QUALITY ASSESSMENT OF SF_6 INSULATION AT WARU 150 KV GIS COMPARTMENT USING PARTIAL DISCHARGE ION MOBILITY SPECTROMETER

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Abstrak

Almost all of modern gas insulated switchgears (GIS) use sulphur hexafluoride (SF_6) as insulation material. Therefore, GIS quality much or less depends on quality of its SF_6. Failure however can arise within operation of SF_6 GIS due to quality decline of SF_6. Quality decline of SF_6 in GIS can be recognized by existence of decomposition product of SF_6, which may appear due to partial discharge, arc during switching, etc. Therefore quality control of SF_6 insulation in GIS is necessary in order to prevent failure occurred due to SF_6 quality decline. In this study, quality assessment of SF_6 at Waru 150 kV SF_6 GIS is done using equipment namely partial discharge ion mobility spectrometer. This equipment assesses quality of SF_6 based on ions mobility. Concentration of decomposition product is then obtained from ion mobility of gas analyzed.

For all compartment tested of Waru 150 kV SF_6 GIS, it was found that the largest concentration of decomposition product is between 1000-2000 ppm_v. Generally, SF_6 condition at Waru 150 kV SF_6 GIS is normal based on CIGRE standard.

Keywords: *GIS, SF_6 Ion Mobility Spectromete*

1. INTRODUCTION

SF_6 have dielectric strength about three times compared to air at the same pressure, therefore the application of SF_6 as insulation material in high voltage equipment increase steadily.

Theoretically, high voltage equipments especially equipment with SF_6 insulation include SF_6 GIS are designed for on site flawless operation for about 30 years. Even SF_6 high voltage equipment is claimed maintenance free, routine test is still necessary to maintain its reliability because along the operation of SF_6 GIS, purity SF_6 may decline due to decomposition product produced by partial discharge, arcing during switching operation, etc [1, 2]. Decline of SF_6 quality may lead to GIS failure and finally breaks the system down.

In this study, assessment quality of SF_6 insulation at Waru SF_6 GIS, which have been operated about 17 years, is done in order to know quality of SF_6 so that failure can be diminish. This assessment is done annually and the results are interpreted according to CIGRE standard.

2. METHOD OF SF_6 INSULATION QUALITY ASSESSMENT

2.1. Base of Analyze of SF_6 Insulation Quality

Some basis of analyze of SF_6 insulation quality are briefly described below.

Purity of SF_6: This testing provides purity of SF_6, which shows SF_6 content per unit volume.

Content of Corrosive Material: Corrosive material is resulted from decomposition products of SF_6 ($S_xO_yF_z$). Another decomposition product of SF_6 is also toxically and its dielectric strength much lower than pure SF_6

Dew Point of SF_6: This analyze is done by using a sensor dew point which shows the temperature in which SF_6 gas freeze (frost point). Dew point is affected by contaminant at SF_6 gas such as water vapor at SF_6 gas [3].

2.2. Ion Mobility Spectrometer

Ion mobility spectrometer (IMS) is an instrument that is used to detect decomposition product of gas. It works based on ion mobility spectrometry. Some advantages of this equipment are high sensitivity, quick data process, portable, on-site detection and can used on-line continuously. However, it cannot detect what kind of gas is the decomposition of the gas.

Principle IMS: Basic used in this technology is measurement of gas ion mobility in an electric field. Mobility of ions is determined by ion velocity, which is measured in a drift cell under effect of electric field. The most important part of IMS method is its IMS-Cell. Process in IMS-Cell is simply depicted in **Figure 1**.

