

**Reliability Address of World Major Company**

**Jun. 23, 2005**

**Global CS Team**

**Written by : J.H. Lim  
Approved by: D.S. Ryu**

## Bench Mark Vehicle Engine / Sealed Comp

*Just do it right from the first!*

	Vehicle Engine	Sealed Compressor
Structure	Disassemble	Not Disassemble
Guaranty Duration	5 years, 10,000Km	10 years
Expectation Life	11.1 years	14.7 years
Maintenance	Changing Oil	None
Operating	Idle Term	Idle Time
Limitation	Energy Efficiency	Energy Efficiency
	Noise	Noise

## ❑ Historical reliability Disaster

*Just do it right from the first!*

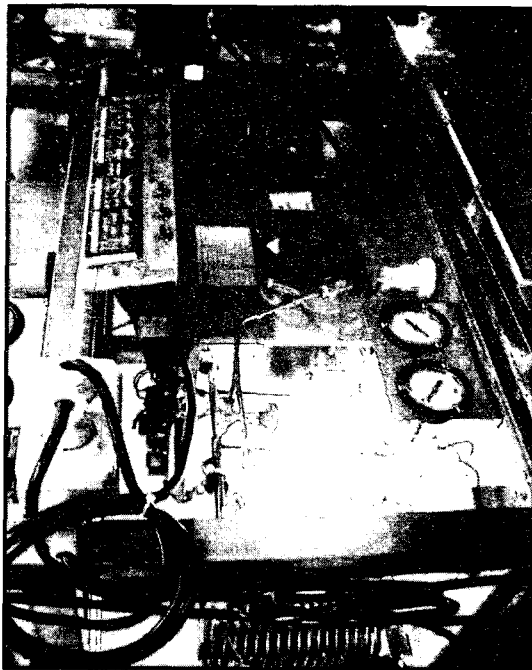
	<b>G Company (USA)</b>	<b>M Company (Japan)</b>
Product	House Hold Refrigerator	
Unit	Rotary Comp (Sealed Refrigerant Compressor)	
Production Date	1986.3	1985.1
Issued date	1987.7	1991.10
Failed Cost	450 Million \$	560 Million \$
Failed Amount	1.1 Million	1 Million
Failure Sight	Abnormal Wear Out (Sintered Iron)	Wear Out (Lubrication at High Temp)
	Oil Reaction	Oil Reaction
	Sludge Imbedding	Sludge Imbedding
User Environment	Worst Case	Worst Case
After Disaster	Withdraw Comp BIZ	Lock Out factory

# □ Re Established Reliability Test Procedure

Just do it right from the first!

- Reliability : High Temp Life Test ( Time to Tendency )
- Manufacturing : Process Capability

	Reliability Test	Sample Size	Test Duration	Evaluation & CTQ' s
Unit Level	High temp life test	9	16 weeks(43°C)	- Capillary tube Impurity
System level	Worst case cabinet long life test	9	12 months(43°C)	- Wear Out - Chemical Reaction



Unit Level : High temp life test

## V. Historical list of failure, evaluation and field problems

<<Compressor>>

The failure of rotary compressor occurred in 1987 could be avoided if the compressor were verified by the accelerated life cycle , such as high temperature life test

<<Defrost>>

1. The TCF-19 parallel reverse cycle defrost evaporator (one single evaporator box with coils for fresh food and freezer with a separate fan and control in fresh food and freezer) had insufficient interchange of heat when liquid was returned to compressor case sump instead of directly onto motor end of pump. Gave low watts and insufficient defrost in fixed time period used, especially low ambient.

2. Ice in evaporator housing of TBF-15 prevented complete defrost and drain hole froze over. This happened in 1968

# □ Bench Mark of Reliability Methodologies

*Just do it right from the first!*

	G Company		M Company	
	Duration	Sample	Duration	Sample
Discharge= 15.2 kgf/cm <sup>2</sup>	672 hrs	3	500 hrs	10
Suction = 0.0 kgf/cm <sup>2</sup>	1,344 hrs	3	1,670 hrs	5
Winding Temp : 135 °C	2,688 hrs	3	2,000 hrs	15
Pull Down Operation				

	G,M Companies		SAMSUNG
Reliability Test	High Temp Life Test		ALT
Reliability Baseline	Past Experience		Novel Concept for Reliability
Sample Size	Determined		Depend on AF, Target FCR
AF	Determined		Variable ( Design, Usage Condition)
Test Duration	Determined		Depend on AF, Sample Size
Test procedure	Pull Down		Duty Cycle
Delivery	16 weeks		Max. 4 Weeks
Test Results	Time to CTQ' s		B <sub>1</sub> Life
			Life Cycles
			FCR & Weak Point
Engineer Activity	Test Procedure		Study

