1. Semiconductor Quality and Reliability

1.1 Basic Concept

1.1.1 Commitment

The Toshiba group principle of management is embodied in the company motto "Committed to people, committed to the future." It is a principle based on respect for humankind. Its goal: "We, the Toshiba Group companies, based on a total commitment to people and to the future, are determined to help create a higher quality of life for all people, and to do our part in ensuring the continued progress of the world community." These ideals are reflected in our efforts to deliver high-quality and cost-competitive products that meet your needs and are backed up by the highest level of support and service.

The Semiconductor Company is devoted to creating quality products. Our continued dedication to quality assurance (QA) activities, as expressed by our slogan "Persistent Improvements and Innovations to achieve the best quality and customer satisfaction in the world," has brought us the honor of the Deming Award as well as certification for the ISO 9000 standard. The name Toshiba is synonymous with quality among customers in the rapidly evolving electronics industry both at home and abroad.

1.1.2 Strategy

The following strategies are used by Toshiba in its quality and reliability (Q&R) assurance activities for semiconductor products:

(1) Integrate Q&R during the Design Stage (Designed-in Q&R)

The following steps are taken to achieve reliability goals at the design stage:

- Strictly enforce DR/AT (design review/approval test).
- Develop reliability evaluation and analysis methods in support of leading-edge technology.

(2) Integrate Q&R during the Manufacturing Stage (Built-in Q&R)

The following steps are taken to integrate Q&R at the processing source:

- Automate the manufacturing process.
- Continuously improve quality using statistical process control (SPC).

(3) Improve Quality through Reliability Monitoring and Failure Analysis (Improvement)

The following steps are taken to assure the quality of shipped product:

- Monitor failure rates through reliability testing.
- Analyze failures and feed the results back to the manufacturing process.
- Set target failure rates and promote continuous quality improvement.

(4) Total Customer Service (Customer Satisfaction)

The following steps are taken to meet market quality requirements and attain customer satisfaction:

- Feed back customer quality requirements to the design and manufacturing processes.

- Provide sufficient quality information services.

1.1.3 ISO 9000 Certification

In September 1992, Toshiba became the first company in Japan to receive ISO 9001 certification for its Oita Operations and Fuchu Operations – Printed Circuit Board and Module. Since then Toshiba has been granted the same certification for its manufacturing works at home and abroad as listed in Table 1.1 Today, efforts are concentrated on maintaining this certification, with continued improvements being made to the company QA system through periodic internal quality audits.

Table 1.1 Toshiba works and affiliate companies qualified for ISO 9000 Series

(Information current as of October 1999)

	Works or Affiliate Company	Certification	Certification Body	Certification No.
Domestic	Toshiba Corporation Oita Operations	ISO 9002	RCJ (Note)	RCJ-92M-02
	Toshiba Corporation Microelectronics Center	ISO 9002		RCJ-93M-01A
	Toshiba Corporation Kitakyushu Operations	ISO 9001		RCJ-93M-06
	Toshiba Corporation Himeji Operations - Semiconductor	ISO 9001		RCJ-93M-07
	Toshiba Corporation Yokkaichi Operations	ISO 9002		RCJ-93M-22
	Toshiba Corporation Fuchu Operations - Printed Circuit Board and Module	ISO 9001		RCJ-92M-03
	Iwate Toshiba Electronics Co., Ltd.	ISO 9002		RCJ-93M-08
	Toshiba Components Co., Ltd.	ISO 9001		RCJ-93M-19
	Kitsuki Toshiba Electronics Corporation	ISO 9002		RCJ-94M-35
	Fukuoka Toshiba Electronics Co., Ltd.	ISO 9002		RCJ-96M-02
	Takeda Toshiba Electronics Co., Ltd.	ISO 9002		RCJ-96M-01
	Oita Precision Co., Ltd.	ISO 9002		RCJ-98C-02
	Buzen Toshiba Electronics Co., Ltd.	ISO 9002	TUV	0910089001
Overseas	Toshiba Semiconductor GmbH (Germany)	ISO 9002	DQS	1393-01
	Toshiba Electronics Malaysia Sdn. Bhd. (Malasia)	ISO 9002	SIRIM	ARO300
	Toshiba Semiconductor (Thailand) Co., Ltd. (Thailand)	ISO 9002	TISI	952031/0032
	Toshiba Electronics Asia, Ltd. (Hong Kong)	ISO 9002	HKQAA	CC367
	Toshiba America Electronic Components, Inc.(USA)	ISO 9001	DNV	96-HOU-AQ-8420
	Wuxi Huazhi Semiconductor Co., Ltd. (China)	ISO 9002	CQEC	0995B096

NOTE **Qualified for the ISO 9000 Series under the IEC Quality Assessment System for Electronic Components of the Reliability Center for Electronic Components of Japan (RCJ).**

1.2 Organization and Procedural Flow

Figure 1.1 shows an organization chart and Figure 1.2 shows a procedural flowchart for the structure and activities, respectively, of the Toshiba QA system.

In the organization chart of Figure 1.1, you can see that each manufacturing department is responsible for improving the quality of its manufacturing processes. The Quality Assurance Department in each works is responsible for assuring the quality of incoming parts and materials, the manufacturing process, instrumentation, shipped products and after-delivery service and for all products that it oversees on behalf of the Engineering Department. In a continuous effort to improve quality and reliability (Q&R), the Quality Assurance Department arranges quality meetings chaired by the plant manager.

The Headquarters Quality Assurance Department manages the Semiconductor Group QA meeting held under the auspices of the Group QA Executive (Group Technology Executive) in which all Quality Assurance Department managers participate. Thus the Headquarters Quality Assurance Department plays an active role in improving the Q&R of all semiconductor products. It is also involved in:

(1) Planning the Q&R targets for semiconductor products.

(2) Performing reliability testing and evaluation of developed products in cooperation with the Engineering Department and assuring the quality of new products during the initial development period.

(3) Collecting information and data related to Q&R and concluding QA contracts with customers.

(4) Promoting education and training in Q&R.