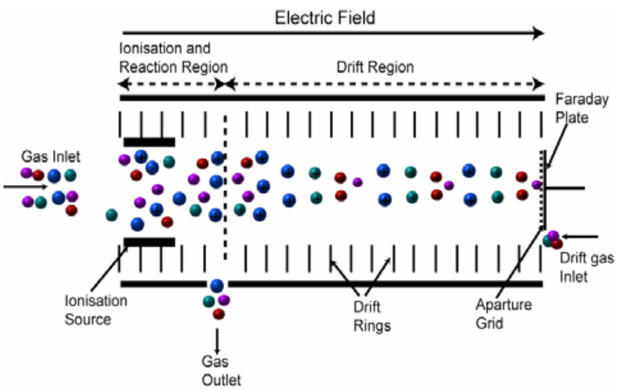

Figure 1. Ion Mobility Spectrometer Cell[5]

Ionization process due to its difference velocity, mass, and difference geometry structure occurs if gas is inserted into IMS-Cell. IMS can generate three kinds of ionization process. They are radioactive (radiation with β-^{63}Ni or ^{3}H light), photo ionization (ultraviolet with energy of 8.5, 9.6, 10.2, 10.6, and 11.7 eV), and partial discharge or corona discharge.

After ionization process, ions mobile with difference velocity depend on its mass and geometry structure. Then ions are separated through ion shutter and they are flown into drift region. Drift region has homogenous electric field of about 150 V/cm until 300 V/cm. Ratio between average drift velocity in certain field (v_d) and electric field strength (E) is known as motion ability of ions in gas and noted as mobility. The ratio is shown in Equation 1. Time required passes drift region is called drift time (t_d). Drift time relates with mobility of each ion therefore ions will be still separate each other. Drift time of ions is known as ions collide a detector (faraday plate) and ions collision result in ion mobility spectrums.

$$K = \frac{v_d}{E} = \frac{d}{t_d \cdot E} \quad (1)$$

Ion mobility spectrum informs condition of measured gas and compared with gas reference. Pure SF_6 gas is used as calibrator of IMS and indicator existence of decomposition [4-6]. Typical result of spectrum analysis of SF_6 is shown in **Figure 2**.

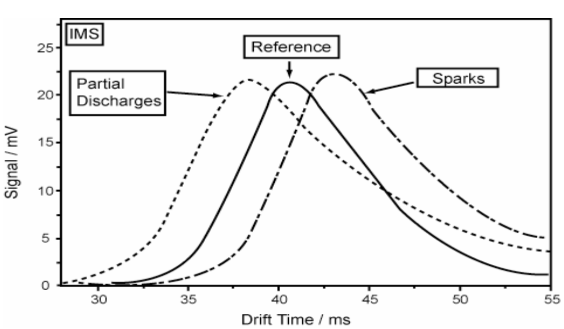

Figure 2. Ion Mobility Spectrometer Cell

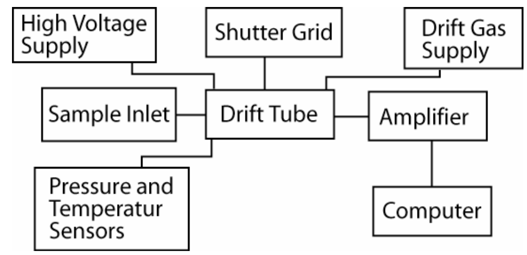

Figure 3. Hardware of Ion Mobility Spectrometer[5]

Components of IMS: Below component of IMS will be briefly described. The component can be fall into two main components: hardware and software.

<u>*Hardware:*</u> The components of IMS can be schematically seen on **Figure 3** and can be described following;

a. Drift tube/ IMS-cell
   Main part of IMS is Drift tube explained before.
b. High voltage supply
   Power source and electric field generator in drift tube. Voltage required is about 90-265 V
c. Sample inlet
   Tested gas is inserted through this inlet. During gas injection, gas should not be contaminated and gas leakage should be avoided.
d. Pressure and Temperature censors
   Censor to detect pressure and temperature of tested gas
e. Shutter grid/ ion shutter
   Shutter grid separates ions which are resulted from ionized gas and can be close/open in 10 μs to 1 ms. If it is opened, ions flow into drift region but ions can be flowed outer if it is closed.
f. Drift gas supply
   As a line to introduce gas used in drift region. The gas flows from faraday plate to ionization region to assure that only ions flow into drift region not free particles.
g. Amplifier
   Amplifies signal obtained from faraday plate. Energy collision of ions on faraday plate is small. It must be amplified so that software or computer can seize it.
h. Computer
   Obtained data such as drift velocity, temperature, and pressure will be processed by computer. Current (nA or pA) obtained from faraday plate will be converted to voltage then to digital signal. The data are then analyzed by IMS software. Ion mobility spectrometer must be protected from outer electric field to avoid disturbance on its results.

