Chapter III
Methodology

3.1 Work Plan

To perform the study and data observation systematically, the author set up work plan and studying procedure to follow. The procedure and its brief description is shown in table 3.1 below.

Table 3-1 The main procedure step of the study.

Main	Steps	Descriptions
Preparation	Literature review	Search for documents that indicated industrial noise, noise control, determination of noise source and prediction model. Obtain the concepts of noise prediction model and characteristic of study area.
	Scouting area	Visit the chosen area, RPP, in order to skim the necessary information and noise source characteristics.
	Planning and Collecting noise data at Rayong Power Plant	Field work study was divided into three parts of data collection (emission noise data , immission noise data and transmission path data) The collection of emission noise data relies on two measurement procedure; point source, non-point source using SPL measurement. For immission noise data grid-system method and double distance criteria will be used. Transmission path data in the vicinity of plant is depending on transmission function of the chosen path, matching with each couple of noise source and immission point.
Operation	Data collection	Collect noise data from RPP to classify source, immission, and transmission data. Calculate the SPL(A) of each 1/1 octave band level.
	Equation selection and Data analysis	Choose mathematical equation for prediction model and noise source. Calculate sound power of noise source for emission part. Prepare the transmission path data and immission data for calibration step.
	Coding program and calibrate model	Develop the power plant noise prediction model using Microsoft visual basic for windows version 3.0. The 20 percents of noise data from Rayong Power Plant were ramdomly selected for model calibration.
	Sensitivity analysis	Use Rayong Power Plant noise data to simulate and test the sensitivity of the model.
	Evaluation	Verify the prediction model by comparing the predicted data with the measurement data.

3.2 Site Selection and Description

Rayong Power Plant (RPP) is one of industrial noise source which almost includes all main types of industrial sound sources. It is very important rationale for site selection to verify the noise prediction model. The model predicts the outstanding polluted area concerning during the planning process of a new power plant or expanding part. That is very useful for noise pollution control and mitigation plan. RPP, one of the most potential site is chosen to be the study area on account of three reasons; numbers of industrial source types, vertical source stratification and remotely situated from communities or other noise sources. Noise source data of RPP would represent the noise level emitting from all equipment, used in combined cycle power plants under operating conditions in Thailand. This study concentrated on emission parameter determination method to be input data of the prediction model using SPL measurement.

Rayong Power Plant (RPP) locates in Huai-Pong, Muang District of Rayong. There are 462 rai and 150 rai for the operation areas. It comprises approximately 4x308 MW of electricity. RPP is a combined cycle, the combination of a gas turbine and steam turbine generation systems. The exhaust heat released from the gas turbine generators will be used to generate and operate the steam turbine generators without any additional fuel requirements. Each block comprise 2x103 MW from the gas turbine generation and 1x102 MW from the steam turbine generation. Designed for dual gas/oil, the gas turbine units will mainly use the domestic natural gas directly supplied by PTT's Gas Separation Plant through 16 inch-diameter pipeline. The maximum gas consumption by each gas turbine unit is approximately 29 million cubic feet per day. The 2x11 million liters storage tanks of standby diesel oil were built within the plant.

RPP will need approximately 12.6 million cubic meters per year of water supplied for its operation and cooling system. The cooling water is mainly supplied from Dok Krai reservoir with 70.8 million cubic meters and from the 200,000 cubic meters standby reservoir within the plant site. The power plant is connected with the national grid system via 2x230 kilovolt double-circuit transmission lines of 54 kilometers length, linking between Rayong Substation II and Ao Phai Substation in Chonburi Province. RPP was designed by GEC Alsthom with the design criteria, plant performance, system specification, and specification as stated in table 3-2, 3-3, 3-4, and 3-5.

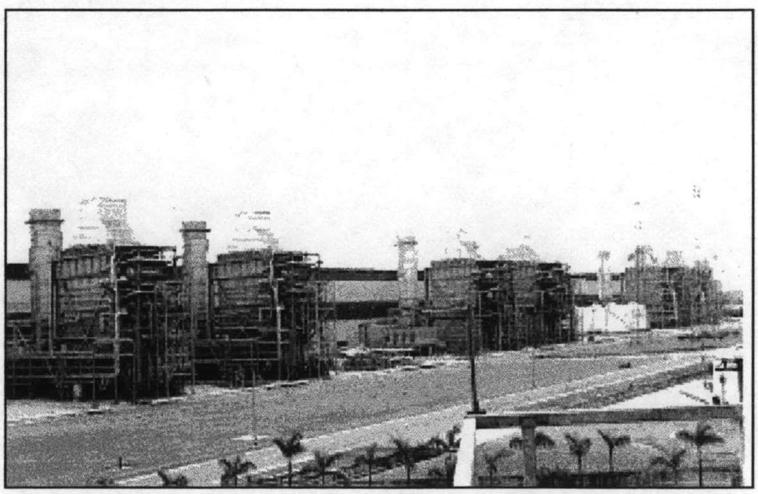


Figure 3-1 The photograph of Rayong Power Plant

Table 3-2 Design Criteria

Parameter	Condition
Ambient Temperature	32.2 degree Celsius
Cooling Water Temperature (Cooling Tower)	36.6 degree Celsius
Barometric Pressure	1.013 BAR
Relative Humidity	75%
Elevation above sea level	3 m.
Fuel	Natural gas distillate

Source : EGAT, 1992

Table 3-3 Plant performance per block ,Based on natural gas site conditions.

Parameter	Condition per block	
	Base load	Peak load
Gross Power Output, MW	313.6	342.5
Net Power Output, MW	308.6	337.3
Net Heat Rate, KJ/KW-H	7545	7368
Net Efficiency, KJ/KW-H	47.8	48.7

Source : EGAT, 1992

Table 3-4 System Specification

Parameter	Condition per block
Bearing assemblies	
Quantity	3
Lubrication	Pressure lubrication
Starting system	
Starting device	Diesel engines start motor
Torque converter	Hydraulic with adjuster drive
Fuel system	
Operator type (Dual fuel)	Natural gas + Distillate
Fuel control signal	Supertonic control system
Fuel pump	Accessory gear-driven
Flow divider (starting motor)	In line,free wheeling 14 elements
Fuel oil stop valve	Electro-Hydraulic servo-control
Fuel oil filter(S)(HP)	1
Gas stop/ratio and control valve	Electro-Hydraulic servo-control OR (No.2 Fuel oil)
Compressor Section	
Number of compressor stages	17
Compressor type	Axial Flow,Heavy duty
Casting split	Horizontal Flange
Inlet guide wanes type	Modulated
Turbine Section	
Number of turbine stages	3
Casting splits	Horizontal
Nozzle	Fixed area
Combustion Section	
Type	14 multiple combustion reverse flow design
Full nozzles	1 per combustion chamber
Spark plugs	2 electrode type, spring-injected selt-rectracting
Flame detection	4 ultra-violet type

