Quality Information

Corporate Quality Policy

Our goal is to exceed the quality expectations of our customers. This commitment starts with top management and extends through the entire organization. It is achieved through innovation, technical excellence and continuous improvement.

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Fig. 1 - Vishay Quality Policy

VISHAY INTERTECHNOLOGY, INC.

ENVIRONMENTAL, HEALTH AND SAFETY POLICY

VISHAY INTERTECHNOLOGY, INC. is committed to conducting its worldwide operations in a socially responsible and ethical manner to protect the environment, and ensure the safety and health of our employees, to conduct their daily activities in an environmentally responsible manner.

Protection of the Environment: Conduct our business operation in a manner that protects the environmental quality of the communities in which our facilities are located. Reduce risks involved with storage and use of hazardous materials. The company is also committed to continual improvement of its environmental performance.

Compliance with Environmental, Health and Safety Laws and Regulations:
Comply with all relevant environmental, health and safety laws and regulations in every location. Maintain a system that provides timely updates of regulatory change. Cooperate fully with governmental agencies in meeting applicable requirements.

Energy, Resource Conservation and Pollution Control: Strive to minimize energy and material consumption in the design of products and processes, and in the operation of our facilities. Promote the recycling of materials, including hazardous wastes, whenever possible. Minimize the generation of hazardous and non-hazardous wastes at our facilities to prevent or eliminate pollution. Manage and dispose of wastes safely and responsibly.

Fig. 2 - Vishay Quality Road Map

QUALITY SYSTEM

QUALITY PROGRAM

At the heart of the quality process is the Vishay worldwide quality program. This program, which has been in place since the early 90's, is specifically designed to meet rapidly increasing customer quality demands now and in the future. Vishay Corporate Quality implements the Quality Policy and translates its requirements for use throughout the worldwide organization.

Vishay Quality has defined a roadmap with specific targets along the way. The major target is to achieve world-class excellence throughout Vishay worldwide.

VISHAY CORPORATE QUALITY

Vishay Corporate Quality defines and implements the Vishay quality policy at a corporate level. It acts to harmonize the quality systems of the constituent divisions and to implement Total Quality Management throughout the company worldwide.

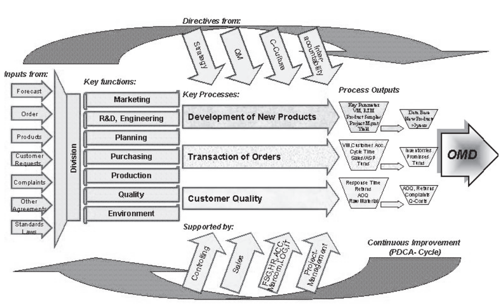
Vishay Zero Defect Program

- Exceeding quality expectations of our customers
- Commitment from top management through entire organization
- Newest and most effective procedures and tools
  - design, manufacturing and testing
  - management procedures (e.g. SPC, TQM)
- Continuous decreasing numbers for AOQ and failure rate
- Detailed failure analysis using 8D methodology
- Continuous improvement of quality performance of parts and technology

QUALITY GOALS AND METHODS

The goals are straightforward: Customer satisfaction through continuous improvement towards zero defects in every area of our operation. We are committed to meet our customers' requirements in terms of quality and service. In order to achieve this, we build excellence into our products from concept to delivery and beyond.

- **Design-in Quality**
  Quality must be designed into products. Vishay uses optimized design rules based on statistical information. This is refined using electrical, thermal, and mechanical simulation together with techniques such as FMEA, QFD and DOE.
- **Built-in Quality**
  Quality is built into all Vishay products by using qualified materials, suppliers, and processes. Fundamental to this is the use of SPC techniques by both Vishay and its suppliers. The use of these techniques, as well as tracking critical processes, reduces variability, optimizing the process with respect to the specification. The target is defect prevention and continuous improvement.
- **Qualification**
  All new products are qualified before release by submitting them to a series of mechanical, electrical, and environmental tests. The same procedure is used for new or changed processes or packages.
- **Monitoring**
  A selection of the same or similar tests used for qualification is also used to monitor the short- and long-term reliability of the product.
- **SPC (Statistical Process Control)**
  SPC is an essential part of all Vishay process control. It has been established for many years and is used as a tool for the continuous improvement of processes by measuring, controlling, and reducing variability.
- **Vishay Quality System**
  All Vishay's facilities worldwide are approved to ISO 9000. In addition, depending on their activities, some Vishay companies are approved to recognized international and industry standards such as ISO/TS 16949.
  Each subsidiary goal is to fulfill the particular requirements of customers. The Opto Divisions of Vishay Semiconductor GmbH are certified according to ISO/TS 16949.



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The procedures used are based upon these standards and laid down in an approved and controlled Quality Manual.

BUSINESS EXCELLENCE

Total Quality Management is a management system combining the resources of all employees, customers, and suppliers in order to achieve total customer satisfaction. The fundamental elements of this system are:

- Management commitment
- EFQM assessment methodology
- Employee Involvement Teams (EITs)
- Supplier development and partnership
- Quality tools
- Training
- Quality system
- Six sigma
- Automotive excellence program (AEP)
- Zero defect

All Vishay employees from the senior management downwards are trained in understanding and use of TQM. Every employee plays its own part in the continuous improvement process which is fundamental to TQM and our corporate commitment to exceed customers' expectations in all areas including design, technology, manufacturing, human resources, marketing, and finance. Everyone is involved in fulfilling this goal. Vishay management believes that this can only be achieved by employee empowerment.

The Vishay corporate core values

- Leadership by example
- Employee empowerment
- Continuous improvement
- Total customer satisfaction

are the very essence of the Vishay Quality Movement process.

- **Training**

Vishay maintains that it can only realize its aims if the employees are well trained. It therefore invests heavily in courses to provide all employees with the knowledge they need to facilitate continuous improvement. A training profile has been established for all employees with emphasis being placed on total quality leadership. Our long-term aim is to continuously improve our training so as to keep ahead of projected changes in business and technology.

