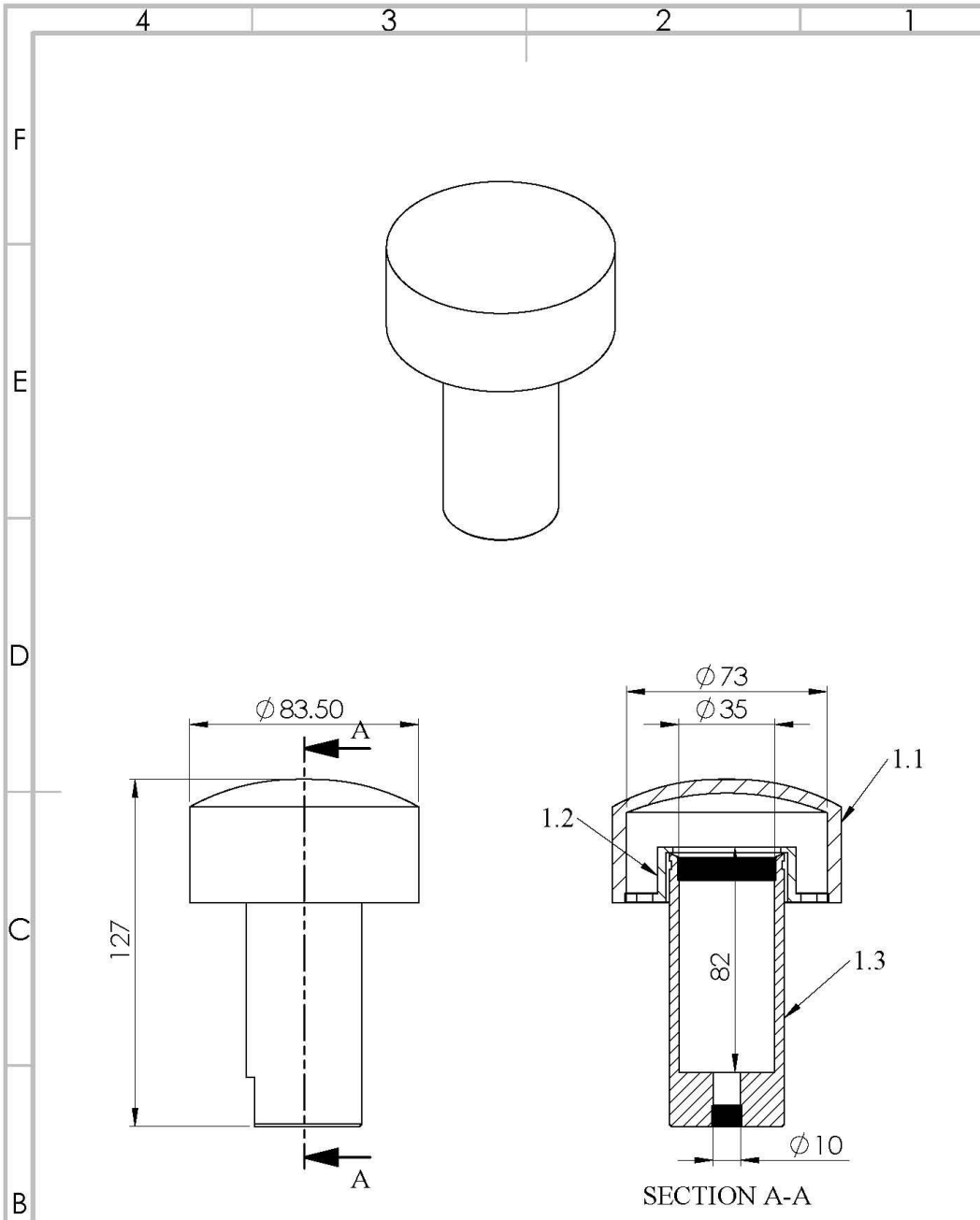
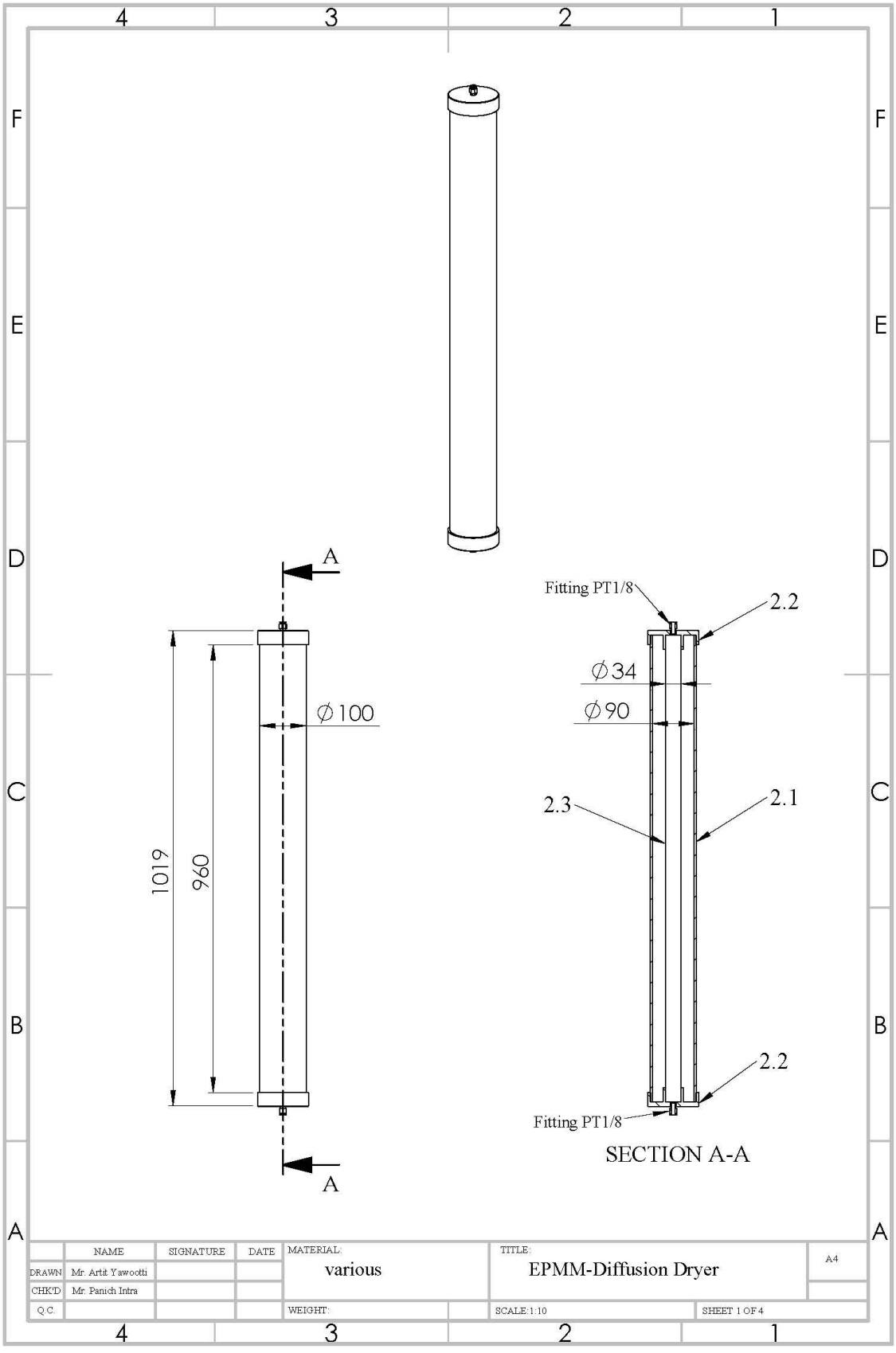
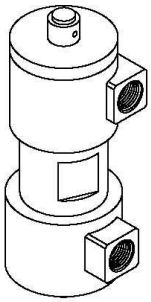
APPENDIX

