least 20 pairs of those bronze standards on the media that the lab provides. The program will immediately calculate the final factor used to calibrate the difference among testers. After calibration is completed, TSPC is performed to confirm the performance of the tester when compensated with factor. If TSPC is failed, tester will be calibrated again until TSPC is passed. When TSPC is verified, each HGAs from the production will be tested 3 times. After those 35 parts are tested for one round, TSPC is needed to be run before continuing the next round. If TSPC is failed, operator has to check the disc for a scratch or damage, and change it as necessary. When those parts are run for 3 rounds, the data is collected and calculated for Covariance (COV) that represents repeatability of the parts. The parts that have COV less then the criteria, as shown in Table 3.1, will be used as second standards, and their COV will be used as the assigned value or reference value for each part. The flow of secondary standard generation process is illustrated in Figure 3.3.

$$\text{COV} = (\text{Standard Deviation} / \text{Mean}) * 100\%$$

Table 3.1: Covariance criteria for secondary standard generation process

Parameter	Covariance (COV)
LFA	< 1.5%
OVW	< 2.5%

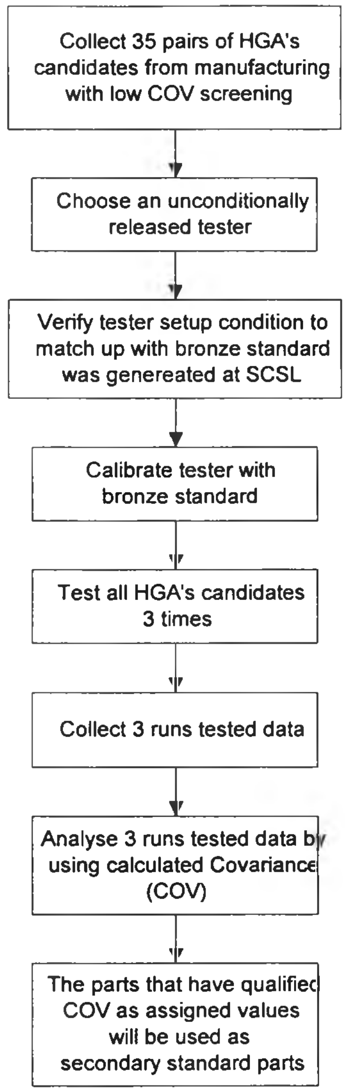

Figure 3.3: Process flow of secondary standard generation

(Source: Seagate document on secondary standard generation process)

3.6 Correlation Procedure

When there is product conversion on the testers or the testers are overdue after they have been released for the assigned period, those testers have to be confirmed testers' status by correlation procedure before they have been released for normally testing HGAs in the production. The correlation procedure is used for correlating electrical testers to the corresponding Seagate Corporate Standards Engineering (SCSE) electrical tester, reference tester, for the purpose of releasing that tester for manufacturing. This procedure provides the released tester to be approximately worked as same as reference tester so that the HGAs testing is going to have high accuracy and precision.

Before implemented the correlation, tester has to be verify that it is properly setup in accordance with the work instruction of product conversion (in case of product conversion) and setup conditions are match up with what correlation set is generated by Seagate Corporate Standard Lab (SCSL). That means the setup conditions of both released tester and reference tester are the same. Setting up the tester can be performed by calibrating read chain, checking emergency stop, checking and calibrating Z-height, checking and calibrating home position, checking spindle runout, checking limit switch and home sensor, cleaning and maintaining lead screw, checking air flow switch, checking tester noise, doing Piezo calibration, checking spindle dogs procedure, cleaning spindle glass scale, and checking write current. All of those are done when there is product conversion. Moreover, some are also performed in preventive maintenance once a year, and some are performed in mini-preventive maintenance on every six months.

Not only the correlation parts are sent from SCSL, but disks and factoring parts are also sent to perform correlation. All correlation parts must be generated and approved by SCSE that all parts must meet minimum repeatability requirement, given by Covariance (COV), as defined in Secondary standard generation process (Section 3.5). Which parameters are selected for correlation depends on test specifications of individual product.

After the tester setup is verified, tester precision will be examined. Three pairs of low covariance HGAs from secondary standard generation process will be designated number 1 to 6 and run on the tester for eight times in randomised test orders shown in Appendix I.

After those parts are run on the tester to verify repeatability of the tester, covariance on each parameter is calculated.