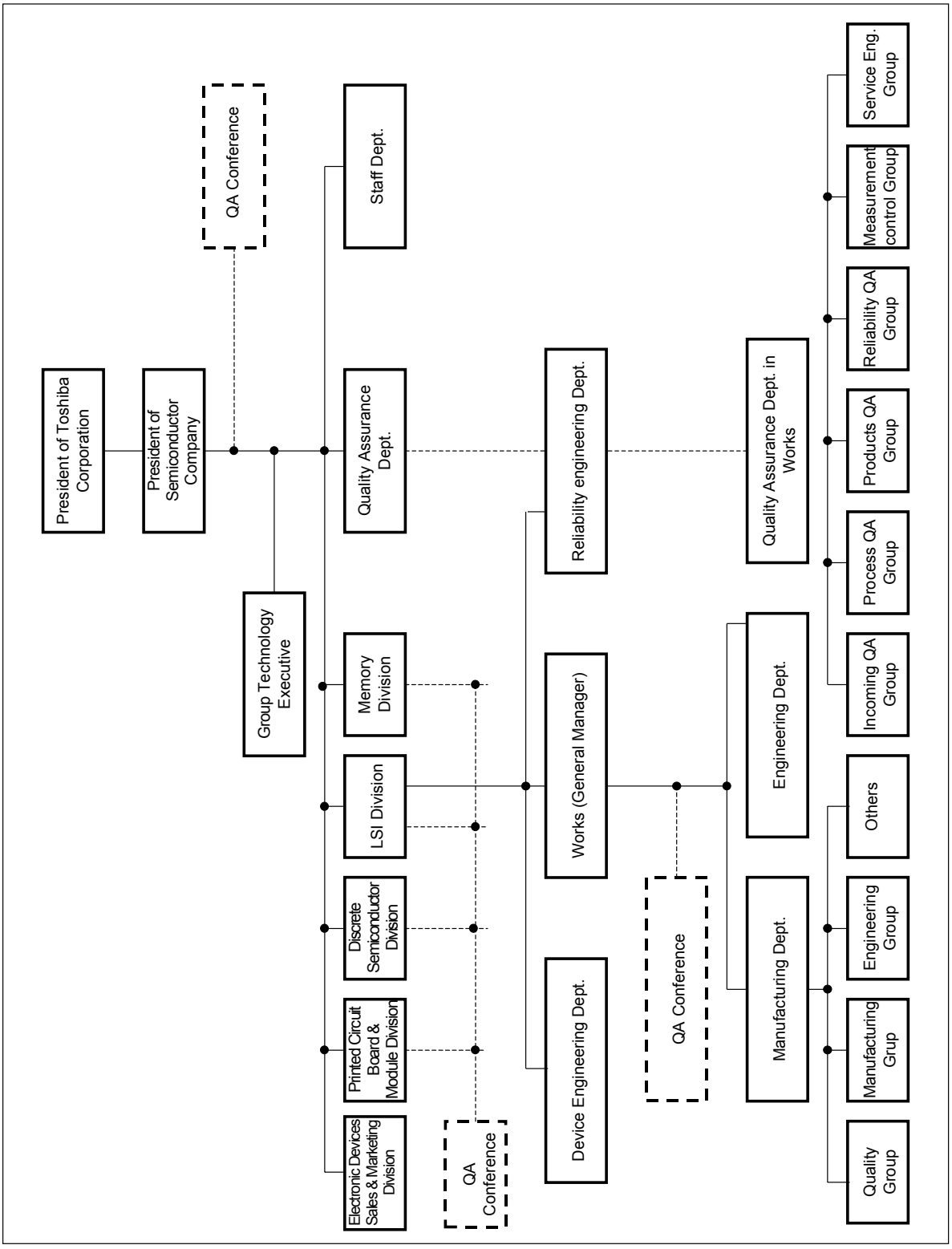


Figure 1.1 Quality assurance (QA) system organization

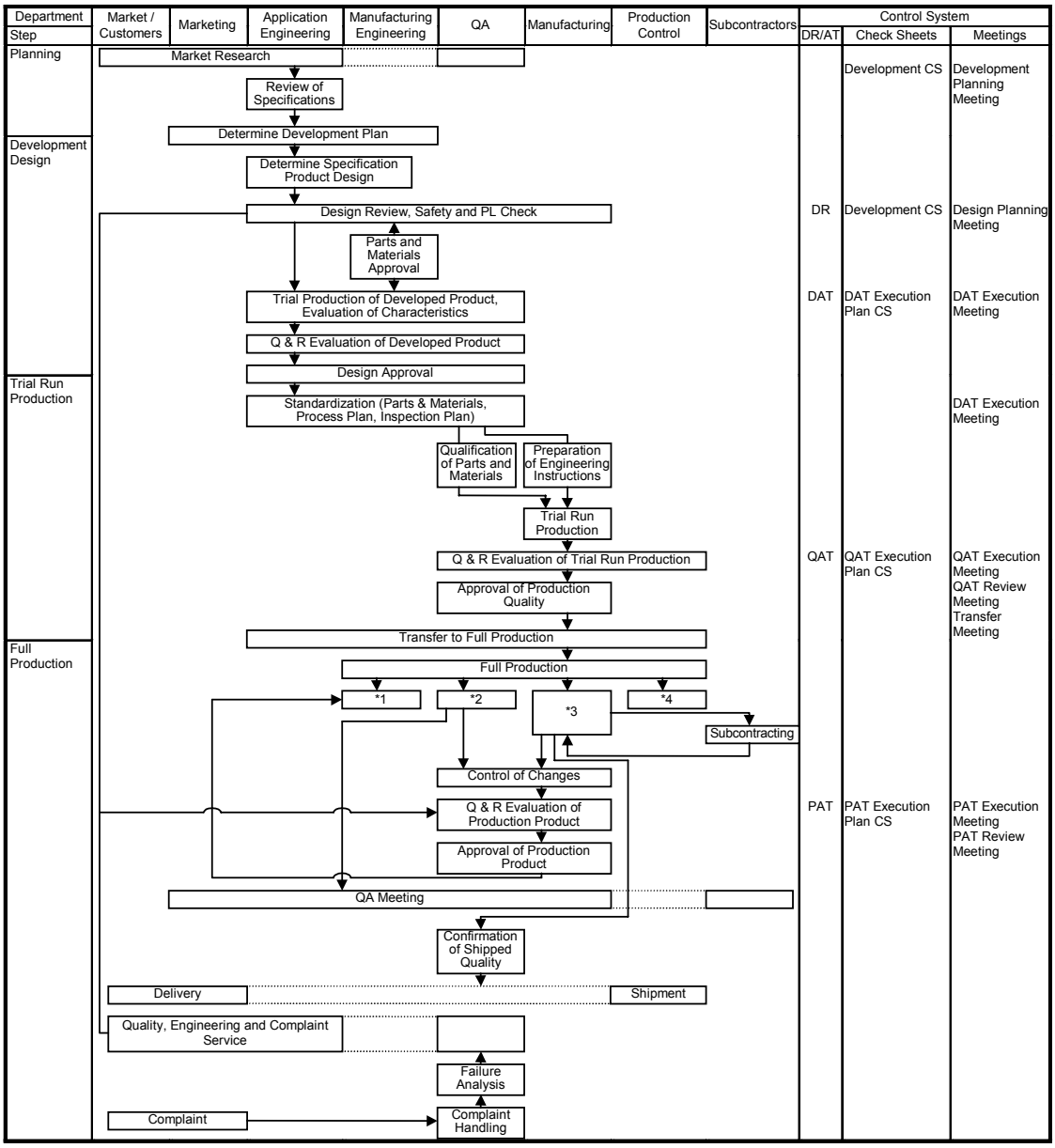
Toshiba are making a supreme effort to understand the customer's needs and to incorporate into product design the levels of quality and reliability dictated by the actual conditions under which products will be used in customer applications. During the design review process several departments are involved in confirming product safety and adherence to product liability safeguards.

Toshiba carry out the Design Assurance Test (DAT) in order to evaluate the quality and reliability of products under development with reference to the Toshiba reliability testing standards. These Toshiba standards have been drawn up in accordance with various accepted standards, such as those of JIS, EIAJ, IEC, ANSI and JEDEC. The components and materials which are to be used in Toshiba products are standardized via a process of primary assurance by the relevant engineering department and secondary assurance by the Quality Assurance Department. If a product passes the Design Assurance Test, the Engineering Department carry out standardization of the components and materials, and of the production process and inspection. In addition, detailed factory standards regarding actual production and management are set in the factory where the products are to be made. Sample products are manufactured in order to evaluate product quality and reliability. If product quality and reliability are successfully assured in this manner, the factory will be put in charge of quality assurance for the actual production process.

During commercial production the Manufacturing Department carry out inspections of the process, work environment and equipment management, and the Reliability Engineering Department are responsible for acceptance inspection, change management, measurement management, regular reliability confirmation and production process auditing. The Engineering Group and the Engineering Department are also involved in problem solving and in improvement and automation of the production process.

In addition, new operators, supervisors and engineers constantly receive instruction and training.

Toshiba products undergo primary quality assurance testing and reliability monitoring by the Quality Assurance Department before shipping. Furthermore, in quality service areas such as the definition of specifications, the holding of meetings on quality and reliability, and the investigation and reporting of product defects, Toshiba are striving to achieve fast response times.



DR: Design Review
DAT: Design Approval Test
QAT: Quality Approval Test
CS: Check Sheet

***1 Improvement of Manufacturing Technology**
Promotion of Automatization
***2 Inspection of Incoming Parts**
Line Audit
Reliability Test
Measurement Control
Quality Training & Education
***3 Manufacturing Control**
Environmental Control
Facility Control
Assurance of Quality, Cost & Delivery
***4 Control of Delivery and Quantity**

Figure 1.2 Quality assurance (QA) system procedural flow

2. Specifications and Quality Assurance Agreements

Customer requirements for performance specifications, as well as quality and reliability (Q&R) standards for products to be shipped and other related items are clarified in the delivery specifications or quality contract. In this way, efforts are concentrated on maintaining and improving quality assurance (QA) particulars to ensure customer satisfaction.

Preparation and issuance of quality contracts are controlled under a specification issuance control system. Figure 2.1 shows the procedural flow for issuing specifications.

If the specifications for a product to be shipped must be changed, the procedure in Section 3.3 is followed after approval has been obtained from the customer. Thus, problems with quality and resulting customer dissatisfaction are avoided, and service is improved.