<u>*Software*</u>: Software of IMS analyzes the obtained data. Spectrums of tested gas are compared to gas reference. Shifted Peak of tested gas spectrum is obtained if decomposition product of SF_6 exists. The software can show value of dew point, quantity of

decomposition product, temperature, pressure of compartment and pressure inside of IMS.

2.3. Assessment of Quality of SF_6 Insulation

Interpretation on tested gas is given according to CIGRE 23.10, which is

1. Purity
   Purity standard used is ≥ 97%
2. Dew point at 1 atm
   ≤ -31^{0}C = content of water vapor ≤ 350 ppm$_v$ for operating voltage ≤ 170 kV.
   ≤ -22^{0}C = content of water vapor ≤ 840 ppm$_v$ for operating voltage > 170 kV.
   ≤ -31^{0}C = content of water vapor ≤ 610 ppm$_v$.
3. Peak shift
   0 ms – 1.5 ms = <500 ppm$_v$.
   1.5 ms – 3 ms = 500 – 1000 ppm$_v$.
   3 ms – 6 ms = 1000 – 2000 ppm$_v$.
   > 6 ms = 2000 ppm$_v$.
4. Content of corrosive material/ Decomposition
   < 500 ppm$_v$ = Normal (purity OK).
   500 – 1000 ppm$_v$ = Normal (purity OK).
   1000 – 2000 ppm$_v$ = Low contamination.
   > 2000 ppm$_v$ = High contamination.

3. RESULTS AND ANALYSIS

All ionization processes in this testing use partial discharge method because with this process number of ion becomes larger and more complex. This method also may show a condition in compartment if partial discharge occurred. Four parts in one compartment were tested. These parts were circuit breaker, disconnector bus (A and B), and disconnector line. These parts were chosen because these parts are often moved mechanically and arc may occur during switching of circuit breaker.

At first gas reference according to IEC 376 standard was injected to IMS for calibration purpose. Spectrum mobility of gas reference is shown in **Figure 4** and its characteristics are:

Moisture /^{0}C Dew point	= -34
Moisture/ ppm	= 178
Sample pressure/bar	= 8.2
System pressure	= 1.4
Temperature/^{0}C	= 24
Amplitude/V	= 0.63
Drift time/ ms	= 35.8

Testing done at Waru 150 kV SF_6 GIS gave many results in form of ion gas spectrums and then compared with spectrum of gas reference. Other results were purity and dew point of SF_6 gas. In this study analysis quality of SF_6 is stressed on value of peak shift because it relates to decomposition product of SF_6. Typical test result of gas sample on line disconnector of transformator 1 is shown in **Figure 5**.

As clearly seen from the figure that drift time of test gas is about 39.4 ms.Therefore obtained peak shift is:

Peak shift = *drift time test gas – drift time gas reference*
= 39.4 – 35.8 = 3.6 ms