Source : EGAT, 1992

Table 3-5 Machine specification

Specification	Units	Name				
		GT	HRSG	ST	GT. GEN	ST. GEN
Manufacture	-	GEC.	CMI	GEC.	GEC.	GEC .
Type	-	9161 E	Double Pressure	Combined Casing	-	-
Model	-		Forced Circulation	Dual Admission	-	-
Number	-	8	8	4	8	4
Base load Rating combined cycle operation	MW	115.2	-	-	-	-
GT Base Load Output at site condition	natural gas MW	101.6	-	-	-	-
	fuel oil MW	100.8	-	-	-	-
Exhaust Gas Flow	T/H	1359	-	-	-	-
Exhaust Gas Temperature Celsius	degree	540	-	-	-	-
Nominal Rating	MVA	119.3	-	-	-	-
Voltage/Frequency	KV/Hertz	11.5 /50	-	-	-	-
Cooling		Hydrogen	-	-	-	-
HP Steam flow	T/H	-	169.4	-	-	-
Conditions at superheater outlet	BAR/degree Celsius	-	72 /510	-	-	-
LP Steam flow	T/H	-	41	-	-	-
Conditions at superheater outlet	BAR/degree Celsius	-	6.4 /210	-	-	-
Gas Temperature(boiler Inlet/Outlet),	degree Celsius	-	540 /141	-	-	-
HP turbine inlet flow	T/H	-	-	338.8	-	-
Steam condition at turbine inlet	BAR/degree Celsius	-	-	70/508.7	-	-
LP turbine inlet flow	T/H	-	-	82	-	-
Steam condition at turbine inlet	BAR/degree Celsius	-	-	5.9/208.7	-	-
Condenser Pressure	BAR	-	-	0.112	-	-
Power Output	MW	-	-	110.4	-	-
Nominal Rating	MVA	-	-	-	135.5	119.26
Voltage/Frequency	KV/Hertz	-	-	-	11.5/50	11.5 /50

GT: GAS TURBINE GT.GEN : GAS TURBINE GENERATOR
ST : STEAM TURBINES ST.GEN : STEAM TURBINE GENERATOR
HRSG: HEAT RECOVERY BOILER GEC. : GEC ALSTHOM

Source : EGAT, 1992

3.3 Instruments

1. Sound level meter (SLM) : Brüel & Kjær Modular Precision sound level meter Type 2231with statistical analysis module Type BZ 7101 and Brüel & Kjær Octave band filter set Type 1625
2. Frequency Analyzer : Rion 1/3 Octave band real-time analyzer Type SA-25
3. Microphone : Condenser microphone
4. Calibrator : Brüel & Kjær Type 4231
5. Brüel & Kjær Graphic Printer Type 2318 and Interface modules Type 9101
6. Windscreen and Tripod
7. Notebook computer for transferring data from SLM
8. Distance measuring tape 5 meters and 30 meters, Germany Barigo Comfortmeter (Thermometer and Hygrometer), and compass.
9. Meteorological data from Huai-Pong Meteorological station: Wind speed and wind direction data at 10 meters above ground.
10. Map of Rayong Power Plant

The apparatus of sound level meter, analyzer, and accessories were shown in Appendix A.

3.4 Measurement Method for RPP

The following procedure is used for noise measuring from RPP to predict noise level by power plant noise prediction model.

3.4.1 Measurement Parameters and Conditions

- The 1/1 octave band SPL for 1 minute inside the main building by 5x5 and 10x10 meter grid-mesh at 1.5, 6.5, 11.5 and 16.5 meters above the ground.
- The 1/1 octave band SPL for 1 minute outside environment by the combine system of the double distances (5, 10, 25, 50, 100, 150, 200 meters from source), the grid-size (25x25, 50x50 and 100x100) and availability of measurement at 1.5 meters above the ground.
- The 1/1 octave band SPL of noise source according to the PWL determination method.
- Sound transmission loss of source building wall.
- Source dimension (width, length and height in meters).
- Mechanical power in Watt of considered noise source.
- Characteristic of sound emitted from the source.
- Operation time of noise source.
- Wind speed and wind direction at 10 meters height of site study areas.
- Air temperature and relative humidity during immission measurement of site study areas.
- Environmental conditions for transmission path determination.

3.4.2 Climate Conditions and Date of Collection Data

Climate in Thailand is divided into dry season (November-April) and wet season (May-October). Prevailing wind at high altitude comes from northeast direction in dry season and from southwest direction in wet season. Local wind character is affected from prevailing wind and local conditions, sometimes, the local conditions have an influence more than prevailing wind. In case of Mataphut Rayong province located close to inner gulf of Thailand, the wind speed and wind direction would be influenced by sea-breeze and air turbulence more than prevailing wind. From the long-term meteorological statistics of Huai Pong meteorological station, located 4 kilometers from the study area, average wind comes from south direction (from the sea) during January to May and September to October, southwest direction during June to August and north to northeast direction during November and December. The average wind speed at 10 meters height was less than or equal to 2 meters per second and sometimes slightly greater in dry season. In 1995 and early 1996, the average wind direction come from north and south direction during dry season and southwest direction during wet season while the average wind speed was 1 meter per second. Thus, the meteorological condition was under the main prediction assumption of ISO 9613 Part II. Noise data collection schedules were as following.

- On the 2-4 March 1995 for scouting area for power plant detail information.
- On the 21-23 September 1995 for checking position of measurement and test the environmental conditions.
- On the 29 November-3 December 1995 for noise source data collection inside the building and the environment, SPL of immission noise data in environment.
- On the 18-21 March 1996 for the same as the last measurement particularly outdoor measurement.

3.4.3 Measurement Method for Noise Source Data

3.4.3.1 Point source data is collected according to ISO 3746 in figure 3-2, and should be fulfilled all of following procedures. (ISO, 1979)

a) Measure source dimension as reference surface near source in meter.

