CHAPTER 4

RESULTS OF TESTING AND INTERPRETATION

On line partial discharge tests on Sirikit hydroelectric generator unit 2 was taken on 4 conditions of test procedure. The tests applied to each of coupler of three phases winding (total 9 couplers). The test data were displayed in form of partial discharge graphs. Using experience papers as defined in section 2.65 of CHATER 2. The measuring procedure was set up into four conditions of test in order to see some effects of temperature and load forces. That experience literature also guided to interpret the data of measurement and table of Chart I and Chart II were also very useful to guide to interpret all data of measurement of generator unit 2.

The tests were completed within 1 hour and 10 minutes, which took time over the recommendation. However, the load condition and temperature required were not changed from test procedure. All test data could be listed into four sections depend on test condition and the interpretation was done in each graph and made a conclusion at the end of each test condition. The results of interpretation and some recommendation were created to used in next maintenance program of generator in November 1998.

4.1 Data of Measurement

The on-line measurement was taken on four conditions in order to investigate how temperature and load forces affected. No load, cold condition was the condition of low temperature and forceless during operation. Full load, cold condition was the condition of low temperature and full load forces during operation. Full load, hot condition was the condition of high temperature and full load forces. No load, hot condition was the condition of high temperature but load forces was decreased into minimum as possible.

4.1.1 No load cold condition

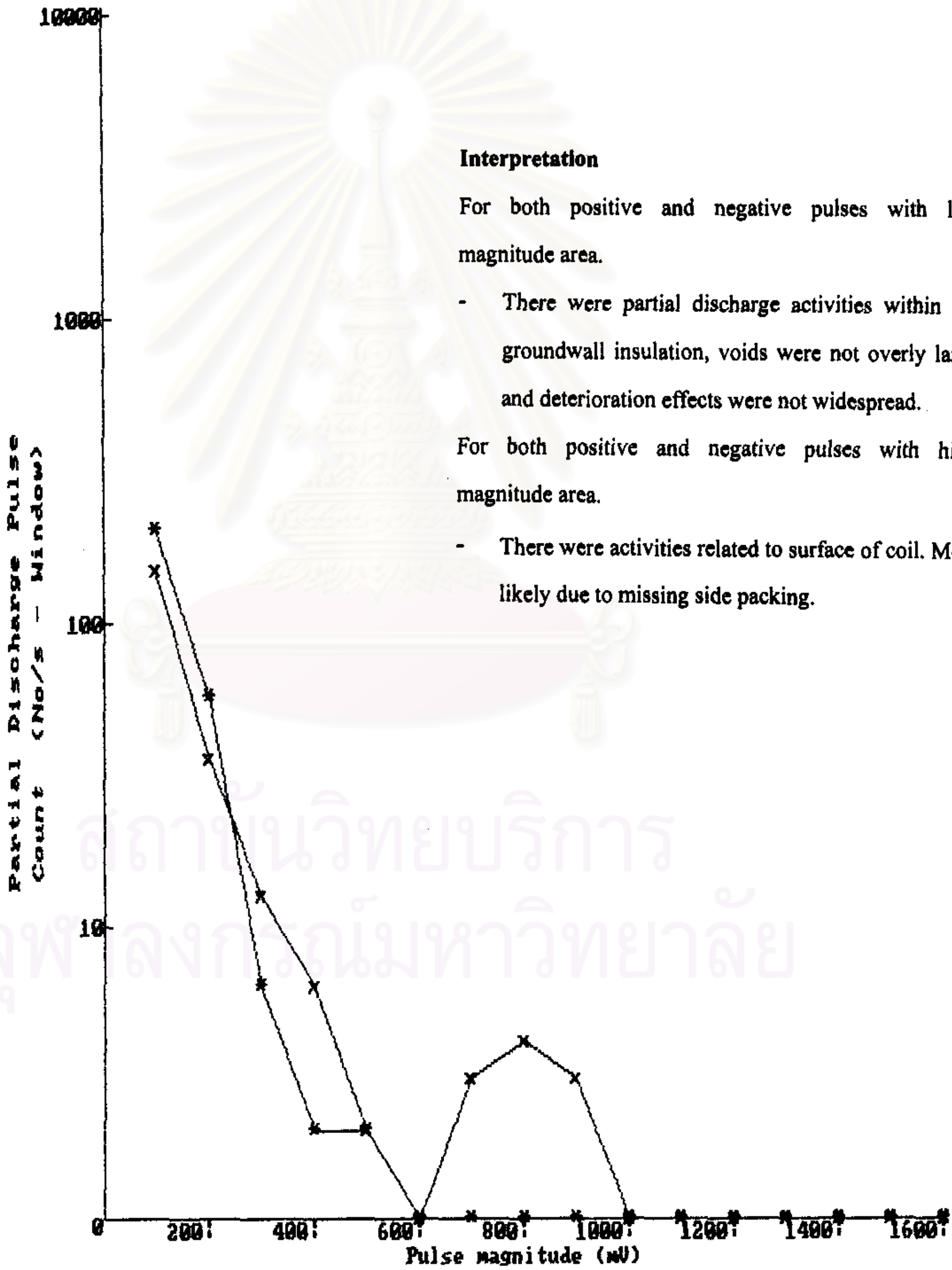
1). Test data of coupler1 of parallel path 1, coupler2 of parallel path 2 and coupler3 of parallel path 3 phase A and their interpretation as shown in Fig.4a to Fig. 4c.

2). Test data of coupler1 of parallel path 1, coupler2 of parallel path 2 and coupler3 of parallel path 3 phase B and their interpretation as shown in Fig. 4d to Fig. 4f.

3). Test data of coupler1 of parallel path 1, coupler2 of parallel path 2 and coupler3 of parallel path 3 phase C and their interpretation as shown in Fig. 4g to Fig. 4j.

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02A01.037 A Phase Coupler 1
Tested on Thu Jun 23,1998 at 09:10:41 Coupler pair A01 Gain 1.00
Voltage reference 228 Temp 50 C **No Load, Cold** Synchronized
Power 0 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 632 Negative Pulses (*) NQN 426



Interpretation

For both positive and negative pulses with low magnitude area.

- There were partial discharge activities within the groundwall insulation, voids were not overly large and deterioration effects were not widespread.

For both positive and negative pulses with high magnitude area.

- There were activities related to surface of coil. Most likely due to missing side packing.

Fig. 4.1.1.1 Data measurement of A Phase, parallel 1

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02A01.037 A Phase Coupler 2
Tested on Thu Jun 23,1998 at 09:10:41 Coupler pair A01 Gain 1.00
Voltage reference 228 Temp 50 C **No Load, Cold** Synchronized
Power 0 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 1248 Negative Pulses (*) NQN 1367

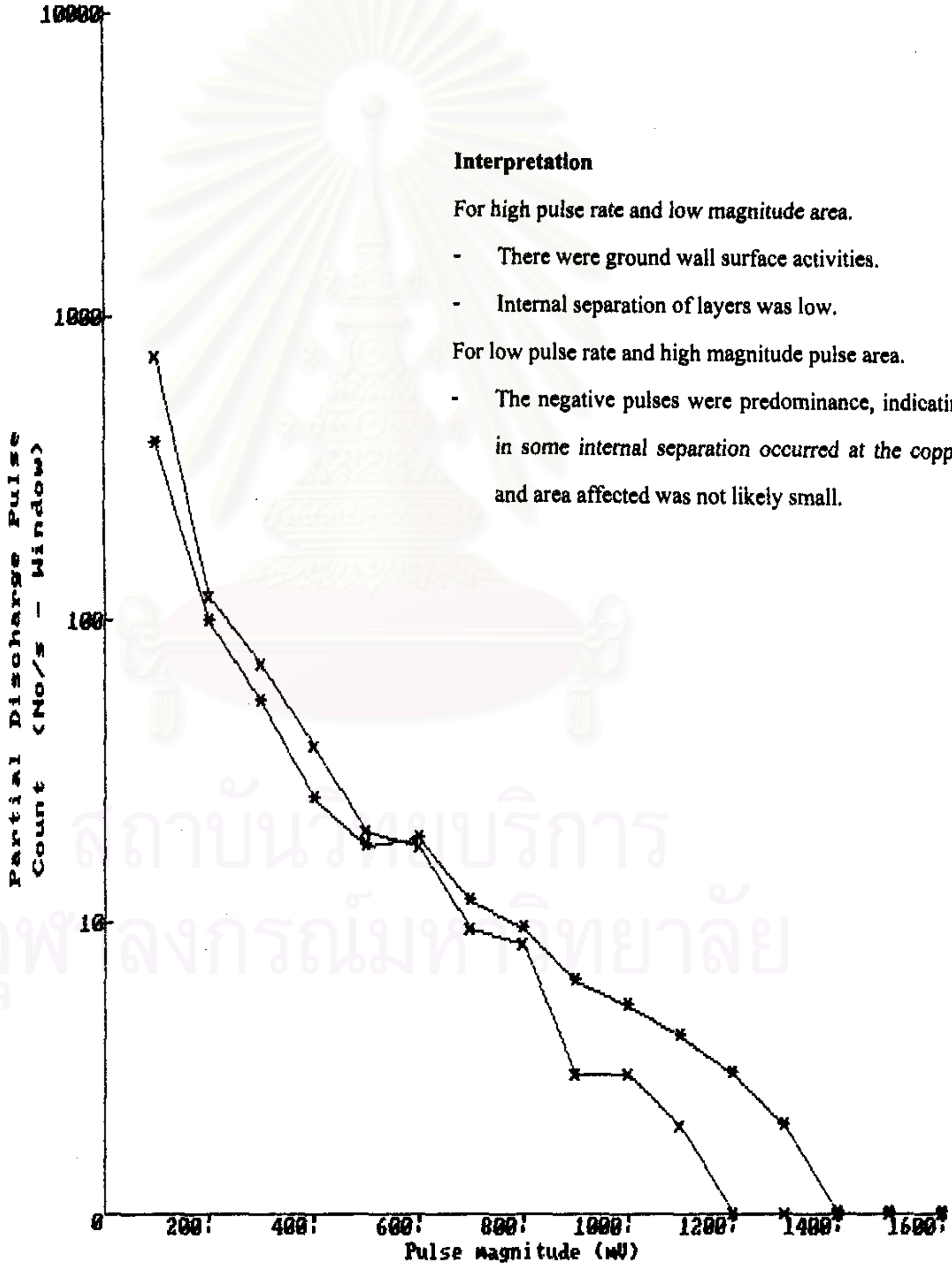
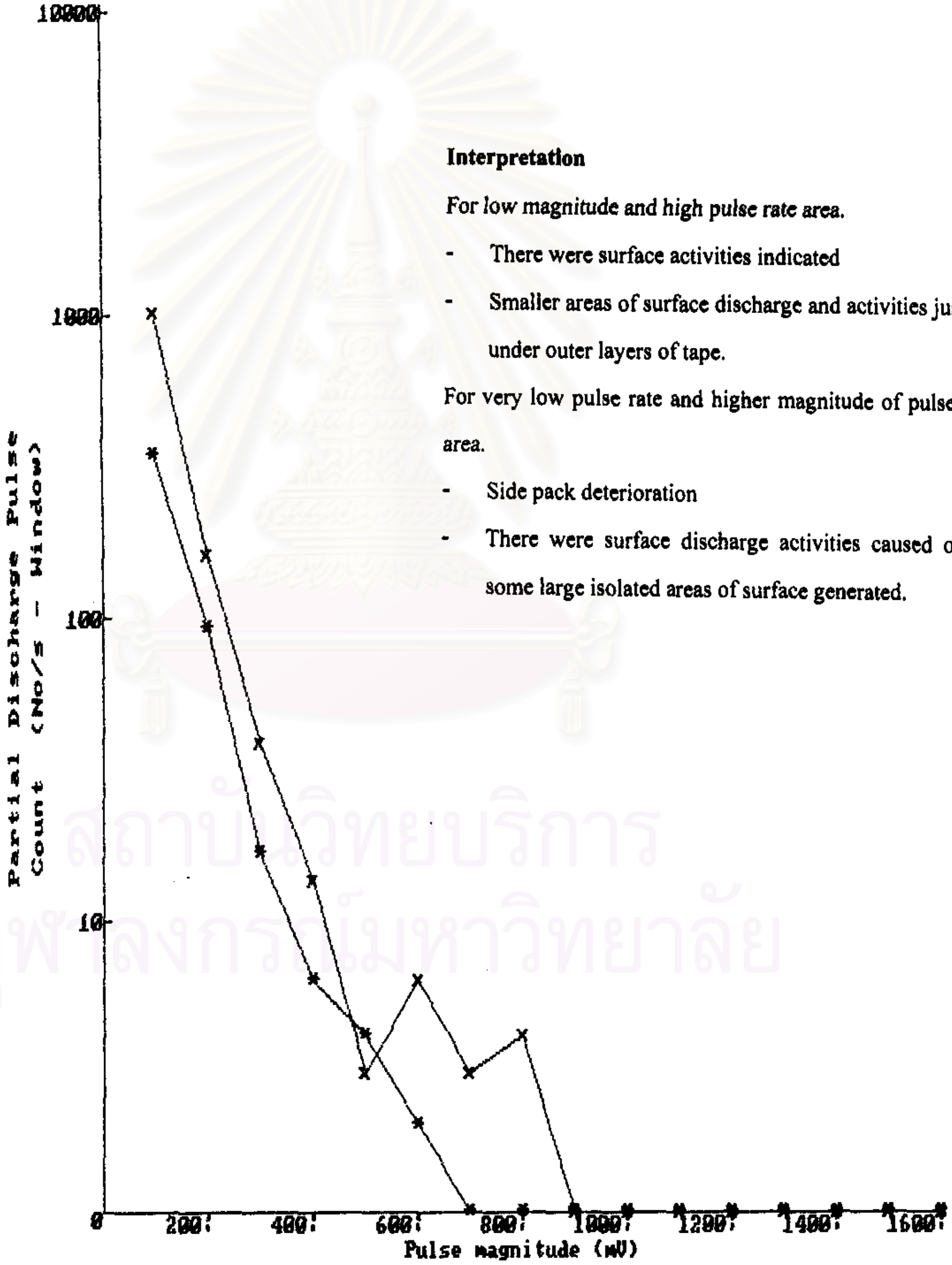


Fig. 4.1.1.2 Data measurement of A Phase, parallel 2

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02A02.038 A Phase Coupler 2
Tested on Thu Jun 23,1998 at 09:13:07 Coupler pair A02 Gain 1.00
Voltage reference 224 Temp 50 C **No Load, Cold** Synchronized
Power 0 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 869 Negative Pulses (*) NQN 609



Interpretation

For low magnitude and high pulse rate area.

- There were surface activities indicated
- Smaller areas of surface discharge and activities just under outer layers of tape.

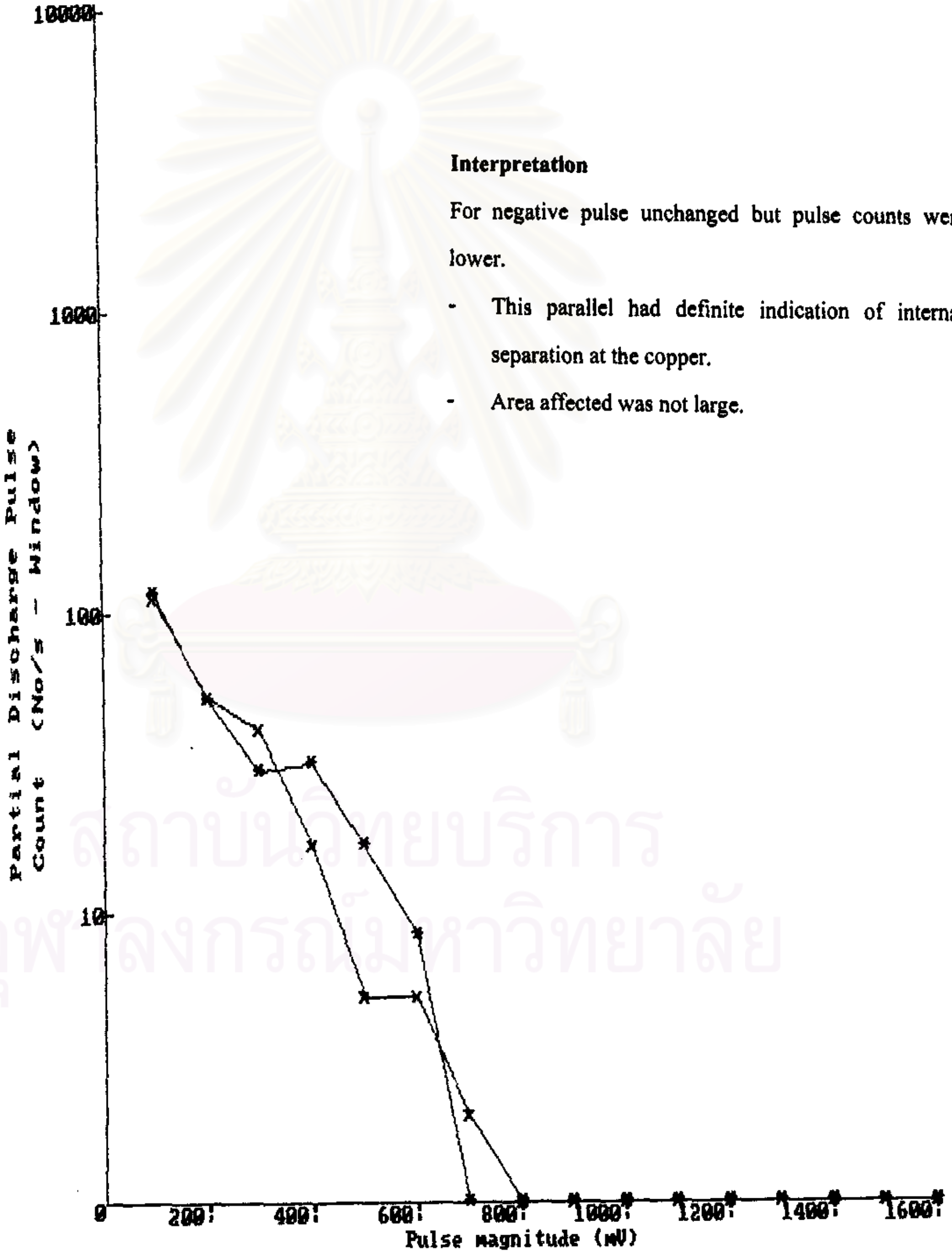
For very low pulse rate and higher magnitude of pulses area.

- Side pack deterioration
- There were surface discharge activities caused of some large isolated areas of surface generated.

Fig. 4.1.1.3 Data measurement of A Phase, parallel 3

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02B03.039 B Phase Coupler 1
Tested on Thu Jun 23,1998 at 09:15:32 Coupler pair B03 Gain 1.00
Voltage reference 222 Temp 50 C **No Load, Cold** Synchronized
Power 0 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 720 Negative Pulses (*) NQN 774



Interpretation

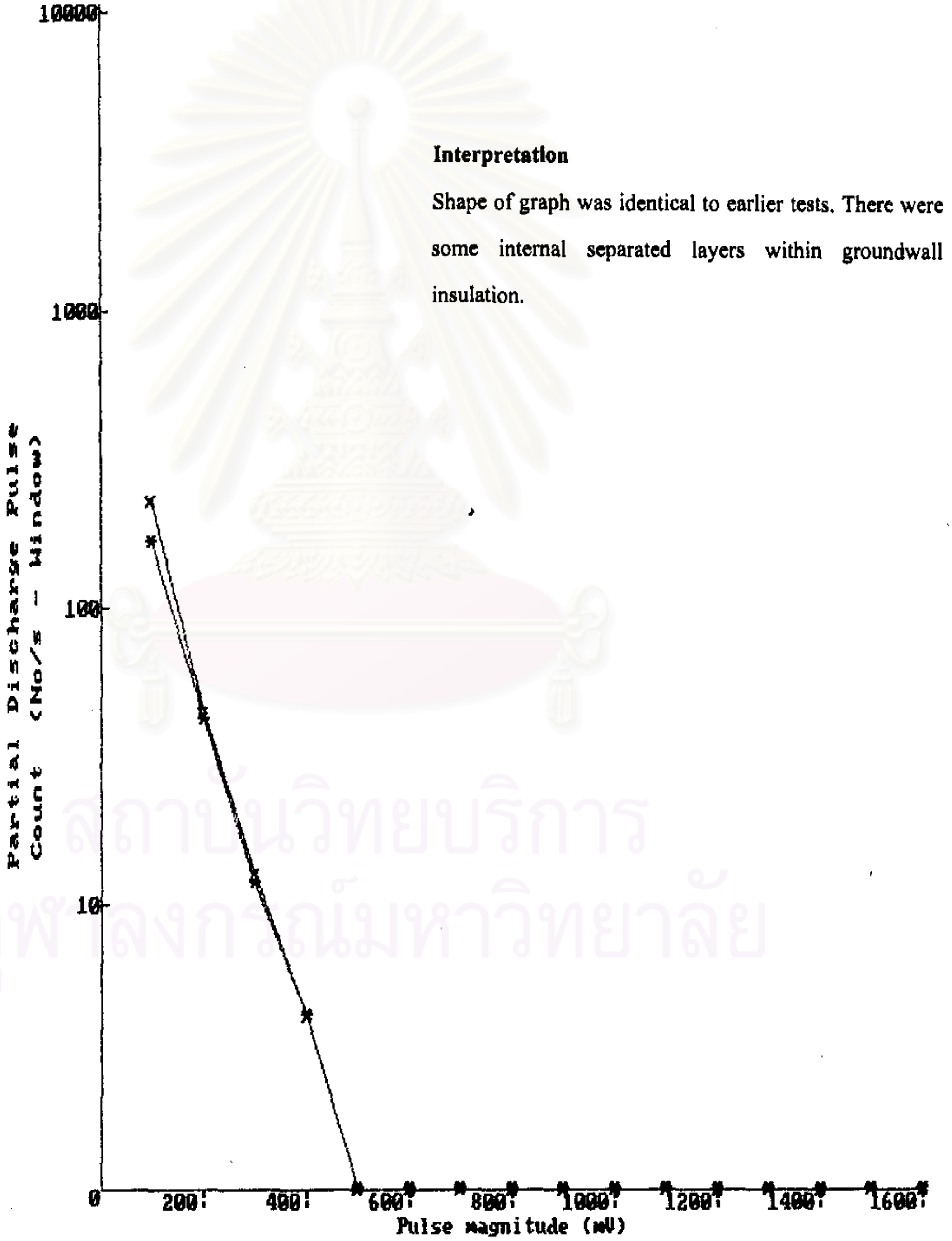
For negative pulse unchanged but pulse counts were lower.