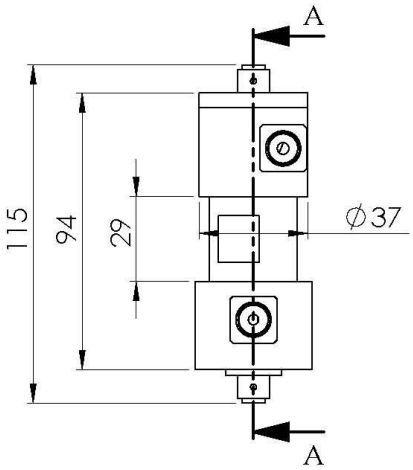
APPENDIX A

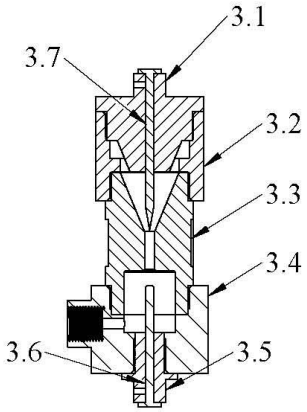
Technical Drawing for the Multi Channel Airborne Particulate Matter Detector by an Electrical Technique


4
3
2
1
F
E
D
C
B
A
∅83.50
A
127
A
∅73
∅35
1.1
1.2
82
1.3
∅10
SECTION A-A
NAME
SIGNATURE
DATE
MATERIAL:
Delrin (R)
TITLE:
EPMM-Head Sampling
A4
DRAWN
Mr. Artit Yawootti
CHK'D
Mr. Panich Intra
Q.C.
WEIGHT:
SCALE:1:2
SHEET 1 OF 4


4
3
2
1
F
E
D
C
B
A
A
A
∅100
1019
960
Fitting PT1/8
2.2
∅34
∅90
2.3
2.1
2.2
Fitting PT1/8
SECTION A-A
NAME
SIGNATURE
DATE
MATERIAL:
various
TITLE:
EPMM-Diffusion Dryer
A4
DRAWN
Mr. Artit Yawootti
CHK'D
Mr. Panich Intra
Q.C.
WEIGHT:
SCALE:1:10
SHEET 1 OF 4

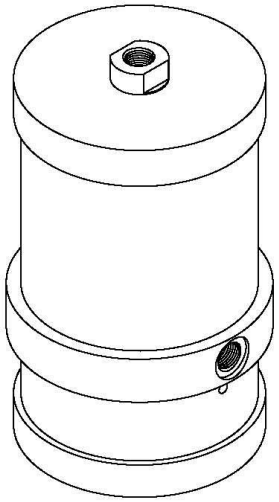


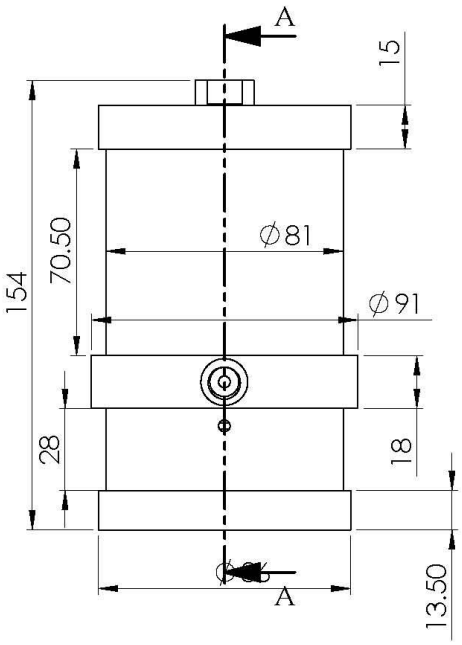


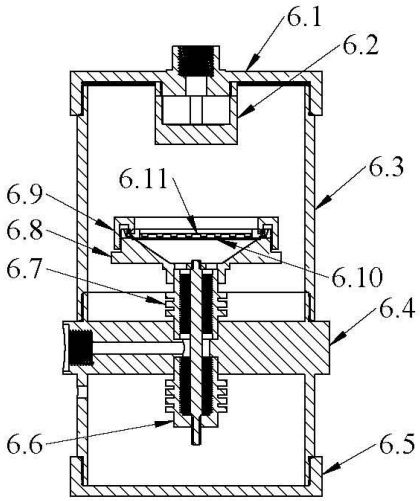


SECTION A-A
SCALE 1 : 2

	NAME	SIGNATURE	DATE	MATERIAL:	TITLE:	
DRAWN	Mr. Artit Yawootti			various	EPMM-Particle Charger	A4
CHK'D	Mr. Panich Intra					
Q.C.				WEIGHT:	SCALE1:2	SHEET 1 OF 8