Freedom from Deficiencies & Dissatisfaction

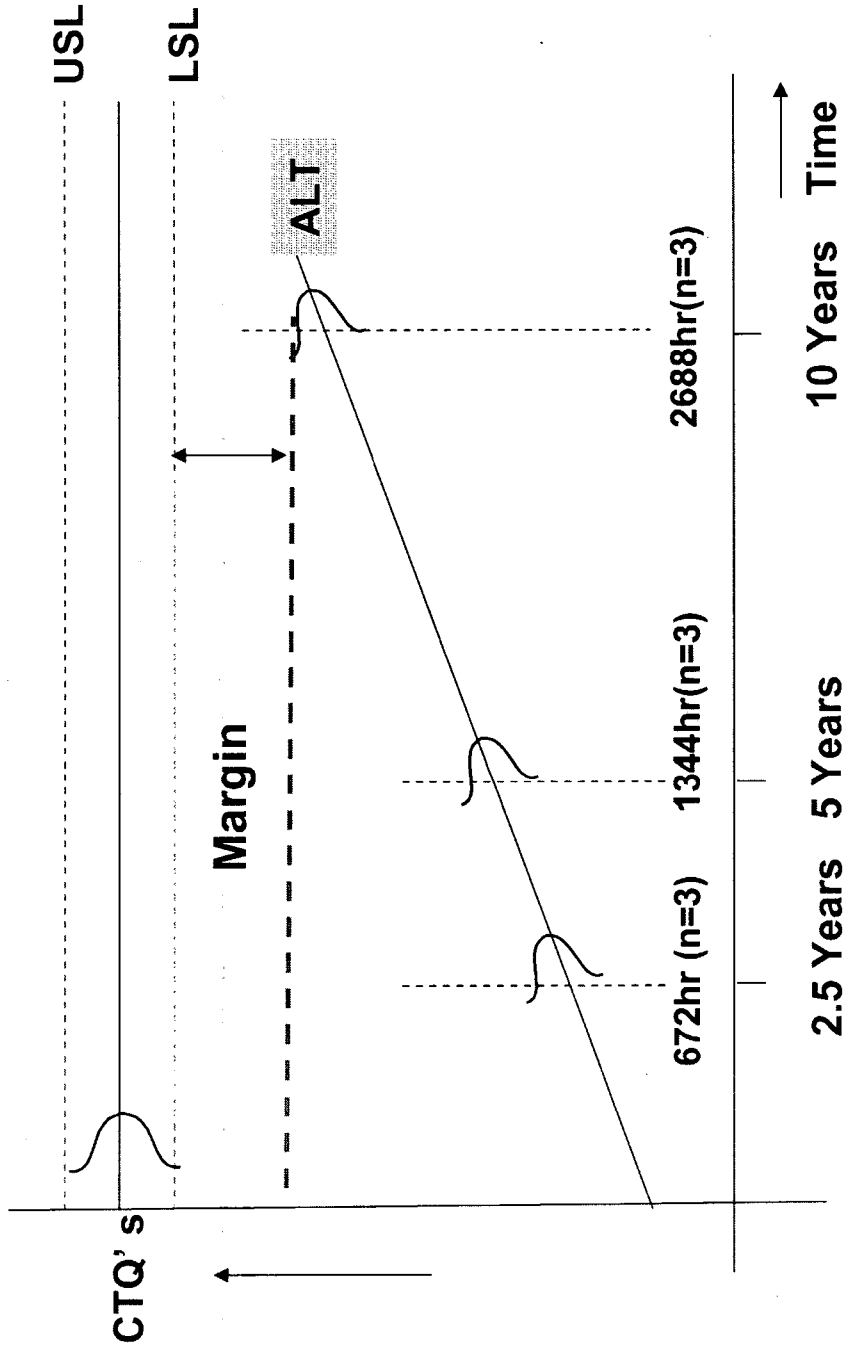
5

Customer Satisfaction by Useful Features!

# □ What is Time to Tendency ?

*Just do it right from the first!*

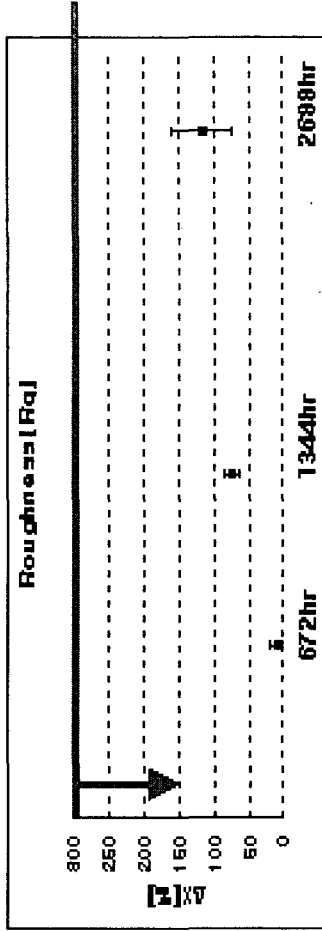
## CTQ's Comparison Test depend on Elapsed Time



Just do it right from the first!