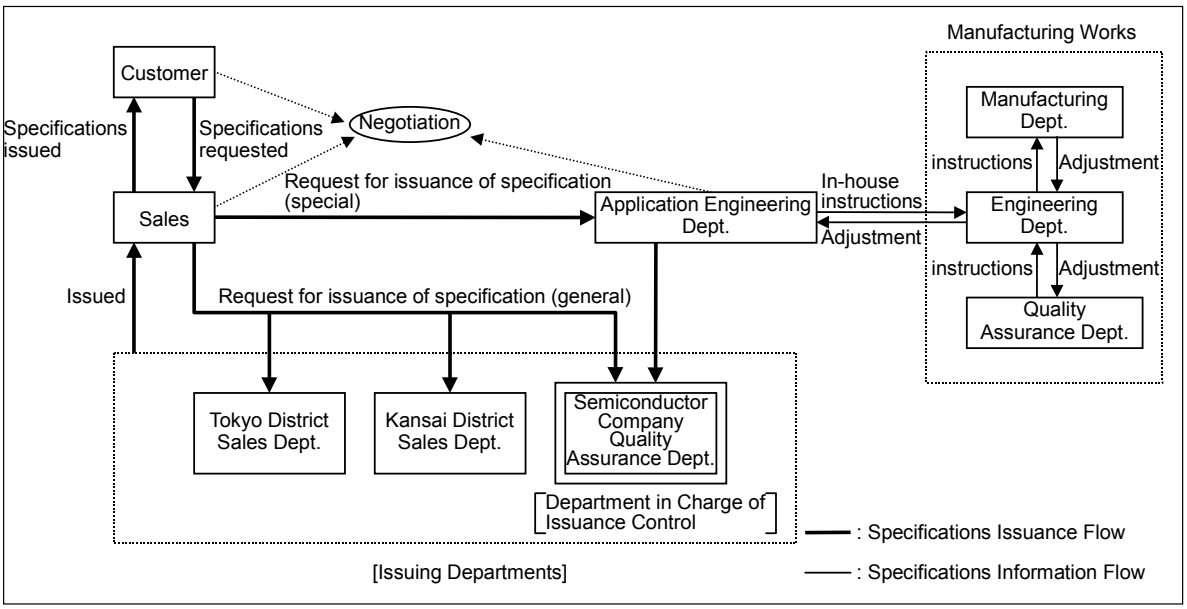


Figure 2.1 Procedural flow for issuing specifications

3. Quality and Reliability from Development to Production

3.1 Overview

Toshiba semiconductor products can be used in a variety of applications such as consumer electronics, industrial equipment, automobiles and aerospace. This section describes the process for integrating the high quality and reliability (Q&R) required by such applications during the semiconductor development and production processes.

3.1.1 Planning

When developing a new semiconductor product, sufficient market research must be performed in advance to ensure that the product satisfies customer objectives and Q&R requirements, as well as to ensure the product's general marketability.

The Sales Department, Application Engineering Department and Quality Assurance Department thoroughly study and examine the type and actual working environment of the equipment in which the product will be used. Circuit conditions, target reliability, design derating, operating conditions and maintenance control are also investigated, in addition to initial device functionality and failure rate. They then determine a set of specifications that encompass the target reliability and, finally, formulate the appropriate development plans.

3.1.2 Design

The quality of semiconductor products depends largely on the design.

Product design is based on development specifications carefully considered during the planning phase. Circuit design, layout design, process design and structural design are considered comprehensively to provide a sufficient processing tolerance and to integrate reliability into the product design.

To achieve optimum design quality, a design review is held to re-evaluate the design from every perspective, taking into account factors such as standards, rules and safety. If there are problems, the design is reconsidered. The design review involves departments such as Development and Design, Manufacturing Engineering, Application Engineering, and Quality and Reliability.

After the design review, an evaluation designed to verify target functions and characteristics is performed using the test production sample, and a design approval test (DAT) is conducted with an emphasis on accelerated testing to verify quality and reliability under actual usage conditions.

The output from the DAT is used to determine design margins and limits. If problems are encountered, the situation is evaluated and analyzed from every point of view to determine the cause, and the results are conveyed back to the design and manufacturing departments so as to improve quality and reliability.

After completion of the above evaluations, the DAT review meeting is held and then, once approval is obtained, the trial production phase is entered.

3.1.3 Production Trial Run

During the trial production phase, quality and reliability are evaluated to determine whether the designed-for quality and reliability can be maintained during continuous production. Furthermore,

Quality Approval Testing (QAT) is conducted to determine initial process yields and other production performance data.

Results are evaluated to determine whether they meet expectations. Evaluation results are conveyed back to the departments concerned. Then, product specifications, QC diagrams and other task standards necessary for production are prepared, and production facilities, instruments and tools are allocated.

The QAT review meeting is held. If all matters are approved, this is followed by the full-production sign-off meeting. The full production phase is entered after completion of the full-production sign-off meeting.

3.2 Design Review and the Approval System

3.2.1 Design Review

The design review (DR) is a part of the approval test (AT) system.

At the end of the design phase, a design review is held with the participation of the Development and Design, Manufacturing Engineering, Application Engineering, and Quality and Reliability departments. During the meeting, design standards, design rules (past problem reports) and PL items are reviewed and evaluation standards are decided upon, taking into consideration the various factors that affect the quality and reliability of the test sample. Safety considerations, such as compliance with international safety standards (UL, VDE and others), are given special attention.

The results of the design review are used as a basis for redesign, if necessary, and for the inclusion of additional test items in the AT as necessary.

3.2.2 Approval Test

The approval test (AT) is performed after completion of the design review. First, the engineering grade of the product is determined and then various evaluations and tests are conducted according to the grade.

Table 3.1 lists engineering grades and corresponding AT classifications.

Table 3.1

Engineering Grade	Technological Level	AT Class
I	(1) Technology new to the world (never before developed) (2) Technology new to Toshiba but already developed by competitors	DAT and QAT
II	(1) Improved conventional technology (2) Conventional technology applied to other products	DAT and QAT
	(3) The manufacturing location is changed during standard product manufacturing stage. (4) Changes are implemented at current manufacturing location during standard product manufacturing stage. (5) Part of the internal process is subcontracted.	QAT
III	Changes are made at the standard product manufacturing stage that do not significantly affect the quality and reliability of parts and materials or processes, or production is resumed after being halted for more than a year.	PAT

DAT: Design approval test QAT: Quality approval test PAT: Production approval test

Table 3.2 shows the actual AT system flow, the departments involved, the nature of the evaluation and check sheet usage.

Reliability testing is also conducted in product family units, such as the design/process family or package family, in order to execute the AT effectively. Electrical performance and functionality are evaluated for each product.

Table 3.2 AT system outline

Classification (Execution Step)	System			
	FLOW	Responsible Dept.	Nature of Evaluation	Check Sheets Used
DR (Development Design)	Development / Process / Package / Material (1) Determine Engineering Grade.	Headquarters Departments Device Engineering Department Device Engineering Department Quality and Reliability Department	Design and evaluation item review	• Development check sheet • Engineering grade review and DR sheets
DAT (Trial Production in Laboratory)	(2) AT Execution Plan Meeting (3) Evaluation and Testing (4) AT Review Meeting (5) AT Review Transfer Meeting Items (1) to (5) are the same as for DAT. (Manufacturing)	Device Engineering Department Application Engineering Department Quality and Reliability Department Device Engineering Department Application Engineering Department Quality and Reliability Department Device Engineering Department Application Engineering Department Quality and Reliability Department Device Engineering Department Quality and Reliability Department Works Departments As for items (1) to (5) above (but works departments, not headquarters departments)	• Basic evaluation • (Process and package) • Initial characteristic evaluation • Product life test • Environment test • Package dimensions and shape • Basic process flow • Structural analysis • PL items • Others • AT review result sheet • Production performance • Initial characteristic evaluation • Product life test • Environment test • Package dimensions and shape/control method • Manufacturing process flow and control status • Inspection results for trial production • Measurement control status • PL items • Others	• AT execution check sheet • AT review result sheet • Engineering grade review sheet • AT execution plan check sheet • AT review result sheet
QAT (Trial Production in Works)				
PAT (Partial Change in Standard Product)	Change Proposal Items (1) to (5) are the same as for DAT. (Manufacturing)	Works Departments As for items (1) to (5) above (but works departments, not headquarters departments)	• Initial characteristic evaluation • Inspection results for trial production • Manufacturing process flow and control status • Measurement control status • PL items • Others	• Engineering grade review sheet • AT execution plan check sheet • AT review result sheet

3.3 Change Control

Semiconductor products are continually improved so as to increase performance and decrease size and cost. Design changes for product improvement require sophisticated product evaluation and process control so as to maintain and improve quality and reliability.

The AT evaluation and approval system provides checks against quality problems which may arise when products evolve in this manner.

If a proposed change requires a modification to the structure, functionality or characteristics of a product, or will have a significant effect on product reliability, customer approval is obtained prior to implementation of the change. Toshiba has established the change control system shown in Figure 3.1 for this purpose.