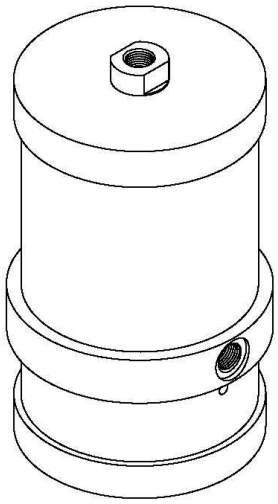


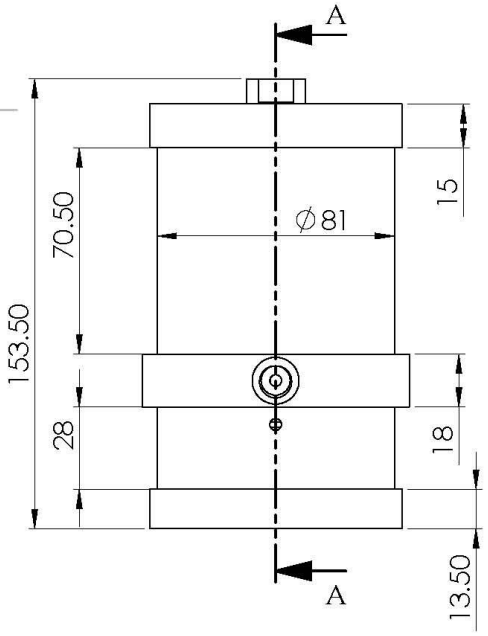


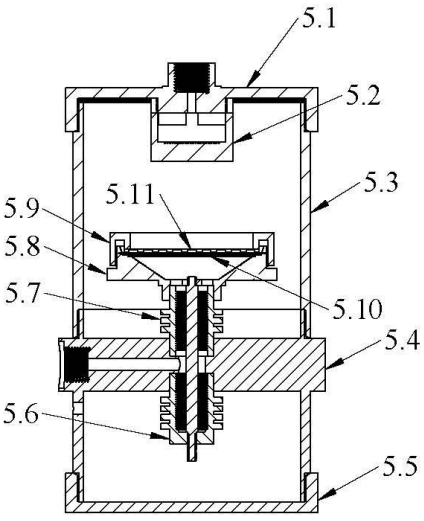


SECTION A-A

	NAME	SIGNATURE	DATE	MATERIAL:	TITLE:	
DRAWN	Mr. Artit Yawootti			various	EPMM-Faraday Cage of PM10	A4
CHK'D	Mr. Panich Intra					
Q.C.				WEIGHT:	SCALE:1:2	SHEET 1 OF 11

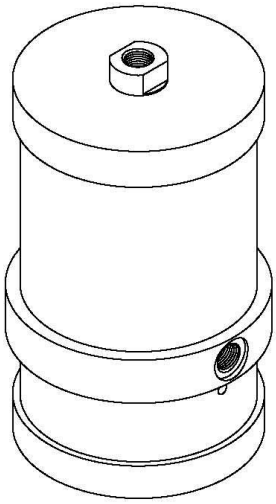


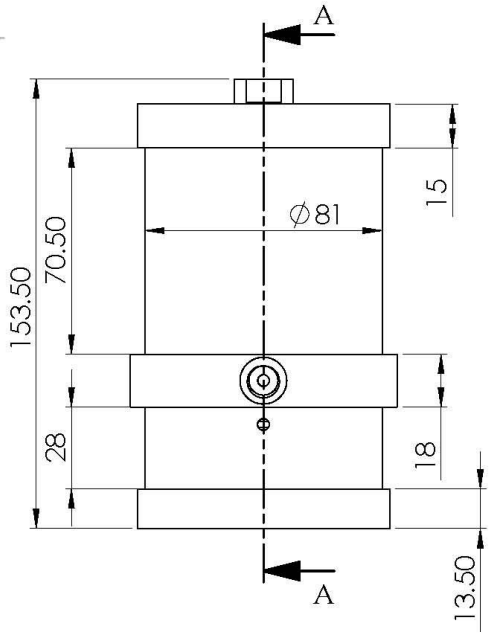


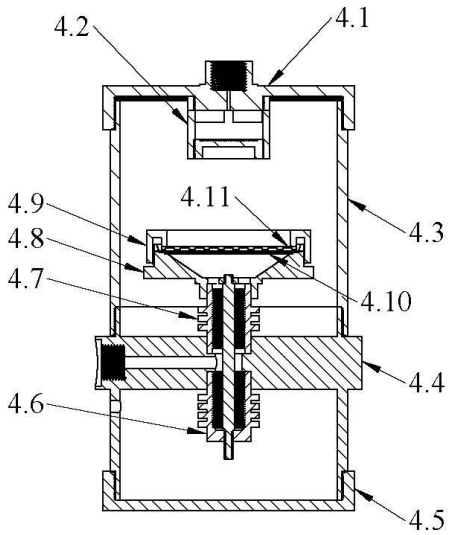


SECTION A-A

	NAME	SIGNATURE	DATE	MATERIAL:	TITLE:	A4
DRAWN	Mr. Artit Yawootti			various	EPMM-Faraday Cage of PM2.5	
CHK'D	Mr. Panich Intra					
Q.C.				WEIGHT:	SCALE:1:2	SHEET 1 OF 11







SECTION A-A

	NAME	SIGNATURE	DATE	MATERIAL:	TITLE:	A4
DRAWN	Mr. Artit Yawootti			various	EPMM-Faraday Cage of PM1.0	
CHK'D	Mr. Panich Intra					
Q.C.				WEIGHT:	SCALE:1:2	SHEET 1 OF 11