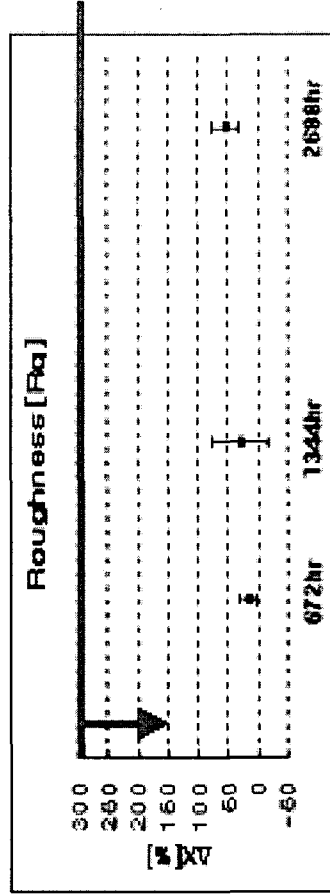
### ex) Compressor parts wear out [Piston]

Rq	672hr	1344hr	2688hr
#1	18.2	66.7	83.3
#2	0	87.5	100
#3	9.1	70.6	166.7
Average	9.1	74.9	116.6
Stan Dev	9.1	11.0	44.1



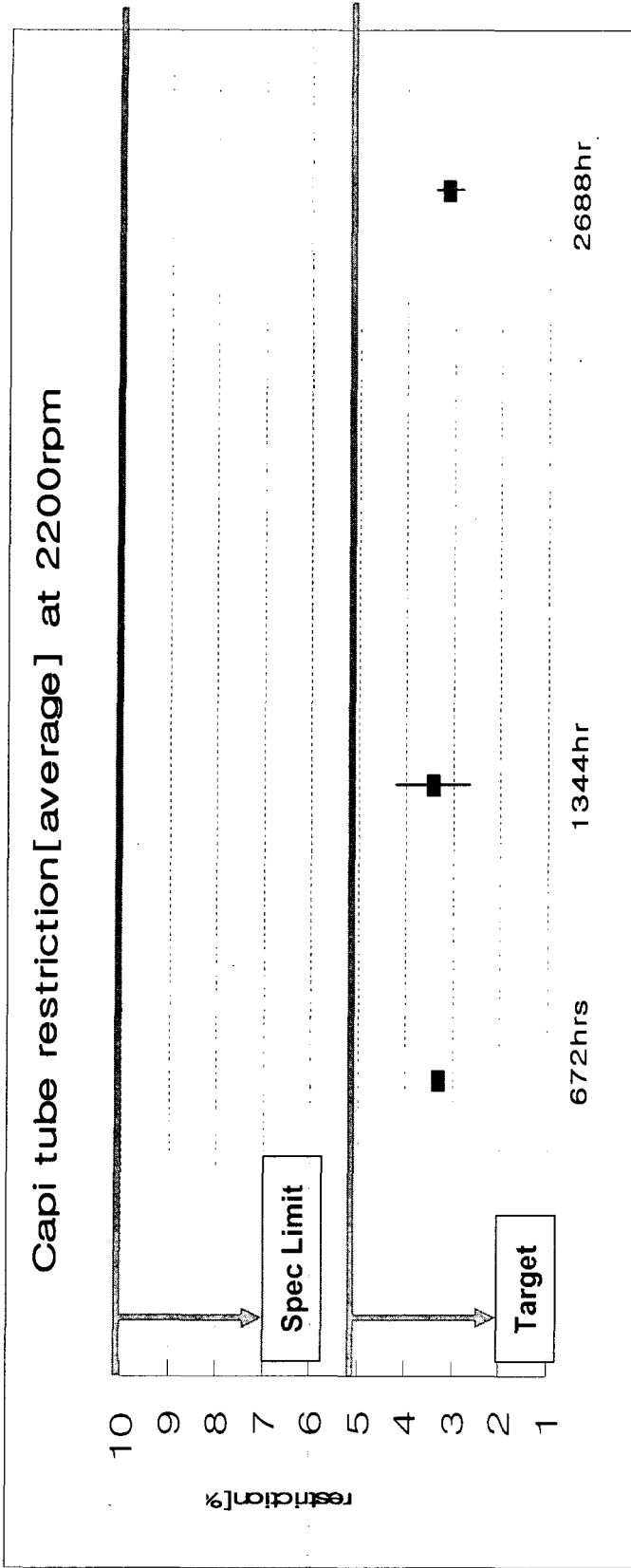
### ex) Compressor parts wear out [Cylinder Block]

Rq	672hr	1344hr	2688hr
#1	0	0	66.7
#2	25.0	0	66.7
#3	20.0	80.0	25.0
Average	15.0	26.6	52.8
Stan Dev	13.2	46.1	24.0



Just do it right from the first!