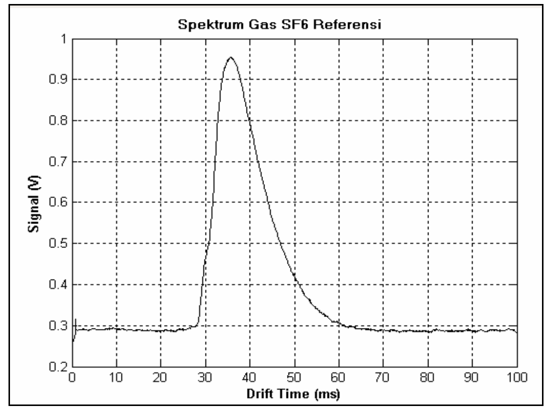

Figure 4. Spectrum Mobility SF_6 Gas Reference

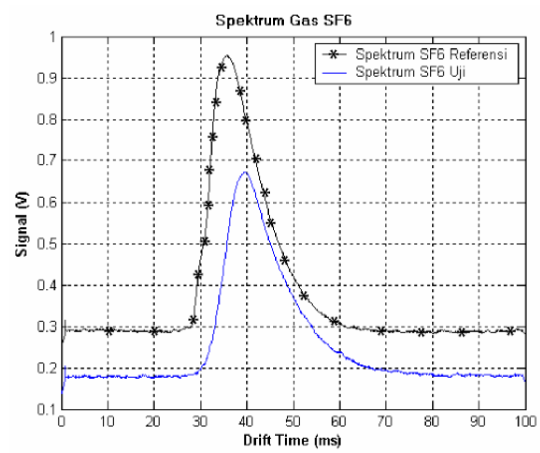

Figure 5. Spectrum Mobility Gas Sample and SF_6 Gas Reference

According to CIGRE 23.10, peak shift of 3.6 ms shows that content of decomposition product is between 1000 – 2000 ppm$_v$, which mean that condition of SF_6 gas is low contaminated (low contamination). All test results of all compartments are summarized in **Table 3** at the end of this paper It clearly seen from the table that 37 or 38.14 % (from 97 tested compartments) of compartment show declining of SF_6 quality according to concentration of decomposition product. The quality decline from 'OK' (< 500 ppm$_v$) to 'OK' (500-1000 ppm$_v$) or from 'OK' to 'LC' (Low Contamination).

From **Table 3**, it shows that Buduran A disconnector has the largest peak shift of about 5.6 ms. This value still less than 6 ms which also means low contamination. However, further investigation must be done in order to know type of decomposition gas to prevent failure of this compartment. Generally condition of all compartment can be said "healthy" because concentration of gas decomposition below 2000 ppm_V.

In order to know the relation of transformator loading and peak shift, correlation between peak shift change and load of Transformator was also determined. Average load each bay at Waru 150 kV SF_6 GIS from year 2006 to year 2008 are shown on **Table 2** and peak shift change and percentage load are shown on **Table 3**. It was found that value of correlation between average load and peak shift change is about 0.75. Its mean that peak shift change correlates with percentage average load. The peak shift has linear relationship with load of GIS.

Table 2. Load Data GIS Waru 150 kV

Bay	Nom. Current(A)	Year						Av. Load (%)
		2006		2007		2008		
		(a)	(b)	(a)	(b)	(a)	(b)	
Trafo 1	322	177	54,87	171	53,05	175	54,35	54,09
Trafo 2	322	155	48,14	171	53,05	203	62,89	54,69
Trafo 3	1.732	1.102	63,63	1.107	63,92	814	46,98	58,18
Trafo 4	1.732	724	41,79	804	46,43	1.089	62,86	50,36
Trafo 5	1.443	1.115	77,25	1.198	82,99	1.138	78,83	79,69
Trafo 6	1.443	1.020	70,71	397	27,52	825	57,17	51,80
Trafo 7	866	551	63,61	638	73,66	795	91,80	76,36
Buduran 1	740	264	35,73	273	36,94	304	41,05	37,91
Buduran 2	740	323	43,58	299	40,43	445	60,14	48,05
D. Grnde1	740	310	41,89	319	43,07	344	46,45	43,81
D. Grnde2	740	310	41,89	319	43,07	345	46,62	43,86
Gresik 1	1480	387	26,13	388	26,21	374	25,25	25,86
Gresik 2	1480	383	25,90	385	26,01	374	25,25	25,72
Ispatindo1	740	268	36,27	245	33,13	283	38,18	35,86
Ispatindo2	740	256	34,64	261	35,33	280	37,84	35,93
K. Pilang1	1480	392	26,47	421	28,43	463	31,25	28,72
K. Pilang2	1480	392	26,47	420	28,38	443	29,90	28,25
Rungkut 1	1480	831	56,17	875	59,09	841	56,84	57,37
Rungkut 2	1480	832	56,20	873	58,95	856	57,85	57,67
Sawahan1	1480	469	31,68	507	34,28	579	39,10	35,02
Sawahan2	1480	455	30,75	507	34,28	579	39,10	34,71

Remark : (a) Load current (Ampere)(b) Load percentage (%)
Load Data up to April 2008.