APPENDIX B

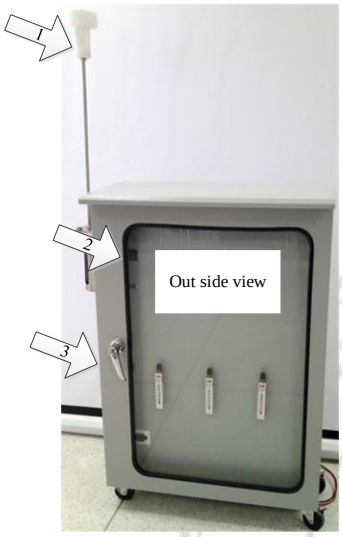
OPERATIONAL MANUAL

This Appendix B provides the operation manual of the multi-channel airborne particulate matter detector by an electrical technique. First Section of the Appendix shows an overview of the PMx detector. Next Section, presents about the structure and components, and finally, operating software of PC and application of smartphone.

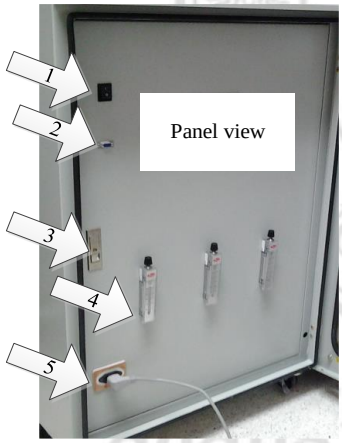
B.1 The PMx detector Overview

Air flow rate	5 L/min (one channel)
Air flow monitor and controller	Dwyer flow meter
Range	PM1.0, PM2.5, and PM10
Time response	Less than 0.1 s
Ambient temperature	15 – 40 ^{o}C
PM temperature	< 50 ^{o}C
Relative humidity	0 – 80 %
Weight	100 kg
Dimension	64 × 92 × 25 cm.
Inlet tube and Outlet tube	PT 1/8
Power consumption and	12 VDC, 100mA (220 VAC, 50Hz) and 12
Power of the vacuum pump	VDC, 5A
Electric fuse	250VAC, 1 A and 12VDC, 10A
Corona voltage	2.8 kV DC
Ion trap voltage	300 V DC
Discharge current	1 µA (First operating)
Pressure	Less than 1 bar
Total air flow rate	15 L/min
Noise filter	Pneumatic silencer
Computer	Pentium processor, MS-Windows XP/7
	LCD color monitor
Monitor	RS-232 to USB
Connector cable	Android/iOS/Windows phone
Smart phone and application	base on Team viewer

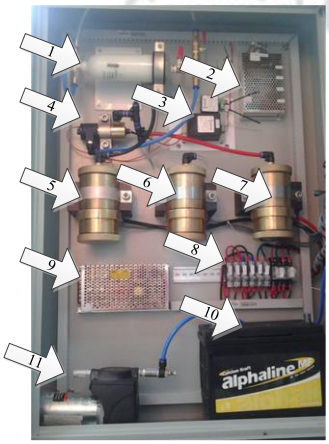
B.2 Structure and Component of the PMx Detector



The detector box has a dimension as 64 × 92 × 25 cm in width, high, and deep, respectively. It is a rectangular box that made from a two layered iron plate. It has a sloping roof on top and four wheels at bottom corners. In addition, it has a glass door at outside for observing a device operation and has an iron plate door at inside for installing any devices. Arrow one shows the head sampling device for inlet of ambient air or PM, arrow two is a glass door and arrow three is a door lock for security.



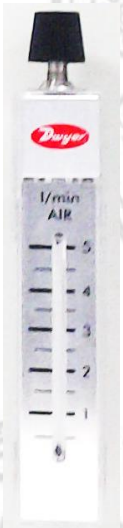
The front panel has the power switch, the communicator port, the lock, Rota-meter, and power connector which is shown in number 1, 2, 3, 4, and 5, respectively.



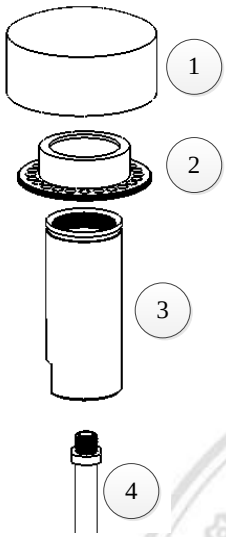
The device installation, number 1 to 11 are the capsule filter, power supply for electrometer, high voltage power supply, the particle charger, PM10 detector, PM2.5 detector, PM1.0 detector, protection fuses, main power supply, battery, and vacuum pump, respectively.

Main switch used for connecting the power system to the detector. The position " I" means operating status while " O" position means not operating status.

RS- 232 port for connecting to the operating computer. The computer has a function for received a measuring signal (PM1. 0, PM2. 5 and PM10 from electrometers) from the measuring device, before converted to mass concentration as shown on a graph on a display.

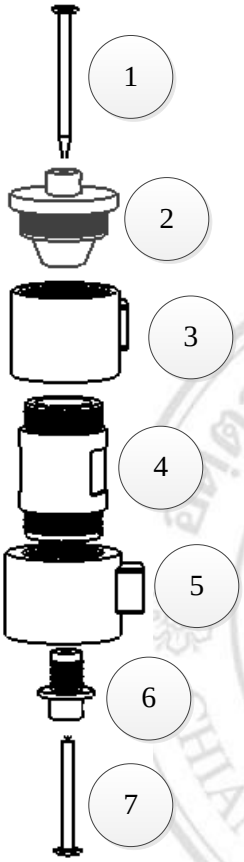


Flow control has a function for limit a sample flow at 5 L/min. In addition, it shows flow rate on a panel. This flow control was installed after the Faraday cage that has a HEPA filter inside, which it need make sure that the HEPA filter still install inside for protected a dirty air at this flow control.

