

# COPY

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Group 7

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Theme: Identifying Deterioration due to Aging of Breaker Mechanisms,  
and Design of Accelerated Test Methods

### Reasons for Theme Selection

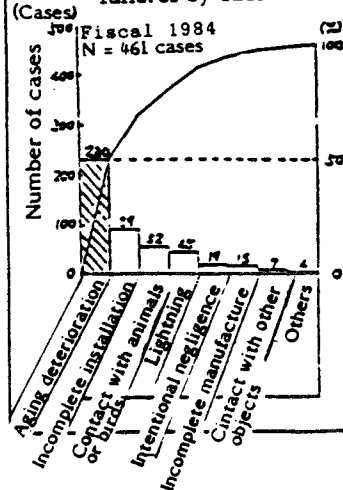
Division Manager's Policy,  
Fiscal 1985

Aim: Enhanced level of  
supply reliability

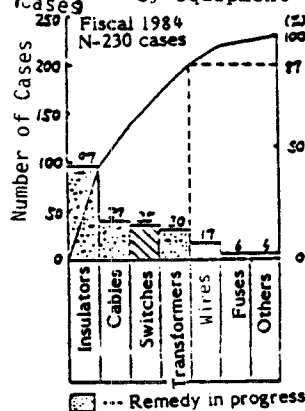
Priority action item:  
Reduction in power  
failures

Principal approach:  
Implementation of  
measures aimed at  
reducing failures resulting  
from improperly  
maintained facilities

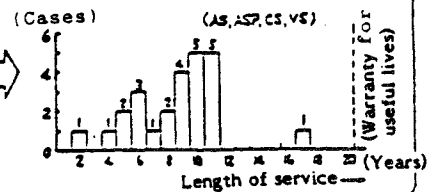
### Pareto diagram of equipment failures by causes



### Pareto Diagram of failures caused by aging deterioration by equipment

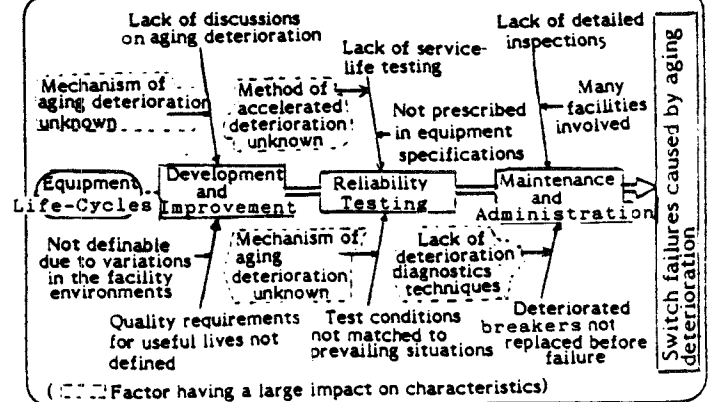


### Length of service of Breaker Mechanisms that failed due to aging deterioration



Breaker mechanism failures,  
most of which have occurred within  
their useful lives  
(20 years).

Investigations were made into  
the reasons why breaker mechanism  
failures due to aging deterioration  
could not be prevented.

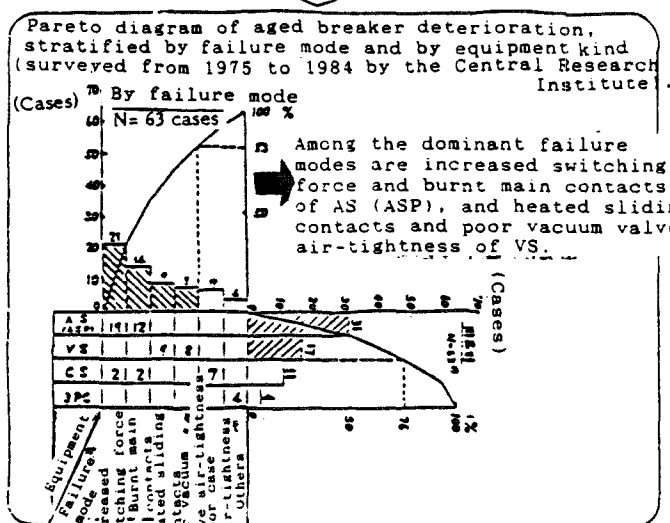


| Aim                                                                                                                                               | Theme                                                                                                |
|---------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|
| To find a method of preventing failures in age-deteriorated breaker mechanisms during equipment development, improvement, and reliability testing | Identifying deterioration due to aging of breaker mechanisms, and design of accelerated test methods |

## 2. Understanding and Designing an Activity Schedule for Current Situation

No 2

In order to understand the detailed failure modes of breaker mechanisms deteriorated by aging, failure modes were extracted from finding of the detailed surveys conducted at the Central Research Institute for last 10 years.