4. CONCLUSION

In order to maintain insulation quality of SF_6 insulation at Waru 150 KV GIS compartment, assessment quality of SF_6 using partial discharge ion mobility spectrometer is done. The results can be summarized as follows.

1. Correlation between load percentage and peak shift change is about 0.75, which mean that peak shift change correlate linearly with load percentage.

Table 3. Data of *Peakshift* change and Percentage of Load per Bay at Waru GIS

Bay	(a)	(b)	Bay	(a)	(b)
Trafo 1	2,325	54,09	Gresik 1	0,325	25,86
Trafo 2	2,525	54,69	Gresik 2	0,45	25,72
Trafo 3	3,925	58,18	Ispatindo	0,6	35,86
Trafo 4	0,325	50,36	Ispatindo	0,35	35,93
Trafo 5	3,175	79,69	Karang Pilang 1	0,35	28,72
Trafo 6	3,025	51,80	Karang Pilang 2	0,675	28,25
Trafo 7	2,275	76,36	Rungkut 1	2,225	57,37
Buduran 1	1	37,91	Rungkut	2	57,67
Buduran 2	0,375	48,05	Sawahan	1,125	33,86
Darmo Grande 1	1,3	43,81	Sawahan 2	1,575	34,71
Darmo Grande 2	0,575	43,86	Spare 1	0,35	-
Kopel Bus	0,74	-	Spare 2	0,575	-

Remark: (a) Average Peakshift Change each Compartment (ms)
(b) Percentage Average Load (%)

2. Peak shift minimum detected is 0.0 ms similar to gas reference and peak shift maximum was 5.6 ms, which mean gas had concentration decomposition product between 1000 – 2000 ppm_v.
3. About 38% of compartment of Waru 150 kV SF_6 GIS show quality decline. However, in general quality of SF_6 quality is still good or OK, because concentration of decomposition product is below 2000 ppm_v.

Further investigation is necessary to recognize type of gas decomposition product to understand from which the decomposition product is generated, e.g. using FTIR (Fourier Transform Infra Red). So that suitable handling can be perform.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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Table 3. Testing Result of SF_6 Gas at Compartment Waru GIS