- This parallel had definite indication of internal separation at the copper.
- Area affected was not large.

Fig. 4.1.1.4 Data measurement of B Phase, parallel 1

SIRIKIT HYDRO POWER PLANT Unit 02

```
D:\PDAH\PDAH\STATIONA\GEN1\SKT02B03.039                 B Phase   Coupler 2
Tested on  Thu Jun 23,1998 at 09:15:32   Coupler pair B03    Gain 1.00
Voltage reference  222    Temp   50  C   No   Load, Cold      Synchronized
Power     0 MW  Reactive     0 MX   Voltage        13.8  Differential Mode
Positive Pulses (x) NQN  447             Negative Pulses (*) NQN  434
```



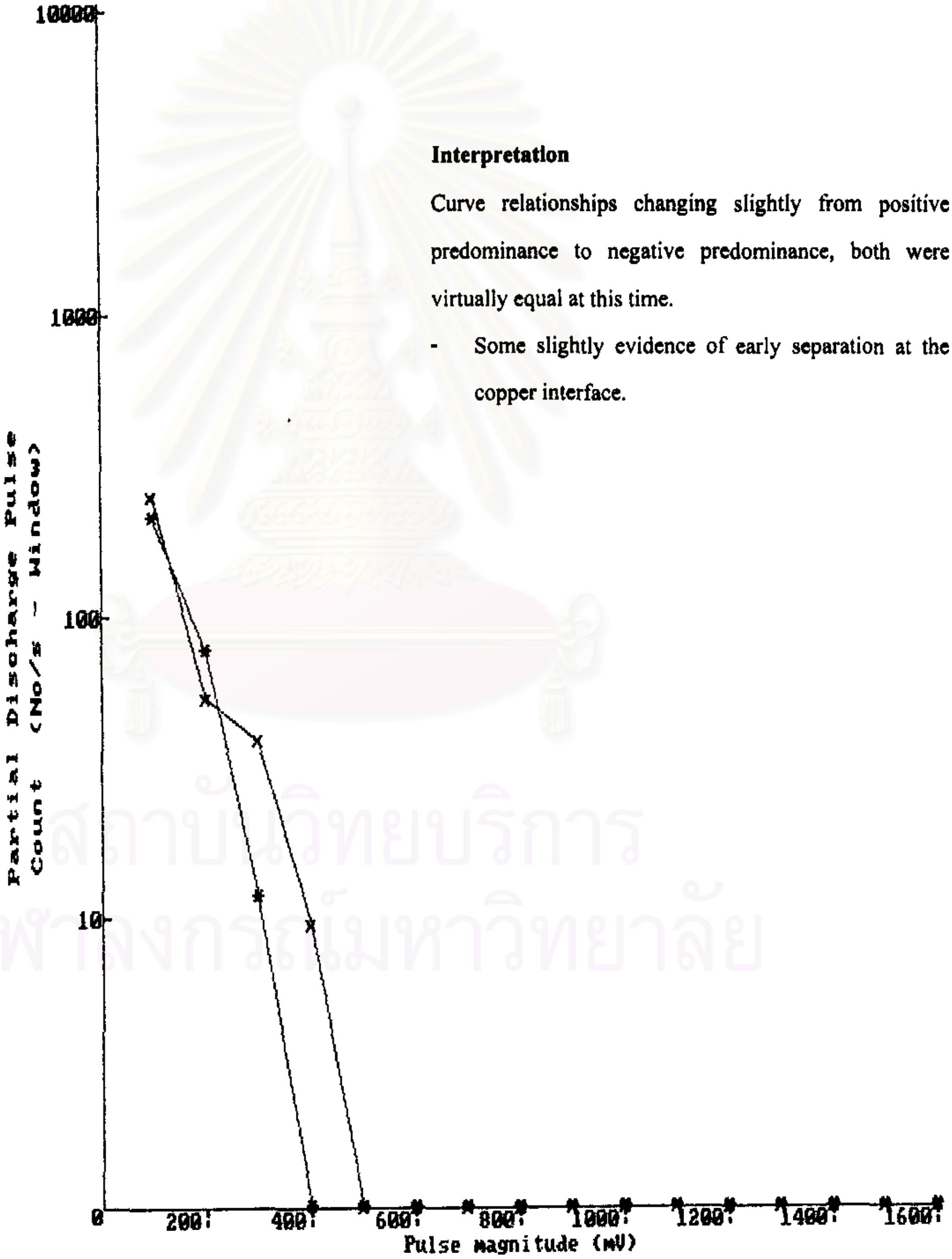
Interpretation

Shape of graph was identical to earlier tests. There were some internal separated layers within groundwall insulation.

Fig. 4.1.1.5 Data measurement of B Phase, parallel 2

SIRIKIT HYDRO POWER PLANT Unit 02

```
D:\PDAH\PDAH\STATIONA\GEN1\SKT02B04.040                   B Phase  Coupler 2
Tested on  Thu Jun 23,1998 at 09:17:52  Coupler pair B04   Gain 1.00
Voltage reference  225    Temp   50  C   No   Load, Cold       Synchronized
Power     0 MW  Reactive     0 MX   Voltage        13.8  Differential Mode
Positive Pulses (x) NQN  541             Negative Pulses (*) NQN  405
```



Interpretation

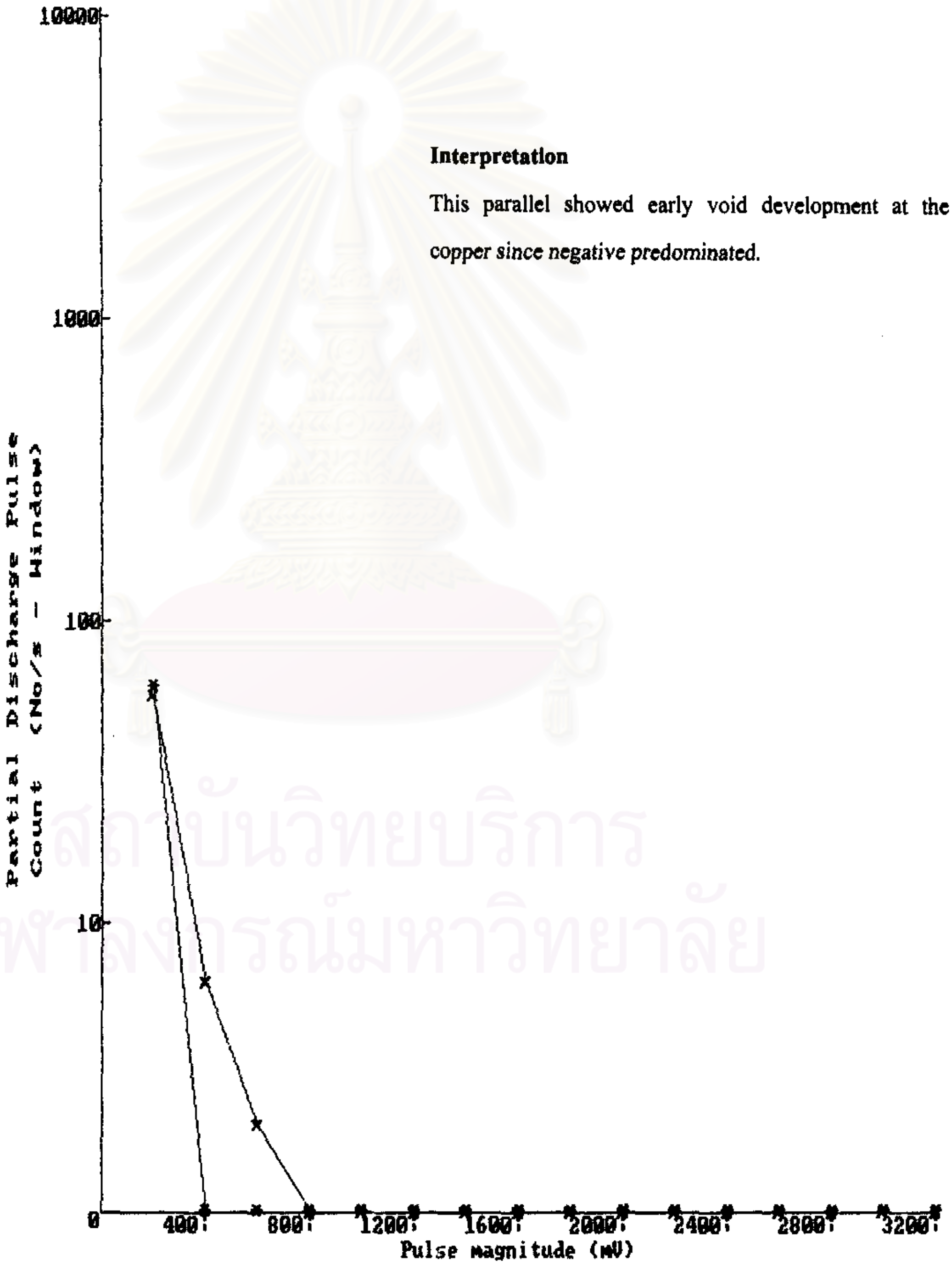
Curve relationships changing slightly from positive predominance to negative predominance, both were virtually equal at this time.

- Some slightly evidence of early separation at the copper interface.

Fig. 4.1.1.6 Data measurement of B Phase, parallel 3

SIRIKIT HYDRO POWER PLANT Unit 02

```
D:\PDAH\PDAH\STATIONA\GEN1\SKT02C05.041                    C Phase  Coupler 1
Tested on  Thu Jun 23,1998 at 09:20:22   Coupler pair C05   Gain 0.50
Voltage reference  215    Temp   50  C   No  Load, Cold      Synchronized
Power     0 MW  Reactive     0 MX   Voltage       13.8  Differential Mode
Positive Pulses (x) NQN  389             Negative Pulses (*) NQN  175
```



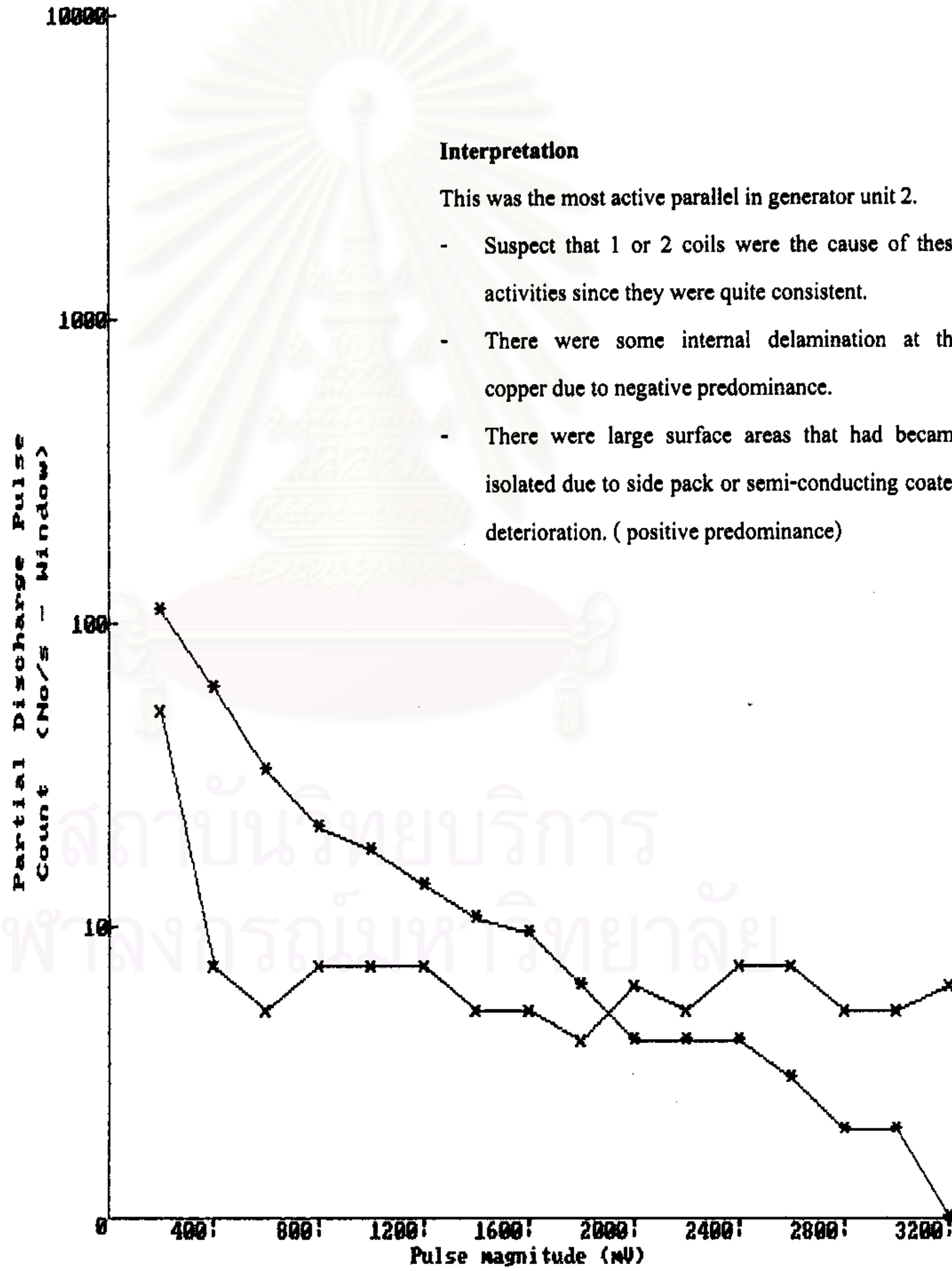
Interpretation

This parallel showed early void development at the copper since negative predominated.

Fig. 4.1.1.7 Data measurement of C Phase, parallel 1

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02C05.041 C Phase Coupler 2
Tested on Thu Jun 23,1998 at 09:20:22 Coupler pair C05 Gain 0.50
Voltage reference 215 Temp 50 C **No Load, Cold** Synchronized
Power 0 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 2622 Negative Pulses (*) NQN 2705
NQN inaccurate due to high PD activity



Interpretation

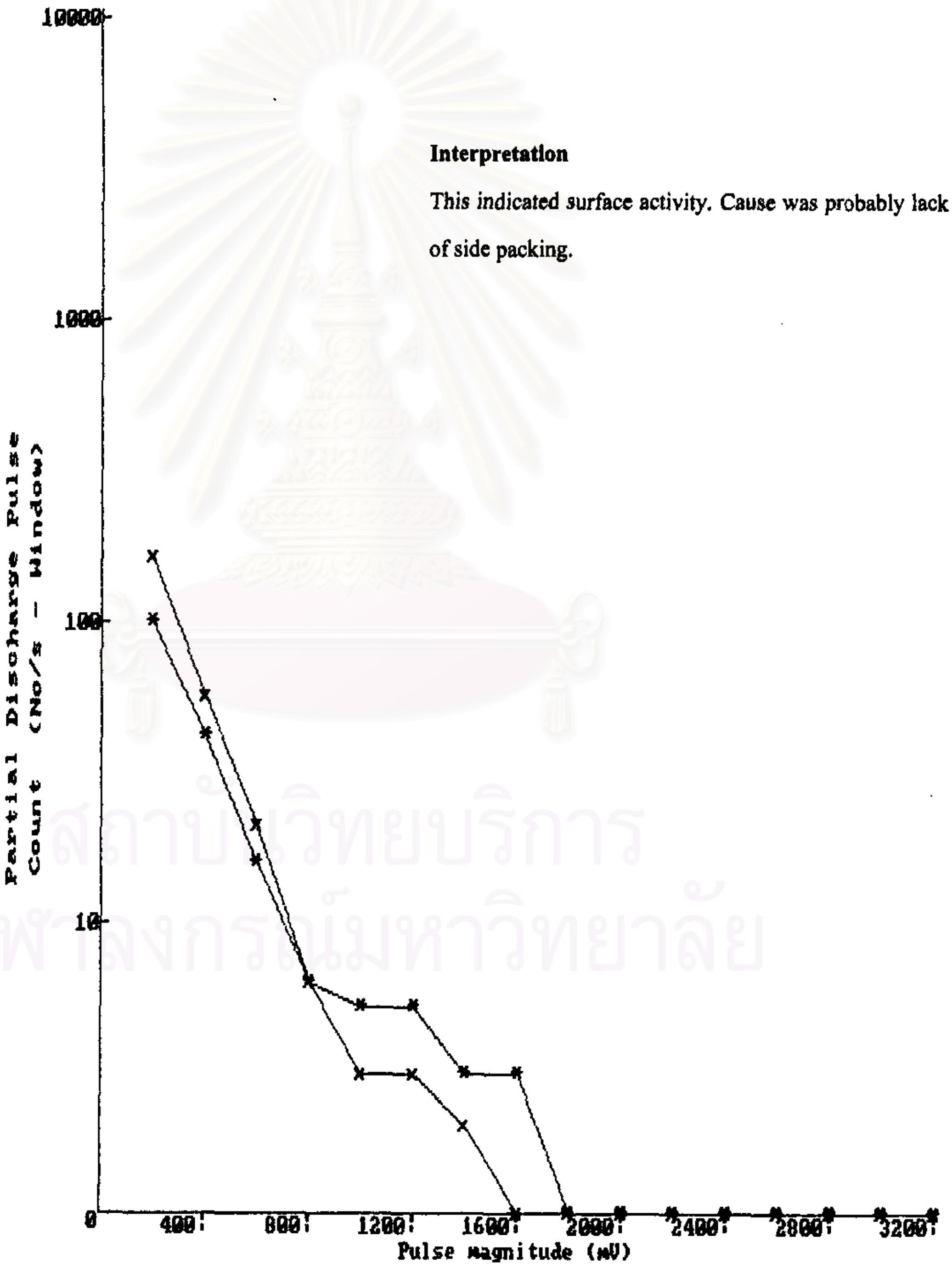
This was the most active parallel in generator unit 2.

- Suspect that 1 or 2 coils were the cause of these activities since they were quite consistent.
- There were some internal delamination at the copper due to negative predominance.
- There were large surface areas that had became isolated due to side pack or semi-conducting coated deterioration. (positive predominance)

Fig. 4.1.1.8 Data measurement of C Phase, parallel 2

SIRIKIT HYDRO POWER PLANT Unit 02

```
D:\PDAH\PDAH\STATIONA\GEN1\SKT02C06.042                 C Phase  Coupler 2
Tested on  Thu Jun 23,1998 at 09:22:55  Coupler pair C06   Gain 0.50
Voltage reference  218    Temp   50  C  No  Load, Cold      Synchronized
Power     0 MW  Reactive     0 MX   Voltage        13.8  Differential Mode
Positive Pulses (x) NQN 1232            Negative Pulses (*) NQN 1379
```



Interpretation

This indicated surface activity. Cause was probably lack of side packing.

Fig. 4.1.1.9 Data measurement of C Phase, parallel 3

4.1.1.1 The interpretation summary on No load cold condition

This condition was less effected from vibration and temperature, stator winding was only under high voltage that generated by itself.

Winding parallel path1 of phase A showed internal discharge with high amount of total partial discharge activities that positive and negative pulses were similarly. The overall picture of winding path1 phase A had some delamination occurred within ground wall insulation and some surface deterioration. The high amount of NQN that over than450 means there were a lot of partial discharge occurred in this parallel path, such as internal discharge, slot discharge and interface discharge.

Winding parallel path2 of phase A showed higher amount of NQN than parallel path1, both positive and negative pulses were predominance, also both NQN were over 1000. These meant a lot of slot or surface discharge and internal discharge occurred within winding parallel path2. The overview of this path showed a lot of deterioration on insulation system at slot portion, coil-end portion and main ground wall insulation.

Winding parallel path 3 of phase A showed surface deterioration. The partial discharge activities were the same as winding parallel path1.

Winding parallel path 1, phase B showed negative pulse to be predominance together with positive pulses. These meant more internal discharge and surface discharge occurred because of ground wall delamination and coil surface deterioration.

Winding parallel path 2 and 3, phase B have similarly graphs that showed only internal discharge occurred. The meaning was some delamination occurred within ground wall insulation. Both NQN were not high values, showing in low partial discharge activities occurred also low insulation deterioration in the overall picture.

Winding parallel path 1 and 3, phase C have similarly graphs same as path 2 and 3 of phase B. there were internal discharge occurred due to ground wall deterioration.

Winding parallel path 2 of phase C showed large amount of discharge occurred within winding (very high values of both NQN). The negative pulses was predominance and positive pulses were also predominance. There were a lot of ground wall delaminations and surface deteriorated occurred within stator winding. High amount of both NQN (over 1000) showed a lot of deterioration within insulation system and may be more pollution inside.