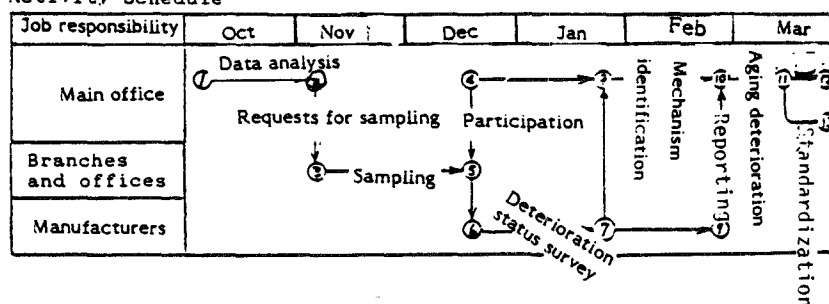
Identify the mechanisms of increased switching force and burnt main contacts of AS (ASP)

The mechanisms of heated sliding contacts valve air-tightness of VS have already been identified.

To No. 6

Effect verification

### Activity Schedule



### Goals

Identify the mechanisms of increased switching force and burnt main contacts of AS (ASP) and VS accelerated deterioration test procedures

## 3. Analysis

### (1) Determination of the number of samples required

Determine the number of samples required on the bases of the switching force, which is the characteristic (see No.3, #2) most closely related to the mechanisms of increased switching force and burnt main contacts of AS (ASP).

Suppose a population with a size of N and n samples. If the mean of operating force is  $\bar{x}$  and its variance is  $\sigma^2$ , then the following expression is derived:

$$\sigma_{\bar{x}}^2 = \frac{N-n}{N-1} \cdot \frac{\sigma^2}{n}$$

To make a relative error of 5% in the 95% confidence interval of  $\bar{x}$ , if 1.96 is equal to 0.05 times  $\bar{x}$ , the relationship is represented as follows:

$$\frac{N-n}{N-1} \cdot \frac{\sigma^2}{n} = \left( \frac{0.05 \bar{x}}{1.96} \right)^2$$

The value of n can then be calculated;

$$n = \frac{N}{1 + \left( \frac{0.05 \bar{x}}{1.96} \right)^2 \cdot \frac{N-1}{\sigma^2}}$$

|         | (AS)                                                      |                                                         | (ASP)                                                  |                                                          |
|---------|-----------------------------------------------------------|---------------------------------------------------------|--------------------------------------------------------|----------------------------------------------------------|
|         | Activating force                                          | Releasing force                                         | Activating force                                       | Releasing force                                          |
| Pretest | n = 10<br>$\bar{X} = 33.37$<br>$S = 28.56$<br>$V = 814.0$ | n = 10<br>$\bar{X} = 13.81$<br>$S = 27.61$<br>$V = 207$ | n = 6<br>$\bar{X} = 26.57$<br>$S = 44.97$<br>$V = 939$ | n = 6<br>$\bar{X} = 27.73$<br>$S = 223.73$<br>$V = 6475$ |

Calculate the number of samples based on the data with a larger variance.

|             | (AS)                                                                                                                                         | (ASP)                                                                                                                                    |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| Calculation | $n = \frac{100 \cdot 399}{1 + \left( \frac{0.05 \cdot 33.37}{1.96} \right)^2 \cdot \frac{100-1}{814.0}} = 48.2 \rightarrow 49 \text{ units}$ | $n = \frac{60 \cdot 557}{1 + \left( \frac{0.05 \cdot 26.57}{1.96} \right)^2 \cdot \frac{60-1}{939}} = 43.1 \rightarrow 44 \text{ units}$ |

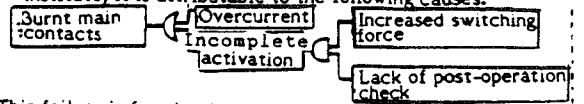
The number of samples required is thus calculated to be 49 units of AS and 44 units for ASP.