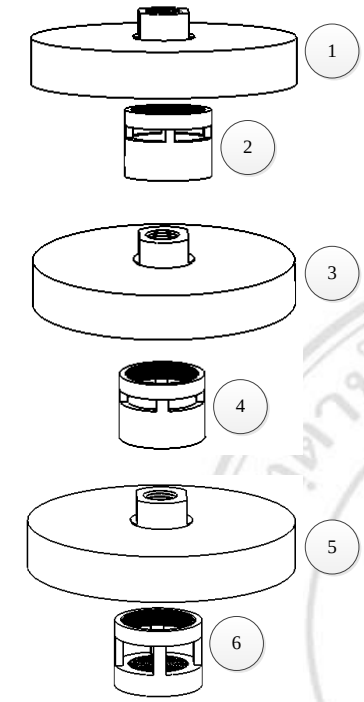


The head sampling has a function for getting an air sampler, then flowing through to the inside of the device. It consists of 1) a cover head, 2) a multi holes inlet, 3) a cylinder body, and 4) air tube. It was special design for getting the only air sample and can be protected the rain and insect into a device. Installation step, First, connecting part number 1 to 2 and 3 to 4, then bring together.

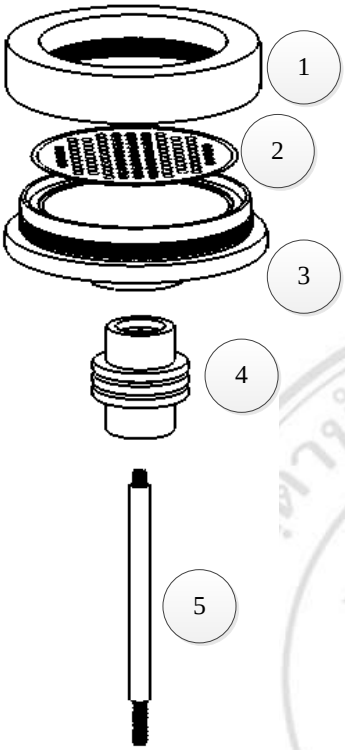
The diffusion dryer has a function to absorb the relative humidity from the sample air. It consists of a fitting air connector, the end cap, inner tube (stainless mesh) and the outer tube (clear plastic), as shown in (1) - (4), respectively. The top side as same as the bottom side. It can be installed by connected (1) against (2), then put (3) and (4) in (2) only bottom side. After that, place a silica gel in a space between the inner and outer tube, and then connected the end cap on top.



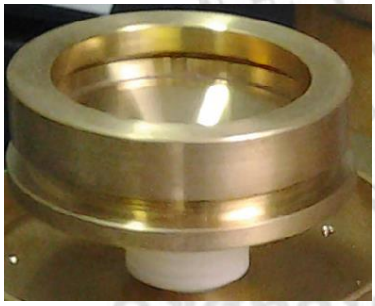
The particle charger has a function of diffusion and field charge in self. In addition, it has the ion trap after charging zone for removing a high concentrated ion out of the particle currents. This part consists of a needle high voltage electrode, a needle frame body, an electrode base, a cone body with ion trap room, an ion trap cap, an ion trap frame body, and an ion trap rod as shown in number 1-7, respectively. It can be installed by connecting all of the components together and used a fitting air PT1/8 for connecting to the inlet/outlet air tube.

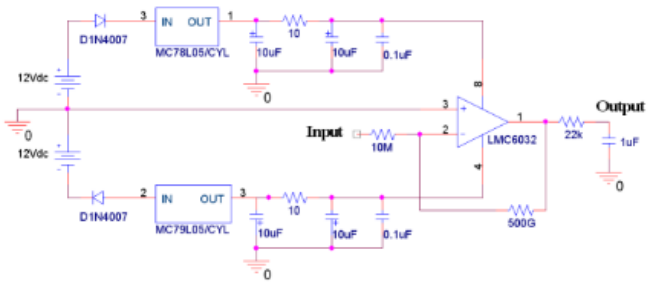


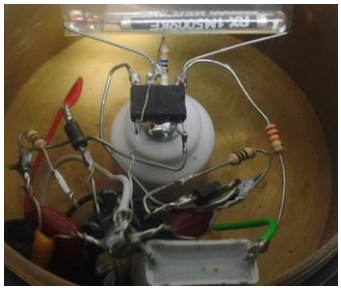
The particle size classification was trapped a particle that has a bigger size than the cutoff in diameter by the inertia and impaction theory. The exact size particle can pass through into the measuring system. The particle air flow accelerates by a nozzle and particles were impacting to the impaction plate which a smaller particle than cutoff diameter can pass around through to the outlet tube. This particle size classification have 3 parts for PM1. 0, PM2. 5, and PM10 particle type, it consists of a body frame that include a nozzle jet as shown in number (1), (3), (5) and the impaction part as shown in number (2), (4), (6) for the particle type PM1. 0, PM2. 5, and PM10, respectively. The particle size classifications have been installing and operating together with Faraday cage.



Faraday cup has a function for collected the particle's charge into a HEPA filter then sending an electric signal to the electrometer circuit for converting and amplifying to the voltage signal. It consists of a cover top, a press and base mesh, Faraday base, an electric insulator, and conductor rod as shown in number (1) to (5) , respectively. It was installed together inside of the Faraday cage.







Electrometer circuit has a function for amplifying signals from the Faraday cup. It is a basic inverting amplifier circuit that consists of an op-amp IC (LMC6032), resistor, capacitor, including a regulator circuit as shown in a picture circuit. Due to the charge of a particle is ultra-low level and high sensitivity for the interfering signal, so the circuit need to float on the air.

The high voltage power supply consists of 2 levels for generating a positive ion and trapping an ion after charging process. It uses IC LM317T circuits for controlling output voltage of the charging section and ion trap section at about 2.8 kV and 300V, respectively.

The battery inside of the measuring device is 12VDC 50Hhr only one that can be back up and generated the electric power more than 10 hours. It has life time about 2 years and need to change for a stabilization of electrical power.

The vacuum pump is a diaphragm type from GAST Company model 22D1180-201-1002, its use 12VDC 5A for the electrical energy. This pump can generate a vacuum flow up to 50 L/min and continuous operating more than 1,500h without maintenance.