4.1.2 Full load cold condition

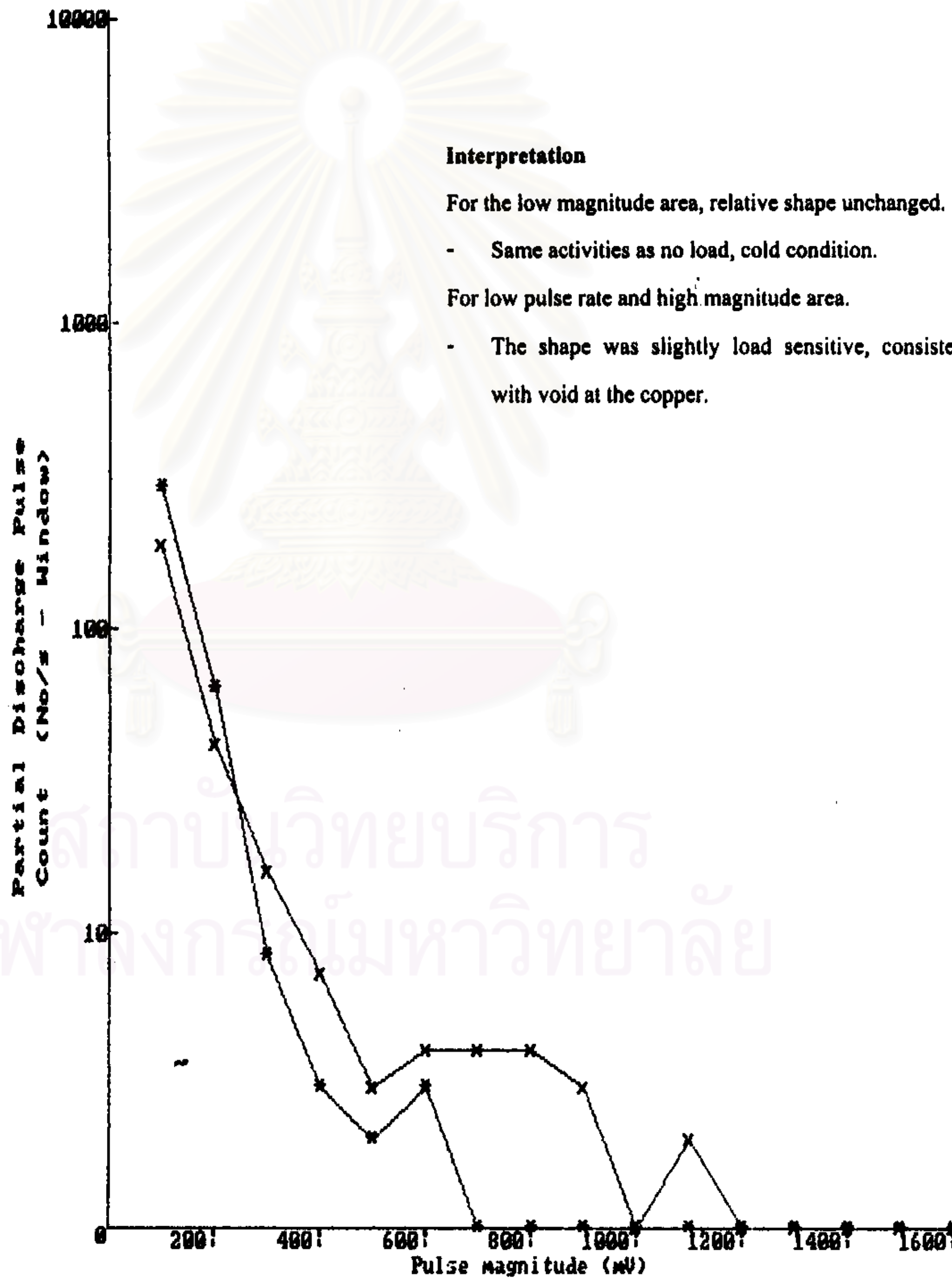
1). Test data of coupler1 of parallel path 1, coupler2 of parallel path 2 and coupler3 of parallel path 3 phase A and their interpretation as shown in Fig. 4.1.2.1 to 4.1.2.3.

2). Test data of coupler1 of parallel path 1, coupler2 of parallel path 2 and coupler3 of parallel path 3 phase B and their interpretation as shown in Fig. 4.1.2.4 to 4.1.2.6.

3). Test data of coupler1 of parallel path 1, coupler2 of parallel path 2 and coupler3 of parallel path 3 phase C and their interpretation as shown in Fig. 4.1.2.7 to 4.1.2.9.

SIRIKIT HYDRO POWER PLANT Unit 02

```
D:\PDAH\PDAH\STATIONA\GEN1\SKT02A01.043                    A Phase   Coupler 1
Tested on  Thu Jun 23,1998 at 09:31:39   Coupler pair A01   Gain 1.00
Voltage reference  222   Temp   50  C   Full Load, Cold       Synchronized
Power    81 MW  Reactive     0 MX   Voltage        13.8  Differential Mode
Positive Pulses (x) NQN  779             Negative Pulses (*) NQN  515
```



Interpretation

For the low magnitude area, relative shape unchanged.

- Same activities as no load, cold condition.

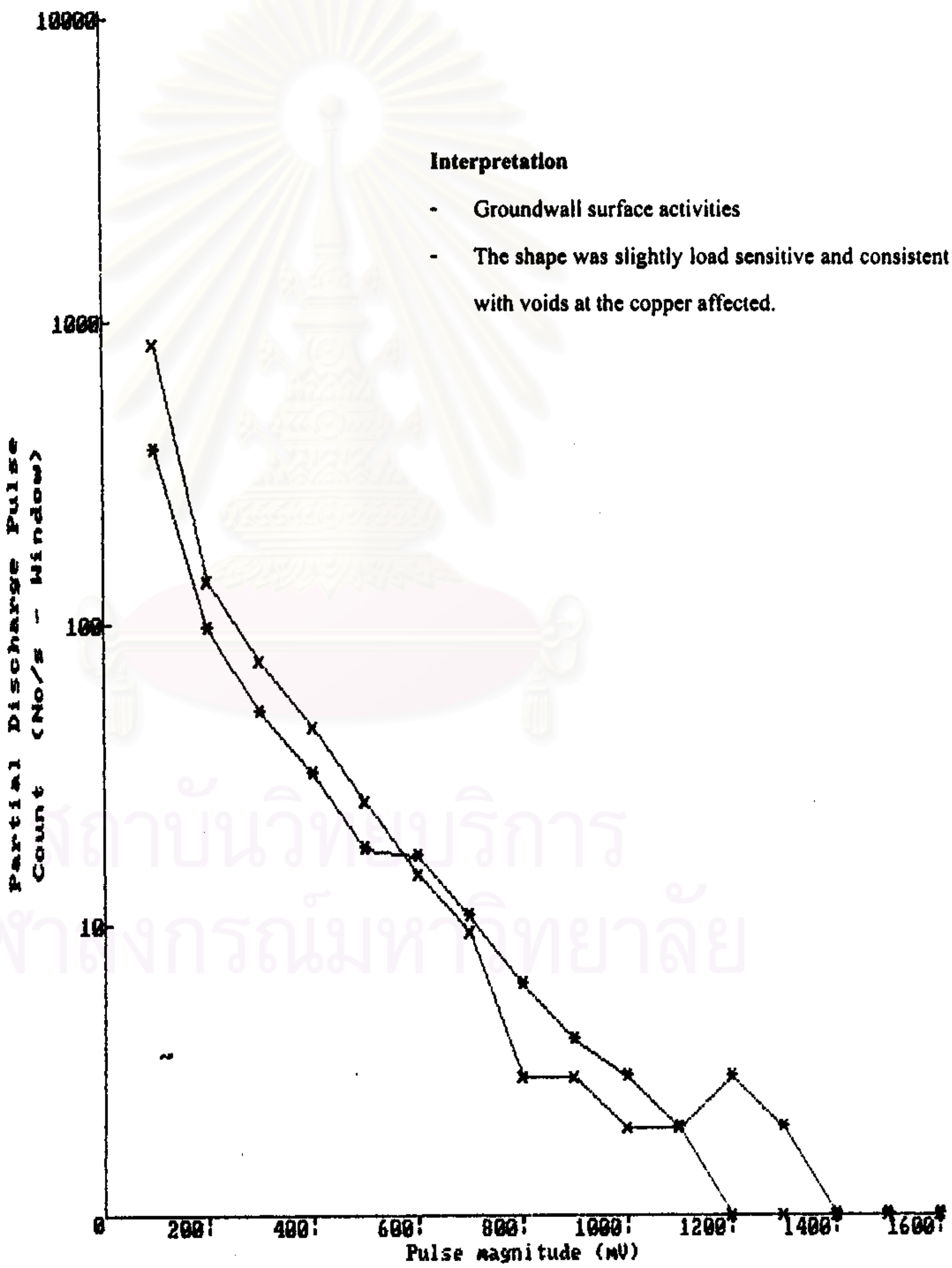
For low pulse rate and high magnitude area.

- The shape was slightly load sensitive, consistent with void at the copper.

Fig. 4.1.2.1 Data measurement of A Phase, parallel 1

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02A01.043 A Phase Coupler 2
Tested on Thu Jun 23,1998 at 09:31:39 Coupler pair A01 Gain 1.00
Voltage reference 222 Temp 50 C Full Load, Cold Synchronized
Power 81 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 1209 Negative Pulses (*) NQN 1276



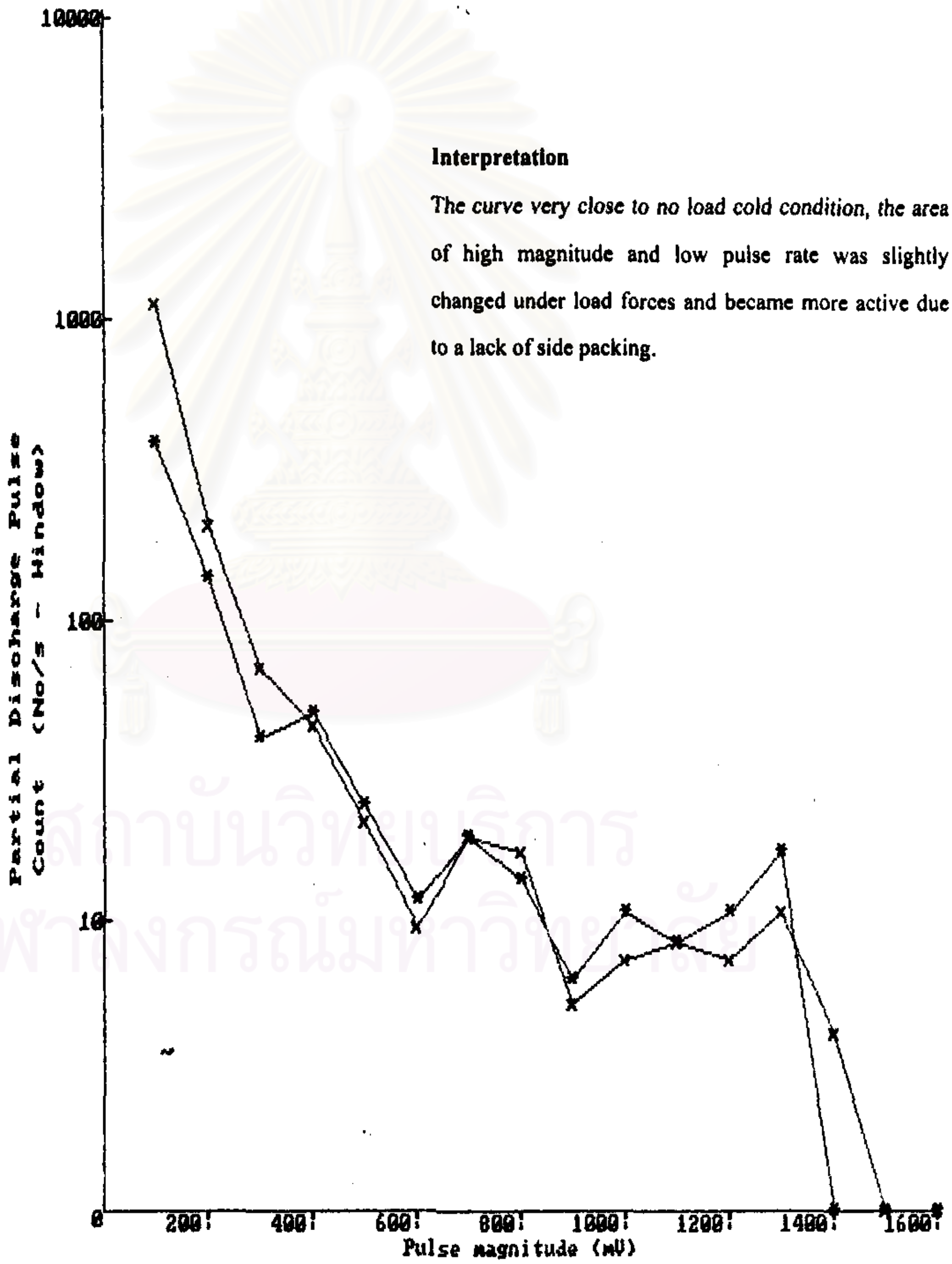
Interpretation

- Groundwall surface activities
- The shape was slightly load sensitive and consistent with voids at the copper affected.

Fig. 4.1.2.2 Data measurement of A Phase, parallel 2

SIRIKIT HYDRO POWER PLANT Unit 02

```
D:\PDAH\PDAH\STATIONA\GEN1\SKT02A02.044                    A Phase   Coupler 2
Tested on  Thu Jun 23,1998 at 09:34:05   Coupler pair A02   Gain 1.00
Voltage reference  214   Temp   50  C   Full Load, Cold       Synchronized
Power    81 MW  Reactive     0 MX   Voltage        13.8  Differential Mode
Positive Pulses (x) NQN 1685            Negative Pulses (*) NQN 1629
```



Interpretation

The curve very close to no load cold condition, the area of high magnitude and low pulse rate was slightly changed under load forces and became more active due to a lack of side packing.

Fig. 4.1.2.3 Data measurement of A Phase, parallel 3

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02B03.045 B Phase Coupler 1
Tested on Thu Jun 23,1998 at 09:36:23 Coupler pair B03 Gain 1.00
Voltage reference 215 Temp 50 C **Full Load, Cold** Synchronized
Power 81 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 659 Negative Pulses (*) NQN 786

Interpretation

This shape very close to no load cold. There were internal separation at the copper.

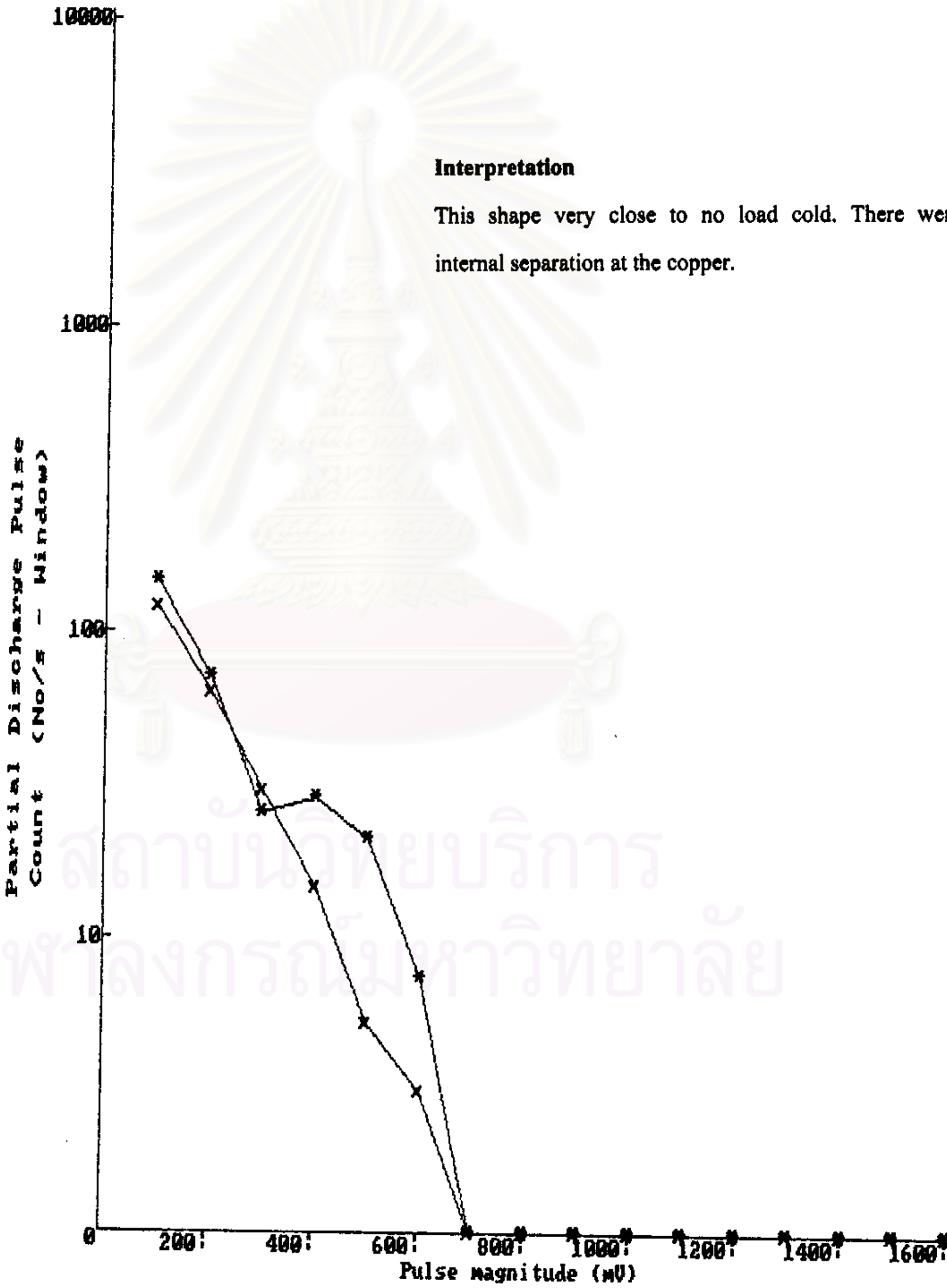


Fig. 4.1.2.4 Data measurement of B Phase, parallel 1

SIRIKIT HYDRO POWER PLANT Unit 02

```
D:\PDAH\PDAH\STATIONA\GEN1\SKT02B03.045                    B Phase   Coupler 2
Tested on  Thu Jun 23,1998 at 09:36:23  Coupler pair B03   Gain 1.00
Voltage reference  215    Temp   50  C  Full Load, Cold       Synchronized
Power    81 MW  Reactive     0 MX   Voltage        13.8  Differential Mode
Positive Pulses (x) NQN  455            Negative Pulses (*) NQN  460
```

Interpretation

No change from no load to full load. There were some voids in the layers of insulation only.

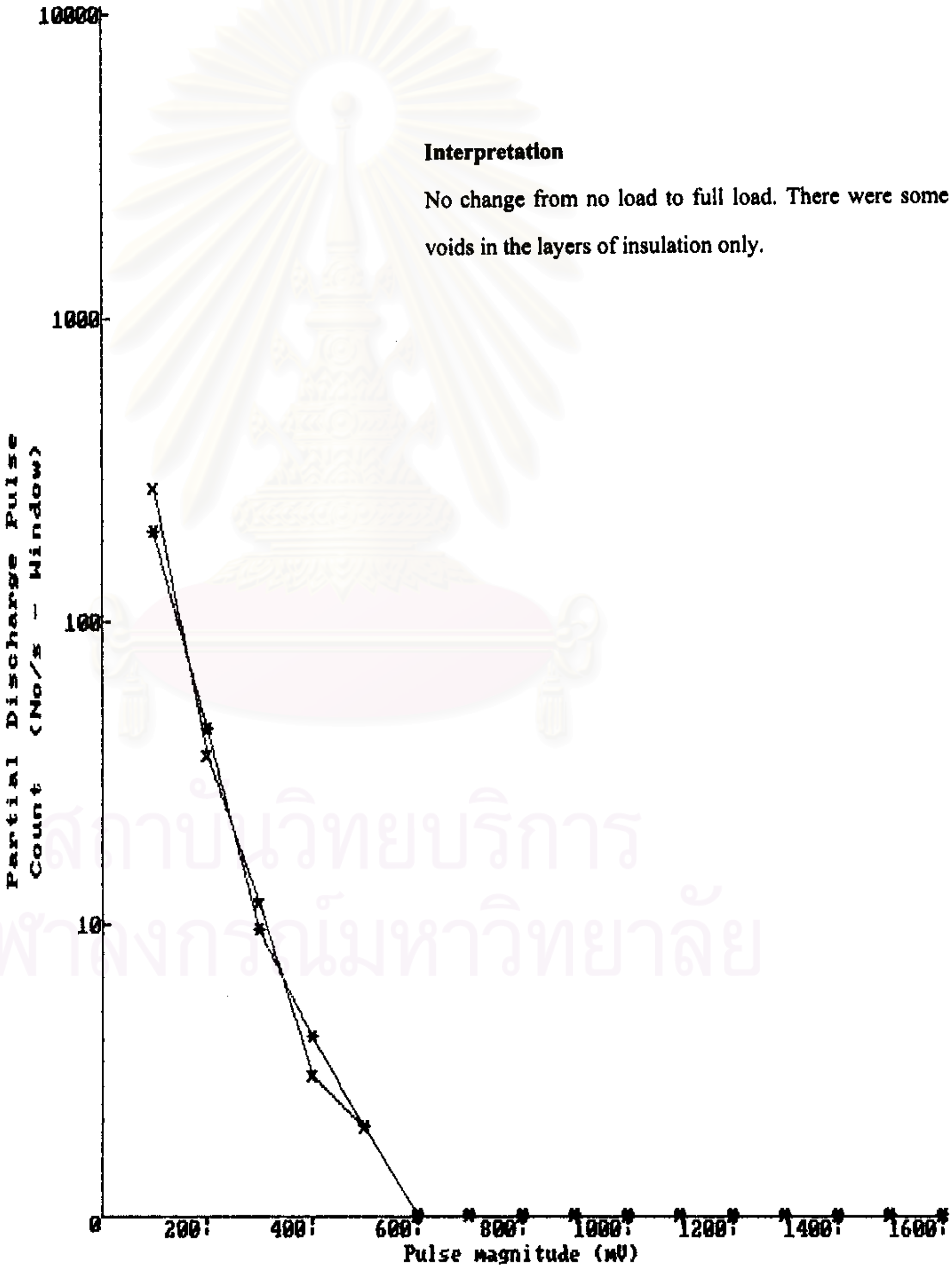
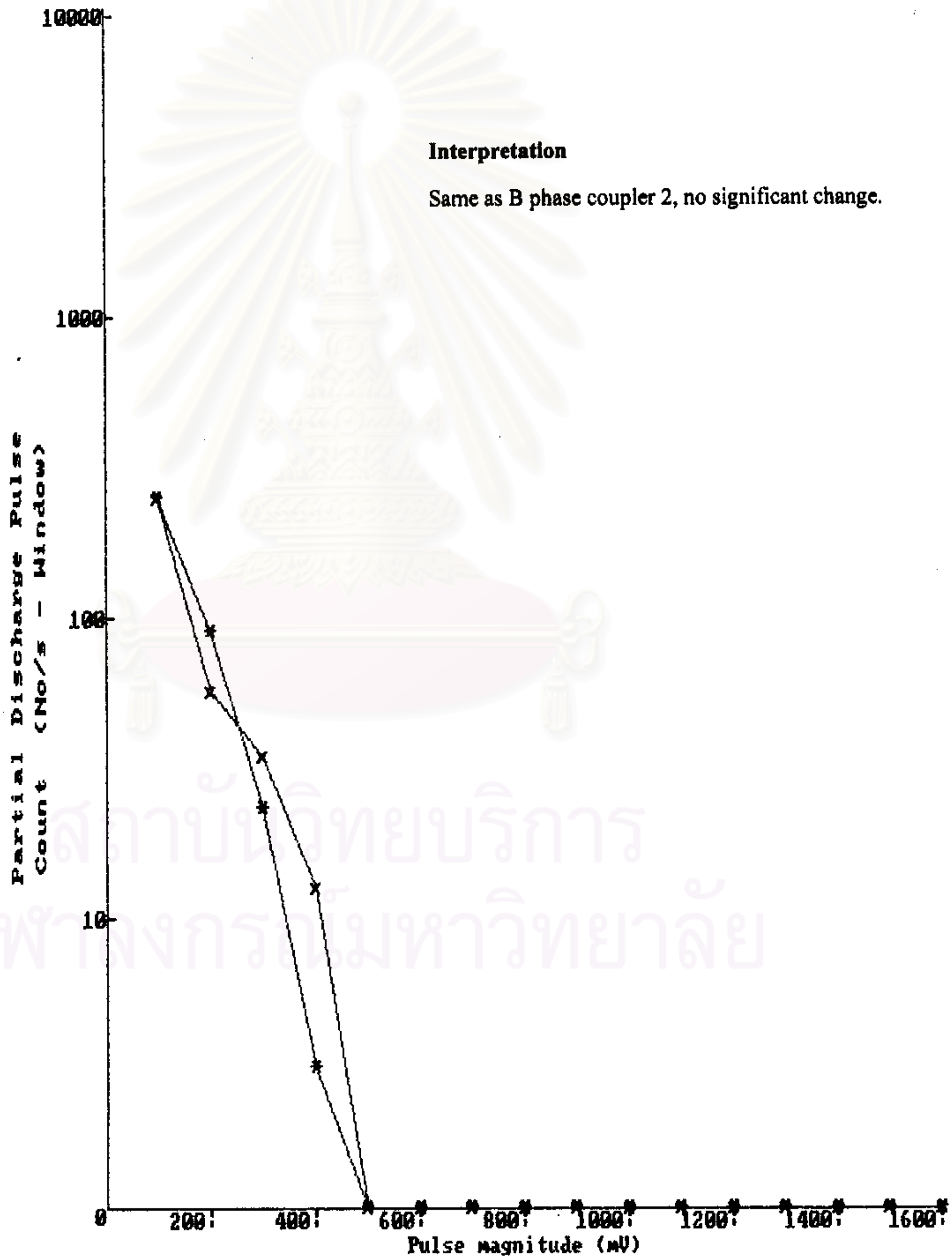