Kompartemen	Testing on year 2005						Testing on year 2008					
	Purity (%)	Dew Point (°C)	Drift Time (ms)	Peak shift (ms)	Concentration of Decomposition Product (ppm_v)	Remarks.	Purity (%)	Dew Point (°C)	Drift Time (ms)	Peak shift (ms)	Concentration of Decomposition Product (ppm_v)	Remarks
TRAFO 1												
PMT	99,9	-18	32,9	2,9	500-1000	OK	99,9	-30	37,5	1,7	500-1000	OK
PMS A	99,9	-17	35,4	0,4	<500	OK	99,9	-18	38,2	2,4	500-1000	OK
PMS LINE	100,0	-15	35,8	0,0	<500	OK	100,0	-20	39,4	3,6	1000-2000	LC
PMS B	99,9	-30	36,1	0,3	<500	OK	99,9	-21	38,6	2,8	500-1000	OK
TRAFO 2												
PMT	99,9	-11,0	36,1	0,3	<500	OK	99,9	-30	38,6	2,8	500-1000	OK
PMS A	99,8	-15	38,7	2,9	500-1000	OK	99,8	-19	39,6	3,8	1000-2000	LC
PMS LINE	99,8	-17	35,5	0,3	<500	OK	99,8	-19	39,3	3,5	1000-2000	LC
PMS B	99,9	-29,0	35,5	0,3	<500	OK	99,9	-26	39,6	3,8	1000-2000	LC
TRAFO 3												
PMT	99,9	-21,0	37,5	1,7	500-1000	OK	99,9	-21	40,7	4,9	1000-2000	LC
PMS A	100	-17,0	35,3	0,5	<500	OK	100,0	-21	40,2	4,4	1000-2000	LC
PMS LINE	100	-16,0	35,4	0,4	<500	OK	100,0	-21	40,7	4,9	1000-2000	LC
PMS B	100	-27,0	36,0	0,2	<500	OK	100,0	-24	40,1	4,3	1000-2000	LC
TRAFO 4												
PMT	100,0	-18	33,2	2,6	500-1000	OK	100,0	-30	38,8	3,0	500-1000	OK
PMS A	100,0	-17	38,8	3,0	500-1000	OK	100,0	-21	38,2	2,4	500-1000	OK
PMS LINE	100,0	-15	38,2	2,4	500-1000	OK	99,9	-19	38,3	2,5	500-1000	OK
PMS B	100,0	-28	38,2	2,4	500-1000	OK	100	-30	38,4	2,6	500-1000	OK
TRAFO 5												
PMT	99,9	-20	33,8	2,0	500-1000	OK	99,9	-33	39,2	3,4	1000-2000	LC
PMS A	99,9	-20	34,7	1,1	<500	OK	99,9	-24	40,1	4,3	1000-2000	LC
PMS LINE	99,9	-18	35,6	0,2	<500	OK	99,9	-20	40,4	4,6	1000-2000	LC
PMS B	100,0	-27	36,2	0,4	<500	OK	100,0	-26	39,9	4,1	1000-2000	LC
TRAFO 6												
PMT	99,8	-28,0	33,4	2,4	500-1000	OK	99,8	-27	36,1	0,3	<500	OK
PMS A	100,0	-17,0	36,7	0,9	<500	OK	100,0	-19	38,6	2,8	500-1000	OK
PMS LINE	100,0	-16	35,3	0,5	<500	OK	100,0	-17	40,3	4,5	1000-2000	LC
PMS B	99,9	-28,0	35,5	0,3	<500	OK	99,9	-24	40,2	4,4	1000-2000	LC
TRAFO 7												
PMT	99,9	-12,0	33,1	2,7	500-1000	OK	99,9	-33	39,9	4,1	1000-2000	LC
PMS A	99,9	-20,0	38,6	2,8	500-1000	OK	99,9	-27	38,5	2,7	500-1000	OK
PMS LINE	99,8	-17	36,5	0,7	<500	OK	99,8	-20	40,4	4,6	1000-2000	LC
PMS B	100,0	-29	36,2	0,4	<500	OK	99,9	-23	39,9	4,1	1000-2000	LC
BUDURAN 1												
PMT	99,8	-22	35,8	0,0	<500	OK	99,8	-32	37,6	1,8	500-1000	OK
PMS A	99,9	-19	41,4	5,6	1000-2000	LC	99,8	-22	39,3	3,5	1000-2000	LC
PMS LINE	99,8	-19,0	40,0	4,2	1000-2000	LC	99,8	-21	39,9	4,1	1000-2000	LC
PMS B	100,0	-29	39,6	3,8	1000-2000	LC	100	-29	39,6	3,8	1000-2000	LC
BUDURAN 2												
PMT	99,8	-25,0	32,2	3,6	1000-2000	LC	99,8	-32	39,2	3,4	1000-2000	LC
PMS A	99,8	-20,0	40,3	4,5	1000-2000	LC	99,8	-21	40,7	4,9	1000-2000	LC
PMS LINE	99,8	-18,0	40,0	4,2	1000-2000	LC	99,8	-19	39,3	3,5	1000-2000	LC
PMS B	99,8	-28,0	39,5	3,7	1000-2000	LC	99,7	-29	39,7	3,9	1000-2000	LC
DARMO GRD 1												
PMT	99,8	-31,0	33,3	2,5	500-1000	OK	99,7	-34	40,2	4,4	1000-2000	LC
PMS A	99,7	-20,0	39,8	4,0	1000-2000	LC	99,7	-21	40,2	4,4	1000-2000	LC
PMS LINE	99,7	-18,0	38,8	3,0	500-1000	OK	99,7	-19	40,5	4,7	1000-2000	LC
PMS B	99,7	-30,0	38,5	2,7	500-1000	OK	99,7	-21	39,7	3,9	1000-2000	LC
DARMO GRD 2												
PMT	99,8	-30,0	32,7	3,1	1000-2000	LC	99,8	-31	39,9	4,1	1000-2000	LC
PMS A	99,8	-19,0	40,5	4,7	1000-2000	LC	99,8	-20	39,9	4,1	1000-2000	LC
PMS LINE	99,8	-18	39,8	4,0	1000-2000	LC	99,8	-21	40,0	4,2	1000-2000	LC
PMS B	99,8	-12	34,0	1,8	500-1000	OK	99,5	-20	38,1	2,3	500-1000	OK
GRESIK 1												
PMT	99,9	-25	37,4	1,6	500-1000	OK	99,9	-32	38,0	2,2	500-1000	OK