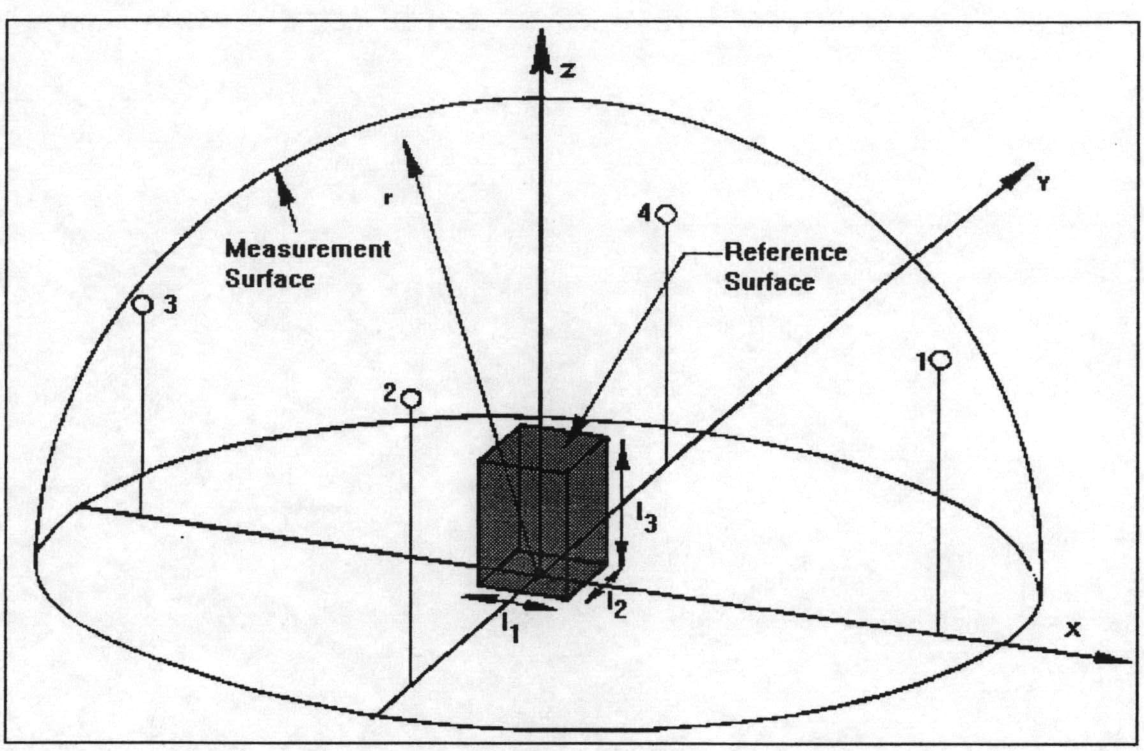
b) Define measurement surface of noise source. The hemispherical surface is for small source such as electric motor and electric pumps. The rectangular surface for box source such as cooling fin fan, air compressor, set of electric pumps and large pumps. This method was not significant to measure SPL to determine PWL of large source because it was affected from reflection of ground plane and short distance measurement. Noise measurement would be at least about 1 meter from the center of the source to prevent interference noise from other sources and to reflect from its surface. Our measurements were 1 meter from the edge of the source.

c) Microphone height of hemispherical surface was 2/3 of source height in table 3-6 and figure 3-2 (a). The microphone height of rectangular surface was 1/2 of source height in table 3-7 and figure 3-2 (b).

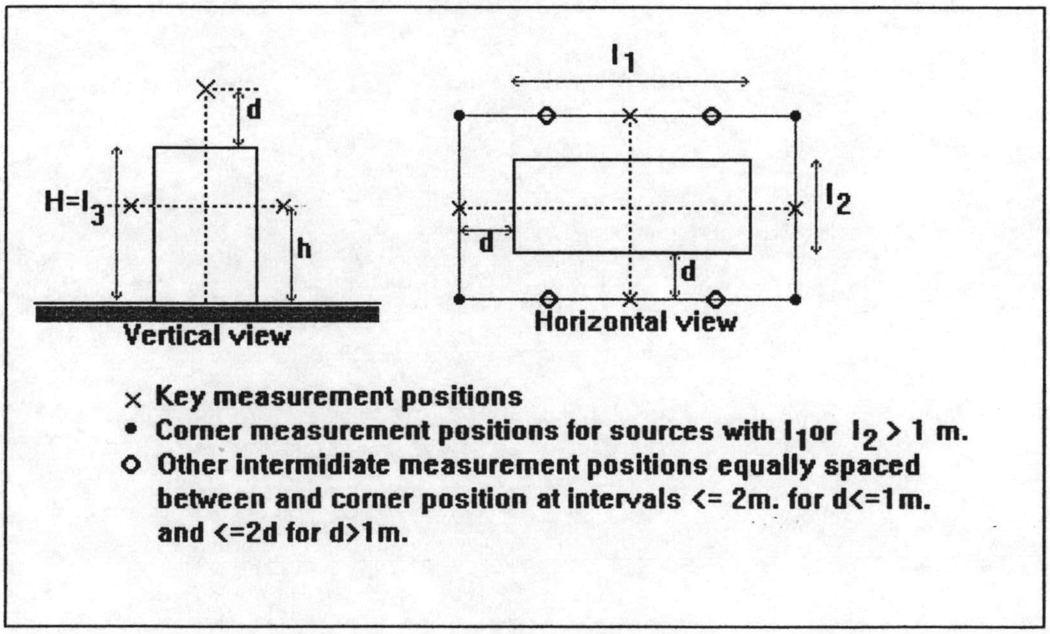
d) Microphone directly set to face the source plane. Microphone position on the measurement surface of hemispherical surface was at least 4 positions and 5 positions for rectangular surface. Pump and motor used the minimum limit while cooling fin fan, set of pumps or motors used more microphone numbers.

e) Record measurement condition. (Operation time, Noise characteristic, Reflecting plane, Wind condition, Power of machine and Noise interference)

f) Record background noise. (if the preliminary difference exceeds ± 3dB between measurement surface and source surface)



(a) Hemispherical Surface



(b) Rectangular Surface

Figure 3-2 Measurement Surface of Point Source Determination Method according to ISO 3746. (ISO, 1979)

Table 3-6 Co-ordinates of microphone positions in terms of distances from center of hemisphere along three mutually perpendicular axes (x, y, z)

Microphone no.	Microphone at height z= 0.6 r			Microphone just above reflecting plane		
	x/r	y/r	z/r	x/r	y/r	z/r
1	0.8	0.0	0.6	1.0	0.0	<0.05 m.
2	0.0	0.8	0.6	0.0	1.0	<0.05 m.
3	-0.8	0.0	0.6	-1.0	0.0	<0.05 m.
4	0.0	-0.8	0.6	0.0	-1.0	<0.05 m.

Source : ISO, 1979 (ISO 3746)

Table 3-7 Effective Microphone Height of Rectangular Measurement Surface

Source Height , H (m.)	Microphone Height , h (m.)
≤ 2.5	(H+d)/2
> 2.5	(H+d)/2 for key positions and H+d for corner positions

Source : ISO, 1979 (ISO 3746)

3.4.3.2 Non-point source is collected depending on equals angle method (Jenkins, Salvidge and Utley, 1976) and ISO 1996/1. (ISO, 1971)

a) Microphone positions were lying along with sources having 5 meters from the edge of sources and 15 meters between the adjacent points. Equal angle method was explained in Appendix C.1.

b) Microphone height were collected only at 1.5 meters in any distance around the source.