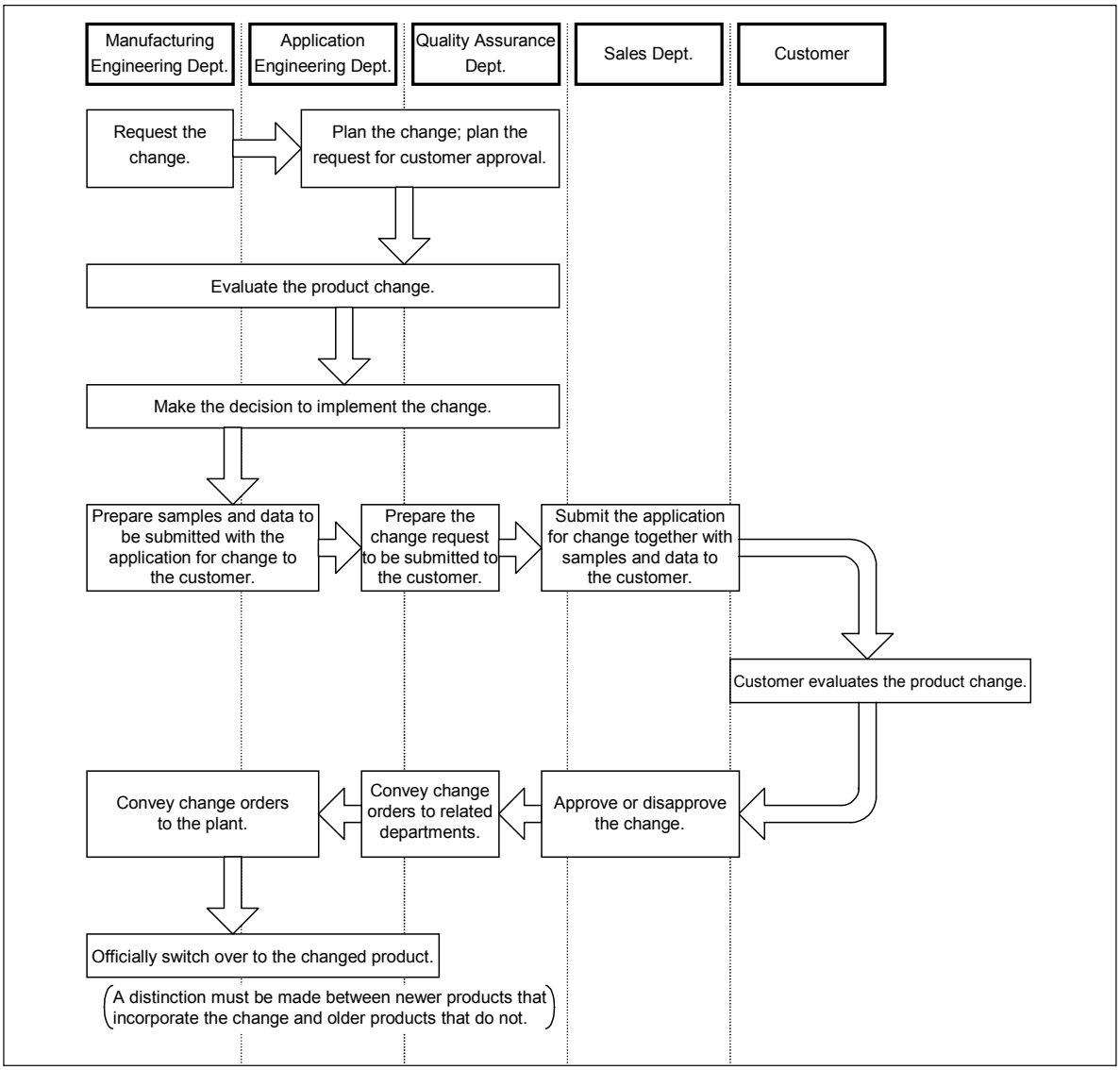


Figure 3.1 Procedure for product change

4. Document Control

4.1 Standardization

Toshiba standards apply at every step in the design and manufacture of its products. Rules and procedures for the effective utilization of these standards are made available, and each standard is continually reviewed and updated to maintain its applicability.

At present, efforts are underway to incorporate these standards into an on-line database so as to establish a more efficient control structure.

Figure 4.1 shows how Toshiba standards are organized.

4.2 Control

Documents and data are controlled as follows:

(1) Performance, quality and reliability standards required by the customer and items related to quality assurance (QA) that appear in the customer specifications are integrated into the standardization structure to ensure proper notification of the departments concerned. (See Figure 4.1.)
This information is confidential.

(2) A controlling department for quality-related documents and data is clearly identified so that the information can be effectively utilized together with the applicable standards. Such information includes internal approval documents and data, reliability test data and process audit records.
To ensure proper storage, the retention period of documents and data is prioritized according to the contents.

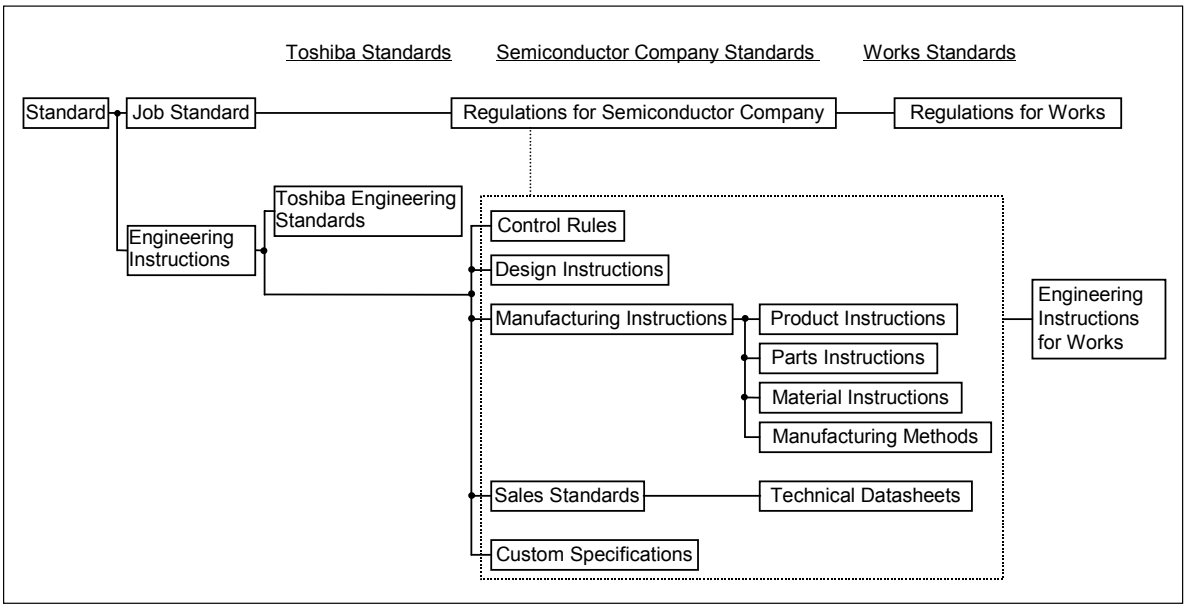


Figure 4.1 Organization of standards

5. Production Procedures

5.1 Control of Parts and Materials

The proper allocation of high-quality parts and materials for the manufacturing process is essential to continued production at the required quality and reliability levels.

Therefore, the specification and quality objectives for parts and materials are defined during the product design phase and this information is used to guide incoming parts and materials inspection and approval (in the case of chemicals, periodic analysis is performed).

For parts and materials procured from outside vendors, a quality assurance (QA) agreement is drawn up to provide guidelines for:

- Submission of a QA implementation plan
- Quality control (such as SPC) guidance and education
- Guidance for ISO 9000 Series compliance
- Process audit

In addition, parts and materials are stored in a proper environment in accordance with rules and guidelines to prevent deterioration.

5.2 Subcontracting

When subcontracting part of the semiconductor manufacturing process, items such as QC status, management status, engineering status and the condition of facilities are investigated and confirmed, so as to ensure that an appropriate subcontractor is selected. (This applies to Toshiba subsidiaries as well as to collaborating companies.)

After production starts, support is provided to guide subcontractors in quality and engineering training and to aid facility planning. In addition, periodic quality audits are performed to check the process control and environment status. Furthermore, subcontractor quality meetings are held periodically to obtain action plans for items reported during quality audits, to verify the status of other quality items and to provide assistance in quality improvement. Table 5.1 shows an example of a subcontractor control plan and its implementation.