Kompartemen	Testing on year 2005						Testing on year 2008					
	Purity (%)	Dew Point (^oC)	Drift Time (ms)	Peak shift (ms)	Concentration of Decomposition Product (ppm_v)	Remarks.	Purity (%)	Dew Point (^oC)	Drift Time (ms)	Peak shift (ms)	Concentration of Decomposition Product (ppm_v)	Remarks.
PMS A	100,0	-20	39,4	3,6	1000-2000	LC	99,7	-20	39,0	3,2	1000-2000	LC
PMS LINE	99,7	-19,0	38,9	3,1	1000-2000	LC	99,7	-19	39,1	3,3	1000-2000	LC
PMS B	99,8	-28	37,9	2,1	500-1000	OK	99,8	-29	37,8	2,0	500-1000	OK
GRESIK 2												
PMT	99,8	-21,0	38,9	3,1	1000-2000	LC	99,8	-32	39,0	3,2	1000-2000	LC
PMS A	100,0	-20,0	40,5	4,7	1000-2000	LC	99,6	-20	39,1	3,3	1000-2000	LC
PMS LINE	99,7	-19	38,9	3,1	1000-2000	LC	99,7	-20	38,9	3,1	1000-2000	LC
PMS B	99,9	-28	38,5	2,7	500-1000	OK	99,6	-28	38,2	2,4	500-1000	OK
ISPATINDO 1												
PMT	100	-30	32,9	2,9	500-1000	OK	100	-35	38,9	3,1	1000-2000	LC
PMS A	100	-19	39,6	3,8	1000-2000	LC	100	-24	39,0	3,2	1000-2000	LC
PMS LINE	100	-19	40,0	4,2	1000-2000	LC	100	-21	39,4	3,6	1000-2000	LC
PMS B	100	-28	40,0	4,2	1000-2000	LC	100	-24	39,0	3,2	1000-2000	LC
ISPATINDO 2												
PMT	100,0	-30	32,9	2,9	500-1000	OK	100	-35	38,6	2,8	500-1000	OK
PMS A	100,0	-19	40,8	5,0	1000-2000	LC	100	-25	40,6	4,8	1000-2000	LC
PMS LINE	99,9	-18	38,5	2,7	500-1000	OK	99,9	-21	39,2	3,4	1000-2000	LC
PMS B	99,8	-28,0	39,3	3,5	1000-2000	LC	99,8	-27	38,9	3,1	1000-2000	LC
K.PILANG 1												
PMT	99,7	-28,0	32,7	3,1	1000-2000	LC	99,7	-21	32,7	3,1	1000-2000	LC
PMS A	99,5	-20	40,9	5,1	1000-2000	LC	99,5	-20	40,0	4,2	1000-2000	LC
PMS LINE	100,0	-20	38,1	2,3	500-1000	OK	99,5	-19	38,4	2,6	500-1000	OK
PMS B	99,7	-29	38,2	2,4	500-1000	OK	99,6	-29	38,0	2,2	500-1000	OK
K.PILANG 2												
PMT	99,9	-25	32,4	3,4	1000-2000	LC	99,8	-30	39,1	3,3	1000-2000	LC
PMS A	99,8	-20	40,6	4,8	1000-2000	LC	99,7	-21	39,9	4,1	1000-2000	LC
PMS LINE	99,8	-18	39,2	3,4	1000-2000	LC	99,8	-19	40,1	4,3	1000-2000	LC
PMS B	99,8	-26	39,0	3,2	1000-2000	LC	99,8	-23	40,0	4,2	1000-2000	LC
RUNGKUT 1												
PMT	99,8	-25	36,8	1,0	<500	OK	99,7	-35	38,8	3,0	500-1000	OK