COV = (Pooled Sigma / Grand Mean) * 100%

$$S_{pooled} = \sqrt{\frac{(n_1 - 1) \bullet s_1^2 + (n_2 - 1) \bullet s_2^2 + ... + (n_6 - 1) \bullet s_6^2}{(n_1 - 1) + (n_2 - 1) + ... + (n_6 - 1)}}$$

Where

S_{pooled}	=	Pooled sigma
$n_1, n_2, \ldots, n_6$	=	Number of measurements of part#1, part#2,..., and part#6
$s_1, s_2, \ldots, s_6$	=	Standard deviation of part#1, part#2,..., and part#6
Grand mean	=	Average of the means of part#1, part#2,..., and part#6

Testers that have covariance (for LFA) and standard deviation (for OVW) less than maximum requirements, as shown in Table 3.2, will be further tested for correlation. Repeatability of LFA uses COV, but OVW's uses standard deviation instead since HGAs are improved resulting in mean of OVW are shifted so the traditional covariance cannot be used anymore. Then, sigma is used instead because mean change does not affected.

Table 3.2: Repeatability requirements

Parameter	Repeatability
LFA	< 1%
OVW	< 0.5 dB

On the other hand, if the result of repeatability is not accepted, or COV or standard deviation excesses maximum requirements, the tester is needed to take corrective action and re-run again as shown in Figure 3.4.

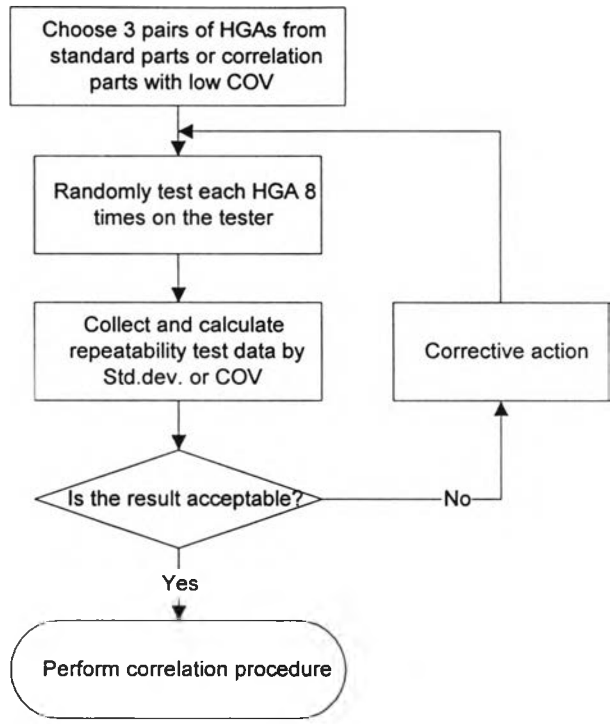

Figure 3.4: Repeatability procedure

(Source: Seagate document on correlation procedure)

After repeatability of tester is verified, that tester will be performed correlation comparing to the reference tester. Before that, tester has to be calibrated with Bronze standard parts which are obtained from SCSL. Calibrating with Bronze standard helps the tester to perform with the same reference as reference tester. After calibration, TSPC is performed to confirm tester's condition. The correlation parts will be tested on the tester only when TSPC is passed. Minimum sample size to initiate correlation recommends 30-35 pairs. No more than 20% of these correlation parts can be removed from the data analysis for each tab. Identification of these potential outliers is also necessary. Generation of a new correlation set may be indicated if removal more than 20% is required to pass correlation requirements.

Correlation calculation and statistical requirements such as R-squared, t-statistic, F-statistic, and so on are used to verify the class of testers that would be released. Normally, there are three classes of testers. When the new product is going to be manufactured, testers may not be promptly arranged. TTM (time-to-market) testers are needed to be temporary released to test HGAs in the production line. This class is intended to be used for 60 days in maximum. After that, they would be upgraded to class Q if the correlation parts for this class are arranged. This class of tester is expected to be in the production line for 90 days in maximum. When the testers are more stable, the correlation parts of class T will be generated. Testers in this class is expected to test HGAs in the production for 180 days in maximum. The number of days specified are used for the tester that all parameters meet all specified requirements below:

→ Class TTM: t-test < t-critical at 95% confidence, F-test < F-critical at 95% confidence

→ Class Q: t-test < t-critical at 95% confidence, F-test < F-critical at 95% confidence, $R^2 > 0.9$ for LFA, $R^2 > 0.8$ for OVW, $0.80 < \text{regression slope} < 1.20$

→ Class T: Paired t-test < t-critical at 95% confidence, F-test < F-critical at 95% confidence, $R^2 > 0.9$ for LFA, $R^2 > 0.8$ for OVW, $0.80 < \text{regression slope} < 1.20$

In addition to classes specified, each class of released testers can also be classified into three categories that what category the tester is depends on whether all requirements are met. The tester categories can be identified as below:

" Approved: This approved status is only given when a tester passes all specified requirements. The maximum release interval is 180 days for class T, 90 days for class Q, and 60 days for class TTM.