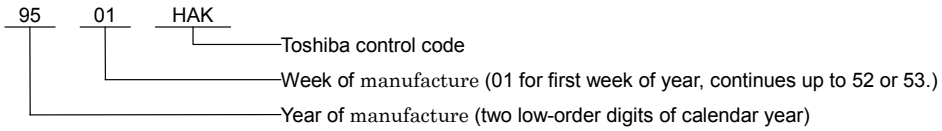
Table 5.1 Example of subcontractor control plan and its implementation

Classification		Plan		Implementation		
		Dept. in Charge	Related Depts.	Outline	Dept. in Charge	Cooperating Depts.
Subcontractor Control	(1) Subcontractor selection surveys (a) Management (b) Engineering status (c) QC status (d) Facility and other considerations	Production Dept.	Engineering Dept. Manufacturing Dept. Quality Assurance Dept.	Surveys • Business activity • Engineering level • Specialty experience and development capability • QC organization, availability of written working instructions • Facility control, instrument control • Material control status • Contractual arrangements	Production Dept.	Engineering Dept. Quality Assurance Dept. Manufacturing Dept.
	(2) Subcontractor Plant Quality Control	Quality Assurance Dept.	Engineering Dept. Manufacturing Dept. Production Dept.	• Process control survey and assistance	Quality Assurance Dept.	Engineering Dept. Manufacturing Dept.
	(3) Subcontractor Plant Technical Assistance	Manufacturing Dept.	Engineering Dept. Production Dept.	• Dispatch of engineer upon request • Communication meetings as necessary • Technical assistance	Manufacturing Dept.	Engineering Dept.

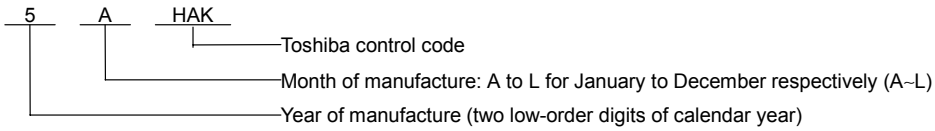
6. Traceability

Product identification control assigns lot codes so that the manufacturing flow of any product can be traced. The following shows typical Toshiba manufacturing lot code fragments.

(1) Weekly code: 4 digits plus 3 letters
(Products for which the marking includes the week of manufacture)



(2) Monthly code: 1 digit plus 4 letters
(Products for which the marking includes the month of manufacture)



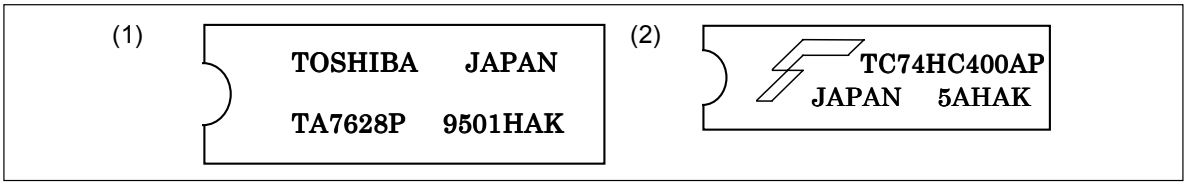


Figure 6.1 Example manufacturing codes

7. Manufacturing Process Control

7.1 Facilities

Facility control regulations guide the improvement and expansion of production facilities and allow safety control to be implemented.

Facility control is based on the concept of total preventive maintenance (TPM) whereby specific tasks, such as inspections at the beginning of work, are defined with the aim of identifying problems that can affect quality before they occur.

7.2 Working Environment

The quality and reliability of semiconductor products are greatly affected by the manufacturing work environment. Cleanliness, temperature control and humidity control are especially important.

Toshiba clean rooms can be controlled to have different levels of cleanliness as required. To maintain a clean room, dust monitors periodically analyze and determine the sources of dust, and temperature and humidity are monitored and controlled as specified for the process.

The purity of the DI water used in the wafer process also greatly affects the quality and reliability of semiconductor products. Therefore, mixed-bed deionization and micron filtering are used to create the DI water, and the result is monitored and analyzed periodically.

Furthermore, an increasing variety of miniaturization and packaging techniques has led to a growing problem with device failure due to electrostatic discharge (ESD). Toshiba has therefore created guidelines to control ESD effectively, mainly during the assembly process.

7.3 Process Control

The semiconductor wafer process is treated as a series of processing units including oxidation, diffusion, deposition, pretreatment, etching, ion implantation and photolithography. The latest multilayered products require some 150~200 steps.

The objective of the assembly process is package integrity and the protection of device functions. The required level of quality and reliability increases yearly due to greater integration and miniaturization and to increase in the number of varieties of package. Therefore, in-process QC is emphasized to achieve the designed-for quality and reliability based on the belief that quality and reliability must be built in during the manufacturing process.

A QC process diagram such as the one shown in Figure 7.1 is used to clarify the control items, conditions, tools, individuals responsible and contingency actions for each manufacturing process. Furthermore, every effort is made to achieve detailed process control. For example, data for each process is recorded to allow checking of process conditions and to enable lots to be traced when problems occur.

Material	Process	Items Controlled and/or Inspected	Primary Control Objectives	Inspection Instrumentation
	Si wafer	Appearance, Specific resistance, Flatness, Oxygen concentration		Flatness tester
	Oxidation	Temperature, Thickness	Temperature profile Film thickness	Thermometer Thickness meter
	P-well deposition	Temperature, Sheet resistance	Temperature profile Film thickness	Thermometer Sheet resistance measuring instrument
	Gate oxidation	Temperature, Thickness	Film thickness, Film quality	Thermometer, Thickness meter
	Poly-Si deposition	Temperature, Thickness	Temperature profile, Time, Film thickness, Resistance	Thermometer, Thickness meter, Resistance meter
	P/N diffusion	Temperature, Sheet resistance	Temperature profile Resistance value	Thermometer, Sheet resistance measuring instrument
	Contact hole photoengraving			
	Metal deposition	Temperature, Thickness	Film thickness, Film quality	Thermometer, Thickness meter
	Passivation deposition	Temperature, Thickness	Film thickness, Temperature profile	Thermometer, Thickness meter
	Characteristics inspection	Electrical characteristics	Electrical characteristics	Tester, Prober
	Wrapping	Thickness	Wafer thickness, Appearance	Dimension measuring instrument Micrometer
	Reception of dicing frame	Appearance, Dimensions		
	Reception of paste	Temperature	Temperature, Time	Thermometer
	Die bonding			
	Reception of Au wire	Strength	Tensile shearing strength	Strength tester
	Bonding			
	Inspection	Appearance	Appearance, Shape	Microscope
	Reception of mold resin received			
	Molding	Temperature	Mold temperature	Thermometer
	Curing	Temperature	Temperature, Time	Thermometer
	External plating			
	Lead trim and forming			
	Marking			
	Final inspection	Electrical characteristics, Appearance	Electrical characteristics, Appearance, Dimensions	Tester
	Packing			
	Quality assurance (QA) test			
	Reliability monitoring			
	Shipping			

Figure 7.1 Example of a QC process diagram (for CMOS ICs)

8. Inspection System

Previous sections of this handbook have described the importance of incorporating quality and reliability into the semiconductor design and manufacturing processes. This section describes the initial QA inspection and periodic reliability tests that are performed in the final manufacturing phase so as to assure the quality and reliability of the final product.

8.1 Inspection

An intermediate in-process inspection, a final inspection, an initial QA inspection and periodic reliability testing are performed based on a standardized master specification sheet (MSS).

Figure 8.1 shows the inspection procedure.