B.3 Operating Software and Smart Phone

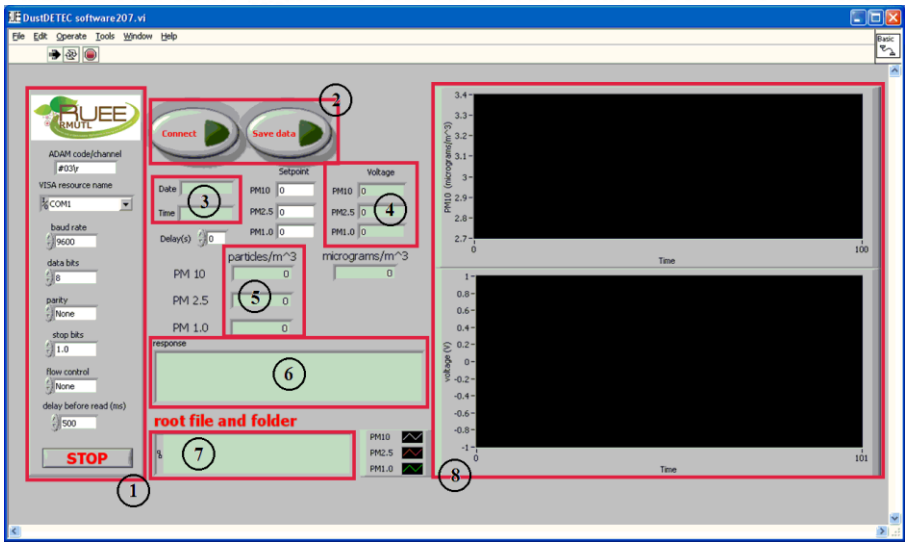
The electrical particulate matter monitor in this thesis can be operating itself for measuring PM1.0, PM2.5, and PM10 in air ambient. It uses 1 phase 220VAC 50Hz in electrical power and has battery backup inside in case of the basic electrical power has an emergency power outage

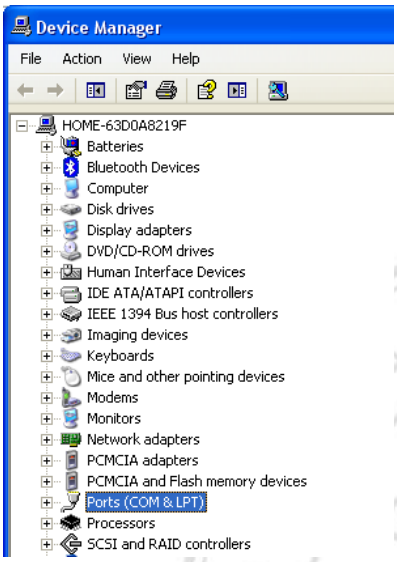
B.3.1 First Operating for the Detector

The detector has easy operating by turn ON power switch after connecting a power plug into the electrical power supply. Then it needs to validate the air flow at the Rota-meter on front panel. If the air flow isn't 5 L/min, it can adjust at spin on top of Rota-meter all 3 channels.

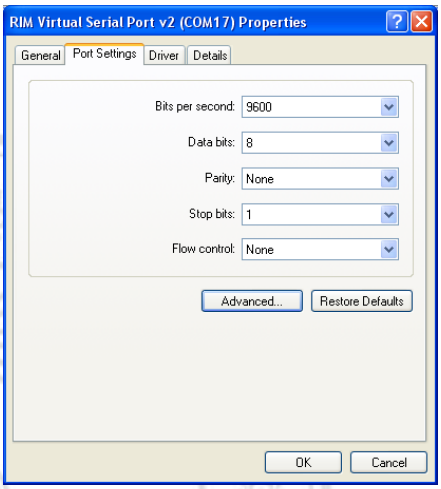
B.3.2 Operating Software

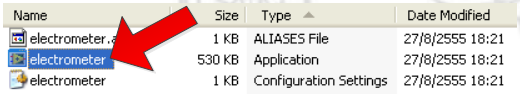
The detector software was developed for recording and showing of the PM measuring data both graph and number digits. The operating function consists of a file, edit, operate, tools, windows, and help functions. The front page shows the operating area include 1) port setting, 2) the connect and record button, 3) date and time box, 4) electrometer voltage box, 5) particle number concentration box, 6) response box, 7) destination of record file, and 8) graph of measuring data.



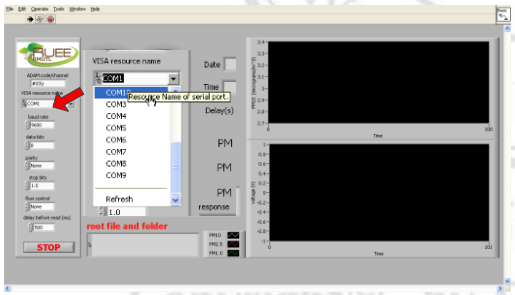


Checking port number from " Device Manager".

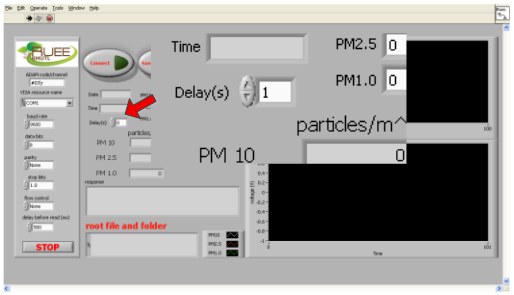




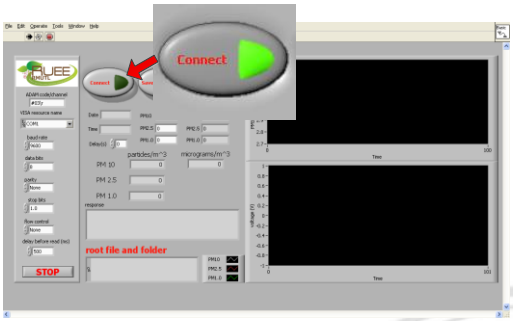
Open file "electrometer" for starting the operating software.



Selecting port number of the personal computer.