3.4.4 Measurement Method for Immission Noise Data

Immission noise data is used to verify the power plant noise prediction model. The procedure that is used to collect this data is explained as ;

a) Microphone height is 1.5 meters above the ground because of availability of measurement and human ear protection.

b) Microphone position relies on grid-system(25x25, 50x50 and 100x100) and double distance system (10, 20, 30, 40, 50, 100, 200, 500).

c) Record the environmental conditions in terms of meteorological conditions.(air temperature, relative humidity, wind speed and wind direction)

3.4.5 Measurement Method for Transmission Path Data

This study divided correction terms for sound propagation outdoor into 5 groups based on Kragh, Andersen and Jakobsen (1982). Divergence attenuation, air absorption attenuation, ground effect (reflection or attenuation), reflecting obstacle attenuation and screening obstacle diffraction were considered. All paths were depend on the pairs of source and receiving point except air absorption correction. It needs to know about the in situ air temperature and relative humidity twice a day. The present environmental conditions should be under downwind with wind speed less than or equals 2 m/s at 10 meters height. Air absorption attenuation, ground effect correction and screening attenuation depends on frequency analysis while reflecting obstacle correction and divergence attenuation were not. Point source considered the source height at 2/3 of source height for hemispherical measurement surface and at 1/2 of source height for rectangular measurement surface to represent H_s of the prediction model. Non-point source considered the source height at 1/2 of source height in every calculation methods to represent H_S. The input parameters for transfer function which were observed during the measurement should be followed by table 3-8. Explanation of each input parameter was in section 2.5.2.3.

Table 3-8 Required data for input in each transmission path

Transfer function	Input parameter required
Divergence	dsi, Hs, Hi
Air absorption	Temperature, relative humidity, dsi, Hs, Hi
Ground effects	Gc, Gi, Gs, dsi, Hs, Hi
Reflecting obstacle	dsc, reflecting coefficient, reflecting angle, diameter of silo
Screening	Hscr, Lscr, SKLx, SKRx, IKLx, IKRx

3.5 The Development of Power Plant Noise Prediction Model

To develop the power plant noise prediction model, all of procedures in figure 3-3 and 3-4 would be thoughtfully considered. Input data of the prediction model explained in equation 2.36. They can predict the SPL at any immission point around the sources. The most significant parameter were carefully considered being the PWL determination of noise source and divergence attenuation. RPP had a several types of sound source. Only point source equation was practically not enough to represent every types of source in short distance of outdoor conditions because of the dissimilar arrangement of source positions. The directivity of source was absolutely changed by those arrangements. Thus, the measurement methods and calculation methods were also changed. There are three methods for determining PWL of sound source; SPL, intensity, and vibration measurement. In this study selected SPL measurement to determine sound source because of it needs only ordinary SLM with octave filter set to determine. For this reason, the author proposed four methods for determining PWL of the RPP's sources. The PWL determination of source showed in figure 3-5 and the calculation method of each determination were described in section 3.5.1.

3.5.1 Sound Source Determination

The methodology was used in this study, separated into two groups; point-source and non point-source, according to the criteria in table 3-9.

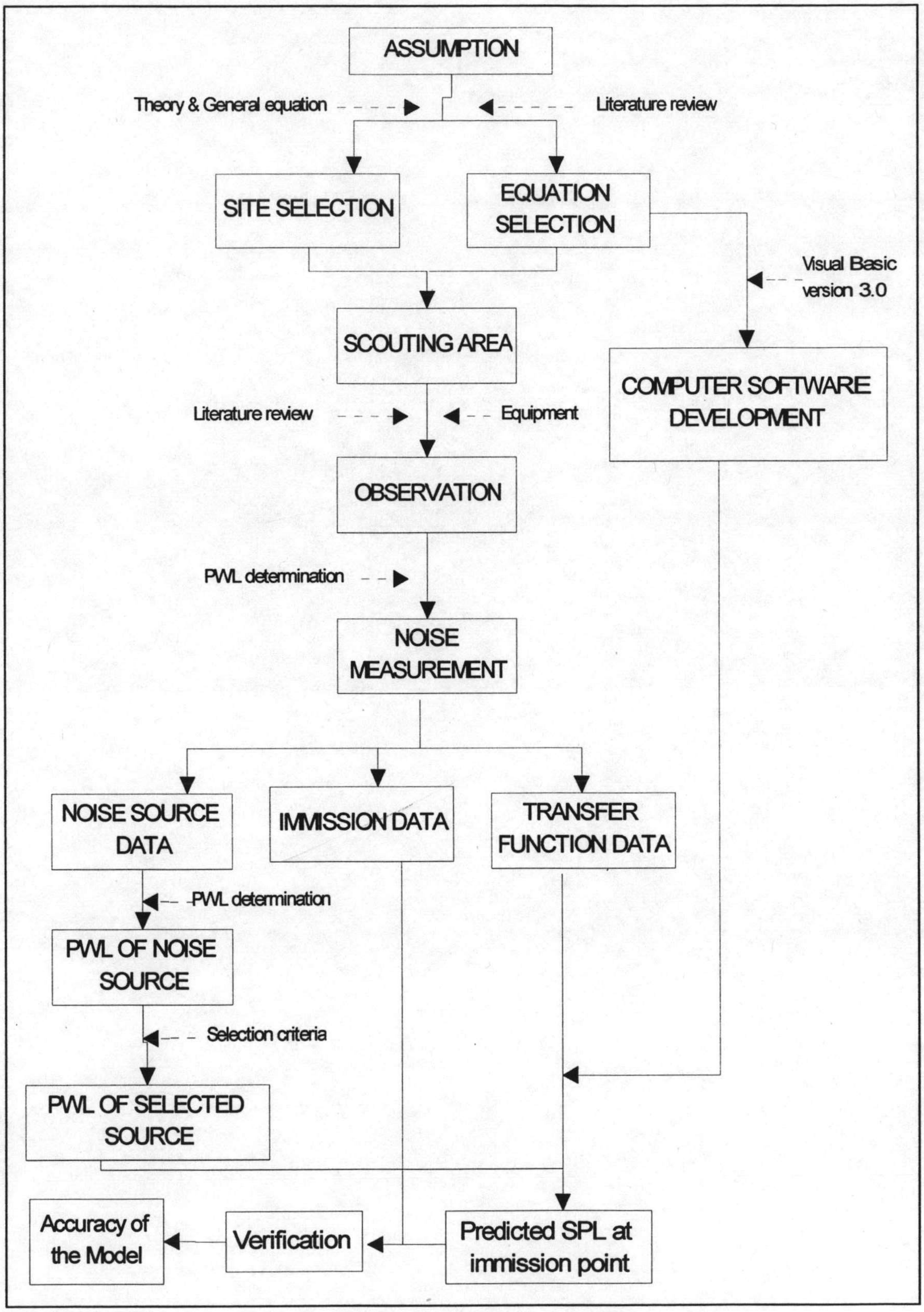
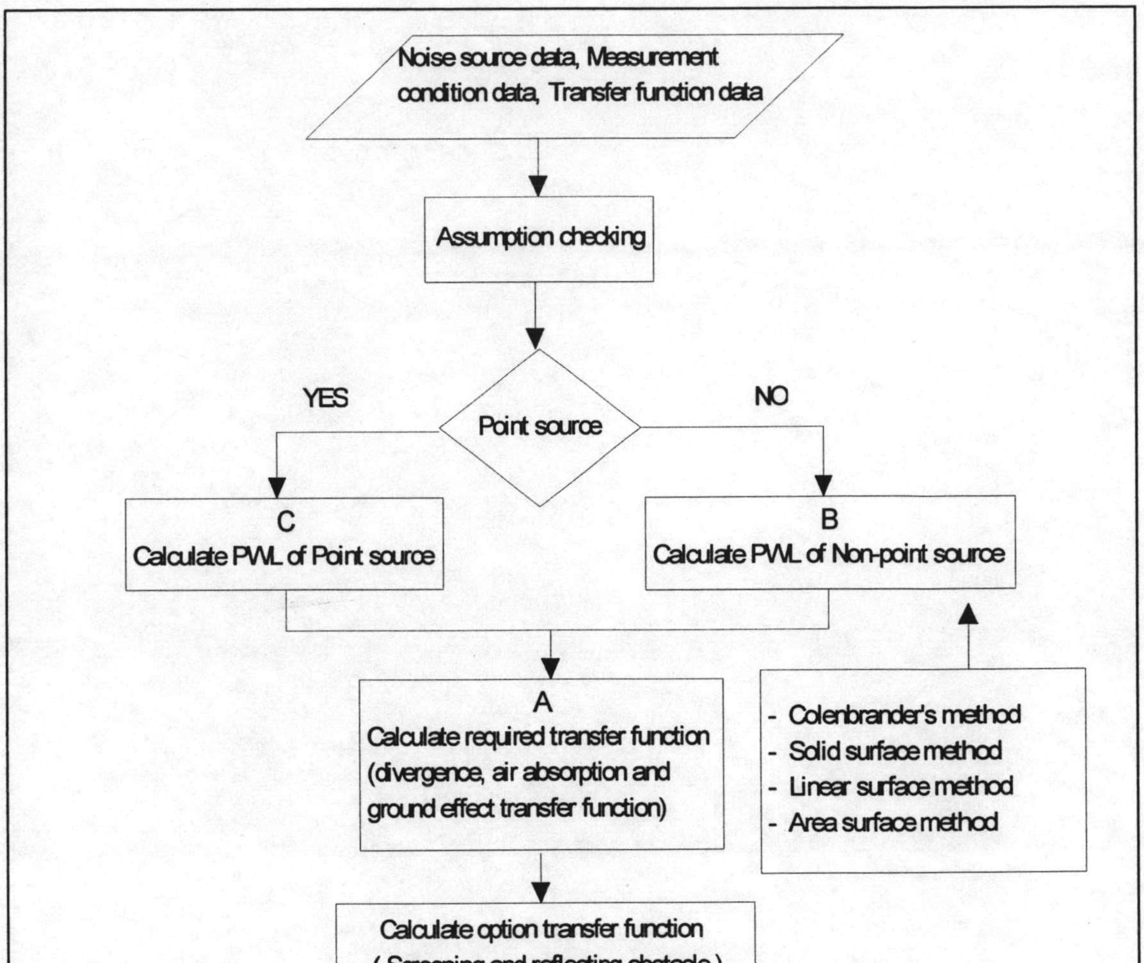