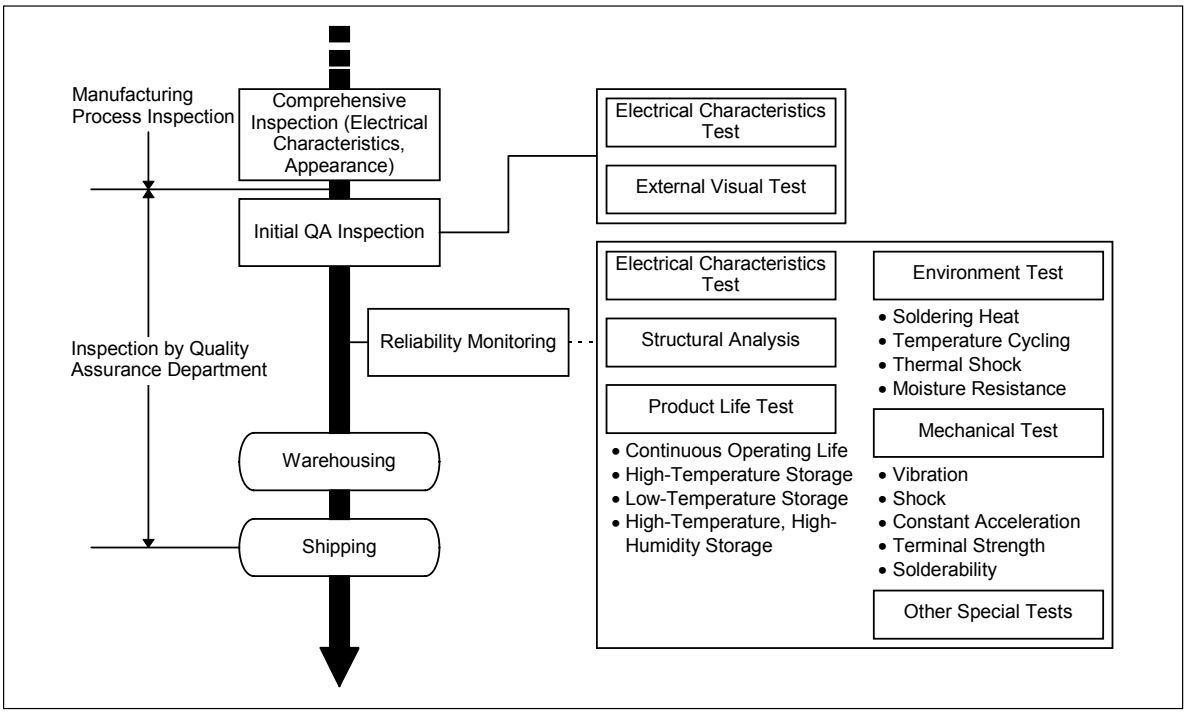


Figure 8.1 Inspection procedure

The initial QA inspection verifies the initial electrical characteristics and external specifications of each product. This is essential to assure the quality and reliability of final products. Each product type is inspected using a sampling process (see Section 8.2). The reliability test, on the other hand, is conducted in terms of process type and package family type, so as to assess reliability from those perspectives.

Reliability monitoring is carried out for product families whose quality has proven stable. This entails periodic checks of initial and random failure rates on the manufacturing line and analysis using the bathtub curve (see Section 1 of Chapter 2) for each process and package family. Trends in quality and reliability levels are taken into account when setting target failure rates, and this information is passed back to the manufacturing process to help improve quality levels.

8.2 Acceptable Quality Levels

Inspection sampling assures the acceptable quality levels (AQLs) shown in Table 8.1.

Table 8.1 Acceptable quality levels (AQLs) for lots based on ANSI Z1.4-1993 (normal inspection by single sampling)

Item \ Type		ICs/LSIs	Memory
Electrical Characteristics		0.15%	0.065%
Appearance	Serious Defect	0.15%	
	Minor Detect	0.25%	

Recently, customer requirements have reached levels that are difficult to meet using ordinary sampling inspection. To cope with increasing requirements for designed-in quality, in addition to normal inspections, a control method based on the parts-per-million (PPM) defect ratio has been implemented so as to further improve quality and reliability.

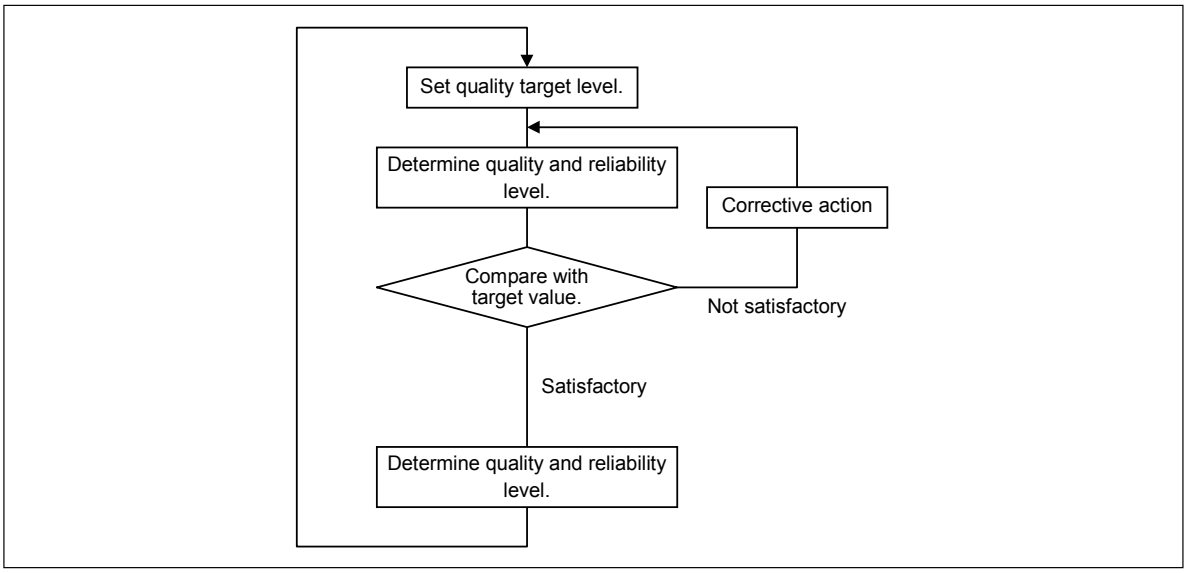


Figure 8.2 PPM control procedure

9. Calibration Control

Calibration control rules guide the use of measuring instruments.

Calibration instruments (those used as a standard reference) are regulated by law and must be inspected and approved by authorized agencies before being used. Thereafter, they are inspected periodically and the results filed with and maintained by the Quality Assurance Department.

Often, however, semiconductor manufacturing involves very small dimensions for which there are no existing national standards. In such cases, Toshiba standards and Semiconductor Company standards, formulated in cooperation with instrumentation manufacturers and overseas agencies, are used with standard calibration instruments at each works.

Procurement inspections, periodic inspections and spot inspections are performed on general instrumentation. The results are filed with and maintained by the Quality Assurance Department. Approved instruments are identified clearly by a seal which indicates the effective period of approval and the next inspection date.

The department which owns an instrument is responsible for its routine regulation and maintenance according to the control standards.

Figure 9.1 shows the system used to assure instrumentation accuracy.

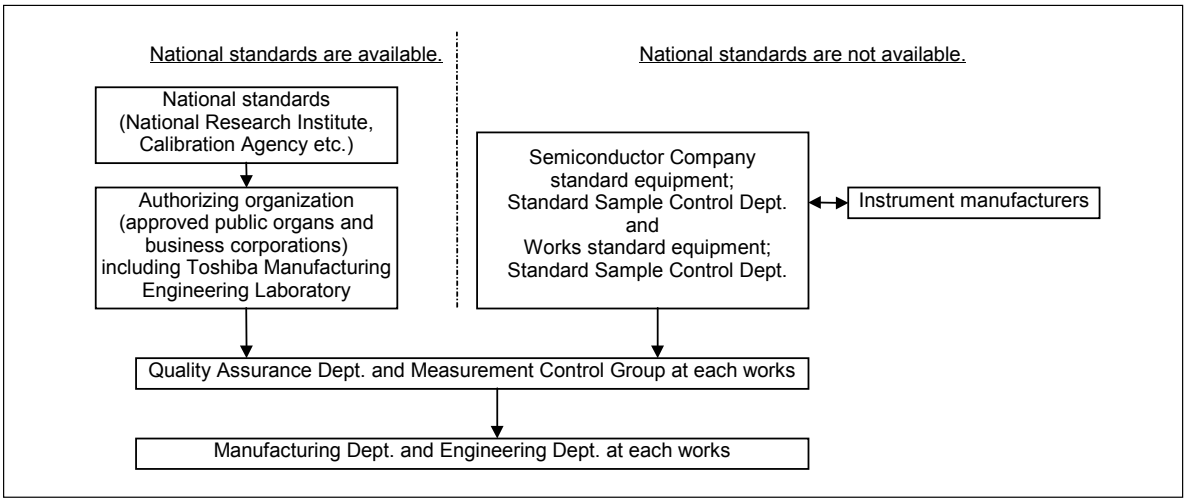


Figure 9.1 Traceability system

10. Inspection and Test Status

To track goods in process and maintain a manufacturing history, the following identification control procedures are used:

- Materials and semi-finished, finished, repaired and returned products are placed on shelves in containers classified by shape, color and markings which identify their product storage and processing status.
- For final inspection and inspections performed during the manufacturing process, products are identified as awaiting inspection, as in the process of being inspected, or as having just been inspected.
- Lots for which processing is in progress are accompanied by a travel sheet or check sheet showing their process history.