- **EFQM Assessment Methodology**

From 1995, VISHAY has started to introduce the EFQM (European Foundation for Quality Management) methodology for structuring its Total Quality Management approach. This methodology, similar to the Malcolm Baldrige process, consists in self-assessing the various VISHAY divisions and facilities according to nine business criteria:

- Leadership
- People
- Policy and strategy
- Partnership and resources
- Processes
- People results
- Customer results
- Society results
- Key performance results (see figure 3)

The assessments are conducted on a yearly basis by trained and empowered, internal Vishay assessors.
This permits the identification of key-priority improvement projects and the measurement of the progress accomplished.
The EFQM methodology helps Vishay to achieve world-class business excellence.

- **Employee Involvement Teams**

At Vishay we believe that every person in the company has a contribution to make in meeting our target of customer satisfaction. Management therefore involves employees to higher and higher levels of motivation, thus achieving higher levels of effectiveness and productivity. Employee involvement teams, which are both functional and cross functional, combine the varied talents from across the breadth of the company. By taking part in training, these teams are continually searching for ways to improve their jobs, achieving satisfaction for themselves, the company and most important of all the customer.

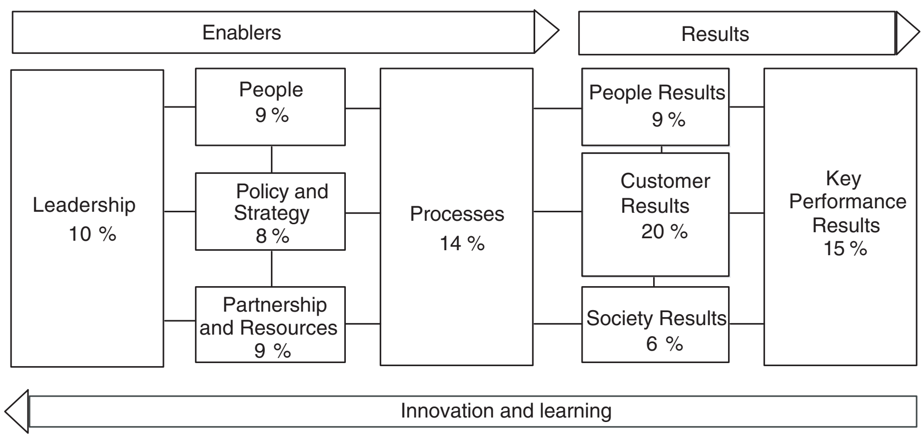

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Fig. 3 - EFQM Criteria for Self-Assessment

TQM TOOLS

As part of its search for excellence, Vishay employs many different techniques and tools. The most important of them are:

- **Auditing**

As well as third party auditing employed for approval by ISO 9000 and customers, Vishay carries out its own internal and external auditing. There is a common auditing procedure for suppliers and sub-contractors between the Vishay entities. This procedure is also used for inter-company auditing between the facilities within Vishay. It is based on the “Continuous Improvement” concept with heavy emphasis on the use of SPC and other statistical tools for the control and reduction of variability.
Internal audits are carried out on a routine basis. They include audits of satellite facilities (e.g., sales offices, warehousing etc.). Audits are also used widely to determine attitudes and expectations both within and outside the company.

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- **Failure Mode and Effect Analysis (FMEA)**

FMEA is a technique for analyzing the possible methods of failure and their effect upon the performance/reliability of the product/process. Process FMEAs are performed for all processes. In addition, product FMEAs are performed on all critical or customer products.

- **Design of Experiments (DOE)**

There is a series of tools that may be used for the statistical design of experiments. It consists of a formalized procedure for optimizing and analyzing experiments in a controlled manner. Taguchi and factorial experiment design are included in this. They provide a major advantage in determining the most important input parameters, making the experiment more efficient and promoting common understanding among team members of the methods and principles used.

- **Gauge Repeatability and Reproducibility (GR and R)**

This technique is used to determine equipment's suitability for purpose. It is used to make certain that all equipment is capable of functioning to the required accuracy and repeatability. All new equipment is approved before use by this technique.

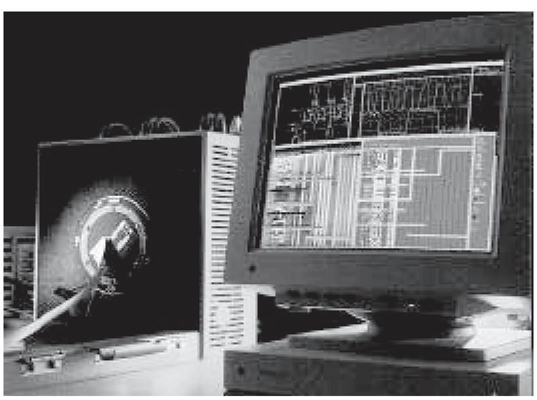
- **Quality Function Deployment (QFD)**

QFD is a method for translating customer requirements into recognizable requirements for Vishay's marketing, design, research, manufacturing and sales (including after-sales). QFD is a process, which brings together the life cycle of a product from its conception, through design, manufacture, distribution, and use until it has served its expected life.

QUALITY SERVICE

VISHAY believes that quality of service is equally as important as the technical ability of its products to meet their required performance and reliability. Our objectives therefore include:

- On-time delivery
- Short response time to customers' requests
- Rapid and informed technical support
- Fast handling of complaints
- A partnership with our customers



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- **Customer Quality**

Complaints fall mainly into two categories:

- Logistical
- Technical

Vishay has a procedure detailing the handling of complaints.

Initially complaints are forwarded to the appropriate sales office where in-depth information describing the problem, using the Vishay **P**roduct **A**nalysis **R**equest and **R**eturn **F**orm (**PARRF**), is of considerable help in giving a fast and accurate response. If it is necessary to send back the product for logistical reasons, the Sales Office issues a Returned Material Authorization (RMA) number.

On receipt of the goods in good condition, credit is automatically issued.