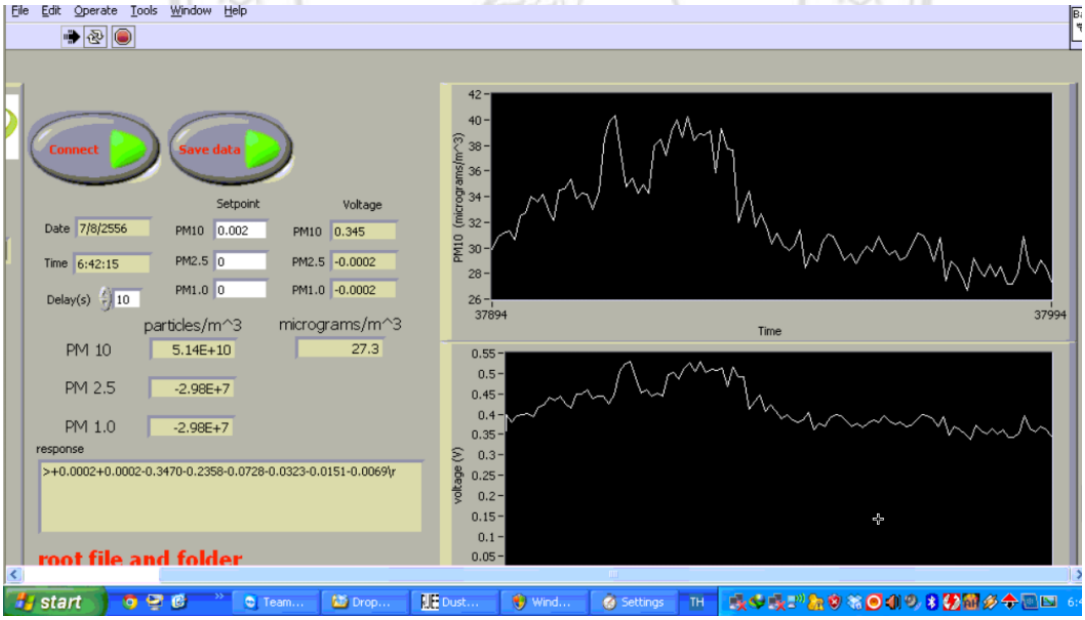


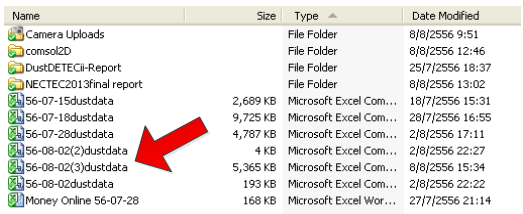
Selecting "Data Log" for Example "1s" mean recording every 1 second.



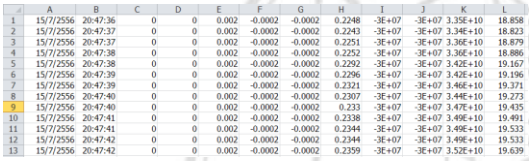
Press " Connect" button, then it' s shown "Dialog box" for select directory position (File format is a "CSV" that can open by "Excel").

Press " Save data" for recording the measuring data in to the record file (green button shown recording status).





The recording file can be browsed from the root directory in csv file format.



	A	B	C	D	E	F	G	H	I	J	K	L
1	15/7/2556	20:47:36	0	0	0.002	-0.0002	-0.0002	0.2248	-3E+07	-3E+07	3.35E+10	18.858
2	15/7/2556	20:47:37	0	0	0.002	-0.0002	-0.0002	0.2243	-3E+07	-3E+07	3.34E+10	18.823
3	15/7/2556	20:47:37	0	0	0.002	-0.0002	-0.0002	0.2251	-3E+07	-3E+07	3.36E+10	18.879
4	15/7/2556	20:47:38	0	0	0.002	-0.0002	-0.0002	0.2252	-3E+07	-3E+07	3.36E+10	18.886
5	15/7/2556	20:47:38	0	0	0.002	-0.0002	-0.0002	0.2292	-3E+07	-3E+07	3.42E+10	19.167
6	15/7/2556	20:47:39	0	0	0.002	-0.0002	-0.0002	0.2296	-3E+07	-3E+07	3.42E+10	19.196
7	15/7/2556	20:47:39	0	0	0.002	-0.0002	-0.0002	0.2321	-3E+07	-3E+07	3.46E+10	19.371
8	15/7/2556	20:47:40	0	0	0.002	-0.0002	-0.0002	0.2307	-3E+07	-3E+07	3.44E+10	19.273
9	15/7/2556	20:47:40	0	0	0.002	-0.0002	-0.0002	0.233	-3E+07	-3E+07	3.47E+10	19.435
10	15/7/2556	20:47:41	0	0	0.002	-0.0002	-0.0002	0.2338	-3E+07	-3E+07	3.49E+10	19.491
11	15/7/2556	20:47:41	0	0	0.002	-0.0002	-0.0002	0.2344	-3E+07	-3E+07	3.49E+10	19.533
12	15/7/2556	20:47:42	0	0	0.002	-0.0002	-0.0002	0.2344	-3E+07	-3E+07	3.49E+10	19.533
13	15/7/2556	20:47:42	0	0	0.002	-0.0002	-0.0002	0.2359	-3E+07	-3E+07	3.52E+10	19.639

The recording data in any column as shown in the excel table has meaning following 1) A is Year/ Month/ Date that recording, 2) B is recording time that reference from the computer, 3) C,D, and E are the set point constant of the electrometer channel PM1.0, PM2.5, and PM10, respectively, 4) F, G, and H are Electrometer voltage from PM1.0, PM2.5, and PM10, respectively 7) I, J, and K are the particle number concentration from PM1.0, PM2.5, and PM10, respectively, 8) L, M, and N are the particle mass concentration from PM1.0, PM2.5, and PM10, respectively.

B.3.3 Operation by Smart Phone

The smartphone is applied to monitor the operation of detector by operating with the computer. Software and application of the smart phone name "TeamViewer" used for this operation. The measuring data from detector that send to the computer can be shown at smart phone by "TeamViewer" application on internet network.