Figure 3-3 The methodology for development of prediction model.



Remarks : All of details procedure flowchart were described in Appendix C.

Figure 3-4 The development of computer software for power plant noise prediction model.

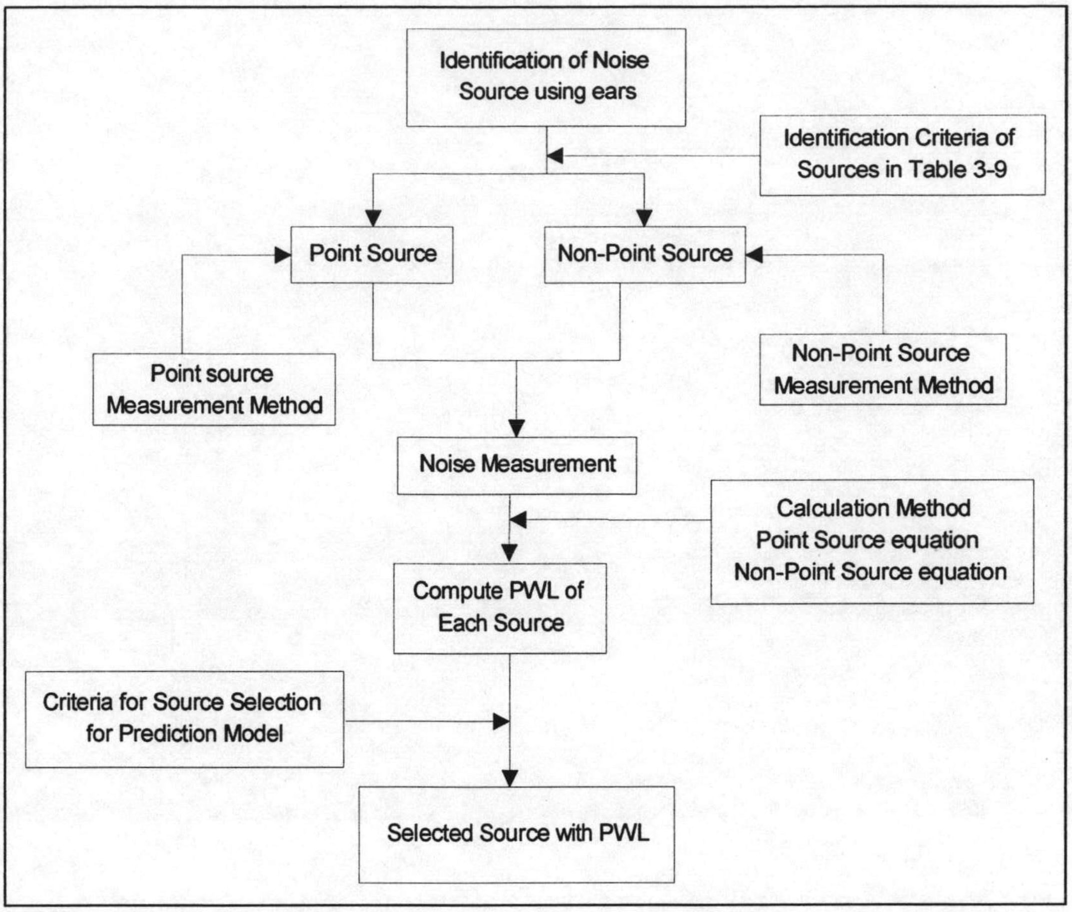


Figure 3-5 The determination procedure of sound source, applied in RPP's study.