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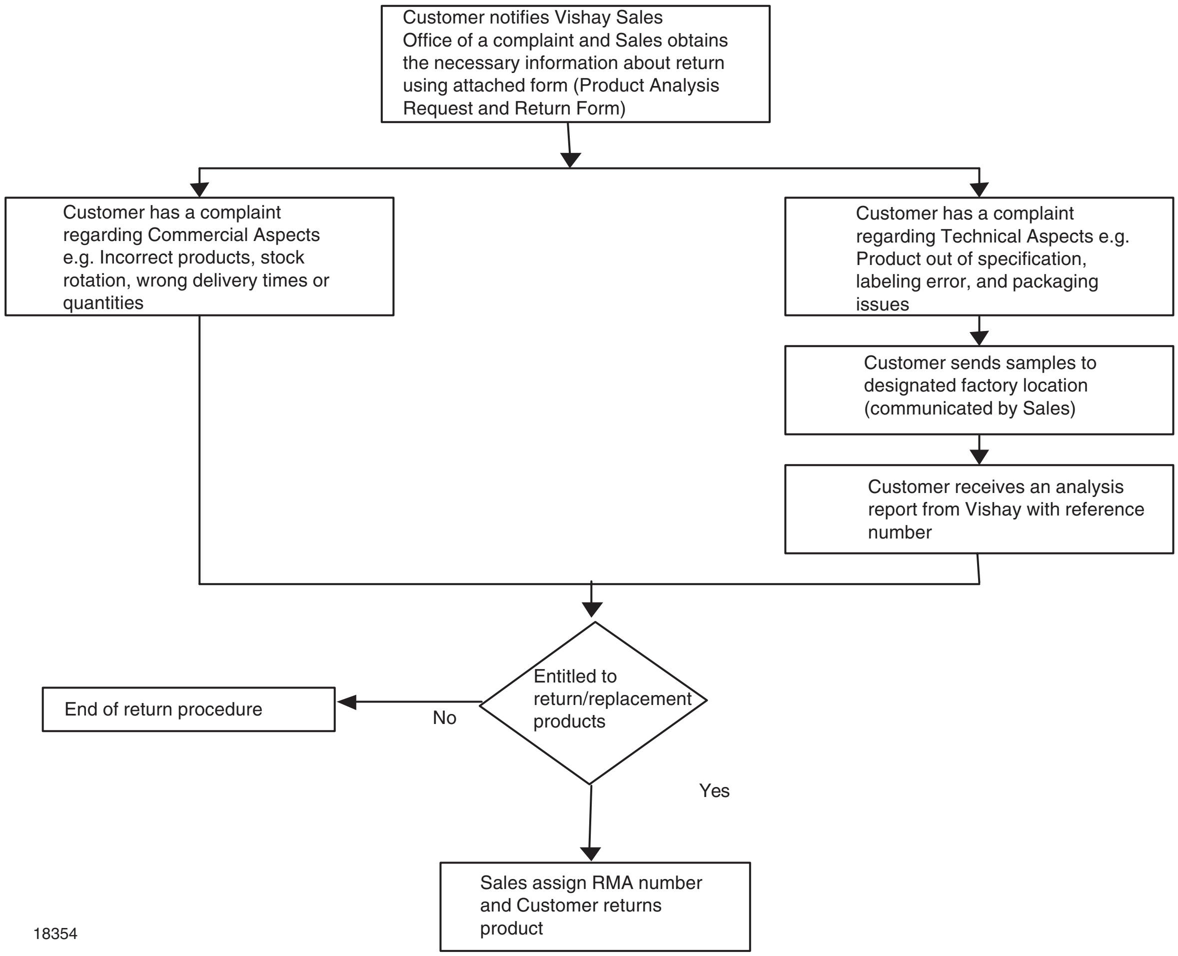
If there is a technical reason for complaint, a sample together with the **PARRF** is sent to the Sales Office for forwarding to the Failure Analysis Department of the supplying facility. The device's receipt will be acknowledged and a report issued on completion of the analysis. The cycle time for this analysis has set targets and is constantly monitored to improve response time. Failure analysis normally consists of electrical testing, functional testing, mechanical analysis (including X-ray), decapsulation, visual analysis and electrical probing. Other specialized techniques (e.g. LCD, thermal imaging, SEM, acoustic microscopy) may be used if necessary.

If the analysis uncovers a quality problem, a Corrective Action Report (CAR) in 8D format will be issued. Any subsequent returns are handled with the RMA procedure.

Quality Information



Complaint and Return Procedure

For technical questions concerning emitters, contact: emittertechsupport@vishay.com
For technical questions concerning detectors, contact: detectortechsupport@vishay.com
Document Number: 80087
Rev. 1.3, 05-Sep-08

Product Analysis Request and Return Form

Address Data

Customer:	**Sales Ref.No:**
Address:	**Sales Office:**
	Incoming Date:
Customer Ref.-No:	
Cust. Contact Person:	**Sales Contact Person:**
E-Mail:	**E-Mail:**
Phone:	**Phone:**
Fax:	**Fax:**

Product Analysis Request

Device:		**Qty. for Analysis:**
Date Code:	**Plant Code:**	**Failure Rate:**

Type of Complaint (pls. specify) — Failure description

- **Electr.** ☐
- **Mechan.** ☐
- **Others** ☐

Point of Failure:

Incoming ☐	**Qualification** ☐
Assembly ☐	**Reliability** ☐
Field Failure ☐	**Others** ☐

Stress Conditions before Failure:
(Temp / %HR / Voltage / Others)

Application:
(please specify)

Remarks / Other Data:
(please specify)

Return Request

Device:	**RMA-No. :** **(mandatory)**
Date Code:	
Inv. No.:	
Commercial Return ☐	
Technical Return ☐	
CAR-No. of 8D - Report:	

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Product Analysis Request and Return Form (PARRF)

VISHAY Semiconductor GmbH
8D Report

CAR Number:	
Page: 1	
Report Date:	

Complete following for all applicable items:

Date Opened:		Originator		*Company Specific Information*	
Vishay Location:		Vishay Part No.			
Customer:		Date Code:		Plant Code:	
Customer Location:		Device Type:		Lot Serial No.:	
Customer Ref. Code:		Value:		Lot Size:	
Customer Part No.:		Tolerance:		Sample Qty:	
Customer P.O. No.:		RMA Number:		Failure Rate:	
		Package Type:			

8D APPROACH – Disciplines 1, 2, and 4 below must be completed for ALL requests.

DISCIPLINE 1: ESTABLISH TEAMS

DISCIPLINE 2: DESCRIBE PROBLEM

DISCIPLINE 3: CONTAINMENT ACTIONS

DISCIPLINE 4: ROOT CAUSE/RESULTS

If VALID, ALL Disciplines must be completed.