### ex) N2 Gas Flow rate of Capillary tube



	Before	After	%
#1	6.87	6.64	3.35
#2	6.85	6.62	3.36
#3	6.87	6.65	3.20
AVG	-	-	3.30
STD	-	-	0.09

	Before	After	%
#1	6.92	6.62	4.33
#2	6.91	6.71	2.89
#3	6.89	6.68	3.04
AVG	-	-	3.42
STD	-	-	0.79





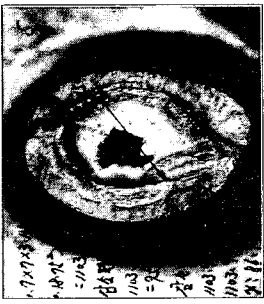
	Before	After	%
#1	6.89	6.66	3.34
#2	6.84	6.62	3.22
#3	6.84	6.65	2.78
AVG	-	-	3.11
STD	-	-	0.29



Just do it right from the first!

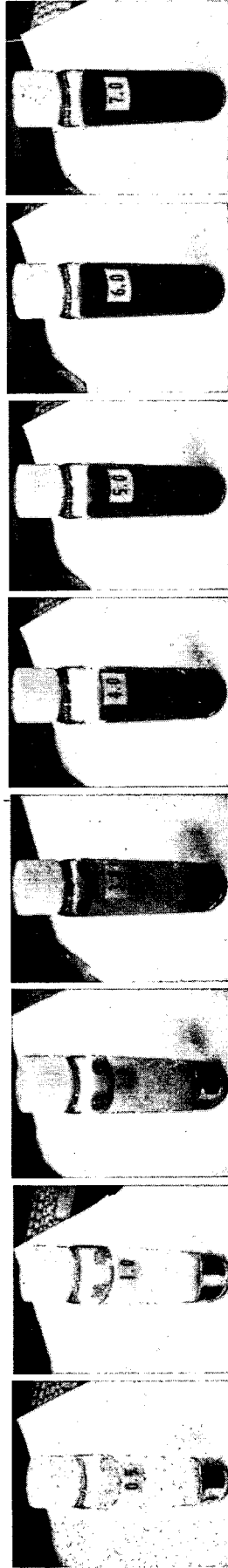
### ex) Capillary Tube Cut Test

- Naked Eye Test ( Sludge Imbedding Rate)

1 Class	2 Class	3 Class	4 Class	5 Class
				

### ex) Oil Reaction

- Naked Eye Test & Chemical Analysis



Freedom from Deficiencies & Dissatisfaction

Customer Satisfaction by Useful Features!

# □ Reliability Design for Compressor by Novel Concept

Just do it right from the first!

## 1. Operating Environment

	Environment Condition		
	Temperature	Humidity	Vibration
Compressor	- 4 ~ 50 °C	0 ~ 90 %	0.2 ~ 0.24g

## 2. Operating Cycles

	1 Day			10 Years		
	Normal	Worst		Normal	Worst	
Compressor	10	24		36,500	87,600	

## 3. ALT Design

$$n \geq (r + 1) \cdot \frac{1}{x} \cdot \left( \frac{L_B}{AF \cdot h} \right)^\beta = 2 \cdot \frac{1}{0.01} \cdot \left( \frac{87,600}{13.19 \times 12,600} \right)^{4.7} \approx 10$$

- Product Mission Cycles  $L_B$ : 24 Cycles / day × 365 × 10 Years = 87,600 Cycles
- ALT Mission Cycles  $h$  = 12,600 Cycles
- $AF = 13.9$ ,  $\beta = 4.67$

Target 

87,600 Cycles

This ALT is designed to guarantee B1 life with Confidence Level 60% if the failure mode happens less than 1EA in ALT Mission Cycles

## ALT Design details

### 1. Define Product Operating Condition

(R600a :95gr, n=2)

Pressure & Temperature	Product Operating Condition			
	Unit	RT 32	RT 38	RT 43
Discharge Pressure	kgf/cm <sup>2</sup>	7.6	(9.3)	10.9
Dome Temp	°C	74	(82)	90

### 2. AF Design- 3 Parameters

ALT Baseline

Operation Block Diagram	ALT Level Design			Pulldown	
	Level 1	Level 2	Level 3		
Duty Operating 	Discharge Pressure, kgf/cm <sup>2</sup>	10.9	15	20	
	Comp. dome, °C	90	100	120	
	AF	1	3.2	13.9	
	Sample Size	5	5	10	10