Fig. 4.1.2.5 Data measurement of B Phase, parallel 2

SIRIKIT HYDRO POWER PLANT Unit 02

```
D:\PDAH\PDAH\STATIONA\GEN1\SKT02B04.046                  B Phase  Coupler 2
Tested on  Thu Jun 23,1998 at 09:38:39   Coupler pair B04   Gain 1.00
Voltage reference  221    Temp   50  C   Full Load, Cold      Synchronized
Power    81 MW  Reactive     0 MX   Voltage        13.8  Differential Mode
Positive Pulses (x) NQN  551               Negative Pulses (*) NQN  493
```



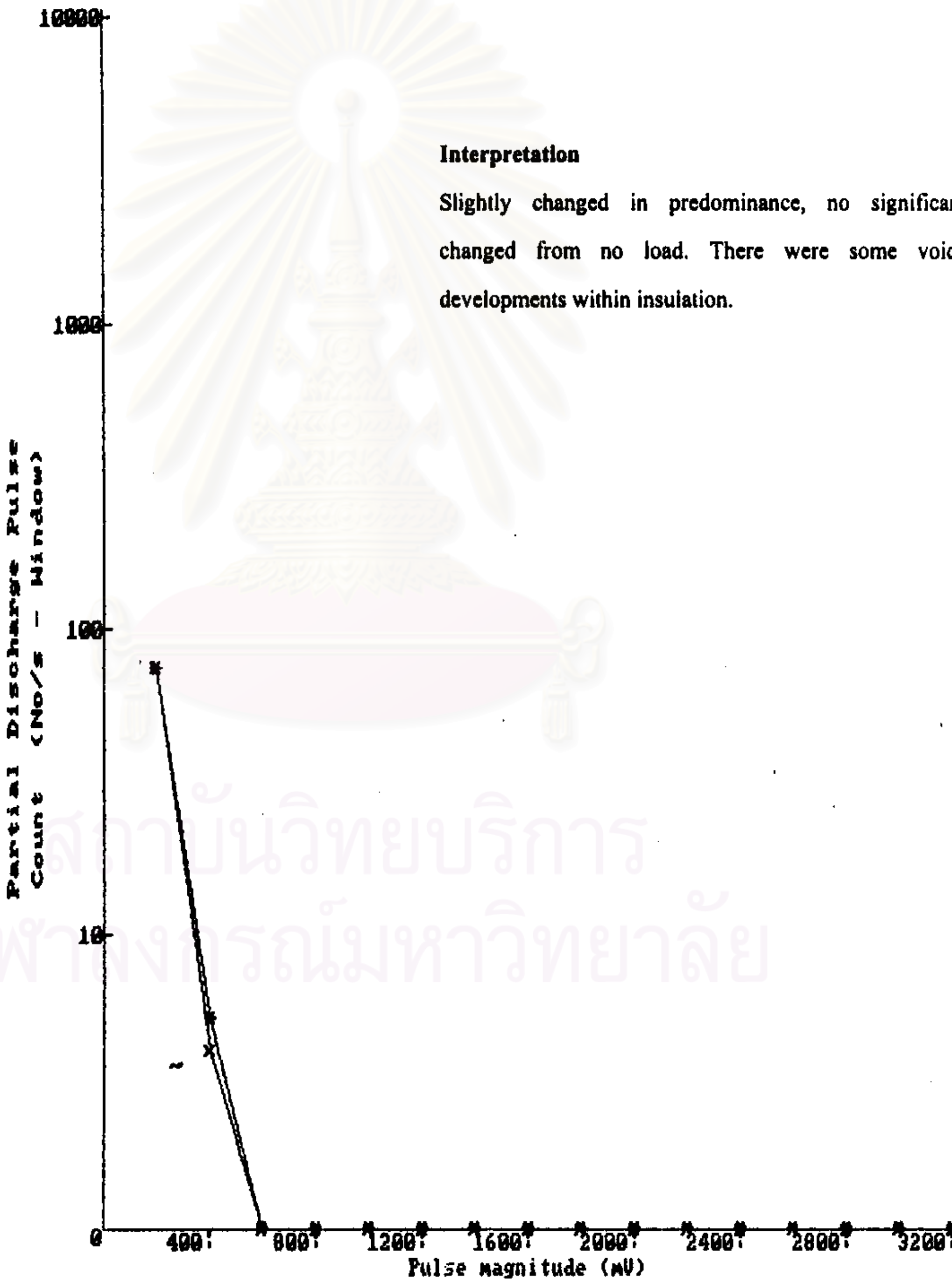
Interpretation

Same as B phase coupler 2, no significant change.

Fig. 4.1.2.6 Data measurement of B Phase, parallel 3

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02C05.047 C Phase Coupler 1
Tested on Thu Jun 23,1998 at 09:40:59 Coupler pair C05 Gain 0.50
Voltage reference 209 Temp 50 C **Full Load, Cold** Synchronized
Power 81 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 305 Negative Pulses (*) NQN 324



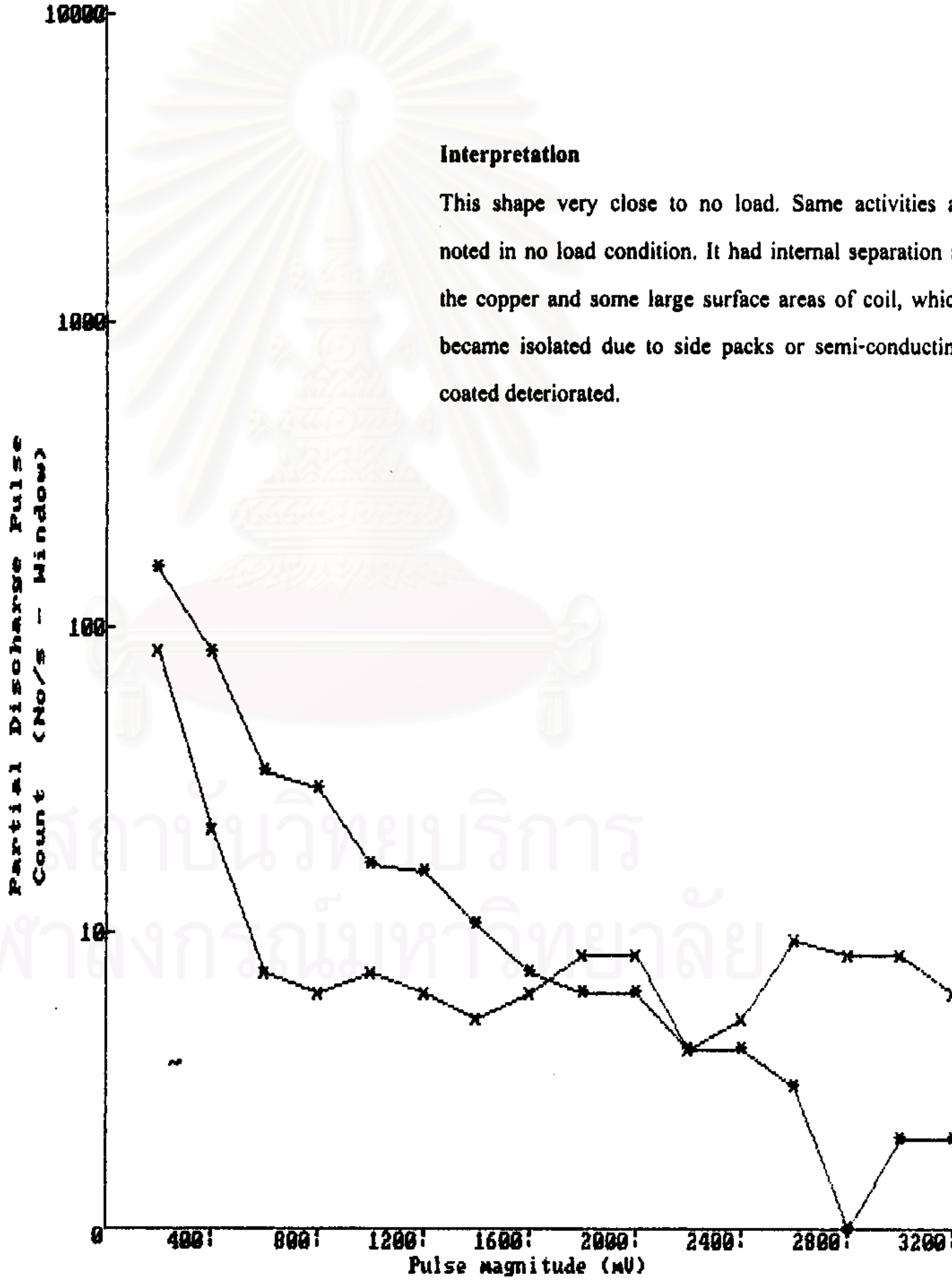
Interpretation

Slightly changed in predominance, no significant changed from no load. There were some voids developments within insulation.

Fig. 4.1.2.7 Data measurement of C Phase, parallel 1

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02C05.047 C Phase Coupler 2
Tested on Thu Jun 23,1998 at 09:40:59 Coupler pair C05 Gain 0.50
Voltage reference 209 Temp 50 C Full Load, Cold Synchronized
Power 81 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 2884 Negative Pulses (*) NQN 2799
NQN inaccurate due to high PD activity



Interpretation

This shape very close to no load. Same activities as noted in no load condition. It had internal separation at the copper and some large surface areas of coil, which became isolated due to side packs or semi-conducting coated deteriorated.

Fig. 4.1.2.8 Data measurement of C Phase, parallel 2

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02C06.048 C Phase Coupler 2
Tested on Thu Jun 23,1998 at 09:43:17 Coupler pair C06 Gain 0.50
Voltage reference 213 Temp 50 C **Full Load, Cold** Synchronized
Power 81 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 2400 Negative Pulses (*) NQN 2661

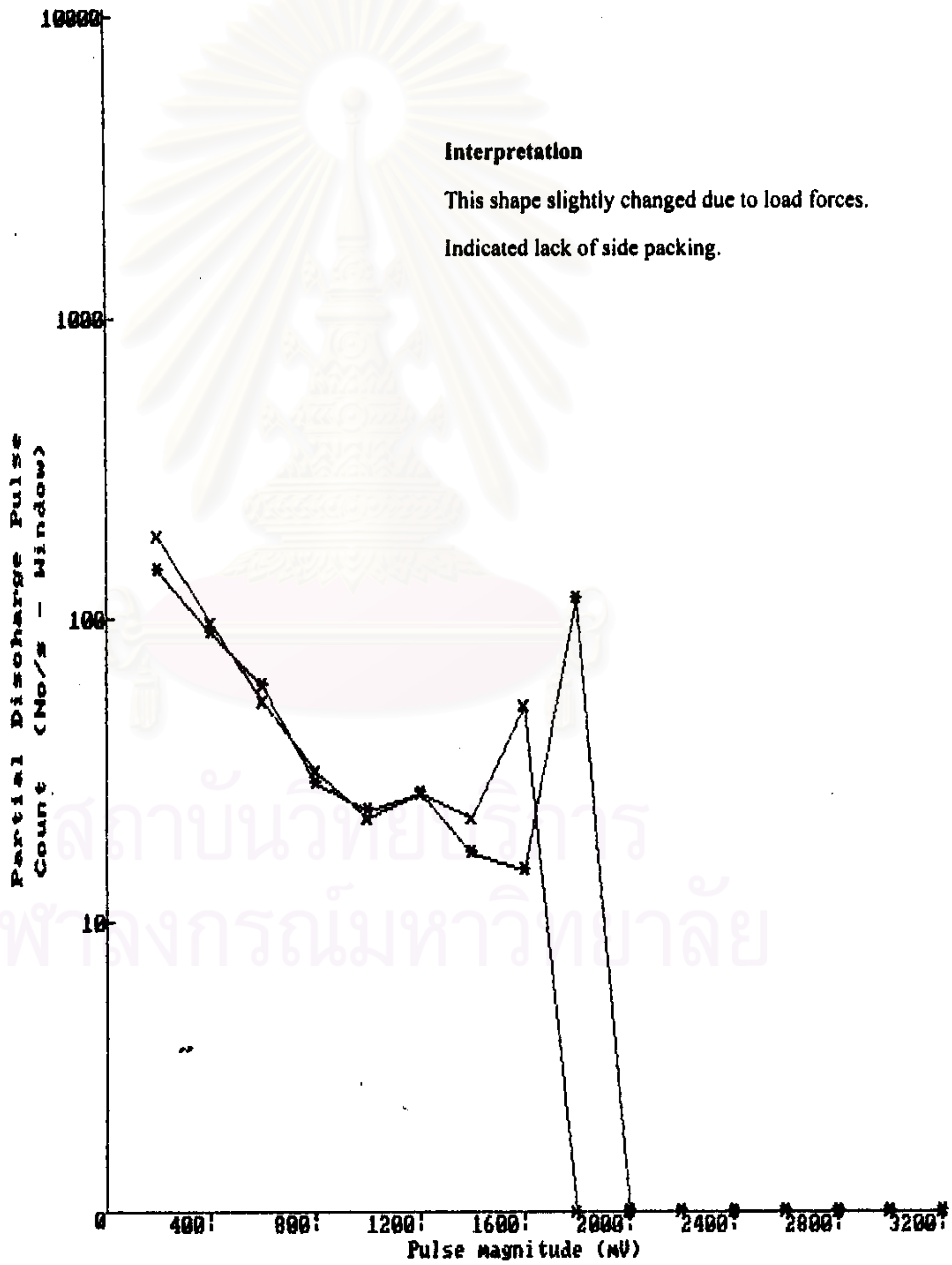


Fig. 4.1.2.9 Data measurement of C Phase, parallel 3

4.1.2.1 The interpretation summary on Full load cold condition

This condition provided some vibration from full load operation. Stator winding was in status of low temperature but under vibration while operating. The overall picture of winding showed some partial discharges occurred and had some deterioration like No load condition.

Winding parallel path 1, and 3, phase A showed high value of both NQN and had internal separation in ground-wall and some surface deterioration. The total partial discharge activities were slightly increased more than no load condition.

Winding parallel path 2, phase A showed higher amount of NQN and both positive and negative were predominance. These activities were slightly increased higher than no load condition. These meant overall picture of winding had deterioration on surface of coils at slot portion, delamination on ground wall insulation and deterioration on coil end portion.

Winding parallel path 1, phase B showed internal discharge and slot discharge due to both negative and positive pulses were predominance. The magnitude and pulse rates were slightly higher than no load condition. There was deterioration on winding at slot portion and delamination with in ground wall.

Winding parallel path 2 and 3, phase B showed status same as no load condition. The quantity of NQN was not so high, so that it had lower deterioration within insulation than parallel path 1.

Winding parallel path1 and 3, phase C showed negative pulses were predominance. This meant internal discharge occurred within winding cause of ground wall delamination.

Winding parallel path 2, phase C showed very high amount of NQN and both positive and negative were predominance. These showed a lot of deterioration occurred on anywhere of winding as slot discharge, internal discharge and surface discharge around coil end. The winding might be tight, that partial discharge activities were less effected from vibration.

4.1.3 Full load hot condition

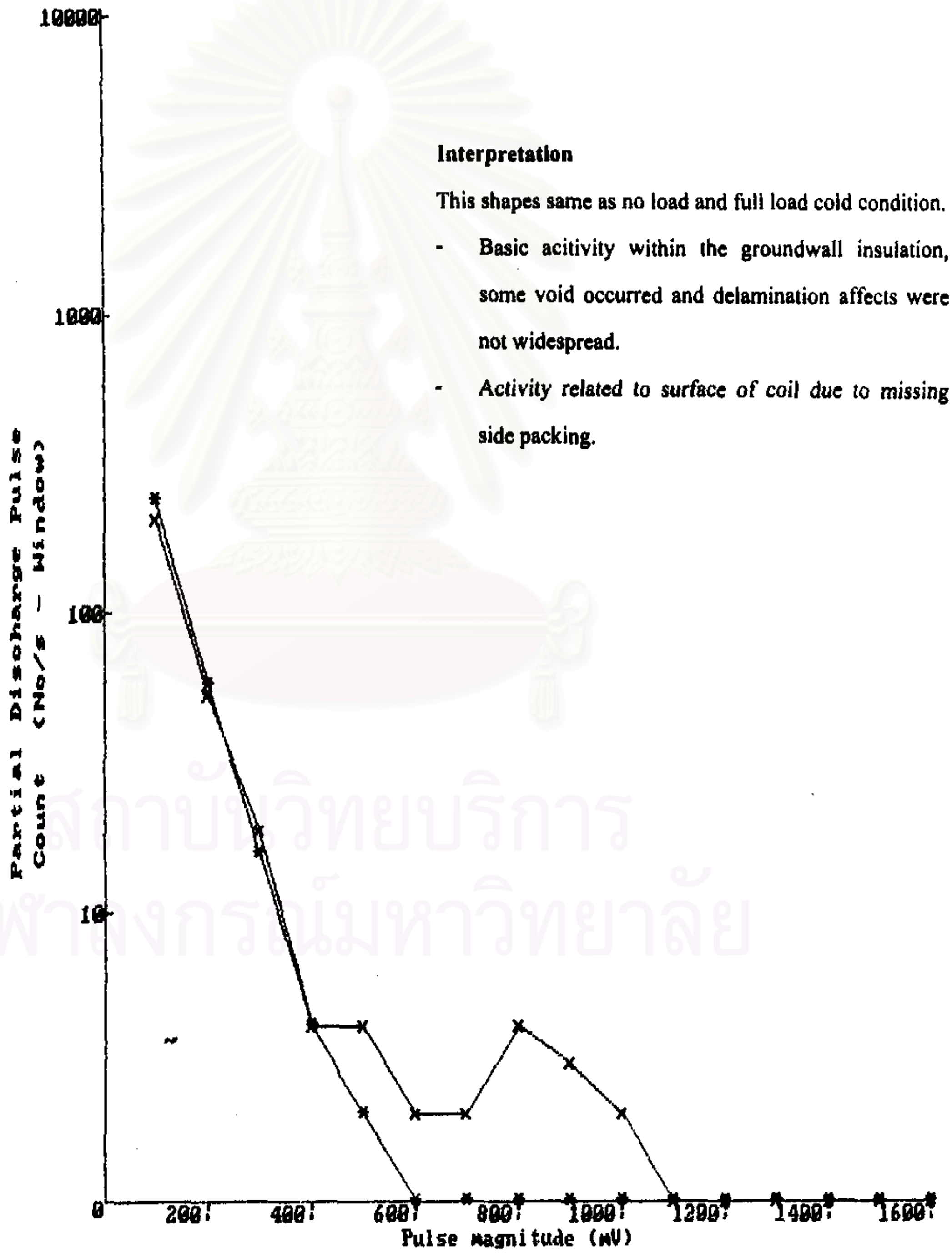
1). Test data of coupler1 of parallel path 1, coupler2 of parallel path 2 and coupler3 of parallel path 3 phase A and their interpretation as shown in Fig. 4.1.3.1 to 4.1.3.3.

2). Test data of coupler1 of parallel path 1, coupler2 of parallel path 2 and coupler3 of parallel path 3 phase B and their interpretation as shown in Fig. 4.1.3.4 to 4.1.3.6.