DISCIPLINE 5: CORRECTIVE ACTIONS

DISCIPLINE 6: IMPLEMENT CORRECTIVE ACTIONS

DISCIPLINE 7: PREVENT RECURRENCE

DISCIPLINE 8: CONGRATULATE TEAM

Revised by:		Rev.:		Date:	
Approved by:		Date:		Date Closed:	

Major Vishay Brands Dale * Draloric * Foil Resistors * Lite-On PSC * Measurements Group * Roederstein * Sfernice * Siliconix * Sprague * Telefunken * Thin Film * Vitramon

Confidential Information

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Vishay 8D Form

- **Change Notification**

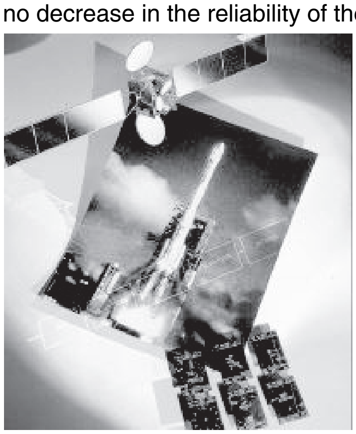
All product and process changes are controlled and released via ECN (Engineering Change Notification). This requires the approval of the relevant departments. In the case of a major change, the change is forwarded to customers via Sales/ Marketing before implementation. Where specific agreements are in place, the change will not be implemented unless approved by the customer.

QUALITY AND RELIABILITY

ASSURANCE PROGRAM

Though both quality and reliability are designed into all Vishay products, three basic programs must assure them:

- Average Outgoing Quality (AOQ) - 100 % testing is followed by sample testing to measure the defect level of the shipped product. This defect level (AOQ) is measured in ppm (parts per million)
- Reliability qualification program - to assure that the design, process or change is reliable
- Reliability monitoring program - to measure and assure that there is no decrease in the reliability of the product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AOQ PROGRAM

Before leaving the factory, all products are sampled after 100 % testing to ensure that they meet a minimum quality level and to measure the level of defects. The results are accumulated and expressed in ppm (parts per million). They are the measure of the average number of potentially failed parts in deliveries over a period of time. The sample size used is determined by AQL or LTPD tables depending upon the product. No rejects are allowed in the sample.

The AOQ value is calculated monthly using the method defined in standard JEDEC 16:

$$AOQ = p \cdot LAR \cdot 10^6 (ppm)$$

where:

$$p = \frac{\text{number of devices rejected}}{\text{total number of devices tested}}$$

LAR = lot acceptance rate:

$$LAR = 1 - \frac{\text{number of lots rejected}}{\text{total number of lots tested}}$$

The AOQ values are recorded separately with regard to electrical and mechanical (visual) rejects by product type and package.

RELIABILITY AND QUALIFICATION

Qualification is used as a means of verifying that a new product or process meets specified reliability requirements. This is also used to verify and release changes to products or processes including new materials, packages, and manufacturing locations. At the same time it provides a means to obtain information on the performance and reliability of new products and technologies.

There are three types of qualification and release:

- Wafer process/technology qualification
- Package qualification
- Product/device qualification

The actual qualification procedure depends on which of these (or combinations of these) are to be qualified. Normally there are three categories of qualification in order of degree of qualification and testing required.

For the qualification there are two different standards. For Commodity and Industrial products the Vishay internal standard is used. For Automotive grade parts, the qualification is done according to AEC-Q101.

Accelerated testing is normally used in order to produce results fast. The stress level employed depends upon the failure mode investigated. The stress test is set so that the level used gives the maximum acceleration without introducing any new or untypical failure mode.

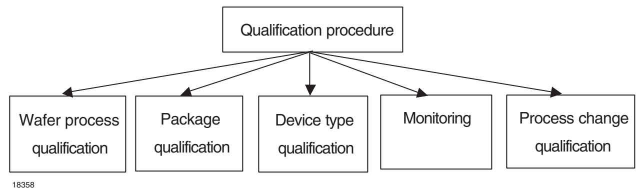
The tests used consist of a set of the following:

- High temperature life test (static)
- High temperature life test (dynamic)
- HTRB (high temperature reverse bias)
- Humidity 85/85 (with or without bias)
- Temperature cycling
- High-temperature storage
- Low-temperature storage
- Marking permanency
- Lead integrity
- Solderability
- Resistance to solder heat
- Mechanical shock (not plastic packages)
- Vibration (not plastic packages)
- ESD characterization

SMD devices only are subjected to preconditioning to simulate board assembly techniques using the methods defined in standard J-STD-020C before being subjected to stresses.

Normally, the endpoint tests are related to the datasheet or to specified parameters. Additionally, they may include:

- Destructive physical analysis
- X-ray
- Delamination testing using scanning acoustic microscope
- Thermal imaging
- Thermal and electrical resistance analysis



A summary of the reliability test results combined with process flows and technological data will be prepared when the device has passed the Vishay qualification tests. The summary is named QualPack.

For Automotive grade devices also additional information according to the PPAP requirements will be provided on request.

Example of the QualPack

RELIABILITY MONITORING AND WEAR OUT

The monitoring program consists of short-term monitoring to provide fast feedback on a regular basis in case of a reduction in reliability and to measure the Early-life Failure Rate (EFR). At the same time, Long-term monitoring is used to determinate the Long-term steady-state Failure Rate (LFR). The tests used are a subset from those used for qualification and consist of:

- Life tests
- Humidity tests
- Temperature-cycling tests

The actual tests used depend on the product tested.
Depending on the assembly volume a yearly monitoring and wear-out test plan is created.
Wear-out data is particularly important for optoelectronic devices.

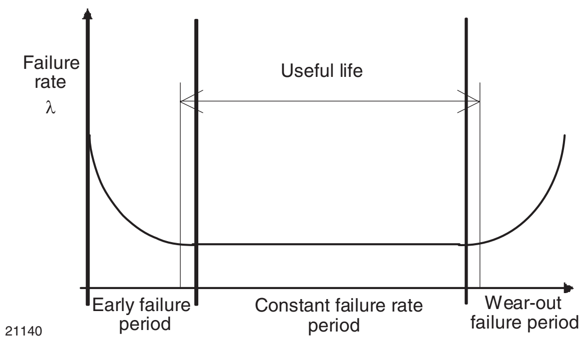


Fig. 4 - Bathtub Curve

The lifetime distribution curve is shown on figure 4. This curve is also known as the 'bath-tub curve' because of its shape. There are three basic sections:

- Early-life failures (infant mortality)
- Operating-life failures (random failures)
- Wear-out failures

Out of that data degradation curves can be made. These curves show the long time behavior of the different devices. Some typical curves are attached in this report.