(2) Study Survey

| Item | Number of units surveyed | Number of units with outstanding symptoms |                        |
|------|--------------------------|-------------------------------------------|------------------------|
|      |                          | #1 Increased switching force              | #3 Burnt main contacts |
| AS   | 46                       | 40                                        | 0                      |
| ASP  | 44                       | 28                                        | 0                      |

\*1 Though original plans called for the 49 AS samples to be divided into seven groups according to their year of manufacture from those units removed from the field, only three units could be extracted from those of pre-1966 manufacture.

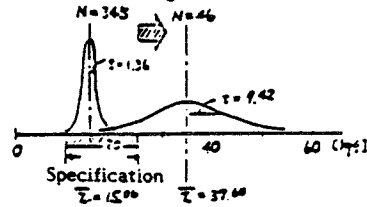
- \*2 In excess of the upper limit of the switching force, prescribed in the equipment specifications.
- \*3 None of the present samples surveyed had this failure, but according to the data available at the Central Research Institute, it is attributable to the following causes:



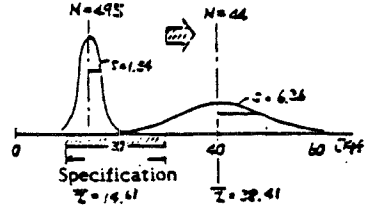
This failure is found to have occurred in the path shown in boldface above. Hence, the mechanism of burnt main contacts could be determined by identifying the cause of increased switching force.

Trends towards increased switching force.

[AS] New units Aged units



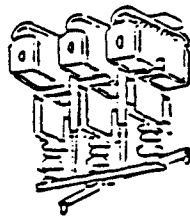
[ASP] New units Aged units



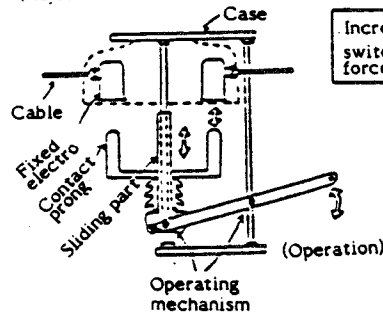
The average switching force required and the standard deviation increase with the length of service.

Causes of increased switching force were extracted for an FT analysis diagram.

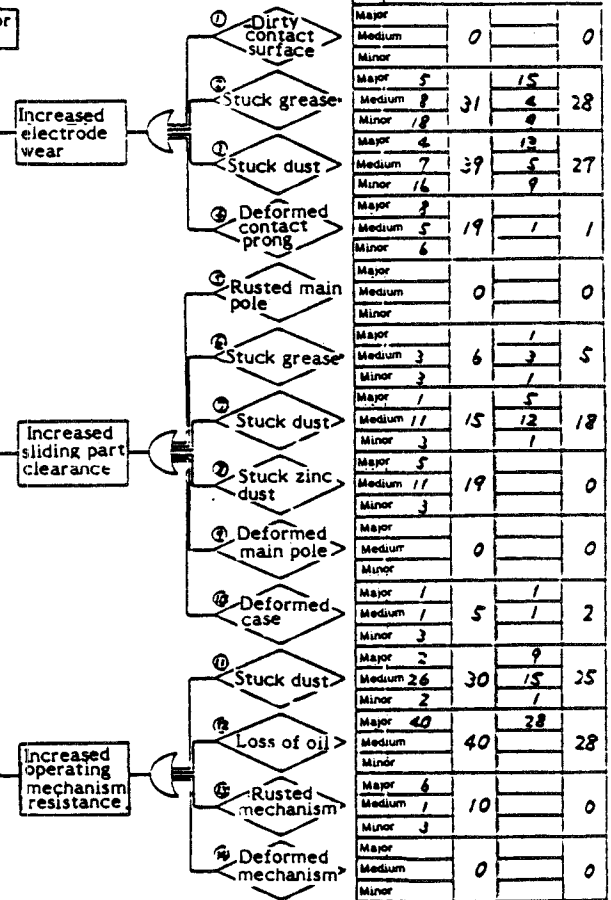
(External view of AS)



(AS structure schematic)



Note: The terminal events in the FT analysis diagram in this analysis stage....

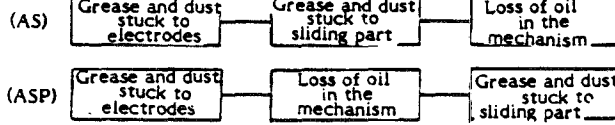


(3) Even weighting

Measure and score reductions in the switching force by the factor erasure method and scored for the purpose of weighting the basic events.