3). Test data of coupler1 of parallel path 1, coupler2 of parallel path 2 and coupler3 of parallel path 3 phase C and their interpretation as shown in Fig. 4.1.3.7 to 4.1.3.9.

SIRIKIT HYDRO POWER PLANT Unit 02

```
D:\PDAH\PDAH\STATIONA\GEN1\SKT02A01.049                        A Phase   Coupler 1
Tested on  Thu Jun 23,1998 at 09:58:14   Coupler pair A01   Gain 1.00
Voltage reference  214    Temp   68  C   Full Load, Hot        Synchronized
Power   81 MW  Reactive     0 MX   Voltage        13.8  Differential Mode
Positive Pulses (x) NQN  729             Negative Pulses (*) NQN  499
```



Interpretation

This shapes same as no load and full load cold condition.

- Basic acitivity within the groundwall insulation, some void occurred and delamination affects were not widespread.
- *Activity related to surface of coil due to missing side packing.*

Fig. 4.1.3.1 Data measurement of A Phase, parallel 1

SIRIKIT HYDRO POWER PLANT Unit 02

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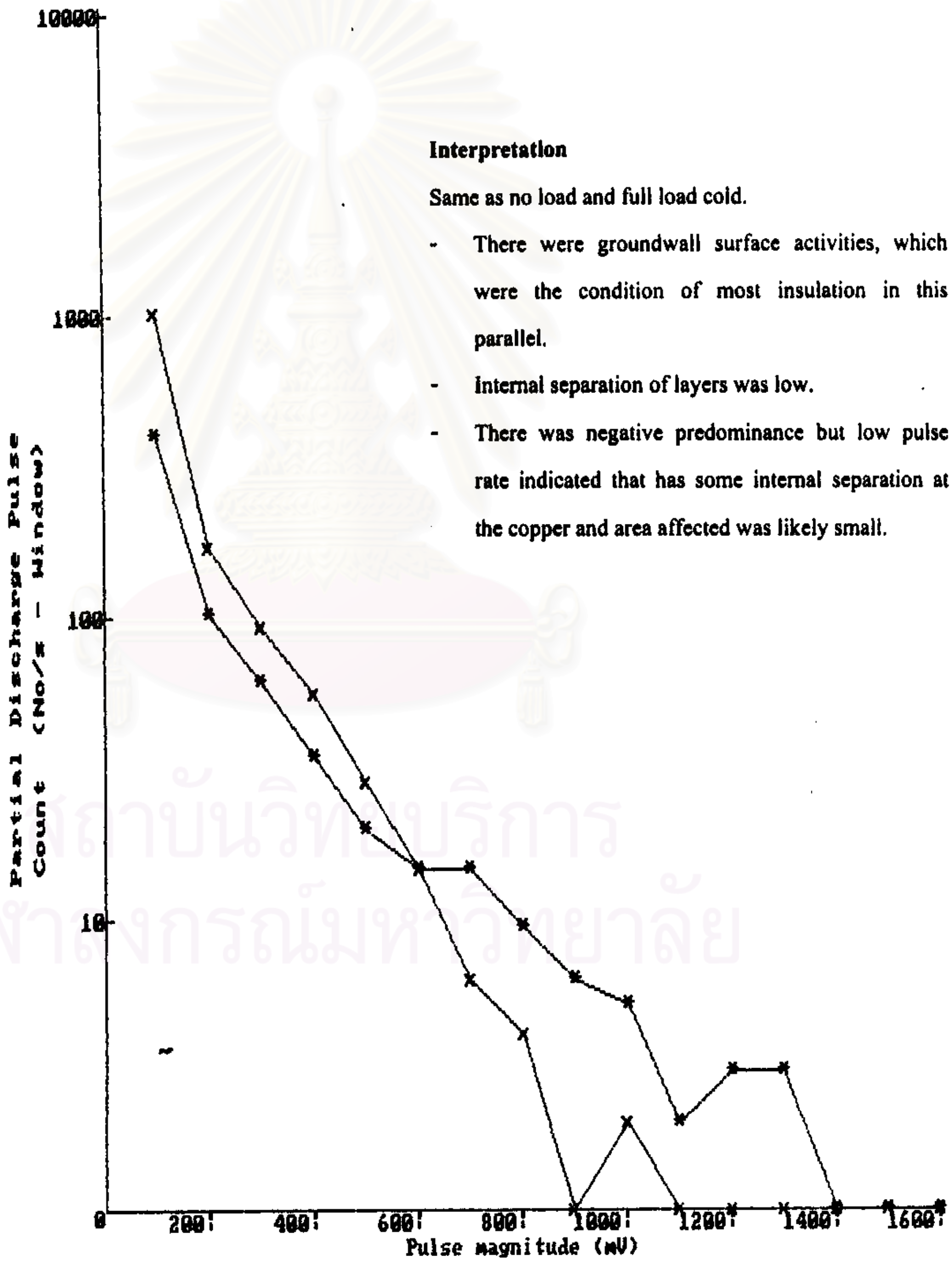
D:\PDAH\PDAH\STATIONA\GEN1\SKT02A01.049                  A Phase   Coupler 2
Tested on  Thu Jun 23,1998 at 09:58:14   Coupler pair A01   Gain 1.00
Voltage reference  214    Temp   68  C   Full Load, Hot       Synchronized
Power    81 MW  Reactive     0 MX   Voltage        13.8  Differential Mode
Positive Pulses (x) NQN 1163              Negative Pulses (*) NQN 1382
```



Interpretation

Same as no load and full load cold.

- There were groundwall surface activities, which were the condition of most insulation in this parallel.
- Internal separation of layers was low.
- There was negative predominance but low pulse rate indicated that has some internal separation at the copper and area affected was likely small.

Fig. 4.1.3.2 Data measurement of A Phase, parallel2

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02A02.050 A Phase Coupler 2
Tested on Thu Jun 23,1998 at 10:00:29 Coupler pair A02 Gain 1.00
Voltage reference 213 Temp 68 C Full Load, Hot Synchronized
Power 81 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 1052 Negative Pulses (*) NQN 650

Interpretation

Same as no load and full load, cold condition.

- Overall surface activities indicated.
- Poor side packing and may had some large isolated areas of surface.

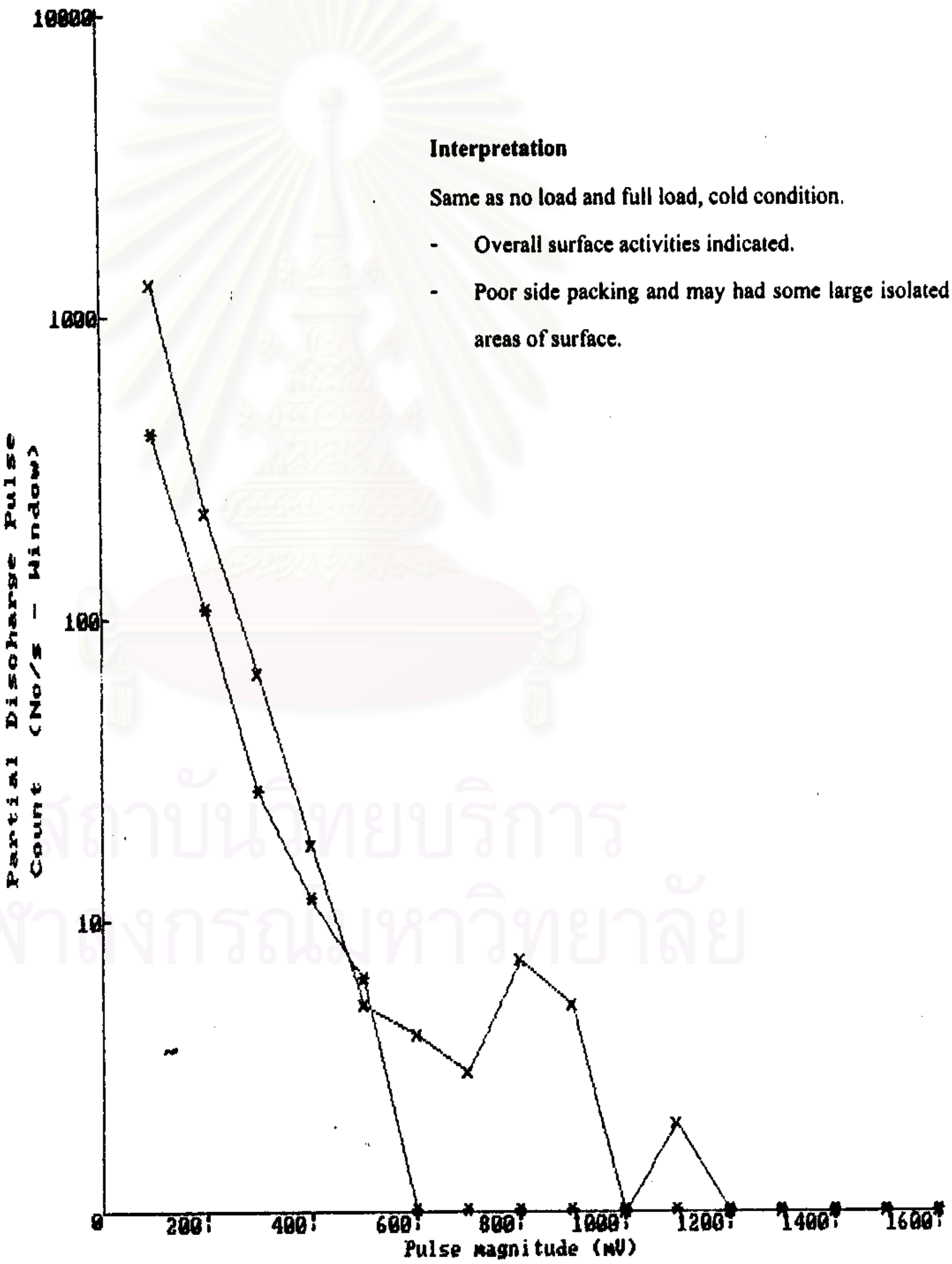


Fig. 4.1.3.3 Data measurement of A Phase, parallel 3

SIRIKIT HYDRO POWER PLANT Unit 02

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D:\PDAH\PDAH\STATIONA\GEN1\SKT02B04.052                   B Phase  Coupler 1
Tested on  Thu Jun 23,1998 at 10:04:58   Coupler pair B04   Gain 1.00
Voltage reference  221    Temp   68  C   Full Load, Hot         Synchronized
Power    81 MW  Reactive     0 MX   Voltage        13.8  Differential Mode
Positive Pulses (x) NQN  545               Negative Pulses (*) NQN  561
```
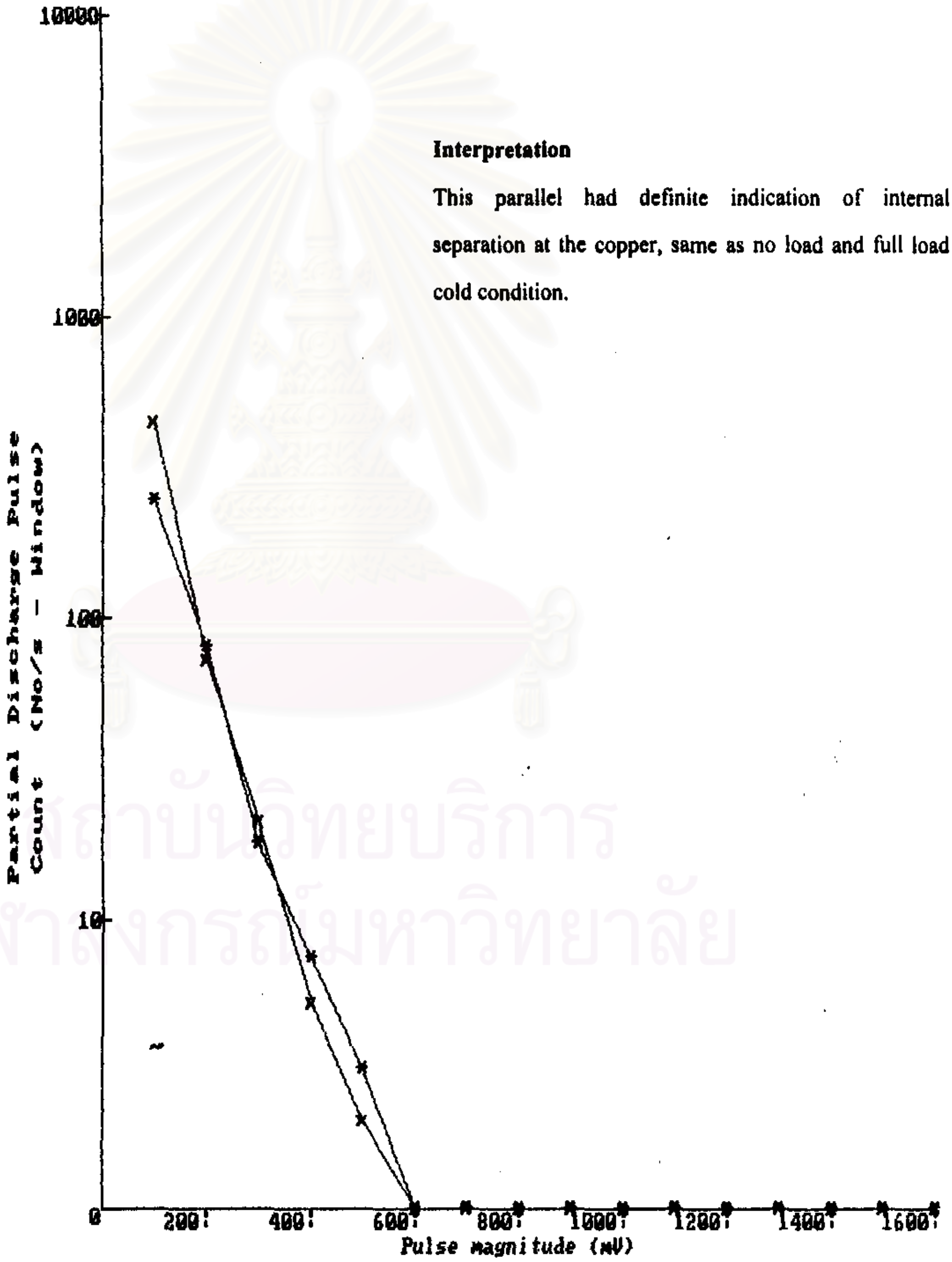



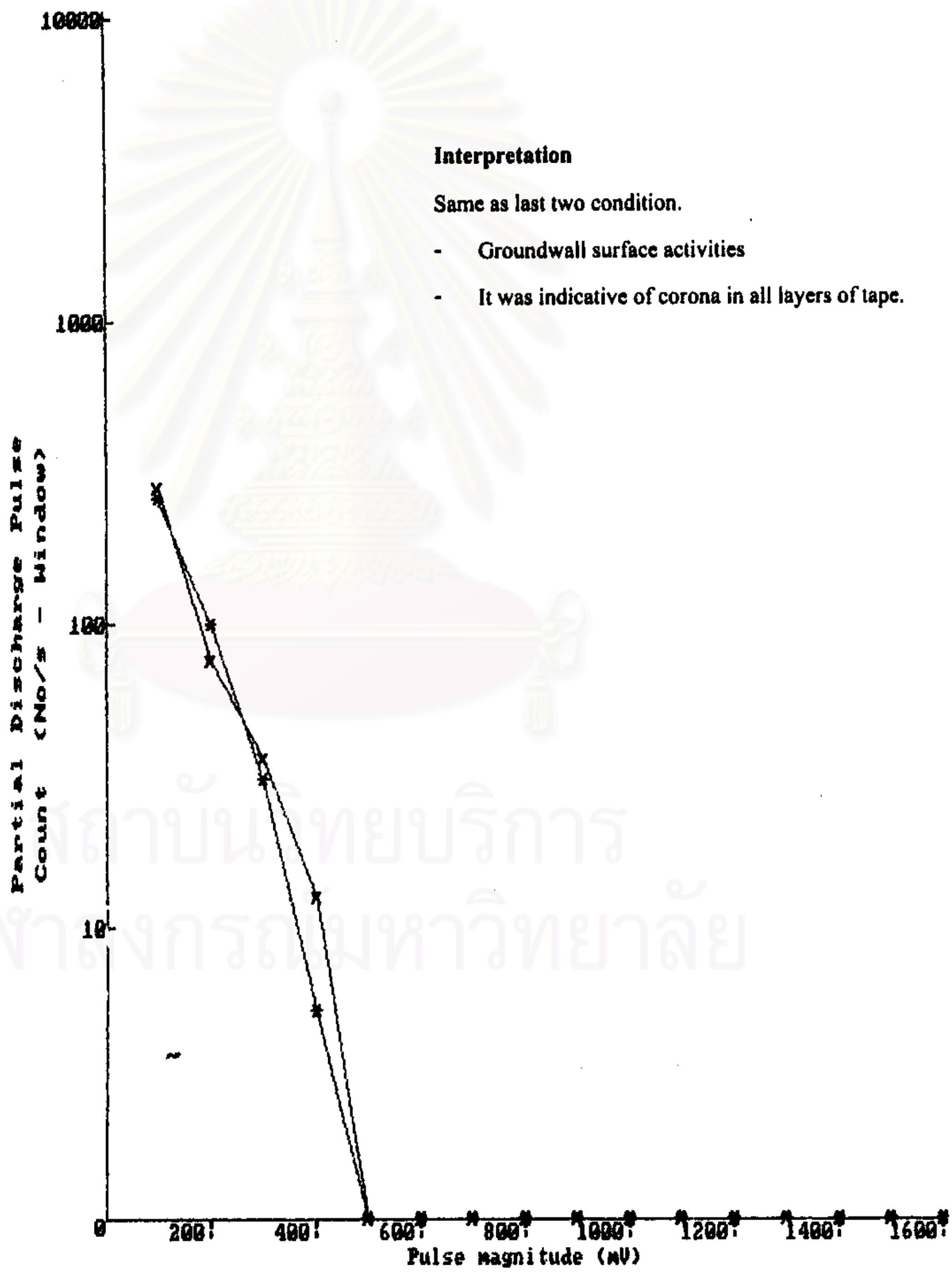
Interpretation

This parallel had definite indication of internal separation at the copper, same as no load and full load cold condition.

Fig. 4.1.3.4 Data measurement of B Phase, parallel 1

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02B04.052 B Phase Coupler 2
Tested on Thu Jun 23,1998 at 10:04:58 Coupler pair B04 Gain 1.00
Voltage reference 221 Temp 68 C Full Load, Hot Synchronized
Power 81 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 568 Negative Pulses (*) NQN 532



Interpretation

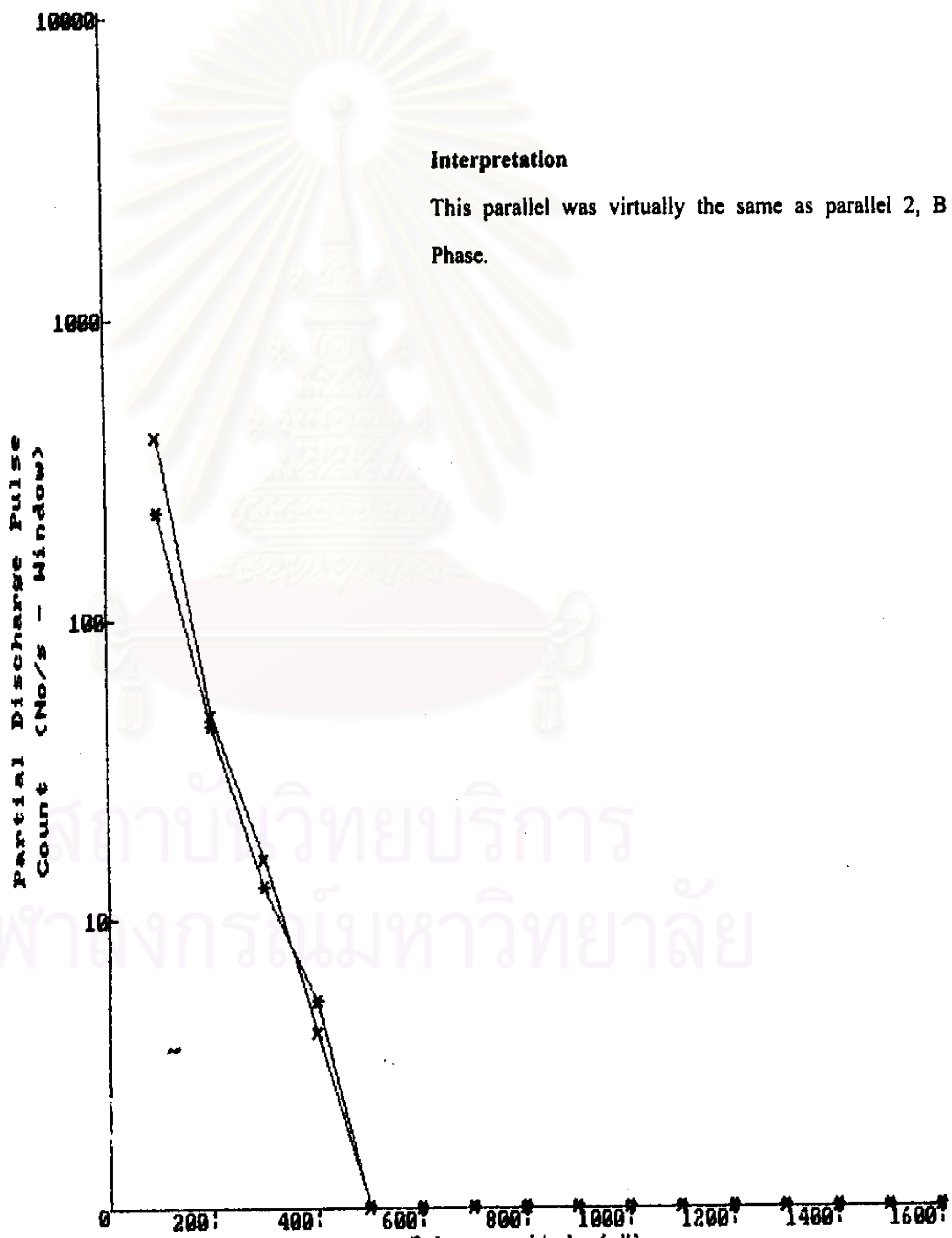
Same as last two condition.