RELIABILITY PRINCIPLES

Reliability is the probability that a part works operated, under specific conditions, performs properly for a given period of time.

$F(t) + R(t) = 1$ or $R(t) = 1 - F(t)$

where:

$R(t)$ = probability of survival

$F(t)$ = probability of failure

$F(t) = 1-e^{-\lambda t}$

where

λ = instantaneous failure rate

t = time

thus,

$R(t) = e^{-\lambda t}$

MTTF, MTBF

MTTF (mean time to failure) applies to parts that will be thrown away on failing. MTBF (mean time between failures) applies to parts or equipment that is going to be repaired. MTTF is the inverse failure rate.

$$MTTF = \frac{1}{\lambda}$$

So R(t) becomes to:

$$R_{(t)} = e^{-\lambda t} = e^{-\frac{t}{MTTF}}$$

After a certain time, t will be equal to MTTF, R(t) becomes:

$$R_{(t)} = e^{-1} = 0.37$$

If a large number of units are considered, only 37 % of their operation times will be longer than MTTF figure.

The failure rate (λ) during the constant (random) failure period is determined from life-test data. The failure rate is calculated from the formula:

$$\lambda = \frac{r}{\Sigma(fi \cdot ti) + (N \cdot t)} = \frac{r}{C}$$

where

λ = failure rate (h^{-1})

r = number of observed failures

f_i = failure number

t_i = time to defect

N = good sample size

t = entire operating time

C = number of components X h

The result is expressed in either

a) % per 1000 component hours by multiplying by 10^5

or in

b) FITs by multiplying by 10^9 (1 FIT = 10^{-9} h^{-1})

Example 1: Determination of failure rate λ
500 devices were operated over a period of 2000 h (t) with:
1 failure (f1) after 1000 h (t1)
The failure rate of the given example can be calculated as follows:

$$\lambda = \frac{1}{(1 \cdot 1000\ h) + 499 \cdot 2000\ h}$$

$$\lambda = 2 \cdot 10^{-6} h^{-1}$$

That means that this sample has an average failure rate of **0.1 %/1000 h or 1001 FIT**

Observed failure rates as measured above are for the specific lot of devices tested. If the predicted failure rate for the total population is required, statistical confidence factors have to be applied.

The confidence factors can be obtained from "chi square" (χ^2) charts. Normally, these charts show the value of ($\chi^2/2$) rather than χ^2. The failure rate is calculated by dividing the $\chi^2/2$ factor by the number of component hours.

$$\lambda_{pop} = \frac{(\chi^2/2)}{C}$$

The values for $\chi^2/2$ are given in table 1

TABLE 1 - $\chi^2/2$ CHART

NUMBER OF FAILURES	CONFIDENCE LEVEL	
	60 %	90 %
0	0.92	2.31
1	2.02	3.89
2	3.08	5.30
3	4.17	6.70
4	5.24	8.00
5	6.25	9.25
6	7.27	10.55

Example 2: The failure rate of the population
Using example 1 with a failure rate of 1001 FIT and 1 failure: $\chi^2/2$ at 60 % confidence is 2.02

$$\lambda_{pop} = \frac{2.02}{9.99 \cdot 10^5} = 2022\ \text{FIT}$$

This means that the failure rate of the population will not exceed 2022 FIT with a probability of 60 %.

- **Accelerated Stress Testing**

In order to be able to assure long operating life with a reasonable confidence, Vishay carries out accelerated testing on all its products. The normal accelerating factor is the temperature of operation. Most failure mechanisms of semiconductors are dependent upon temperature. This temperature dependence is best described by the Arrhenius equation.

$$\lambda_{T2} = \lambda_{T1} \times e^{\left[\frac{E_A}{k} \times \left(\frac{1}{T1} - \frac{1}{T2}\right)\right]}$$

where

k = Boltzmann's constant 8.63 x 10^{-5} eV/K
E_A = activation energy (eV)
T_1 = operation temperature (K)
T_2 = stress temperature (K)
λ_{T1} = operation failure rate
λ_{T2} = stress-test failure rate

Using this equation, it is possible from the stress test results to predict what would happen in use at the normal temperature of operation.

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ACTIVATION ENERGY

Provided the stress testing does not introduce a failure mode, which would not occur in practice, this method gives an acceptable method for predicting reliability using short test periods compared to the life of the device. It is necessary to know the activation energy of the failure mode occurring during the accelerated testing. This can be determined by experiment. In practice, it is unusual to find a failure or if there is, it is a random failure mode. For this reason an average activation energy is normally used for this calculation. Though activation energies can vary between 0.3 eV and 2.2 eV, under the conditions of use, activation energies of between 0.6 eV and 0.9 eV are used depending upon the technology.

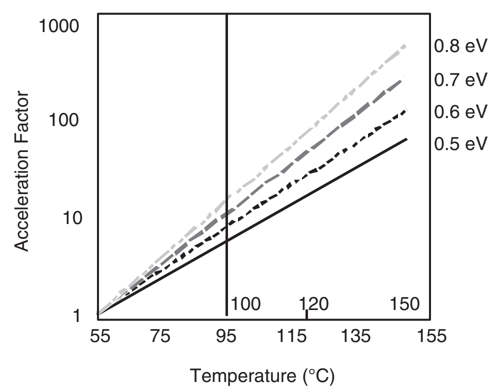

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Fig. 5 - Acceleration Factor for different Activation Energies Normalized to T = 55 °C

ACTIVATION ENERGIES FOR COMMON FAILURE MECHANISMS

The activation energies for some of the major semiconductor failure mechanisms are given in the table below. These are estimates taken from published literature.

TABLE 2 - ACTIVATION ENERGIES FOR COMMON FAILURE MECHANISM

FAILURE MECHANISM	ACTIVATION ENERGY
Mechanical wire shorts	0.3 to 0.4
Diffusion and bulk defects	0.3 to 0.4
Oxide defects	0.3 to 0.4
Top-to-bottom metal short	0.5
Electro migration	0.4 to 1.2
Electrolytic corrosion	0.8 to 1.0
Gold-aluminum intermetallics	0.8 to 2.0
Gold-aluminum bond degradation	1.0 to 2.2
Ionic contamination	1.02
Alloy pitting	1.77

Failure rates are quoted at an operating temperature of 55 °C and 60 % confidence using an activation energy (E_A) of 0.8 eV for optoelectronic devices.