11. Contingency Procedures

When a control limit is exceeded during processing or when there is a problem with the quality of a product being processed, the lot containing the item in question is identified and isolated, and contingency action is taken immediately according to the procedural flow shown below. In addition, the problem description, preliminary action and corrective action are reported to relevant departments (and documented) according to predefined procedures.

If there is any chance that a problem which is detected may have affected products that have already shipped, the Quality Assurance Department ensures that the necessary recovery action is taken.

If the problem is known to affect product reliability, it is investigated immediately according to predefined procedures so as to prevent a recurrence. At the same time, all necessary recovery action, including notification of customers, is taken.

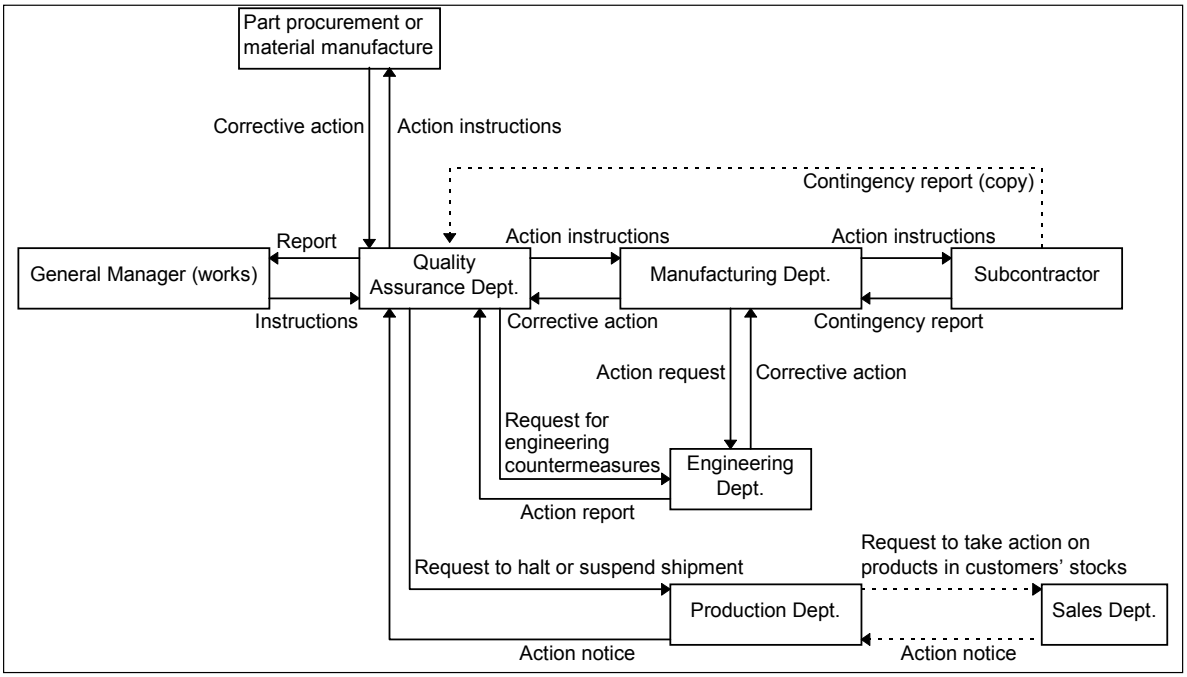


Figure 11.1 Contingency action flow

12. Complaint Services

Figure 12.1 shows the procedure used for complaint services. It enables quick analysis and quick response to customer complaints. In addition, information concerning complaints is fed back to the manufacturing process and related departments to prevent the recurrence of problems and to improve reliability. In this way, improvements can be monitored to determine whether they are effective in the long term.

New analysis methods and techniques (including the use of new analytical equipment) are continuously being introduced to further improve analysis efforts.

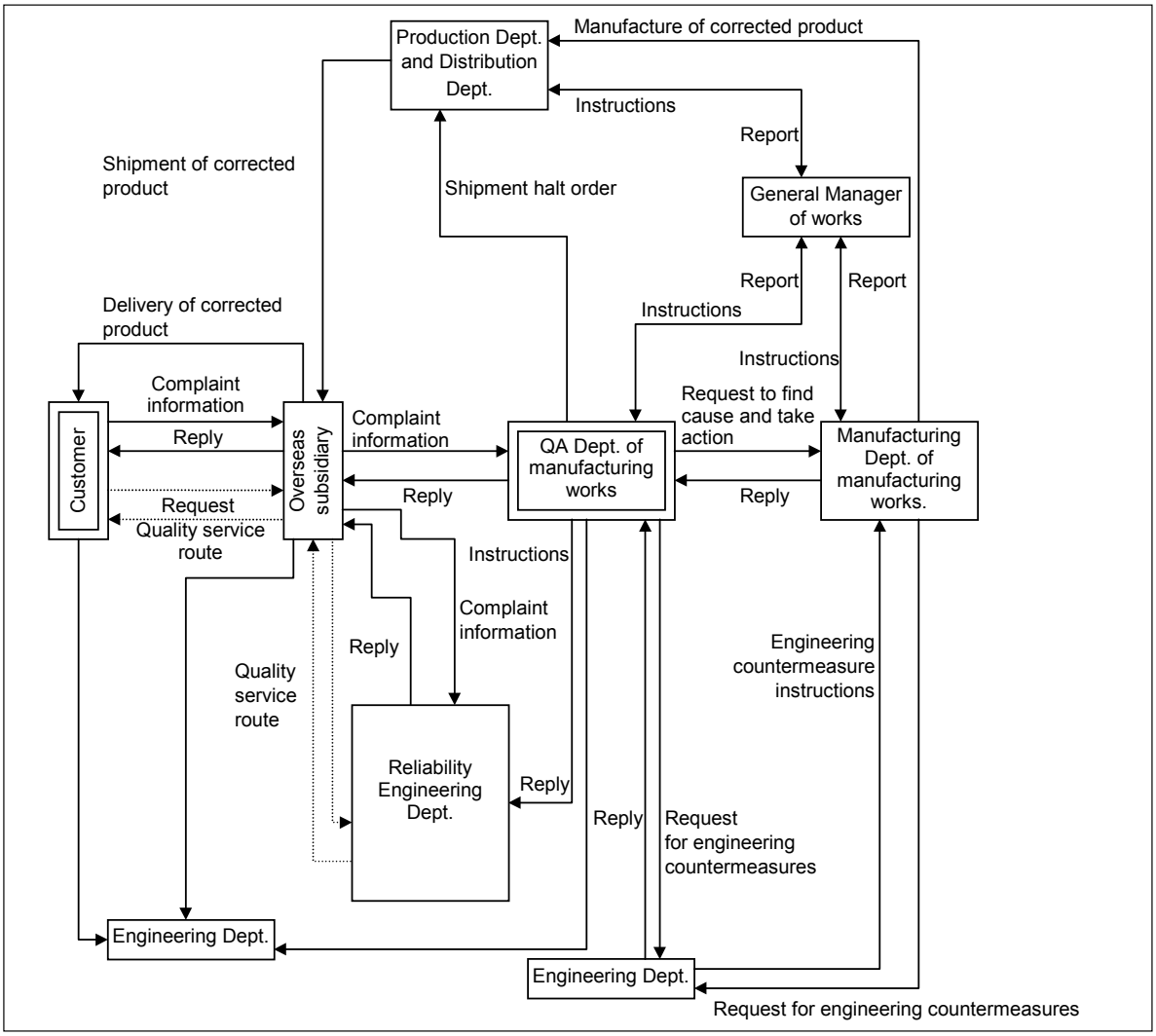


Figure 12.1 Quality service and complaint processing flow (for complaints from overseas)

13. Product Control after Final Inspection

Products satisfying prescribed inspection standards have a seal or stamp affixed to their cartons. The cartons are then warehoused. This method of marking approved products is referred to as the quality assurance (QA) seal, an example of which is shown in Figure 13.1.

Warehoused products are classified according to type, customer-required standard and lot, and are readied for shipment. Custom products for specific customers are indicated as such to prevent shipping errors.

Products are packed (with precautions against humidity as necessary) and then stored in a warehouse that is environmentally controlled for temperature, humidity, dust and corrosive gases so as to prevent deterioration. Furthermore, control of product inventory and order status is computerized so as to accurately determine the product supply and demand situation, and to enable quick response to customer requests.