Table 3-9 Criteria for identifying noise source determination in outdoor conditions.

Criteria	Point source	Non-point source
Distance between emission and immission point, dsi	dsi ≥ 1	dsi > 1
Practically of measurement	Could measure the position above sound source	Could not measure the position above the source or at any height
Source enclosure	No building enclosure	Building enclosure
Other effective noise sources	If it is presented, background noise correction is needed	If it is presented, background noise correction is needed
Source type & dimensions	Single small source	Multi-source or Large source

3.5.1.1 Point Source Determination

When the important noise source is considered to be point source, we firstly identified the measurement surface. The measurement surface is an hypothetical surface surrounding a definite source containing all of emitted energy from sources. The hemispherical surface is a default surface for point source. However it have the rectangular surface depending on source shape. Hemispherical and rectangular surface can be calculated by equation 3.1 and 3.2 respectively. Point source can mainly be measured using methods in section 3.4.3.1. Figure 3-7 explained the calculation method for determining PWL of point source. PWL can be calculated by equation 2.37-2.38. Some point sources were not use this method because that position was dangerous or risky to take a measurement. The source height of point source were set by the center of mass concept. Hemisphere is 2/3 of source height and rectangular is 1/2 of source height. Microphone position would be situated around the source simulating the measurement surface as shown in figure 3-2. If the difference of SPL at the measurement position and reference position is lower than 3 dB(A), the background noise should be taken into consideration. Measurement and calculation method of point sources, depended on ISO 3746, have 4-5 dB(A) uncertainty levels. Measured SPL data used for the PWL determination of RPP, presented in appendix B.1.

$$S = 2\pi r^2 \qquad \text{........ (3.1)}$$
$$S = 4(ab + bc + ca) \qquad \text{........ (3.2)}$$
$$S = 2l_1 l_3 + 2l_2 l_3 + l_1 l_2 \qquad \text{........ (3.3)}$$

(a, b, c, and d described in figure 3-4)

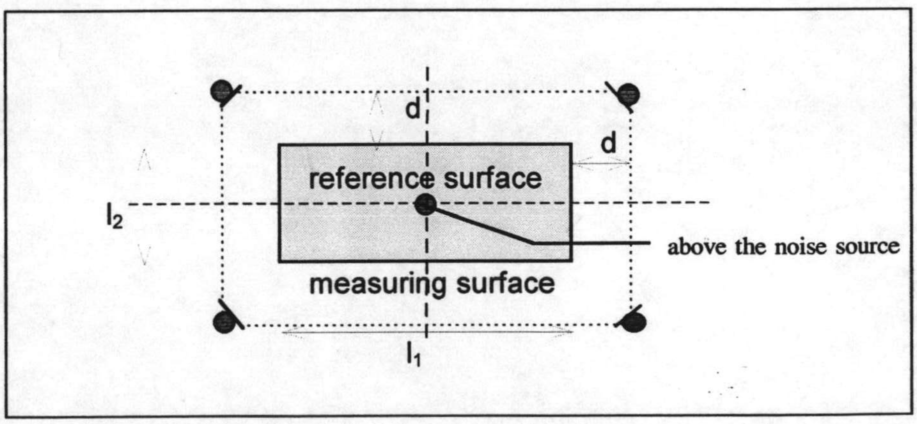


Figure 3-6 Determination of the measurement area of the ractangular surface.

a : $(l_1 / 2) + d$ (m.)
b : $(l_2 / 2) + d$ (m.)
c : $H + d$ (m.)

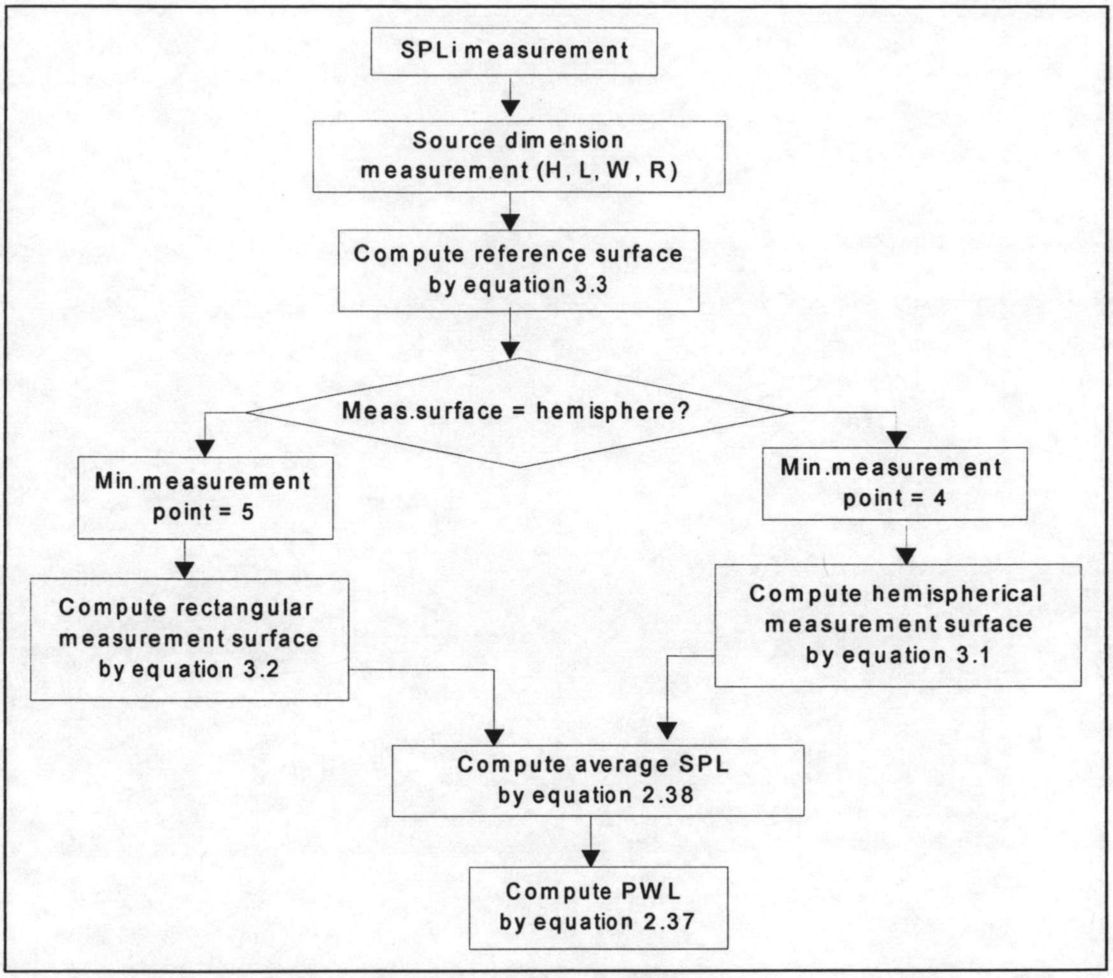


Figure 3-7 Point source calculation method.