Example 3: Conversion to 55 °C

In Example 2, the life test was out at 125 °C so to transform to an operating temperature of 55 °C.

T1 = 273 + 55 = 328K

T1 = 273 + 125 = 398K

Acceleration factor =

$$\frac{\lambda_{(T2)}}{\lambda_{(T1)}} = \frac{\lambda_{(423K)}}{\lambda_{(328K)}} = 144$$

thus

$$\lambda_{(328K)} = \frac{\lambda_{(423K)}}{144} = \frac{2022}{144}$$

= 14 **FIT**

(at 55 °C with a confidence of 60 %)

This figure can be re-calculated for any operating/junction temperature using this method.

- **EFR (Early Life Failure Rate)**

This is defined as the proportion of failures that will occur during the warranty period of the system for which they were designed. To standardize this period, Vishay uses 1000 operation hours as the reference period. This is the figure also used by the automotive industry; it equates to one year in the life of an automobile. In order to estimate this figure, Vishay normally operates a sample of devices for 48 h or 168 h under the accelerated conditions detailed above. The Arrhenius law is then used as before to calculate the failure rate at 55 °C with a confidence level of 60 %. This figure is multiplied by 1000 to give the failures in 1000 h and by 10^6 to give a failure in ppm. All EFR figures are quoted in ppm (parts per million).

The value of EFR and LFR is also depending on the amount of new products brought to market in the period. If a lot of new products are released the EFR and the LFR value can also be increased in that period due to increased rejects.

- **Climatic Tests Models**

Temperature cycling failure rate

The inverse power law is used to model fatigue failures of materials that are subjected to thermal cycling. For the purpose of accelerated testing, this model relationship is called Coffin-Manson relationship, and can be expressed as follows:

$$A_F = \left(\frac{\Delta T_{stress}}{\Delta T_{use}}\right)^M$$

where:

A_F = acceleration factor

ΔT_{use} = temp. range under normal operation

ΔT_{stress} = temp. range under stress operation

M = constant characteristic of the failure mechanism.

TABLE 3 - COFFIN - MANSON EXPONENT

FAILURE MECHANISM	M
Al wire bond failure	3.5
Intermetallic bond fracture	4.0
Au wire bond heel crack	5.1
Chip-out bond failure	7.1

For instance:

ΔT_{use} = 15 °C/60 °C = 45 °C

ΔT_{stress} = - 25 °C/100 °C = 125 °C

$$A_F = \left(\frac{125\ °C}{45\ °C}\right)^3 \approx 21$$

Relative Humidity failure rate

Moisture effect modeling is based upon the Howard-Pecht-Peck model using the acceleration factor of the equation shown below:

$$A_F = \left(\frac{RH_{stress}}{RH_{use}}\right)^C \cdot e^{\left[\frac{E_A}{k}\left(\frac{1}{T_{use}} - \frac{1}{T_{stress}}\right)\right]}$$

where:

RH_{stress} = relative humidity during test

RH_{use} = relative humidity during operation

T_{stress} = temperature during test

T_{use} = temperature during operation

E_A = activation energy

k = Boltzmann constant

C = material constant

For instance:

RH_{stress} = 85 %, RH_{use} = 92 %

T_{stress} = 85 °C, T_{use} = 40 °C

$$A_F = \left(\frac{85\ \%\ RH}{92\ \%\ RH}\right)^3 \times e^{\left[\frac{0.8}{8.617 \times 10^{-5}}\left(\frac{1}{313} - \frac{1}{358}\right)\right]}$$

$A_F \approx 33$

This example shows how to transform test conditions into environmental or into another test conditions. This equation is applicable for devices subjected to temperature humidity bias (THB) testing.
Using these acceleration factors the useful lifetime can be calculated. Applying the acceleration factor once more, useful lifetime for the moisture effect model for parts subjected to THB can be estimated by the following equation:

$$\text{Useful life}_{\text{Years}} = \frac{A_F \cdot \text{test hours}}{\text{hours per year}}$$

with:
test hours = 1000
hours per year = 8760
$A_F \approx 118$ (40 °C/60 % RH)

$$\text{Useful life}_{\text{Years}} = \frac{118 \cdot 1000}{8760} \approx 13.5 \text{ years}$$

This means that operation in 40 °C/60 % RH environment is good for around 13 years, calculated out of the 85 °C/85 % RH 1000 h humidity stress test.

- **Soldering**

All products are tested to ascertain their ability to withstand the industry standard soldering conditions after storage. In general, these conditions are as follows

- Wave soldering: double-wave soldering according to CECC 00802 s
- Reflow soldering: According to JEDEC STD 20C

Note: certain components may have limitations due to their construction

- **Dry pack**

When being stored, certain types of device packages can absorb moisture, which is released during the soldering operations, thus causing damage to the device. The so-called “popcorn” effect is such an example. To prevent this, Surface Mount Devices (SMD) are evaluated during qualification, using a test consisting of moisture followed by soldering simulation (pre-conditioning) and then subjected to various stress tests. In table 4 - Moisture Sensitivity Levels - the six different levels, the floor life conditions as well as the soak requirements belonging to these levels are described. Any device which is found to deteriorate under these conditions is packaged in “dry pack”.
The dry-packed devices are packed generally according to IPC JEDEC STD 33 “Handling, Packing, Shipping and use of Moisture/Reflow sensitive Surface Mount Devices”, IPC-SM-786 “Recommended Procedures for Handling of Moisture Sensitive Plastic IC Packages”.