**AF of Three Level ALT**

	Product	ALT Design		
		Level 1	Level 2	Level 3
Discharge Pressure( kgf/cm <sup>2</sup> )	7.6	10.9	15	20
Dome Temp ( °C )	74	90	100	120
B <sub>1</sub> Life (Cycle/Day)	664,400/4,640	142,000/990	46,300/323	10,740/75
Life Rate	1/ 4.69	1	3.06	13.19

$$AF = \left( \frac{P}{P_0} \right)^n \cdot \exp \left( \frac{Ea}{8.617 \times 10^{-5}} \right) \cdot \left( \frac{1}{T_0} - \frac{1}{T} \right)$$

$$\frac{\text{Level 2}}{\text{Level 1}} : 3.06 = \left(\frac{15}{109}\right)^n \cdot \exp\left(\frac{Ea}{8.617 \times 10^5}\right) \cdot \left(\frac{1}{273+90} - \frac{1}{273+100}\right)$$

$$\frac{\text{Level 3}}{\text{Level 1}} : 13.19 = \left(\frac{20}{109}\right)^n \cdot \exp\left(\frac{Ea}{8.617 \times 10^5}\right) \cdot \left(\frac{1}{273+90} - \frac{1}{273+120}\right)$$

$$\ln(3.06) = n \cdot \ln(1.376) + Ea \cdot 0.8568$$

$$1.1184 = n \cdot 0.3192 + Ea \cdot 0.8568 \quad \dots \dots \dots (1)$$

$$\ln(13.19) = n \cdot \ln(1.8349) + Ea \cdot 2.4396$$

$$2.5795 = n \cdot 0.6069 + Ea \cdot 2.4396 \quad \dots \dots \dots (2)$$

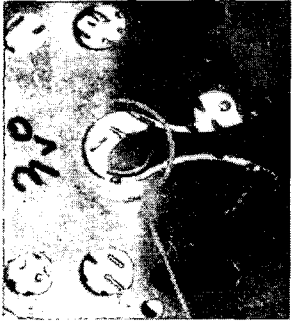
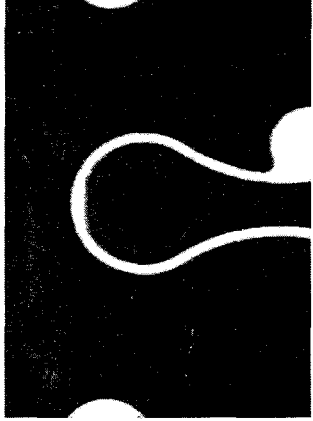
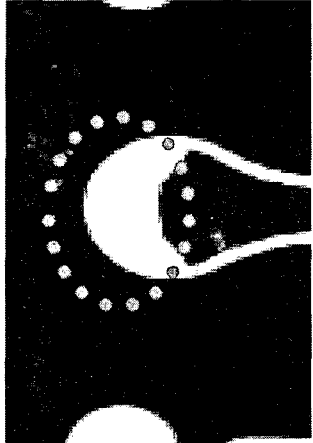




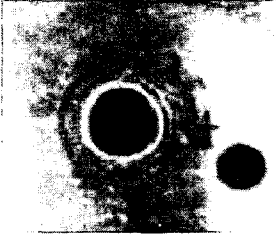


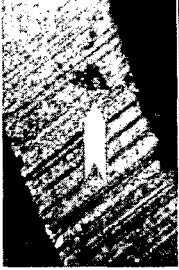
$$Ea = 0.5592, \quad n = 2.003 \quad \text{by (1).(2)}$$

$$\therefore AF = \left(\frac{P}{P_0}\right)^2 \cdot \exp\left(\frac{0.56}{8.617 \times 10^5}\right) \cdot \left(\frac{1}{T_0} - \frac{1}{T}\right)$$


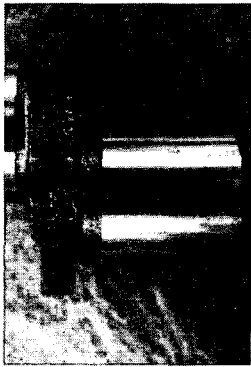


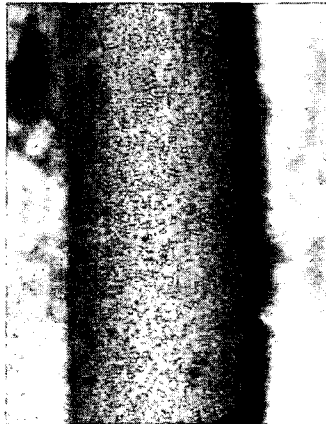
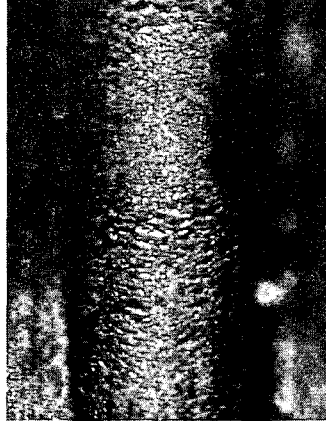
# □ Bench Test on Reliability Methodologies

*Just do it right from the first!*

## 1. Reproducing Capability on Market failure

Market failure Mode	High temp Life Test (G,M Company)	Nobel Concept ALT (SAMSUNG)
		