3.5.1.2 Non-Point Source Determination

Point source equation is not applicable for PWL determination of every source particularly of large source in short distance outdoor conditions. Despite, it was incapable to measure some elevated position on the measurement surface in RPP. Therefore, the author proposed four methods in order to determine PWL of RPP's sources. SPL of each noise source in Appendix B.1 were used to calculate PWL of that sources. Every methods used the same measurement procedure in section 3.4.3.2.

- Colenbrander's Method (The engineering equipment and materials users (EEMUA), 1988) has at least 6 microphone positions to collect SPL around the source according to the contour line according to ISO 6190 for combined cylcle system in figure 3-8. (ISO, 1988) Calculation procedure of this method was explained in figure 3-12.

- Solid Surface Method (The international Trade and Industry of Japan, 1980) has at least 6 microphone positions to collect SPL around the source along with measurement surface. Solid surface is the measurement surface which is non-angle rectangular surmounting the considered sources. (figure 3-9) The calculation

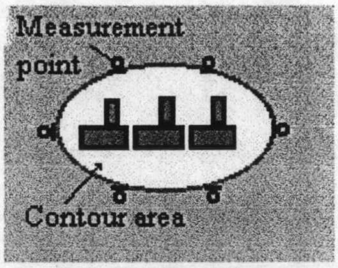


Figure 3-8 Microphone position for Colenbrander's method

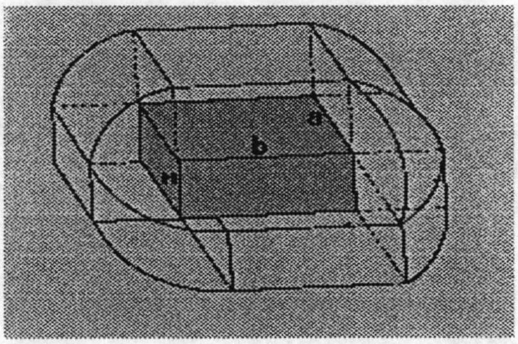


Figure 3-9 Solid surface method microphone position

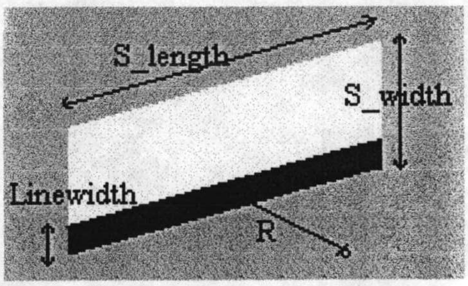


Figure 3-10 Linear surface method for non point source determination

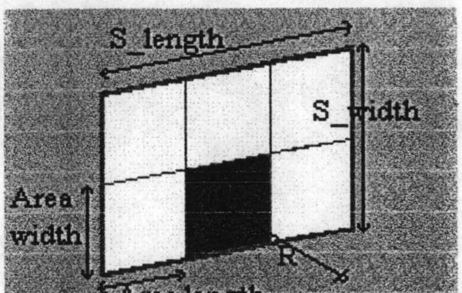


Figure 3-11 Area surface method for non point source determination

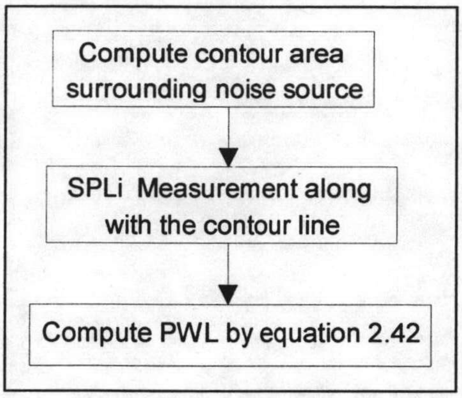


Figure 3-12 Diagram of PWL determination using Colenbrander's method.

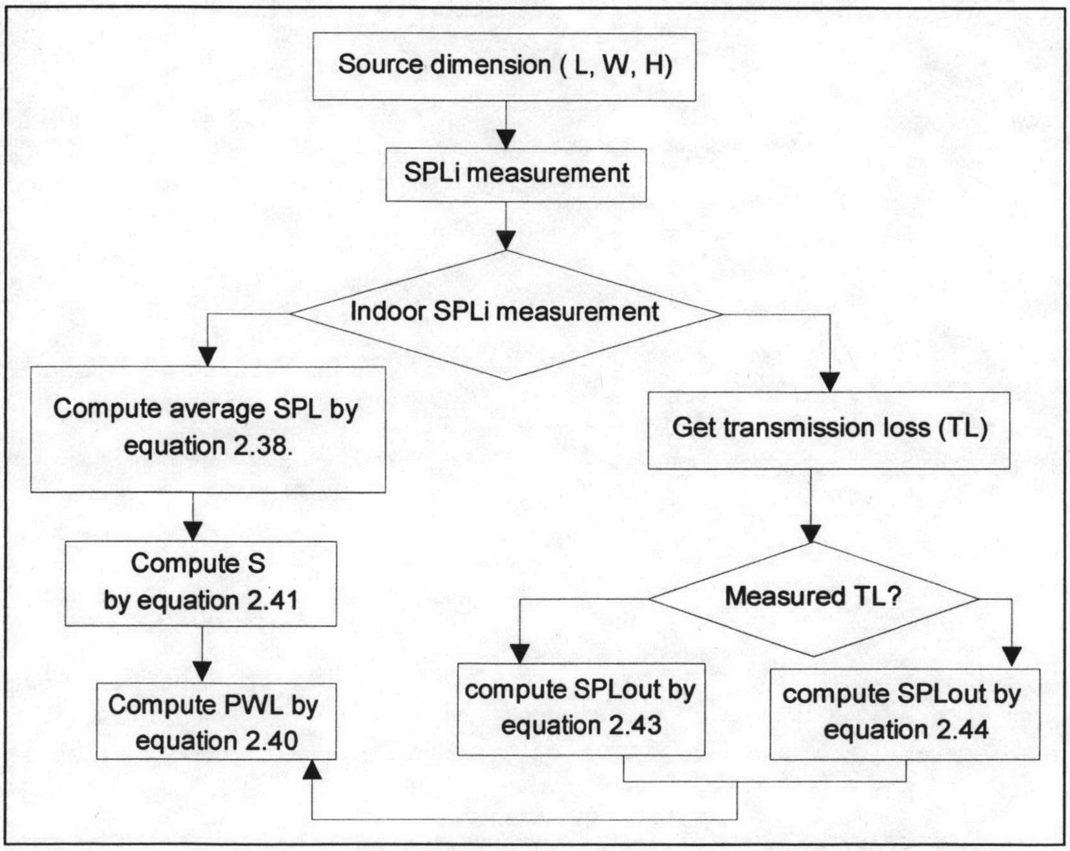


Figure 3-13 Diagram of PWL determination using solid surface method.

equation is applied from point source equation replaced measurement surface by solid surface and a large number of microphone position along with the surface. The determination procedure are in figure 3-13. This method recommeded for determining PWL of the cooling tower. (The international Trade and Industry of Japan, 1980) This method would not be appropriate to determine PWL of main buildings because of the lacking of sound transmission loss database of enclosure wall used in Thailand. Solid surface method can also calculate SPL both indoor and outdoor condition. It is profitable for accuracy, if the numbers of microphone were more observing point.