Following some general recommend dations:

- Shelf life in the packaging at < 40 °C and 90 % RH is 12 months
- After opening, the devices should be handled according to the specifications mentioned on the dry-pack label
- If the exposure or storage time is exceeded, the devices should be baked:
  - Low-temperature baking - 192 h at 40 °C and 5 % RH
  - High-temperature baking - 24 h at 125 °C

TABLE 4 - MOISTURE SENSITIVITY LEVELS

	FLOOR LIFE		SOAK REQUIREMENTS			
LEVEL	CONDITIONS	TIME	TIME (h)			CONDITIONS
1	≤ 30 °C/90 % RH	Unlimited	168			85 °C/85% RH
2	≤ 30 °C/60 % RH	1 year	168			85 °C/60% RH
2a	≤ 30 °C/60 % RH	4 weeks	696			30 °C/60% RH
			X	Y	Z	
3	≤ 30 °C/60 % RH	168 h	24	168	192	30 °C/60% RH
4	≤ 30 °C/60 % RH	72 h	24	72	96	30 °C/60% RH
5	≤ 30 °C/60 % RH	48 h	24	48	72	30 °C/60% RH
5a	≤ 30 °C/60 % RH	24 h	24	24	48	30 °C/60% RH
6	≤ 30 °C/60 % RH	6 h	0	6	6	30 °C/60% RH

X = Default value of semiconductor manufacturer’s exposure time (MET) between bake and bag plus the maximum time allowed out of the bag at the distributor’s facility. The actual times may be used rather than the default times, but they must be used if they exceed the default times.

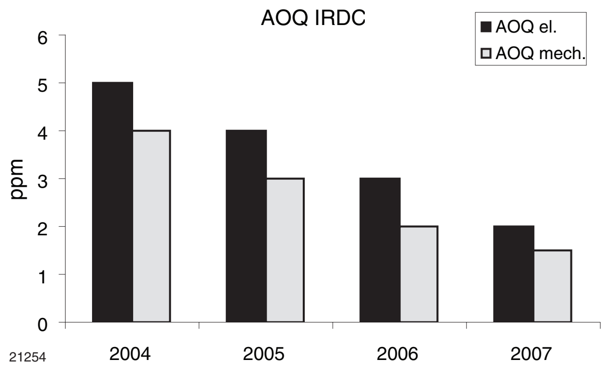
Y = Floor life of package after it is removed from dry pack bag.

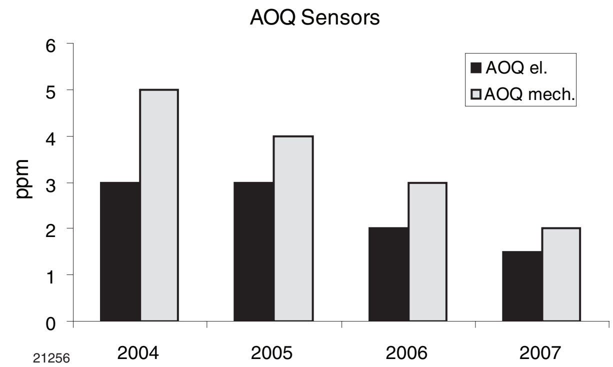
Z = Total soak time for evaluation (X + Y).

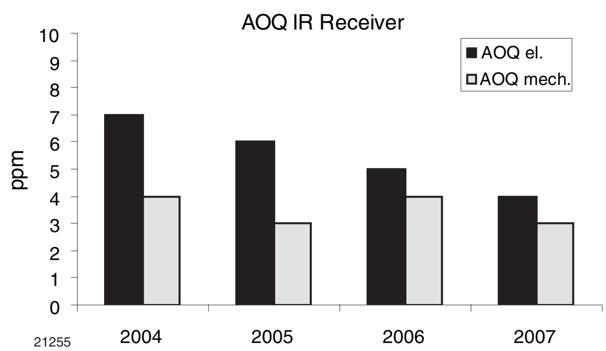
Note: There are two possible floor lives and soak times in level 5. The correct floor life will be determined by the manufacturer and will be noted on the dry pack bag label per JEP 113. “Symbol and Labels for Moisture Sensitive Devices”.

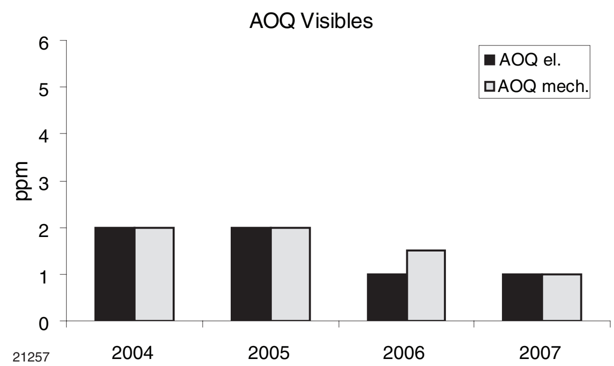
QUALITIY AND RELIABILITY DATA

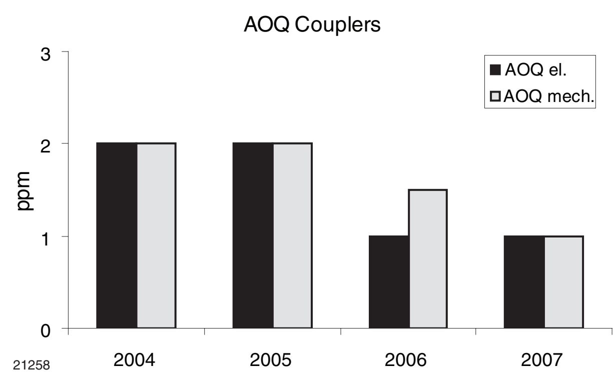
Average Outgoing Quality (AOQ)



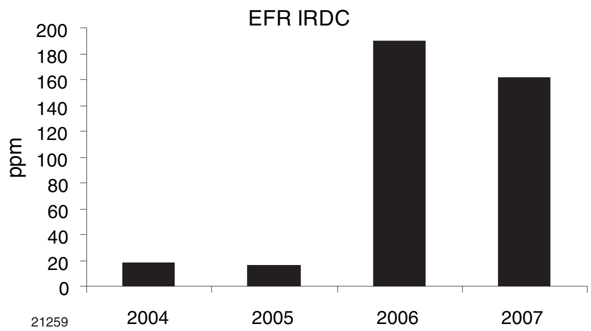






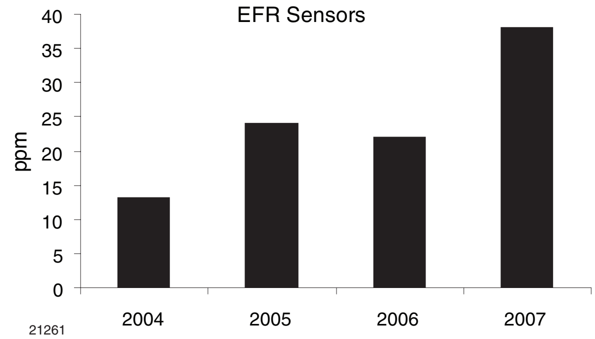


Early Failure Rate (EFR)