 	 	   

*Just do it right from the first!*

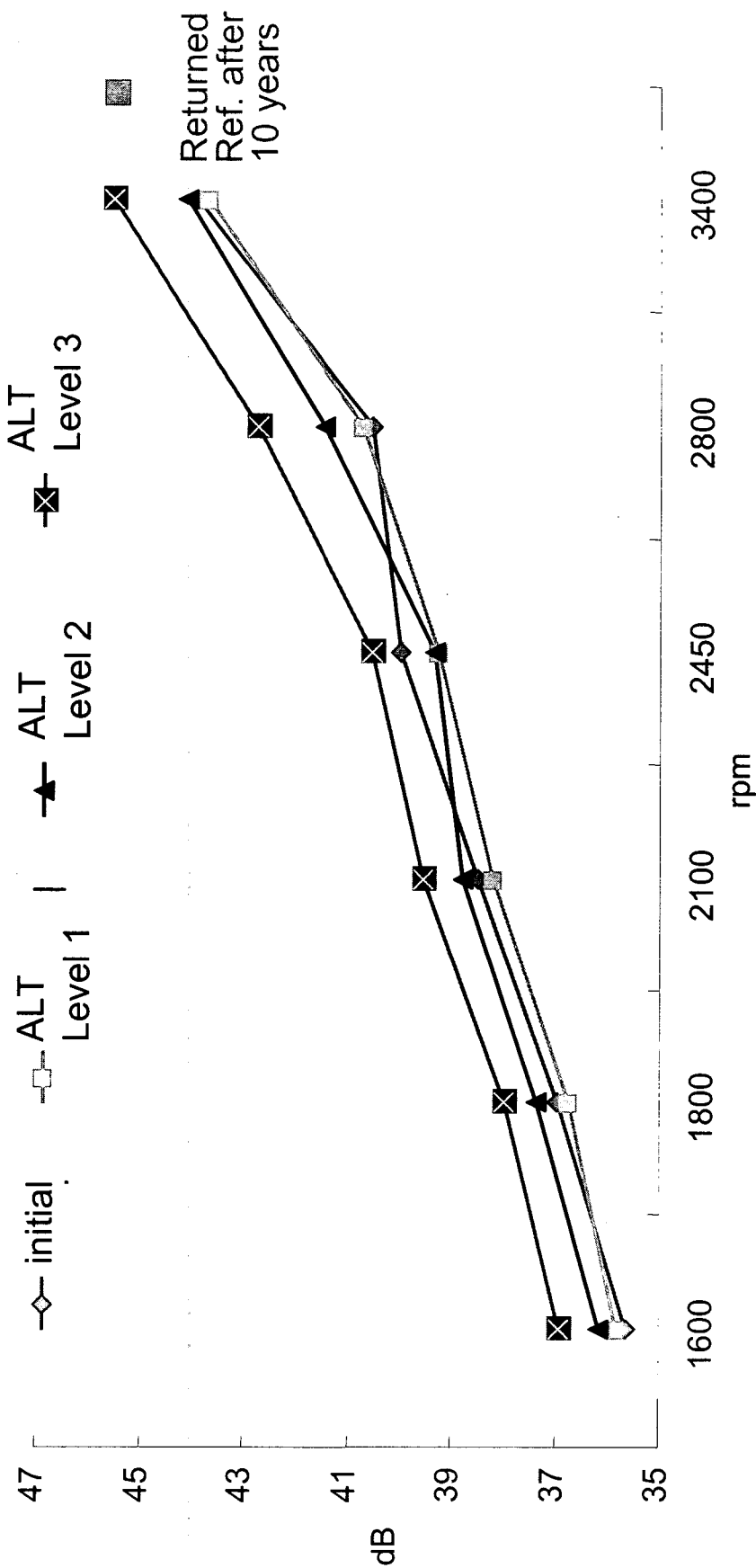
Market Failure Mode	High temp Life Test	Nobel Concept ALT
		
		

*Freedom from Deficiencies & Dissatisfaction*

*Customer Satisfaction by Useful Features!*

Just do it right from the first!



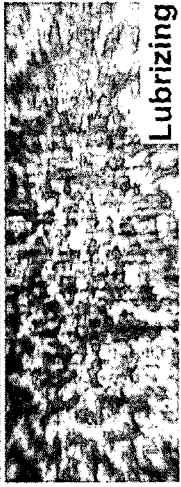

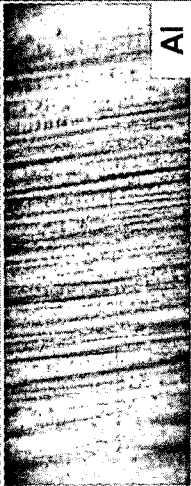

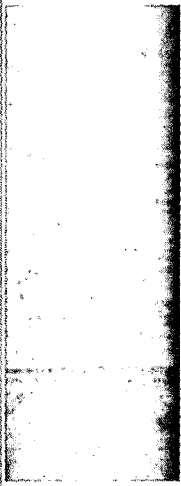
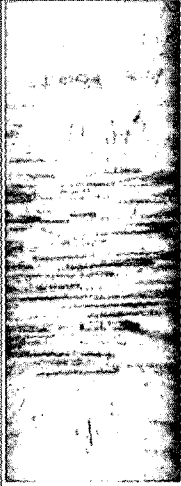