" Conditional: This status is issued when a tester fails some requirements which are no customer impacts and a tester with restriction for tab testing that only one tab is approved, not for others. The maximum release interval is 180 days for class T, 90 days for class Q, and 60 days for class TTM.

" Rejected: This status is issued for testers which have catastrophic failures or customer impacts. The tester that is in this status cannot be used.

If the tester is in rejected status, the corrective action will be taken to fix the tester and then perform the correlation again until it is in the approved or conditional status. The status of the tester is obsolete when the tester correlation has been replaced by more recent correlation or when the correlation is expired.

Before the tester will be released to the production, tester release summary (TRS) that identifies class of tester and category that it meets requirements is sent for approval from SCSE. If the tester has been approved, it will be released to the production to operate its normal operation. Figure 3.5 illustrates the flow of steps in performing correlation of electrical tester for the purpose of releasing tester to the production.

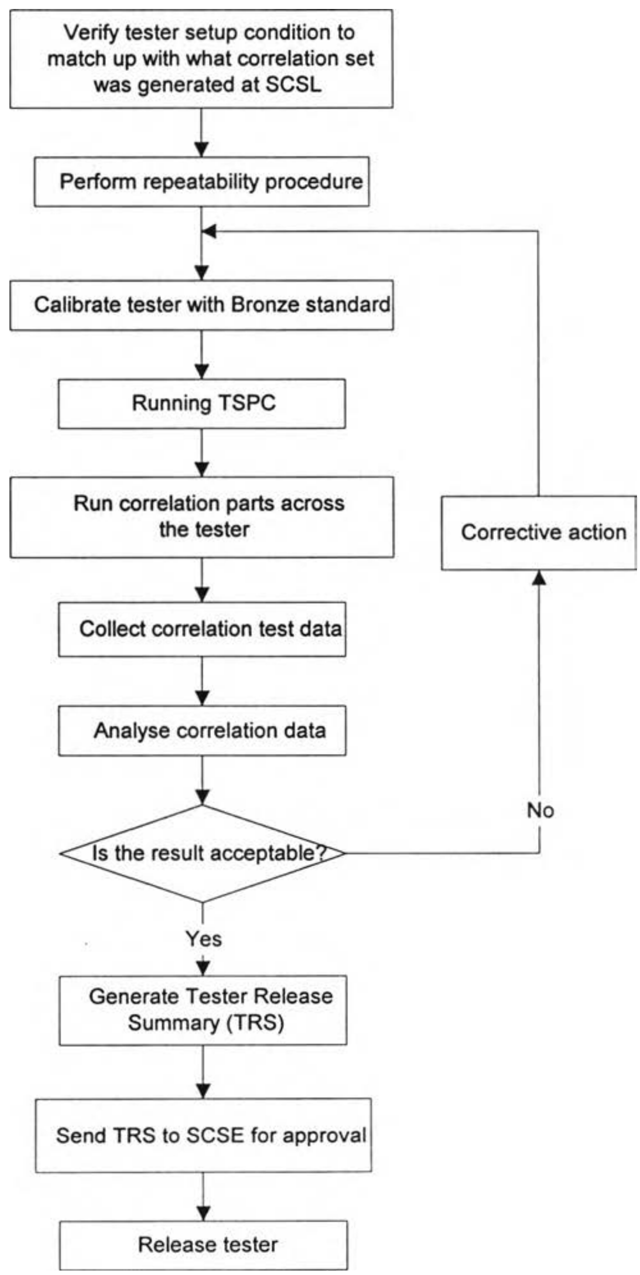

Figure 3.5: Tester correlation procedure

(Source: Seagate document on correlation procedure)

3.7 Conclusion

Electrical tester (ET) is used for testing electrical capability of HGAs. Since it is the important process in HGA manufacturing, ET used for this process must be controlled its performance when testing the production parts. The way to control tester performance uses the knowledge of Statistical Process Control (SPC). It means that performance of testers have to be in statistical control over the period of time. If some assignable causes are taken place, they should be corrected to let those testers operate properly.

Furthermore, testing procedure that should be aware when concerning on the test operation is described. TSPC should be performed in the same manners as testing operation. For example, ESD has to be controlled. The rest of chapter mentioned about the secondary standard generation process and correlation procedure for releasing tester to production. Secondary standard generation process is the process of transferring NIST standard to the production standards. These production standards are used as TSPC pats, factoring parts, and standard parts used for repeatability process. Tester correlation procedure is to qualify tester that needs product conversion before releasing to test HGAs in production. Tester has to be tested for repeatability before doing correlation procedure. When repeatability is satisfied, that tester will be correlated to the reference tester to further use in testing operation.