(AS) 2

| Item No. | Basic events identified by status quo surveys |              |                        |              |            |                 |                     |            |             |                  |
|----------|-----------------------------------------------|--------------|------------------------|--------------|------------|-----------------|---------------------|------------|-------------|------------------|
|          | Electrodes                                    |              |                        | Sliding part |            |                 | Operating mechanism |            |             |                  |
|          | Stuck dust                                    | Stuck grease | Deformed contact blade | Stuck grease | Stuck dust | Stuck zinc dust | Deformed case       | Stuck dust | Loss of oil | Rusted mechanism |
| 1        | 5                                             | 0            | 0                      | 5            | 0          | 0               | 0                   | 0          | 0           | 0                |
| 2        | 4                                             | 0            | 0                      | 4            | 0          | 0               | 0                   | 0          | 0           | 0                |
| 3        | 3                                             | 0            | 0                      | 3            | 0          | 0               | 0                   | 0          | 0           | 0                |
| 4        | 0                                             | 0            | 0                      | 0            | 0          | 0               | 0                   | 0          | 0           | 0                |
| 5        | 5                                             | 0            | 0                      | 0            | 0          | 0               | 0                   | 0          | 0           | 0                |
| 38       | 2                                             | 0            | 0                      | 1            | 0          | 0               | 0                   | 5          | 0           | 0                |
| 39       | 0                                             | 0            | 0                      | 1            | 0          | 0               | 0                   | 5          | 0           | 0                |
| 40       | 5                                             | 0            | 0                      | 3            | 0          | 0               | 0                   | 0          | 0           | 0                |
| Total    | 145                                           |              | 3                      |              |            | 0               | 0                   | 0          | 22          | 0                |



Reduced switching forces and scores (Unit:....)

| Scores | Reduced switching force     |
|--------|-----------------------------|
| 5      | 15 and above                |
| 4      | 12 or more but less than 15 |
| 3      | 9 or more but less than 12  |
| 2      | 6 or more but less than 9   |
| 1      | 3 or more but less than 6   |
| 0      | Less than 3                 |

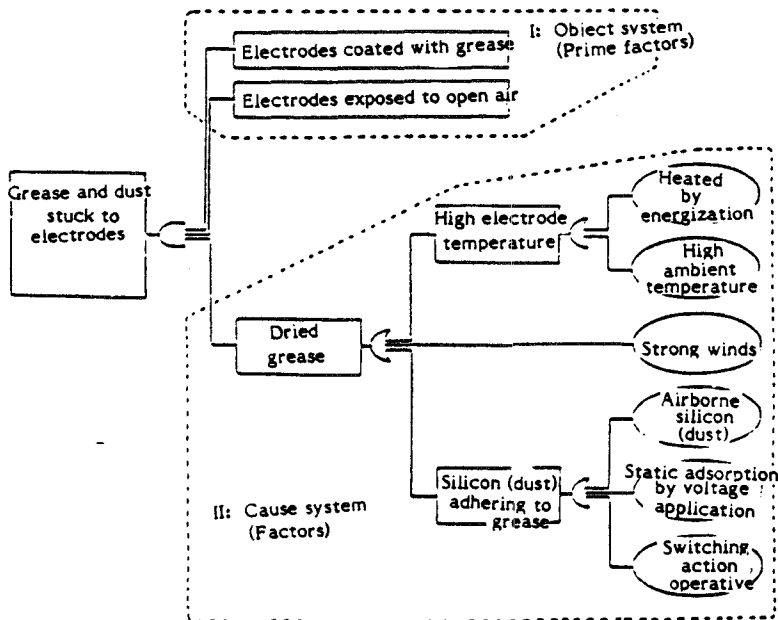
(4) Expansion of events with larger weights and experiment planning.

Expand the events with larger weights in an FT analysis diagram on the basis of analyses of the components of the substances adhering to the electrodes, etc.



Design an experiment regarding switching force increases by using an orthogonal array table (L16(2<sup>13</sup>)), in which each basic event in the cause system is assigned at level 2 as a factor.