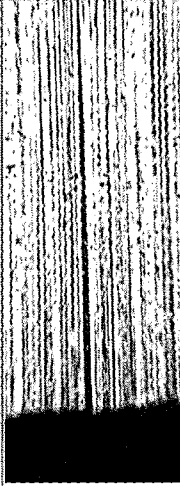


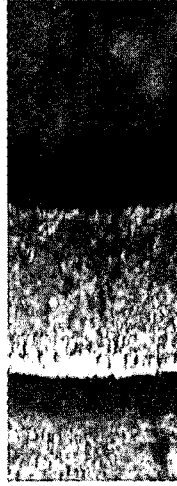

## 2. Time to Tendency (Noise) – ALT Level 3 most close to Market 10 years





Just do it right from the first!

### 3. Time to Tendency (Wearout)--- ALT Level 3 most close to Market 10 years

	ALT Level 3	Market 10 Years	Set life test
Shaft BRG	 Lubrizing	 열처리	 Lubrizing
Con Rod	 신질	 AI	 신질
Pin			
Piston	 Lubrizing		 Lubrizing
Plate			

Freedom from Deficiencies & Dissatisfaction

Customer Satisfaction by Useful Features!

*Just do it right from the first!*

## **Best Practice of ALT**

# ❑ What is deferent ?

*Just do it right from the first!*

## << Summarize on High Temp Life Test of G, M Company >>

G Company			M Company		
Pressure	Duration	Sample	Pressure	Duration	Sample
Discharge=14.9 kgf/cm <sup>2</sup> Suction =0 kgf/cm <sup>2</sup> Winding Temp :135 °C Pull down	672 hrs	3	Discharge=14.9 kgf/cm <sup>2</sup> Suction =0.1 kgf/cm <sup>2</sup> Winding Temp:135 °C Pull Down	500 hrs	10
	1,344 hrs	3		1,670 hrs	5
	2,688 hrs	3		2,000 hrs	15

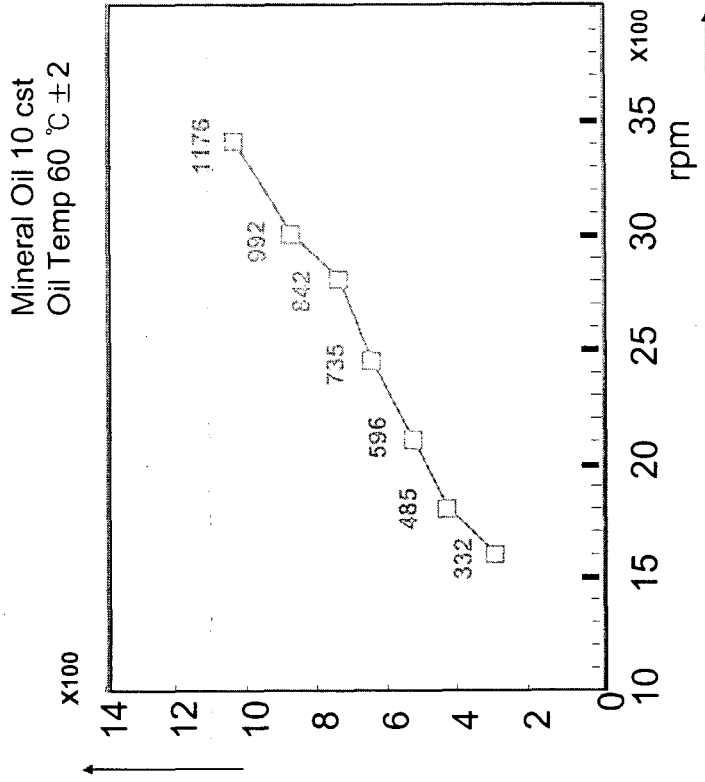
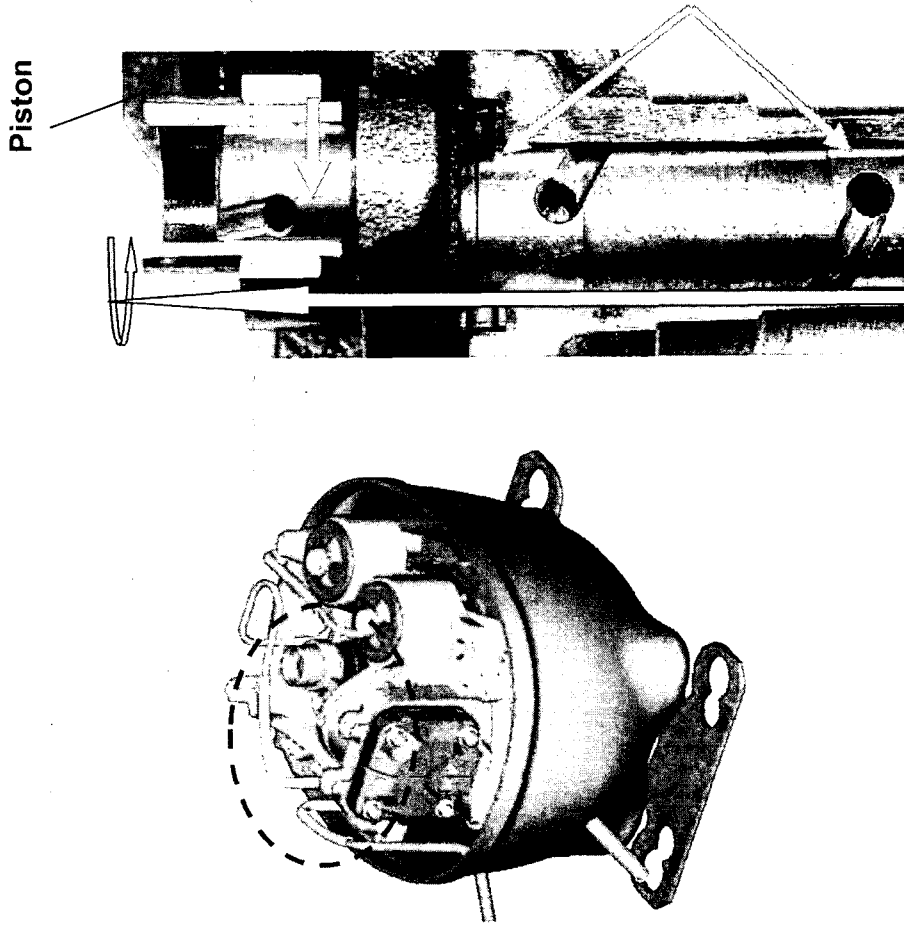
- Fixed Discharge pressure
- Pull down operation without Duty