- Linear Surface Method (The international Trade and Industry of Japan, 1980) has a observing point at the center of the considered linear sources. (figure 3-10) Linear source emitted sound energy in a quarter cylinderal pattern to environment. The predicted PWL of this method needs area, S, of the line to calculation PWL. The explanation of PWL of linear source is in figure 3-14.

- Area Surface Method (The international Trade and Industry of Japan, 1980) has a observing point at the center of the considered area source. (figure 3-11) PWL determination of or area surface surface was shown in figure 3-15.

3.5.2 The Calculation of the Immission Data from RPP

The 1/1 octave band SPL at immission point that were reported by SLM can be added to obtain the overall-band SPL by equation 2.4 and A-weighted by the correction data in table 2-3. The calculation procedure are reported in figure 3-16.

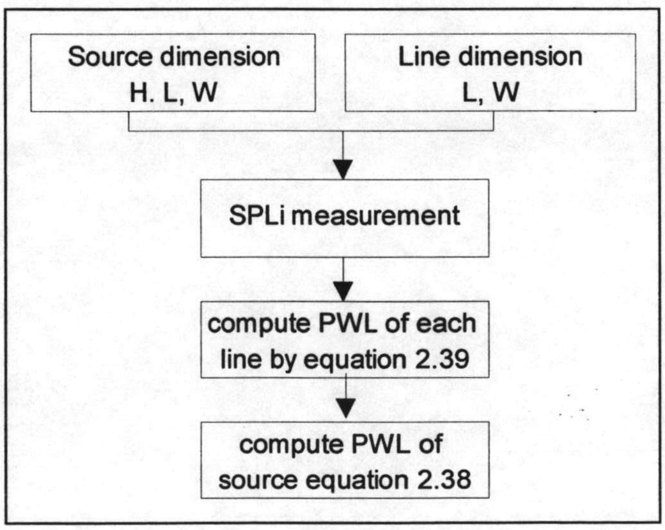


Figure 3-14 Diagram of PWL determination using linear surface method.

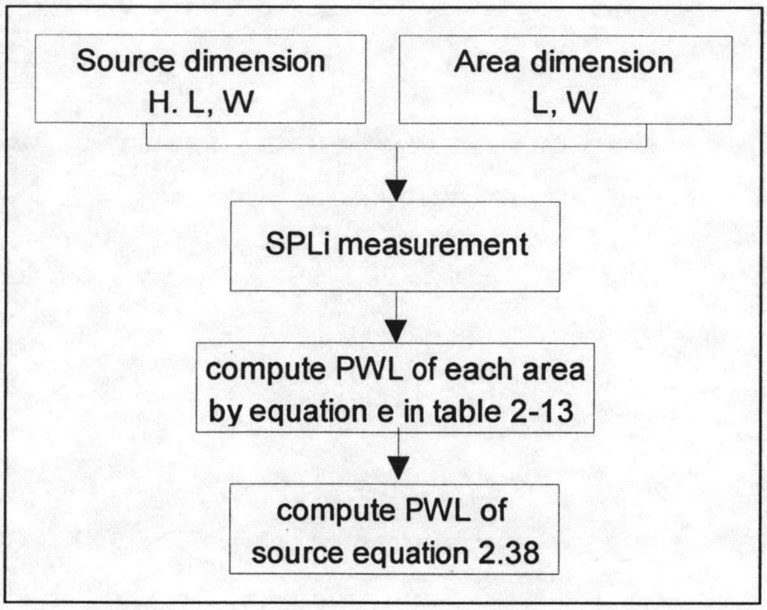


Figure 3-15 Diagram of PWL determination using area surface method.

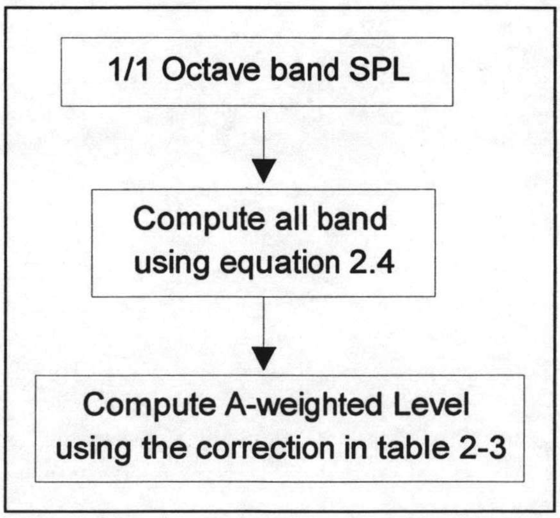


Figure 3-16 All band level and A-weighted level calculation method.

3.5.3 The Calculation of the Transfer Function

In each couple of emission and immission point, on-site transfers function were collected. Divergence, ground effect and air absorption correction were always required to input the prediction model. All of them were observed along with the paths during the SPL measurement at every immission point. The limitation specification of each terms should be followed by section 2.5.2.3. The calculation of all transfer functions were considered in the programming procedure as shown in Appendix C.4. Figure 4-11 showed the image of transmission path at RPP.

3.5.4 The Programming of Power Plant Noise Prediction Model

To facilitate the complicated calculation of power plant noise prediction model, the programming language "visual basic for windows version 3.0" (Microsoft Corporation, 1993) was used for developing the computer software (Remi Planche, 1988) that called " Sonic ". Sonic was developed following main procedure in figure 3-3 and 3-4 and the detail in Appendix C.4. Sonics can calculate PWL of noise source by the condition in this study and SPL at any immission point if it took a set of data input such as distance, ground type, air temperature, relative humidity and so on. This software has an friendly user's interface for understanding the way to input. (Microsoft Corporation, 1994) The limitation of model depended on the model assumption.

3.5.5 Verification

The 20 percent of measurement data were used to calibrate the prediction model during software development. The environmental data was also used to test the sensitivity of each transfer function. The noise source data were used for determining PWL of the significant sources in RPP. The measurement data of appropiate immission point were used to verify the prediction model. The last objective of the verification is testing the model with the other industrial sources. The author used refinery plant for an application testing determining PWL by Stüber method in ISO 8297. (ISO, 1994)