- Groundwall surface activities
- It was indicative of corona in all layers of tape.

Fig. 4.1.3.5 Data measurement of B Phase, parallel 2

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02B03.051 B Phase Coupler 2
Tested on Thu Jun 23,1998 at 10:02:41 Coupler pair B03 Gain 1.00
Voltage reference 217 Temp 68 C Full Load, Hot Synchronized
Power 81 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 472 Negative Pulses (*) NQN 455



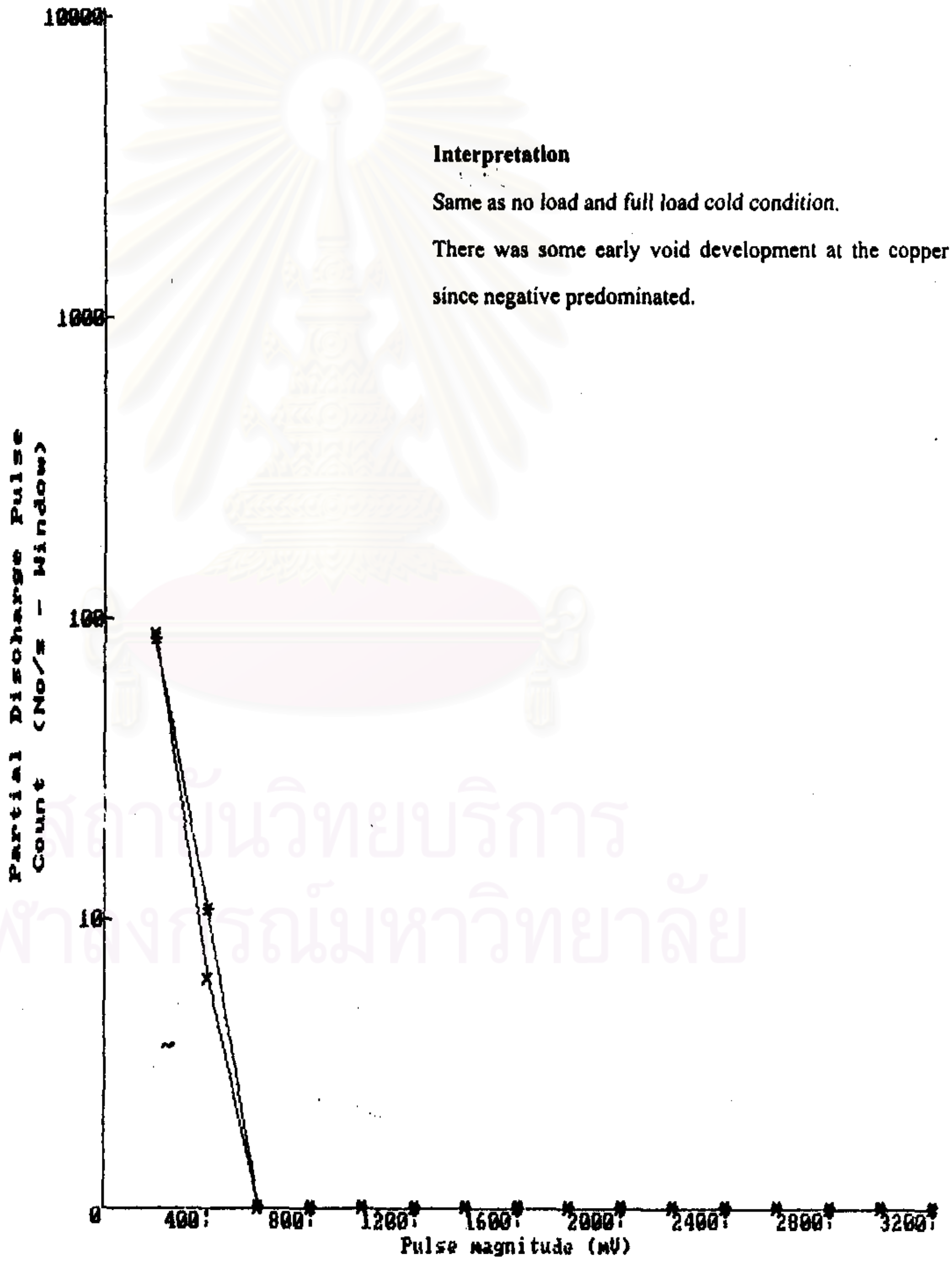
Interpretation

This parallel was virtually the same as parallel 2, B Phase.

Fig. 4.1.3.6 Data measurement of B Phase, parallel 3

SIRIKIT HYDRO POWER PLANT Unit 02

```
D:\PDAH\PDAH\STATIONA\GEN1\SKT02C05.053                    C Phase   Coupler 1
Tested on  Thu Jun 23,1998 at 10:07:17   Coupler pair C05   Gain 0.50
Voltage reference  207    Temp   68  C   Full Load, Hot       Synchronized
Power    81 MW  Reactive      0 MX    Voltage        13.8  Differential Mode
Positive Pulses (x) NQN  348              Negative Pulses (*) NQN  390
```



Interpretation

Same as no load and full load cold condition.

There was some early void development at the copper since negative predominated.

Fig. 4.1.3.7 Data measurement of C Phase, parallel 1

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02C05.053 C Phase Coupler 2
Tested on Thu Jun 23,1998 at 10:07:17 Coupler pair C05 Gain 0.50
Voltage reference 207 Temp 68 C **Full Load, Hot** Synchronized
Power 81 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 3080 Negative Pulses (*) NQN 2798
NQN inaccurate due to high PD activity

Interpretation

This was the most active parallel in generator unit 2 same as last two conditions.

- There was internal delaminating at the copper.
- There were some surface activities that had some large surface areas had become isolated since positive predominated.

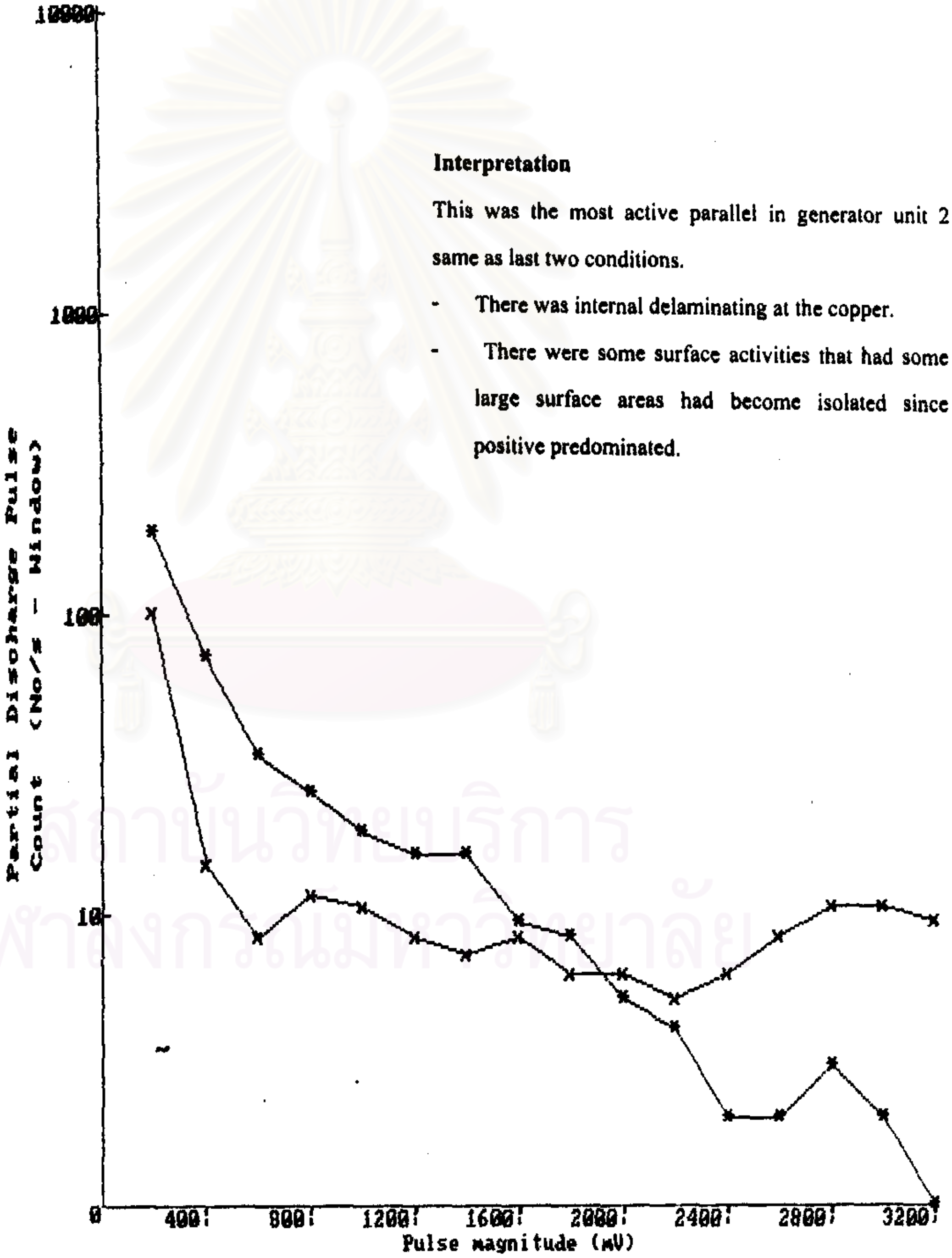
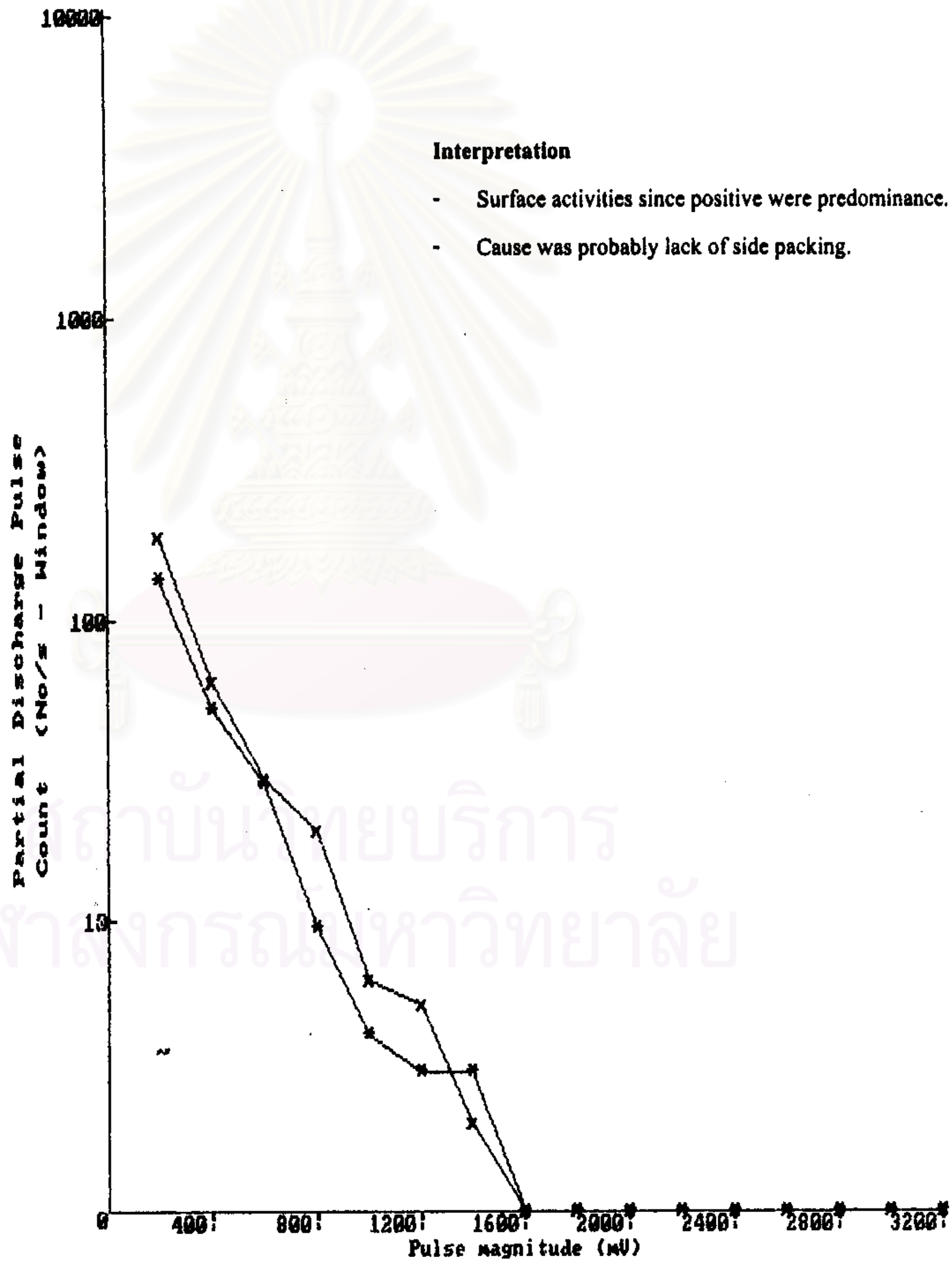


Fig. 4.1.3.8 Data measurement of C Phase, parallel 2

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02C06.054 C Phase Coupler 2
Tested on Thu Jun 23,1998 at 10:09:32 Coupler pair C06 Gain 0.50
Voltage reference 212 Temp 68 C Full Load, Hot Synchronized
Power 81 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 1480 Negative Pulses (*) NQN 1335



Interpretation

- Surface activities since positive were predominance.
- Cause was probably lack of side packing.

Fig. 4.1.3.9 Data measurement of C Phase, parallel 3

4.1.3.1 <u>The interpretation summary on Full load hot condition</u>

This condition was high effected from vibration and temperature while full load operating.

Overview picture of stator winding had some deterioration within winding at any part, delamination on ground wall insulation and some pollution around coil end. Total NQN and size of partial discharge magnitude include pulse rate was slightly higher than full load cold condition.

Winding parallel path 1 of phase A showed the similarly pattern of graph with two conditions at above mentioned, but the total NQN, magnitude and pulse rate were higher. These meant large amount of partial discharges had occurred when temperature increased. Both negative and positive pulses were equal and predominance to show that internal discharges were occurred within winding cause of delamination in ground wall insulation.

Winding parallel path 2 of phase A were the same as path 1, there were internal discharges and surface discharges occurred within winding. Surface discharges had occurred higher than the last two conditions that might be effected from high temperature. These meant some deterioration occurred within surface area of coils in slot portion.

Winding parallel path 3 of phase A showed internal discharge and surface discharges same as path 1, however positive pulses were predominant than negative pulses cause of high vibration and high temperature. Then, there were some deterioration occurred within surface area of coil in slot portion when increased vibration and temperature by full load operation.

Winding parallel path 1 of phase B showed less partial discharge activities than other paths. The negative and positive pulses were about equal, meaning in internal discharges occurring. There was less deterioration of coil surface.

Winding parallel path 2 and 3 of phase B were the same as path 1. Only internal discharges occurred within winding, the total partial discharge activities were less than other paths, meaning in less deterioration of winding insulation.

Winding parallel path 1and path 3 of phase C had similarly pattern of graphs that showed internal discharges occurred within winding insulation. However, path3 showed positive pulses were slightly predominant than negative pulses, meaning in some surface discharge occurring.

Winding parallel path 2 of phase C showed the same pattern of curves as two conditions in the first stage. With higher vibration and temperature, there was large amount of partial discharge activities occurring. The negative pulses were predominance, showing in high interface discharges occurring. There were delaminating between copper conductor and main ground insulation. However, the positive pulses were also predominant, meaning in high surface discharges occurring on coil surfaces. The overall picture showed high partial discharge activities occurred around stator winding (high amount of NQN, high magnitude and pulse rate).

4.1.4 No load hot condition

1). Test data of coupler1 of parallel path 1, coupler2 of parallel path 2 and coupler3 of parallel path 3 phase A and their interpretation as shown in Fig. 4.1.4.1 to 4.1.4.3.

2). Test data of coupler1 of parallel path 1, coupler2 of parallel path 2 and coupler3 of parallel path 3 phase B and their interpretation as shown in Fig. 4.1.4.4 to 4.1.4.6.

3). Test data of coupler1 of parallel path 1, coupler2 of parallel path 2 and coupler3 of parallel path 3 phase C and their interpretation as shown in Fig. 4.1.4.7 to 4.1.4.9.

SIRIKIT HYDRO POWER PLANT Unit 02

```
D:\PDAH\PDAH\STATIONA\GEN1\SKT02A01.055                A Phase   Coupler 1
Tested on  Thu Jun 23,1998 at 10:36:13  Coupler pair A01   Gain 1.00
Voltage reference  218    Temp   64  C   No  Load, Hot        Synchronized
Power     0 MW  Reactive     0 MX   Voltage        13.8  Differential Mode
Positive Pulses (x) NQN  675              Negative Pulses (*) NQN  556
```

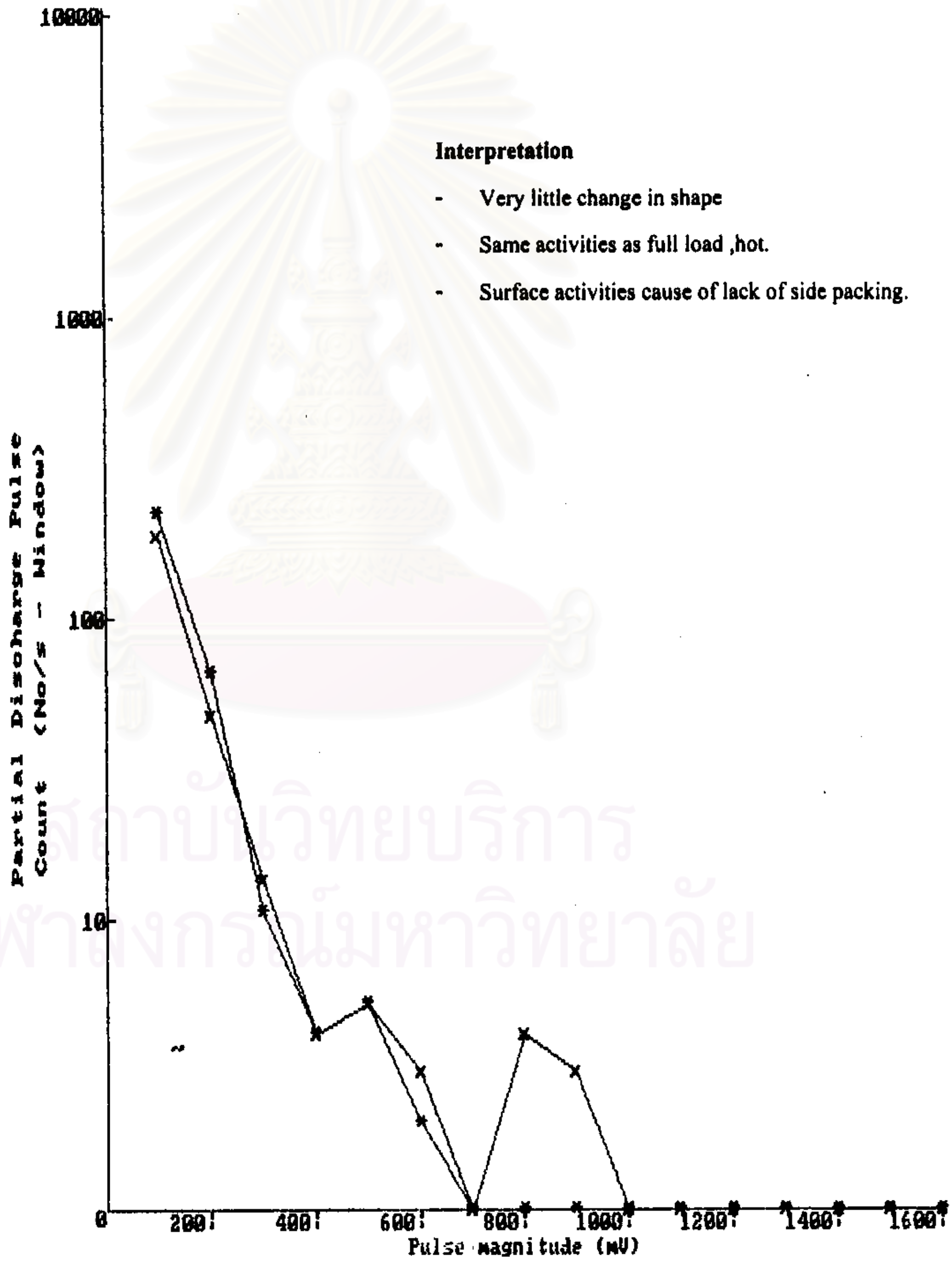
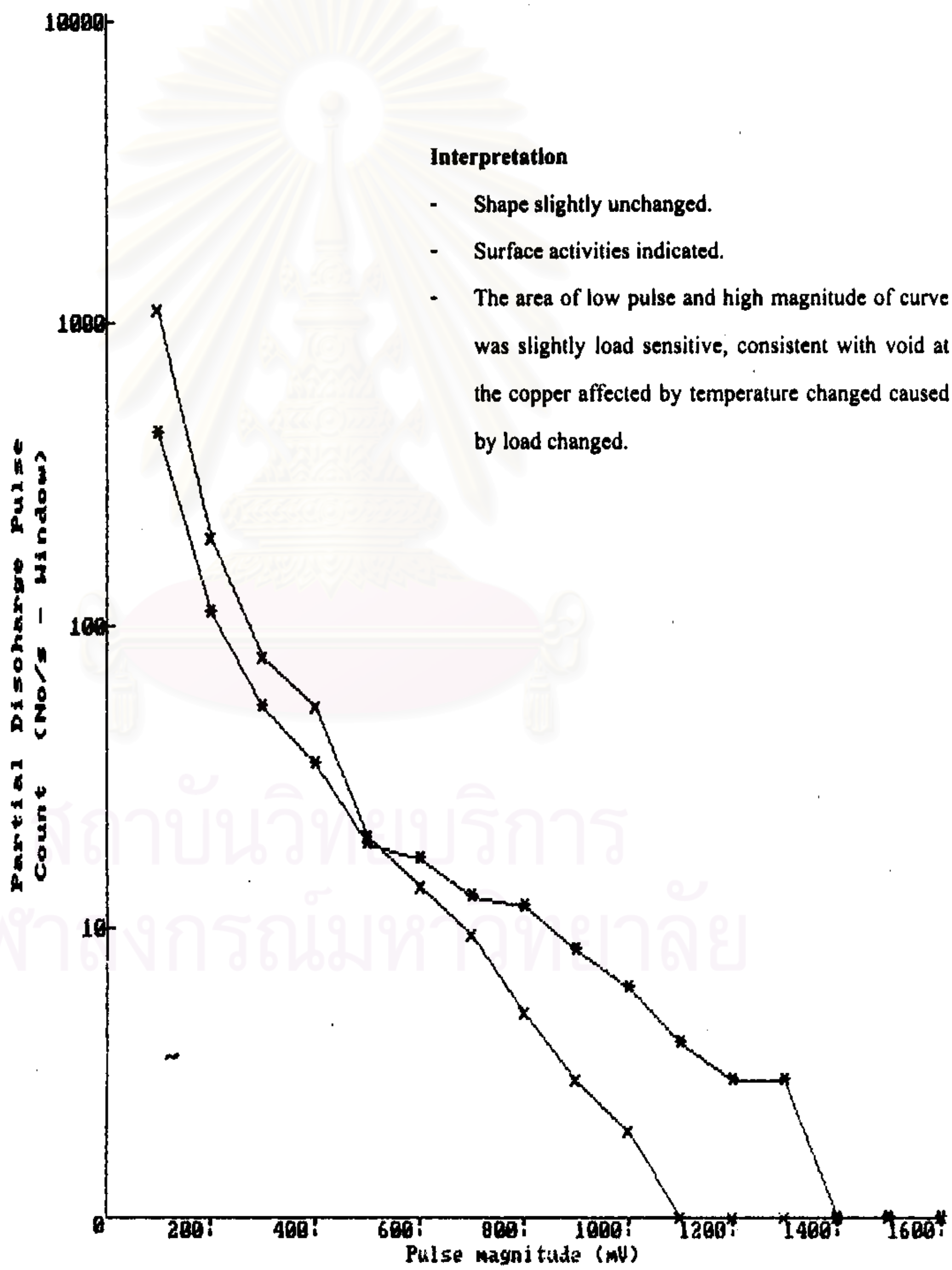