Experimentation



Level 1 Level 2

Conducting Not conducting (Factor A)

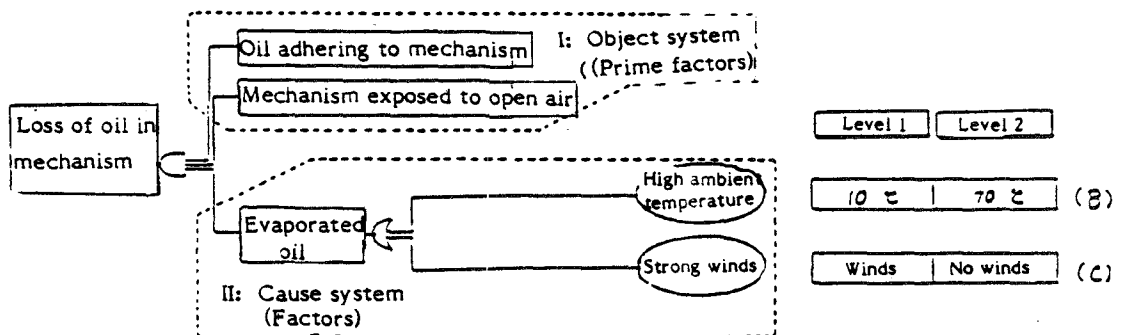
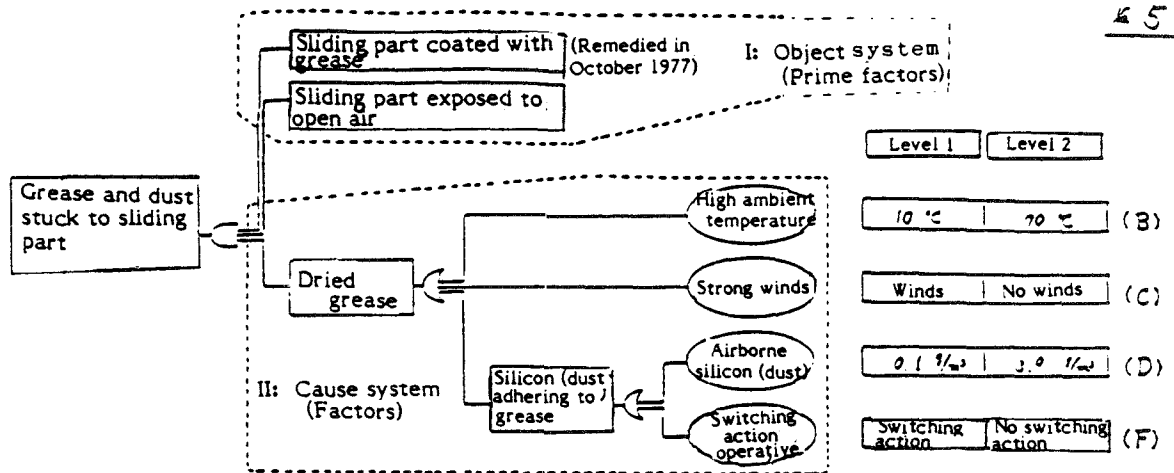
10°C 70°C (Factor B)

Winds No winds (Factor C)

0.1 g/m<sup>3</sup> 3.0 g/m<sup>3</sup> (Factor D)

Applied voltage No applied voltage (Factor E)

Switching action No switching action (Factor F)



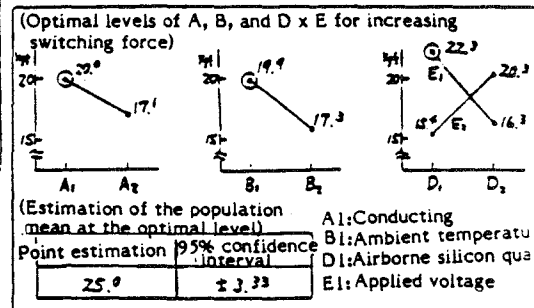
#### 4 Study of Countermeasures

Although D x E was determined to be highly significant and A and B significant with a 5% level of significance each as a result of variance analysis, prepare an analysis of variance table by pooling C and B x D as errors because they have a variance ratio of 2 or less

| Factor                       | Sum of squares | Degrees of freedom | Unbiased variance | Variance ratio      |
|------------------------------|----------------|--------------------|-------------------|---------------------|
| Heating by energization A    | 33.06          | 1                  | 33.06             | 10.80 <sup>a</sup>  |
| Ambient temperature B        | 27.56          | 1                  | 27.56             | 9.01 <sup>a</sup>   |
| Airborne silicone quantity D | 1.21           | 1                  | 1.21              | —                   |
| Applied voltage E            | 2.41           | 1                  | 2.41              | 2.75                |
| Switching action F           | 6.76           | 1                  | 6.76              | 2.21                |
| Alternating action D x E     | 118.81         | 1                  | 118.81            | 38.83 <sup>ab</sup> |
| Residual e' e'               | 27.52          | 9                  | 3.06              | —                   |
| Total T                      | 223.33         | 15                 | —                 | —                   |