PMS A	99,8	-17	34,6	1,2	<500	OK	99,7	-20	40,2	4,4	1000-2000	LC
PMS LINE	99,9	-15	37,6	1,8	500-1000	OK	99,7	-21	39,9	4,1	1000-2000	LC
PMS B	100,0	-29	33,9	1,9	500-1000	OK	99,8	-30	39,1	3,3	1000-2000	LC
RUNGKUT 2												
PMT	99,8	-25	36,8	1,0	<500	OK	99,8	-35	38,6	2,8	500-1000	OK
PMS A	99,8	-18	35,4	0,4	<500	OK	99,8	-22	40,2	4,4	1000-2000	LC
PMS LINE	99,8	-17	38,8	3,0	500-1000	OK	99,8	-21	39,2	3,4	1000-2000	LC
PMS B	99,8	-29	34,3	1,5	<500	OK	99,8	-29	39,1	3,3	1000-2000	LC
SAWAHAN 1												
PMT	99,8	-22	32,9	2,9	500-1000	OK	99,5	-30	38,3	2,5	500-1000	OK
PMS A	99,7	-19	40,1	4,3	1000-2000	LC	99,7	-19	39,9	4,1	1000-2000	LC
PMS LINE	99,9	-20	38,9	3,1	1000-2000	LC	99,9	-19	40,3	4,5	1000-2000	LC
PMS B	99,6	-30	38,3	2,5	500-1000	OK	99,6	-29	40,8	5,0	1000-2000	LC
SAWAHAN 2												
PMT	99,8	-21	33,4	2,4	500-1000	OK	99,8	-25	37	1,2	<500	OK
PMS A	99,7	-19	40,0	4,2	1000-2000	LC	99,7	-22	40,8	5,0	1000-2000	LC
PMS LINE	99,8	-17	38,6	2,8	500-1000	OK	99,8	-22	41	5,2	1000-2000	LC
PMS B	99,8	-30	39,2	3,4	1000-2000	LC	99,8	-30	41,1	5,3	1000-2000	LC
SPARE 1												
PMT	99,7	-27	38,9	3,1	1000-2000	LC	99,7	-24	39,1	3,3	1000-2000	LC
PMS A	99,6	-19	40,0	4,2	1000-2000	LC	99,6	-21	39,7	3,9	1000-2000	LC
PMS LINE	99,6	-18	39,0	3,2	1000-2000	LC	99,6	-19	39,7	3,9	1000-2000	LC
PMS B	99,7	-26	39,1	3,3	1000-2000	LC	99,7	-19	39,3	3,5	1000-2000	LC
SPARE 2												
PMT	98,9	-33	37,4	1,6	500-1000	OK	99,7	-33	38,5	2,7	500-1000	OK
PMS A	100,0	-21	40,1	4,3	1000-2000	LC	99,5	-23	39,4	3,6	1000-2000	LC
PMS LINE	99,8	-24	40,5	4,7	1000-2000	LC	99,8	-18	40,1	4,3	1000-2000	LC
PMS B	99,6	-30	40,0	4,2	1000-2000	LC	99,5	-21	39,9	4,1	1000-2000	LC
KOPEL BUS												
PMT	99,9	-19	32,6	3,2	1000-2000	LC	99,9	-32	40	4,2	1000-2000	LC
PMS A	99,6	-17	39,8	4,0	1000-2000	LC	99,6	-19	40,1	4,3	1000-2000	LC
PMS B	99,8	-17	40,5	4,7	1000-2000	LC	99,8	-21	40,1	4,3	1000-2000	LC
BUS BAR A	99,7	-33	39,2	3,4	1000-2000	LC	99,7	-31	40,3	4,5	1000-2000	LC
BUS BAR B	99,6	-32	39,2	3,4	1000-2000	LC	99,6	-21	40,1	4,3	1000-2000	LC