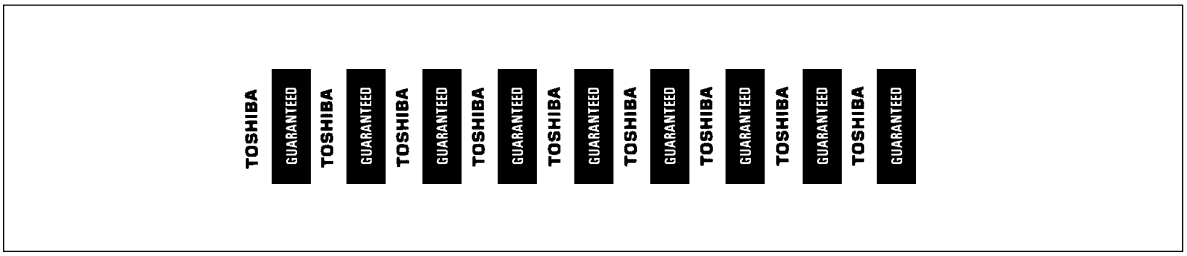


Figure 13.1 QA seal

14. Quality Records

Various records related to quality are identified and kept in storage for a predetermined period.

15. Quality Audits

In the manufacturing department, process control is based on the Toshiba working standard and the QC process diagram, in order to continuously improve quality and reliability. In addition, the Quality Assurance Department periodically audits and evaluates the quality and reliability control status of the Manufacturing Department in order to promote further improvements.

Table 15.1 describes the main types of process audit.

Table 15.1 Types of process audit

Type	Application	Auditor	Frequency	Items checked
Semiconductor Group Audit	• Semiconductor Group • Subsidiary company	Technology Executive Quality Assurance Dept.	Once a year for each department	• Standardization • Process control • Measurement instrument control • Facility control • Change control • Test and inspection control • Education and training • Testing and evaluation implementation status after changes • Others
Manufacturing Works Audit	• Manufacturing section • Subsidiary company • Collaborating company	• Works General Manager • Quality Assurance Dept. • Manufacturing Dept.	Once a year for each department	
Internal Quality Audit	• Staff • Sales • Engineering Dept. • Manufacturing Dept. • Production Dept. • Quality Assurance Dept. • Others	• Audit team (those who have completed designated training)	Once a year for each department	• Items relevant to ISO 9001 (rules, records and implementation status)

16. Education and Training

Toshiba provides education and training programs for new employees, general employees, controllers, supervisors and corporate managers.

Curricula for quality-related education are designed to maintain and improve product quality and promote effective quality control. Table 16.1 describes the curricula provided for engineers.

Two types of education and training courses are offered: those for supervisors and those for engineers engaged in manufacturing, engineering or quality assurance (QA).

Courses for engineers cover a wide range of quality control topics and are geared to the student's level of knowledge and experience.

Table 16.1 Engineer training curricula

Subject	Text
Introduction to QA	In-house educational texts
ISO 9001	
Introduction to Experiment Planning Methods	
Introduction to Reliability Engineering	
Statistical Quality Control	
Case Studies of Quality Problems	
PL and Corrective Measures	
Semiconductor Reliability	
Applying Experiment Planning Methods	
Taguchi Method	

Engineers are encouraged to attend outside lectures and courses as well.

Also, basic and specialized education is provided periodically using the qualification system shown in Figure 16.1, so as to foster semiconductor manufacturing specialists. The process of qualifying personnel for particular tasks in this way uniformly raises the levels of employee experience and quality awareness, helping to maintain a generally high level of quality.

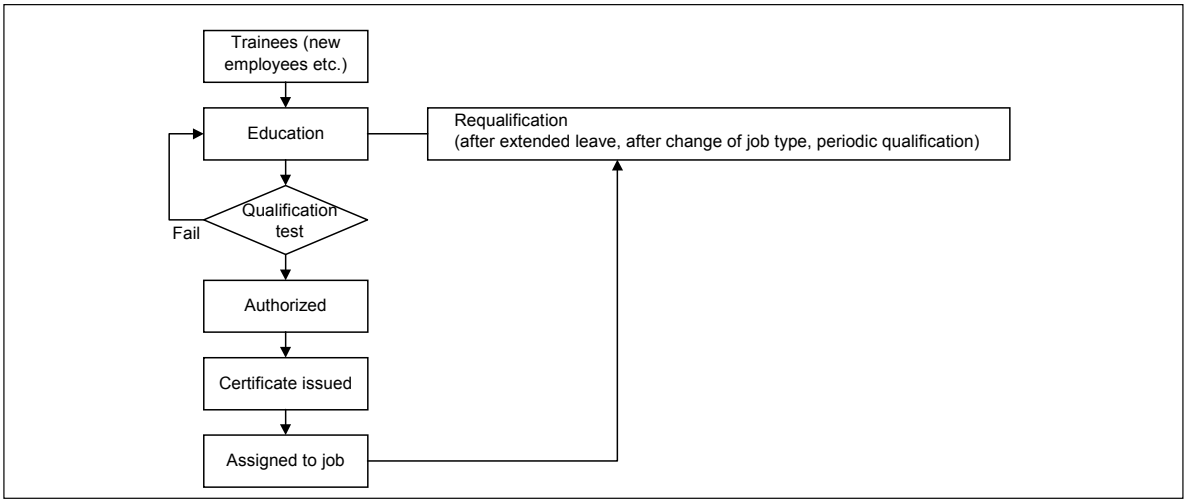


Figure 16.1 Conceptual diagram of qualification system

17. Quality Service Activities

17.1 Overview of Quality Service Activities

Toshiba has established a quality service process for conveying market quality requirements back to processing and design departments, so as to keep them abreast of diverse customer quality requirements and customer satisfaction levels after a product has shipped.

17.2 Quality Information Services

Toshiba provides the following information materials to support the customer product approval process, the inspection of incoming products and assembly.

The following information will be provided promptly upon request:

- Quality and reliability monitoring data, by product family, by process or by package type (quarterly)
- New product approval test data (by product)
- Approval test data for product changes
- Board assembly precautions manual
- Storage and handling precautions manual
- Other data and materials

17.3 Quality Meetings with Customers

Periodic quality meetings are attended by customers and Toshiba Quality Assurance Department members so as to foster a good working relationship.

Information concerning potential product faults, complaints, preventive measures and plans for improvements are exchanged so as to provide a high level of support to the customer.

To satisfy customer expectations concerning quality objectives and to further improve product quality, Toshiba makes every effort to promote better cooperation between Toshiba and its customers, ensuring that even those items which are often overlooked in the day-to-day routine will receive attention.

18. Statistical Process Control (SPC)

Toshiba applies statistical process control methods in the belief that quality is not achieved through inspection, but is built in during processing. Variations in factors affecting quality are quantitatively determined and analyzed so as to improve quality.

Critical control items are defined based on factors that affect quality and reliability, factors related to past problems and factors related to failure, as shown in Figure 18.1. Then, the performance of each process is measured so as to identify and counter factors which lead to failure. In this way, quality can be continuously improved. The latest computer integrated manufacturing (CIM) technology is employed to improve data entry efficiency and provide more effective SPC.

Furthermore, educational curricula are offered to promote the use of statistical methods among line employees and engineers, so as to enable greater quality improvements to be accomplished using SPC.

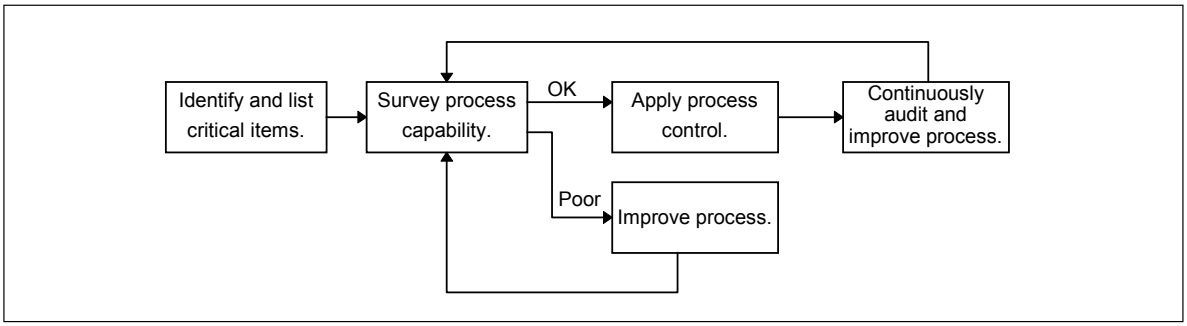


Figure 18.1 Quality improvement process flow