Fig. 4.1.4.1 Data measurement of A Phase, parallel 1

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02A01.055 A Phase Coupler 2
Tested on Thu Jun 23,1998 at 10:36:13 Coupler pair A01 Gain 1.00
Voltage reference 218 Temp 64 C No Load, Hot Synchronized
Power 0 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 1218 Negative Pulses (*) NQN 1437



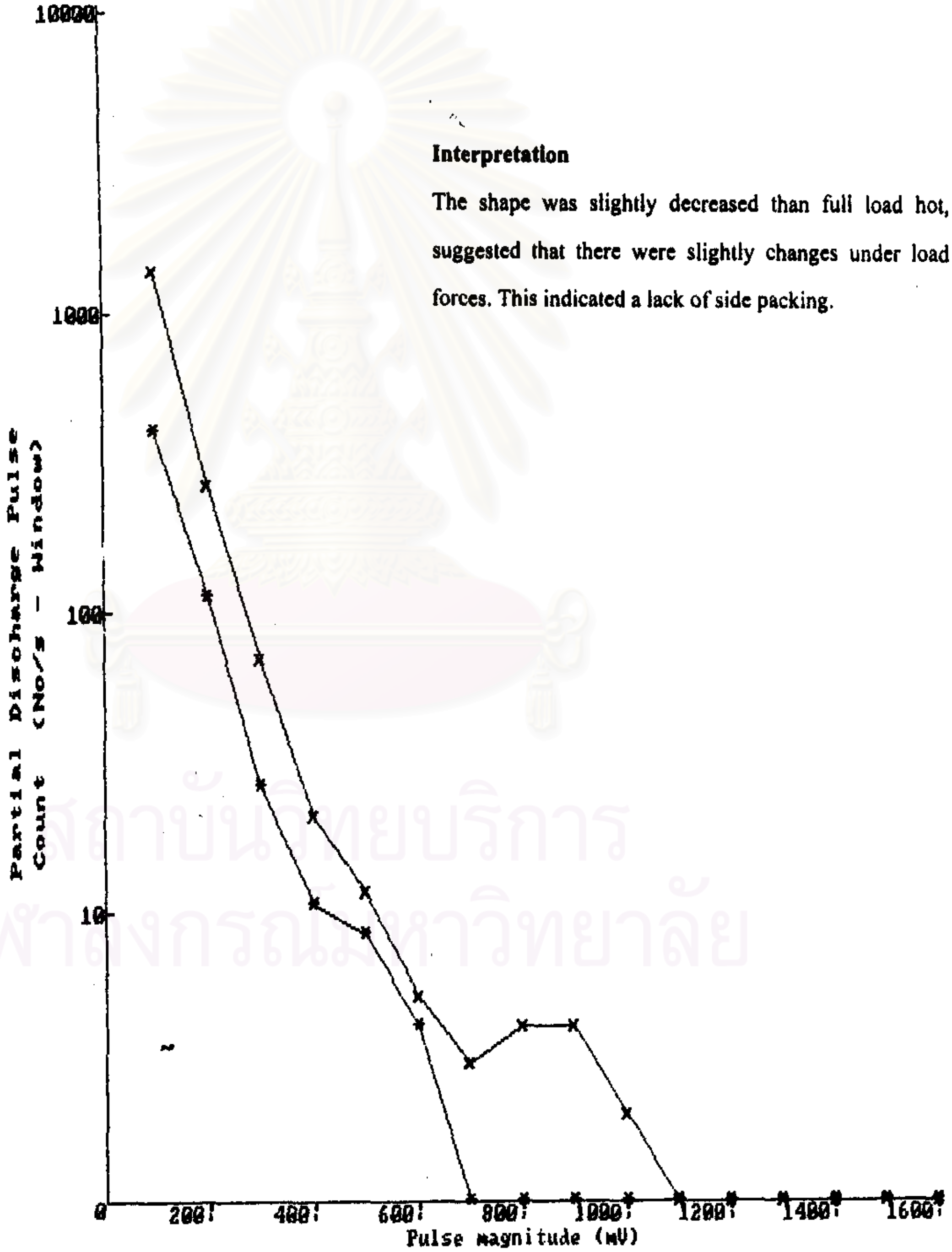
Interpretation

- Shape slightly unchanged.
- Surface activities indicated.
- The area of low pulse and high magnitude of curve was slightly load sensitive, consistent with void at the copper affected by temperature changed caused by load changed.

Fig. 4.1.4.2 Data measurement of A Phase, parallel 2

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02A02.056 A Phase Coupler 2
Tested on Thu Jun 23,1998 at 10:38:21 Coupler pair A02 Gain 1.00
Voltage reference 226 Temp 64 C No Load, Hot Synchronized
Power 0 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 1080 Negative Pulses (*) NQN 722



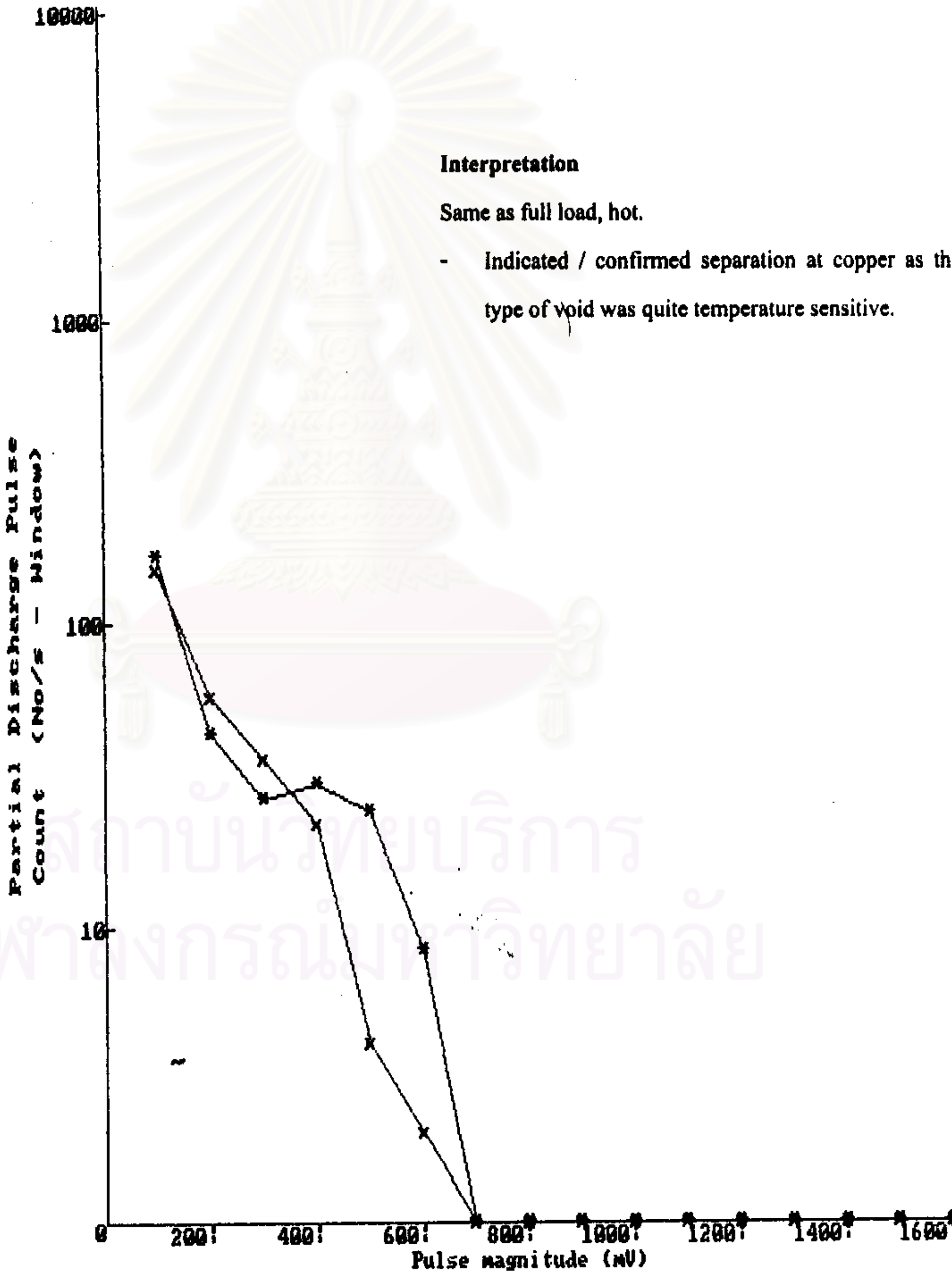
Interpretation

The shape was slightly decreased than full load hot, suggested that there were slightly changes under load forces. This indicated a lack of side packing.

Fig. 4.1.4.3 Data measurement of A Phase parallel 3

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02B03.057 B Phase Coupler 1
Tested on Thu Jun 23,1998 at 10:40:36 Coupler pair B03 Gain 1.00
Voltage reference 218 Temp 64 C No Load, Hot Synchronized
Power 0 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 657 Negative Pulses (*) NQN 781



Interpretation

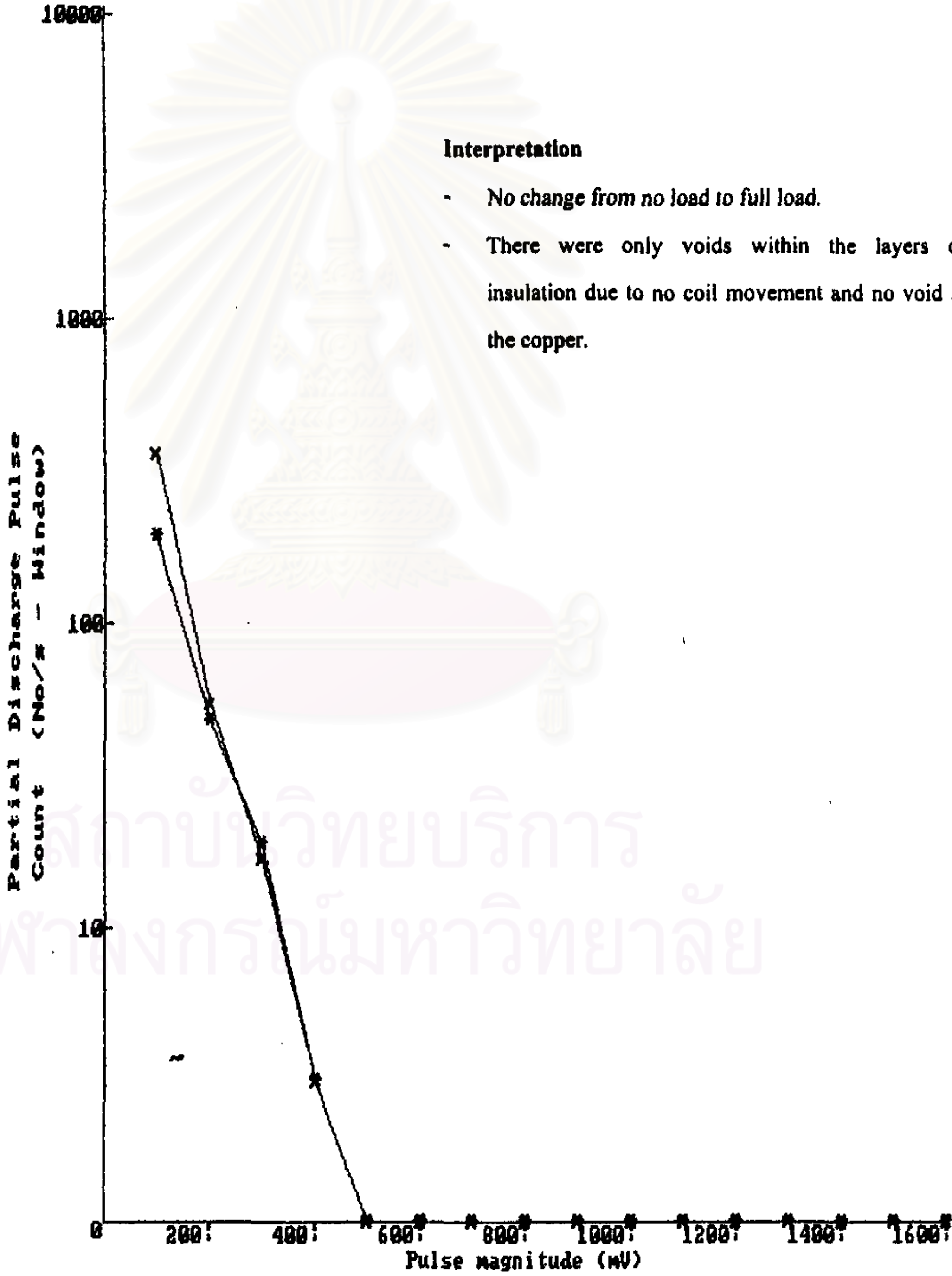
Same as full load, hot.

- Indicated / confirmed separation at copper as this type of void was quite temperature sensitive.

Fig. 4.1.4.4 Data measurement of B Phase, parallel 1

SIRIKIT HYDRO POWER PLANT Unit 02

```
D:\PDAH\PDAH\STATIONA\GEN1\SKT02B03.057                    B Phase   Coupler 2
Tested on  Thu Jun 23,1998 at 10:40:36   Coupler pair B03    Gain 1.00
Voltage reference  218    Temp   64  C   No   Load, Hot       Synchronized
Power      0 MW  Reactive     0 MX   Voltage        13.8  Differential Mode
Positive Pulses (x) NQN  466             Negative Pulses (*) NQN  451
```



Interpretation

- *No change from no load to full load.*
- There were only voids within the layers of insulation due to no coil movement and no void at the copper.

Fig. 4.1.4.5 Data measurement of B Phase, parallel 2

SIRIKIT HYDRO POWER PLANT Unit 02

```
D:\PDAH\PDAH\STATIONA\GEN1\SKT02B04.058                    B Phase   Coupler 2
Tested on  Thu Jun 23,1998 at 10:42:46   Coupler pair B04   Gain 1.00
Voltage reference  222    Temp   64  C   No   Load, Hot       Synchronized
Power     0 MW  Reactive     0 MX   Voltage      13.8  Differential Mode
Positive Pulses (x) NQN  607             Negative Pulses (*) NQN  515
```

Interpretation

- Same as B Phase, parallel 2.
- No significant changed.
- There was low surface activities.

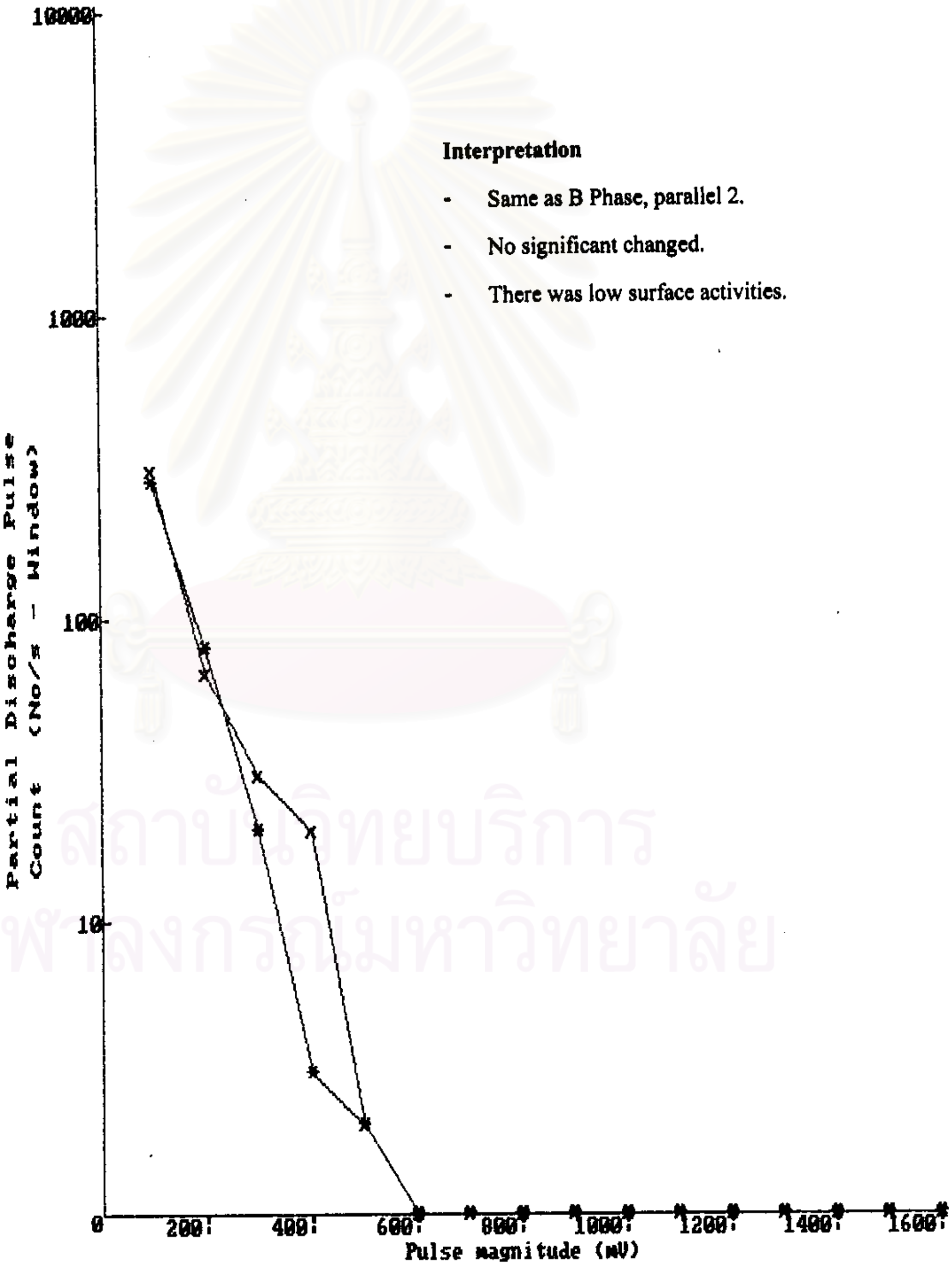


Fig. 4.1.4.6 Data measurement of B Phase, parallel 3

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02C05.059 C Phase Coupler 1
Tested on Thu Jun 23,1998 at 10:45:11 Coupler pair C05 Gain 0.50
Voltage reference 217 Temp 64 C No Load, Hot Synchronized
Power 0 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 502 Negative Pulses (*) NQN 388

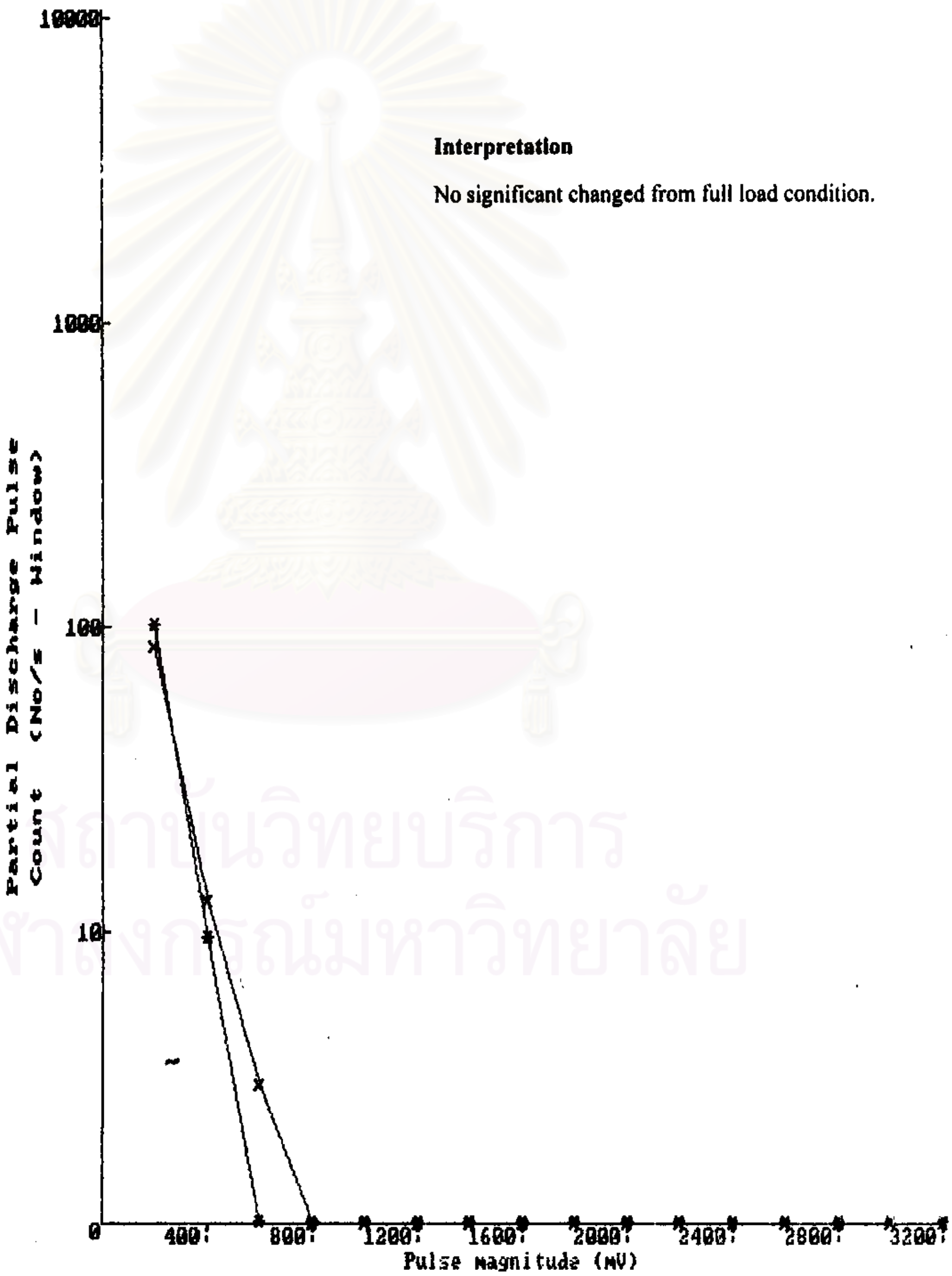


Fig. 4.1.4.7 Data measurement of C Phase, parallel 1

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02C05.059 C Phase Coupler 2
Tested on Thu Jun 23,1998 at 10:45:11 Coupler pair C05 Gain 0.50
Voltage reference 217 Temp 64 C No Load, Hot Synchronized
Power 0 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 3033 Negative Pulses (*) NQN 2738
NQN inaccurate due to high PD activity

Interpretation

- Same as Full load, hot.
- Consistent with voids at the copper.
- Some surface activities occurred, since positive predominated.