<sup>a</sup>  $F_{(0.05)} = 5.59$     <sup>ab</sup>  $F_{(0.01)} = 12.2$

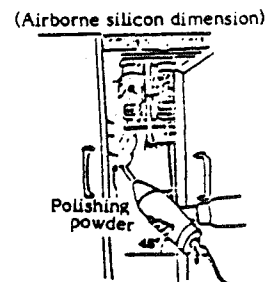
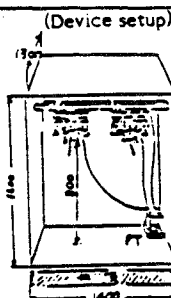
As a result of testing, D x E was found highly significant, and A and B significant with a 5% level of significance.



#### AS (ASP) accelerated deterioration test (Test title: Staining test)

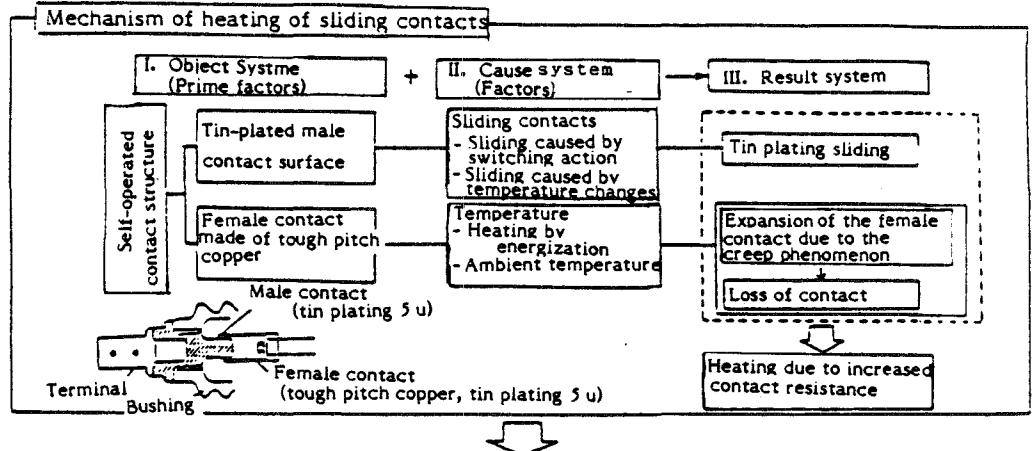
Perform testing with the switching window being set in the assembled state under the conditions specified below. The switching force after the test must not exceed 30 kgf.

|                            |                       |
|----------------------------|-----------------------|
| Ambient temperature        | 70°C                  |
| Airborne silicone quantity | 3.0 mg/m <sup>3</sup> |
| Current                    | Rated current         |
| Voltage                    | Rated voltage         |
| Test duration              | 1,000 hours           |



## VS failure mechanisms and accelerated deterioration testing.

Test conditions for the accelerated deterioration tests regarding heated sliding contacts and loss of the vacuum in vacuum valves were established in the same way as for AS (ASP). The tests are summarized below.



Expand the stresses on the cause system in these mechanisms to the level of basic events as with AS and ASP, and experiment by assigning these basic events at level 2 to determine the optimal level of occurrence of heating of the sliding contacts, thereby designing the conditions for accelerated deterioration.

### 5 Effects

- The mechanism of increased switching force in AS (ASP) could be identified.
- A reliability for AS (ASP) could be conceived.

AS (ASP) ----- Staining test

### 6 Standardization

- Preparation of an accelerated deterioration testing manual (May 1986)
- Reflection in AS (ASP) equipment specifications (July 1986)

### 7 Reflections and Future Approaches

#### Reflections

- Failure to determine the acceleration in accelerated deterioration testing.
- Insufficient understanding of the prevailing ambient conditions in the field.
- Inability to establish VS accelerated deterioration testing conditions.

#### Future approaches

- Study the acceleration in accelerated deterioration tests and review the post-testing quality requirements (specifications).
- Examine the prevailing ambient conditions in the field to study modifications to the accelerated deterioration testing conditions.
- High-temperature heat cycle testing, vacuum corrosion testing, etc. are conceivable as VS accelerated deterioration tests. Design their testing conditions through devising experiments.
- Establish reliability tests for other equipment as well.
- Reflect the mechanisms of deterioration as identified in the practice of field deterioration diagnostics.