TeamViewer can control the computer that connected to detector. User can control and monitoring by the smartphone virtual used the computer.

TeamViewer can download from root [http://www.teamviewer.com/th/download/windows.aspx] or search at google

The Figure shows characteristic of TeamViewer software in computer. In case of the computer was connected to the internet signal, the bottom bar shown green status that meaning "Ready to connect (secure connection)"

The installation at smartphone can download "TeamViewer" from "Play Store" similarly, the other application.

It need make sure that both the computer and smart phone were connected to the internet network before open the "TeamViewer" software.

The connection between the computer and smart phone by "Team Viewer" require "User ID" and "Password" from the computer in every time of the connection.

When connected the computer and smartphone together, the smartphone is virtual the computer. All of details on monitor of computer were shown on a smartphone as same as the detector software as shown in Figure

CURRICULUM VITAE

Author's Name	Mr. Artit Yawootti
Date/Year of Birth	2 July 1978
Place of Birth	Chiang Mai Province, Thailand
Education	2000 BS. Tech. Ed. Degree in Electrical Engineering, King Mongkut's University of Technology Thonburi. 2004 M. Eng. Degree in Electrical Engineering, King Mongkut's University of Technology Thonburi.
Scholarship	Staff Development Fund, Rajamankala University of Technology LANNA 2012
Specialist	Instrument and Automatic Control System, Electric Field Apply, High Voltage Power Supply, Sensor, Computer Programming, CFD Simulation, IOT and Android Application
Research Interest	Design of Instrumentation for Airborne Particulate Matter, Electrostatic Precipitation, Electric Field Application
Publications	1) Intra, P., Yawootti, A., and Tippayawong, N., "Electrostatic Evaluation of a Unipolar Diffusion and Field Charger of Aerosol Particles by a Corona Discharge", Particulate Science and Technology, Vol. 31, No. 6, 2013, pp. 621-631. 2) Intra, P., Yawootti, A., Vinitketkumnuen, U., and Tippayawong, N., " Investigation of Electrical Discharge Characteristics of a Unipolar Corona-Wire Aerosol Charger", Journal of Electrical Engineering and Technology, Vol. 6, No. 4, July 2011, pp. 556-562.

3) Intra, P. , Yawootti, A. , and Tippayawong, N. , “ An Electrostatic Sensor for Continuous Monitoring of Particulate Air Pollution”, Korean Journal of Chemical Engineering, Vol. 30, No. 12, 2013, pp. 2205-2212.

4) Intra, P., Yawootti, A., and Tippayawong, N., “Demonstration of a Modular Electrostatic Precipitator to Control Particulate Emissions from a Small Municipal Waste Incinerator”, Journal of Electrical Engineering and Technology, Vol. 9, No. 1, 2014, pp. 239-246.

5) Intra, P., Yawootti, A., and Rattanadecho, P., “Numerical and Experimental Studies of Collection Efficiency of an Ion Electrostatic Collector for a Mini- Volume Electrical PM Detector”, Journal of Electrostatics, Vol. 72, No. 6, December 2014, pp. 477- 486.

6) Intra, P. , Yawootti, A. , Vinitketkumnuen, U. , and Tippayawong, N. , “ Development of a PM2. 5 sampler with inertial impactor for sampling airborne particulate matter” , Korean Journal of Chemical Engineering, Vol. 29, No. 8, August 2012, pp. 1044-1049.

7) Intra, P. , and Yawootti, A. , “ Production of Submicron Polydisperse Aerosol Particles using Combustion Burner” , Hydromechatronics Engineering, Vol. 40, No. 12, 2012, pp. 1-4.

8) Intra, P., Yawootti, A., and Rattanadecho, P., “Influence of the Corona- Wire Diameter and Length on Corona Discharge Characteristics of a Cylindrical Tri- axial Charger”, Journal of Electrostatics, Vol. 74, No. 1, April 2015, pp. 37 – 46.

9) Yawootti, A., Intra, P., and Tippayawong, N., “Measurement of Unipolar Charged Aerosol Particles Using a Long Electrical Mobility Spectrometer, International Conference on Green and Sustainable Innovation (ICGSI2009) , December 2-4, 2009, Chiang Rai, 2009, pp. 843-846.

10) Yawootti, A., Intra, P., and Tippayawong, N., “A Combustion Aerosol Generator for Submicron Aerosol Production”, The 3rd Technology and Innovation for Sustainable Development International Conference (TISD2010), Khon Kaen University, Thailand, March 4-6, 2010.

11) Yawootti, A., Intra, P., and Tippayawong, N., “Characterization of a Cylindrical Tri-axial Charger as a Critical Component in a Fast Response Particulate Air Pollution Sensor”, 5th WSEAS International Conference on Environmental and Geological Science and Engineering (EG'12), Vienna, Austria, November 10-12, 2012.

12) Yawootti, A., Tippayawong, N., and Intra, P., “Real Time Measurement of Ambient Particulate Matter: Comparison of TEOM and DustDETEC”, International Graduate Research Conference 2014 (iGRC 2014), Chiang Mai University, December 12, 2014.

13) Yawootti, A., Intra, P., Sardyoung,P, Phoosomma, P., Puttipattanasak, R., Leeragreephol, S., and Tippayawong, N., “A Wireless Sensor System for Continuous Monitoring of Particulate Air Pollution”, ICAP 2015 : 17th International Conference on Applied Psychology, Tokyo, Japan May 28 – 29, 2015.

14) Yawootti, A., Intra, P., Tippayawong, N., and Rattanadecho, P., “An Experimental Study of Relative Humidity and Air Flow Effects on Positive and Negative Corona Discharges in a Corona-Needle Charger”, Journal of Electrostatics, Vol. 77, October 2015, pp. 116-122.

15) Yawootti, A., Intra, P., Tippayawong, N., and Sampattagul, S., "Field Evaluation of an Electrostatic PM10 Mass Monitor used for Continuous Ambient Particulate Air Pollution Measurements", Journal of Electrostatics, Vol. 78, No. 1, December 2015, pp. 46-54.