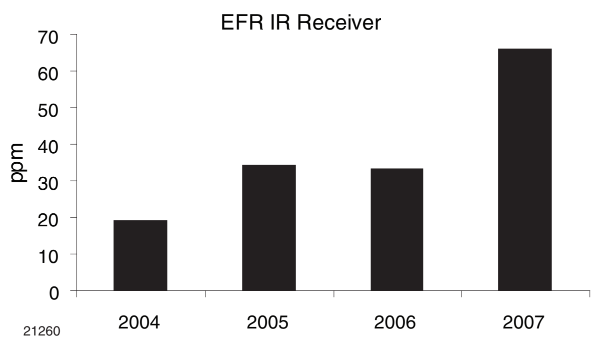
21259

Increase of EFR due to functional rejects in 2006 due to ramp up of new products



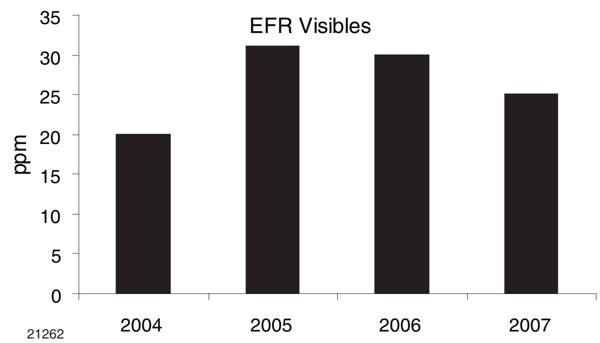
21261

Increase of EFR only due to lower amount of samples, old results were cutted off. No additional rejects in 2007

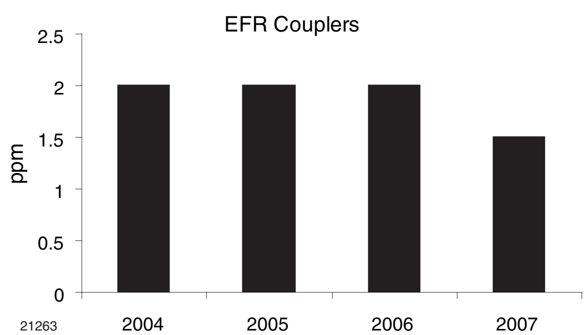


21260

Increase of EFR only due to lower amount of samples, old results were cutted off. No additional rejects in 2007

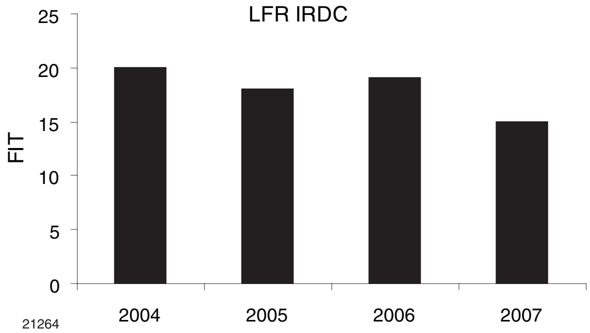


21262

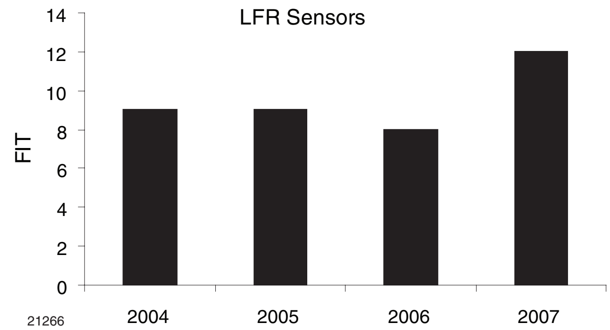


21263

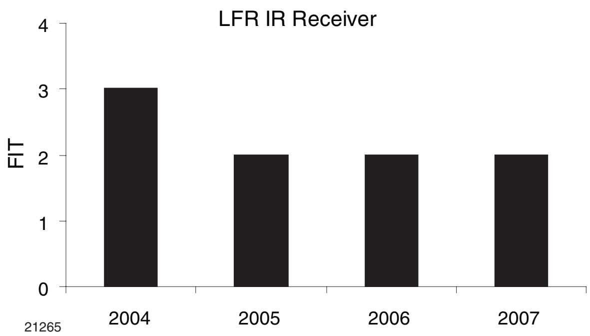
Latent Failure Rate (LFR)



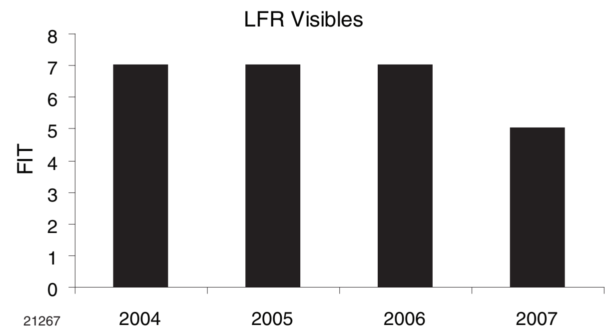
21264



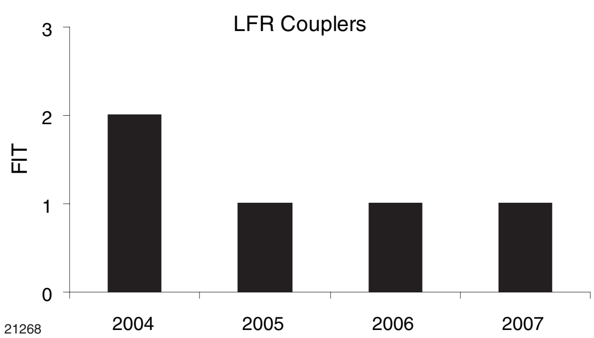
21266



21265



21267



21268