## 1. Fixed Discharge pressure can't response various characteristic of refrigerants

Condensing Temp	R12	R134a	R600a
53.4 °C	14.5 kgf/cm <sup>2</sup>	13.2 kgf/cm <sup>2</sup>	7.74 kgf/cm <sup>2</sup>

*Just do it right from the first!*

## 2. Pulldown operation is improper to sure lubrication trouble as compressor starting repeat frequently in life cycle



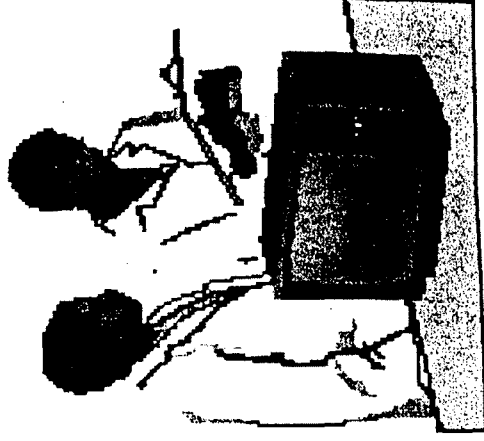
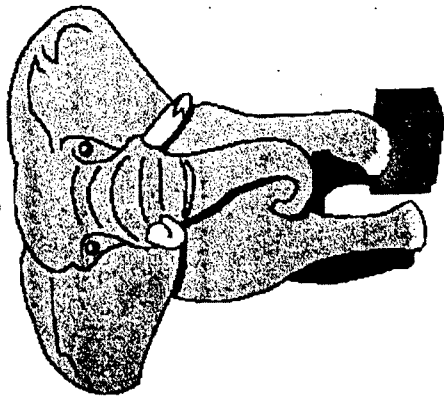
## □ Conclusions

*Just do it right from the first!*

### Novel Concept for Reliability

- Having proper ALT can ....
- Estimate life distribution of the product in a shorter time & small sample size.
- Predict Failure Call Rate under warranty duration.
- Easily compare & optimize on design.
- Decrease the total time and cost required to obtain reliability information
- Get not only reliability information of product but also variation of manufacturing procedure, that of materials and design.

### Past Experience



**Over Stress Test (Qualitative) ≠ Accelerated Life Test (Quantitative)**

*Freedom from Deficiencies & Dissatisfaction*

21

*Customer Satisfaction by Useful Features!*

## Benefit for Viewers

*Just do it right from the first!*

## Reliability Approach

*Freedom from Deficiencies & Dissatisfaction*

22

*Customer Satisfaction by Useful Features!*