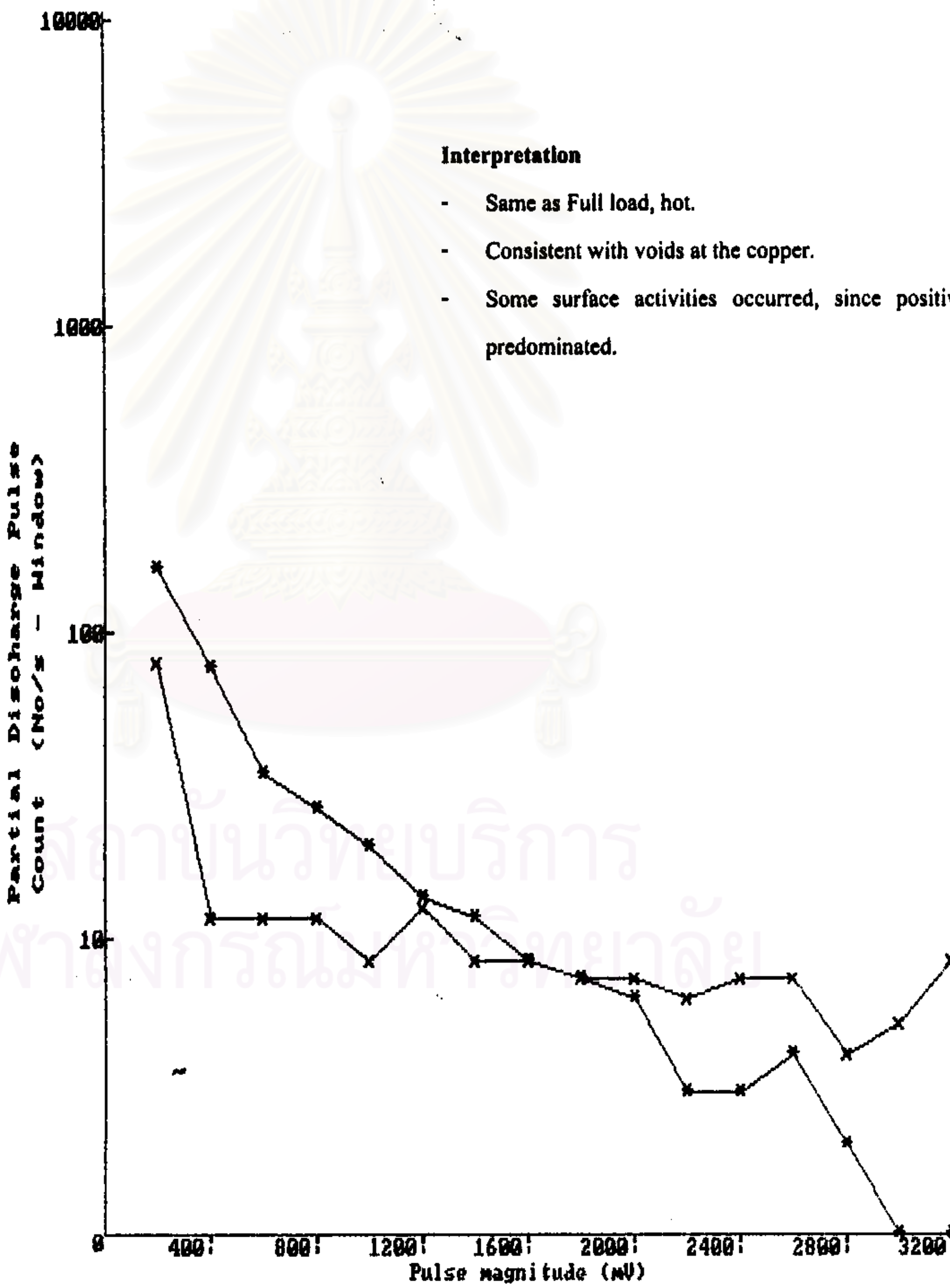


Fig. 4.1.4.8 Data measurement of C Phase, parallel 2

SIRIKIT HYDRO POWER PLANT Unit 02

```
D:\PDAH\PDAH\STATIONA\GEN1\SKT02C06.060                    C Phase   Coupler 2
Tested on  Thu Jun 23,1998 at 10:47:33   Coupler pair C06   Gain 0.50
Voltage reference  221    Temp  64  C   No   Load, Hot       Synchronized
Power     0 MW  Reactive    0 MX   Voltage        13.8  Differential Mode
Positive Pulses (x) NQN 1597             Negative Pulses (*) NQN 1410
```

Interpretation

- Activity was higher at no load than full load condition.
- Some surface activities had occurred due to side packs were not tight.

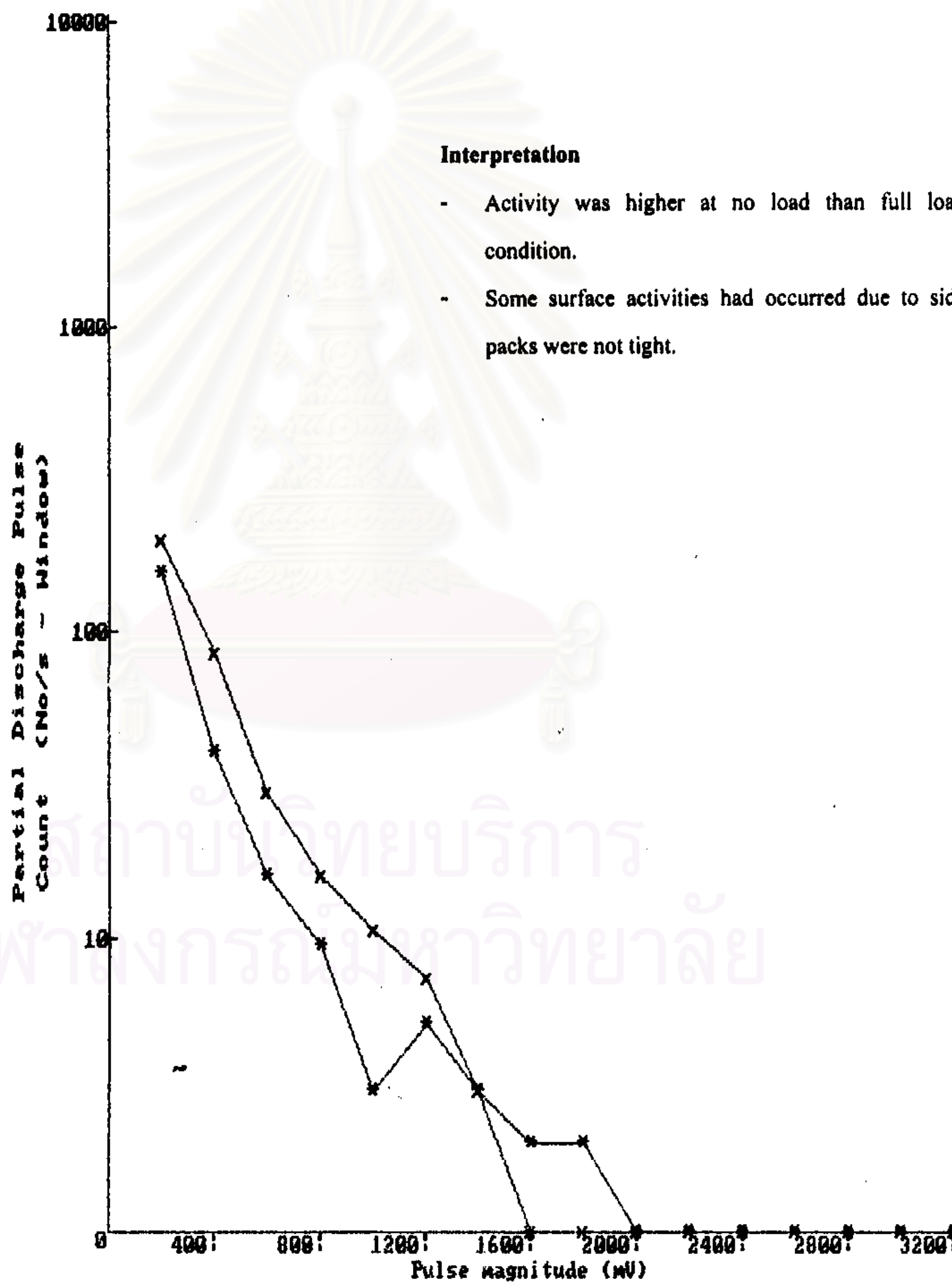


Fig. 4.1.4.9 Data measurement of C Phase, parallel 3

4.1.4.1 The interpretation summary on No load hot condition

This condition was low vibration effect but still had high temperature. The overview showed some positive pulses slightly decreased.

Winding parallel path 1 and 3 of phase A were the same. There were internal discharges and surface deterioration within winding insulation. Path 3 also had positive pulses predominated cause of surface discharges around coil surface in slot portion

Winding parallel path 2 of phase A had high partial discharge activities, both positive and negative pulses were predominance. There were a lot of surface discharges and internal discharges within winding insulation. These meant high deterioration of coil surface occurring and also delaminating within ground wall insulation.

Winding parallel path 1,2 and 3 of phase B had the same pattern of graph. There were internal discharges within winding insulation. Partial discharge activities occurred less than other phases.

Winding parallel path 1 and 3 of phase C had similarly pattern of curves, showing internal discharges within winding insulation. Path 3 had partial discharge activities higher than path 1 (higher both NQN.). These meant there were some delaminations in ground wall insulation.

Winding parallel path 2 of phase C had high partial discharge activities. Total NQN was higher than other phase. The negative pulses were high predominance, meaning in a lot of copper interface discharges occurring. The positive pulses were also predominance. These meant that high surface discharges occurred within winding.

From 4 condition test data, there were high partial discharge activities occurred within parallel path 2 of phase C. the overall picture of stator winding showed a lot of partial discharge activities occurred around stator winding, mostly were interface discharges and surface discharge respectively. There was a few effect of a change in vibration that might be less looseness of coils in slot portion. The temperature had effected to partial discharge activities. High temperature condition showed higher partial discharge activities than low temperature.

There was high amount of NQN that were over 450 for each phase of winding. For polyester insulation system, these meant that there were greater internal copper stack insulation interface delaminations [5].

There was less coil looseness of each phase. It can be determined by using positive pulse curve on no load cold condition compare with positive pulses curve on full load hot condition. Most positive pulse curves on full load were slightly different from curves on no load. The following test data showed slightly change of positive pulse curve on full load and no load of parallel path 2 phase C and other parallel path of each phase were similarly.

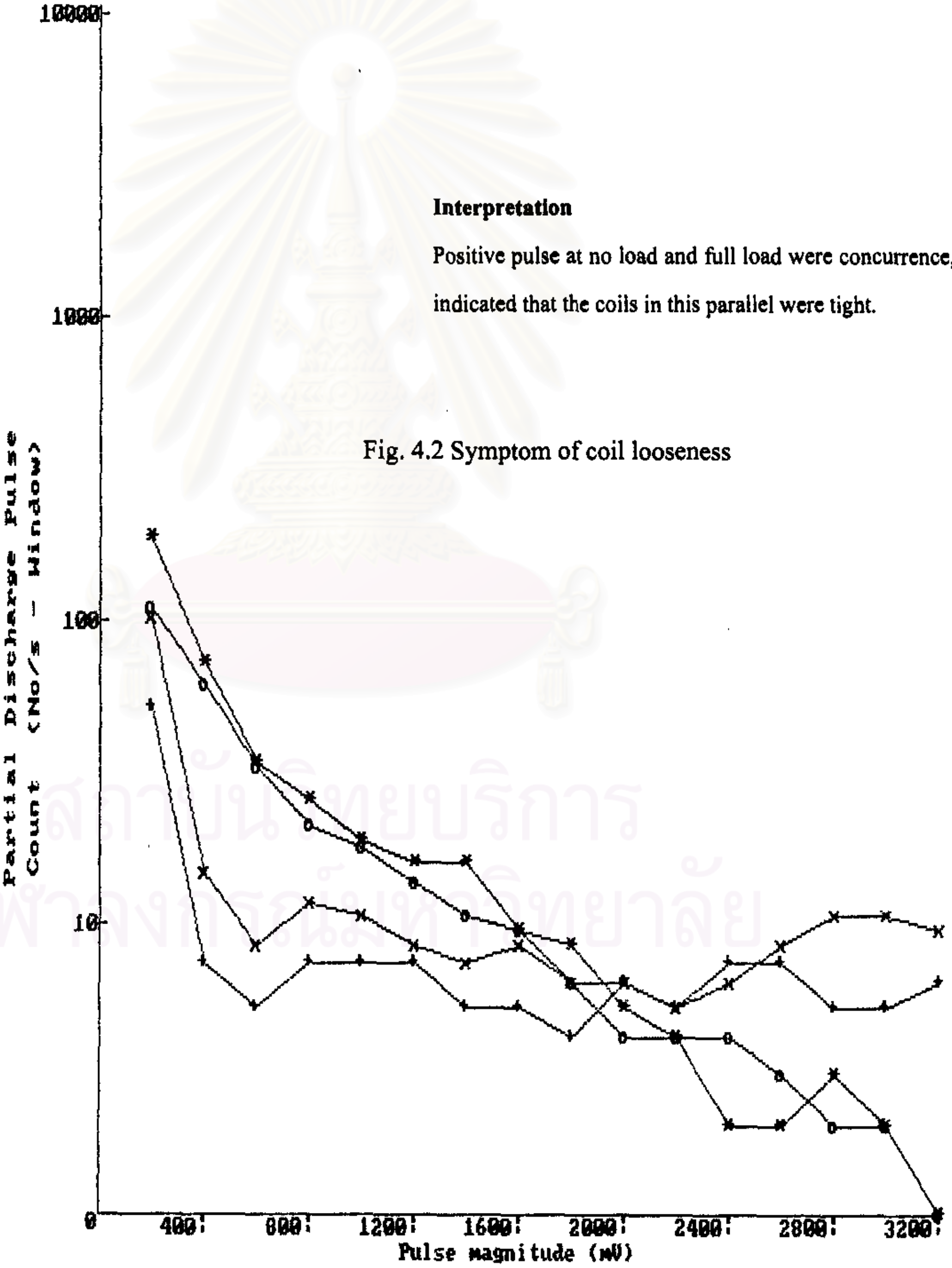
The following graph (Fig. 4.2) came from using data of no load overlay on full load condition in order to see trend of both positive partial discharge pulses. The trends of both positive pulses were not concurrence to each other represented some loose of stator coil occurred.

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02C05.041 C Phase Coupler 2
Tested on Thu Jun 23,1998 at 09:20:22 Coupler pair C05 Gain 0.50
Voltage reference 215 Temp 50 C **No Load, Cold** Synchronized
Power 0 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (+) NQN 2622 Negative Pulses (o) NQN 2705
NQN inaccurate due to high PD activity

SIRIKIT HYDRO POWER PLANT Unit 02

D:\PDAH\PDAH\STATIONA\GEN1\SKT02C05.053 C Phase Coupler 2
Tested on Thu Jun 23,1998 at 10:07:17 Coupler pair C05 Gain 0.50
Voltage reference 207 Temp 68 C **Full Load, Hot** Synchronized
Power 81 MW Reactive 0 MX Voltage 13.8 Differential Mode
Positive Pulses (x) NQN 3080 Negative Pulses (*) NQN 2798
NQN inaccurate due to high PD activity



Interpretation

Positive pulse at no load and full load were concurrence, indicated that the coils in this parallel were tight.

Fig. 4.2 Symptom of coil looseness

4.2 Interpretation results and Recommendation for next Minor Inspection period

There was Minor Inspection of generator unit 2 in next November 1998. The interpreted results were compiled and special recommendation were created for improving condition of stator winding in next inspection period, the details were:

Stator winding deterioration

1. There were surface deterioration occurred around stator end winding and slot portion.
2. A phase, parallel 2 and 3 had more surface deterioration.
3. B phase, 3 parallel had lower surface deterioration.
4. C phase, parallel 2 had a lot of surface deterioration than other phase, suspect some stator coils in this parallel had overly surface discharges and internal separation in groundwall.
5. Overall of stator winding had surface deterioration cause of poor side packed or loose of semi-conducting paints.

Recommendation

1. Request power plant's manager to disassembly generator's covers in order to inspect stator winding.
2. Visuals inspect coil end for surface deterioration at area as defined above.
3. Remove one or two rotor poles in order to check stator wedge tightness.
4. Sample checks by remove some stator wedges of one or two stator slots in order to inspect coil surface and condition of its side packed.

Repairing and materials preparation

1. Clear and clean all deteriorated surface areas by take off one layer of outer tape and use electrical cleaning solvent for cleaning. Apply new specific insulation tapes and treat with insulation varnish.
2. Using high resistive resin to grade voltage at the deteriorated areas of end coil at end slot portion.

3. Rotate the rotor for stator wedge checking and tightening. Checking loose of coil's side packed and semi-conducting paint of each coil, insert some sheet of side packed and apply semi- conducting paint if required.
4. Provide and prepare specific material using for repairing such as, mica insulation tape, glass fibre tape, class f insulation varnish, electrical cleaning solvent, special insulation sheet for stator wedges, high resistive resin and semi- conducting paint, which their specific value same as generator manufacture's recommendation and etc.

4.3 Minor inspection Sirikit hydro generator unit 2 in November 1998

Sirikit Hydro power plant was planned to outage the generator unit 2 for minor inspection in around november1998. The interpretation of on line partial discharge test data that was taken in early 1998 were mentioned to the planner. Then some special insulation materials and semi-conductive paint and resin were purchased in early stage because they were rather expensive and did not keep in store for long time (low shelf life).

During minor inspection, the generator was taken off the top and bottom covers to inspect end winding of stator winding both top and bottom. The inspection results of winding could be listed below:

a). A lot of Surface discharges occurred around end caps and jumpers of top end winding as shown in Fig. 4.3.1

b). Serious Surface discharges occurred on coil surfaces at straight portion, which located over slot portion.

Fig 4.3.1 A lot of surface discharges occurred within end winding

All most deteriorated areas on coil surface of end caps and coil-leads were insulation varnishes discolored, surfaces overheat and somewhere were binder tapes damaged. They were corrected by cleaning and treated with new insulation binder tape and special varnish.

For surface discharges on straight coils over slot portion, most deterioration were outer insulation tapes damaged and overheat cause of high discharges occurring due to high electric field strength in these areas. The correction was done by cleaning that damaged area and applied high resistive paint overlap the existing low resistive semi-conducting paint in order to decrease gradient voltage for that area of coil with respect to ground. The stator wedge checking showed that most of stator wedges were still tight. Sample checking by removed some wedges to inspect coil surface and its side packed. It found some deteriorated surface and loose of side packed. Clearing and applied new semi-conducting paint to each deteriorated area and insert new semi-conducting sheets as new side packed for coil tightening.

The deterioration on above areas could be eliminated as indicated by the interpretation results of testing, the correction and approving were done but did not cover all deteriorated parts, some slot discharge as reported from the tests still did not correct. When generator was put in service, the frequency of partial discharge tests should be done to observe slot discharge closely. The high deviation will show more increasing of slot discharges and the next overhaul period should be planned to start at the early stage.

The great benefit of on line partial discharge test of unit 2 was to know in actual main problems of stator winding and the appropriate method include materials for correction were prepared before start the inspection period, resulting in keeping schedule on time. Some parts of winding were improved and corrected to make good condition for generator.