

# Experience Sharing on Remote Sensing (RS) of Exhaust Emissions from On-road Vehicles

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Hong Kong Experience

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*Hong Kong EPD*

# Contents

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1. Experience in the use of RS Technology
  2. Advantages & Limitations
  3. Equipment QA/QC and Site Selection
  4. Factors that Affect RS Data Accuracy
  5. The Application of RS Technology in Hong Kong
  6. Good Remote Sensing Equipment
  7. Preferable Future Model of RS
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# 1. Experience in the Use of RS Technology

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- Start using RS since 1993
    - For fleet emission profiles after introducing unleaded petrol and TWC
    - First for CO & HC and later included NOx measurement
    - Mainly for petrol & LPG vehicles
  
  - Model of RSDs used:
    - FEAT (prototype), Smog Dog, RSD 3000, MR Inspector, 4-gas Professional, RSD 4500/4600
  
  - Test & Study Projects
    - Survey for RS measurement sites
    - Co-relation tests with dynamometer using various cycles
    - Determine the cut points for gross emitter control programme
    - Feasibility of using ALPRS system in RS (in progress)
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# Remote Sensing Units

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Modern FEAT Unit



Smog Dog



4-gas/Professional



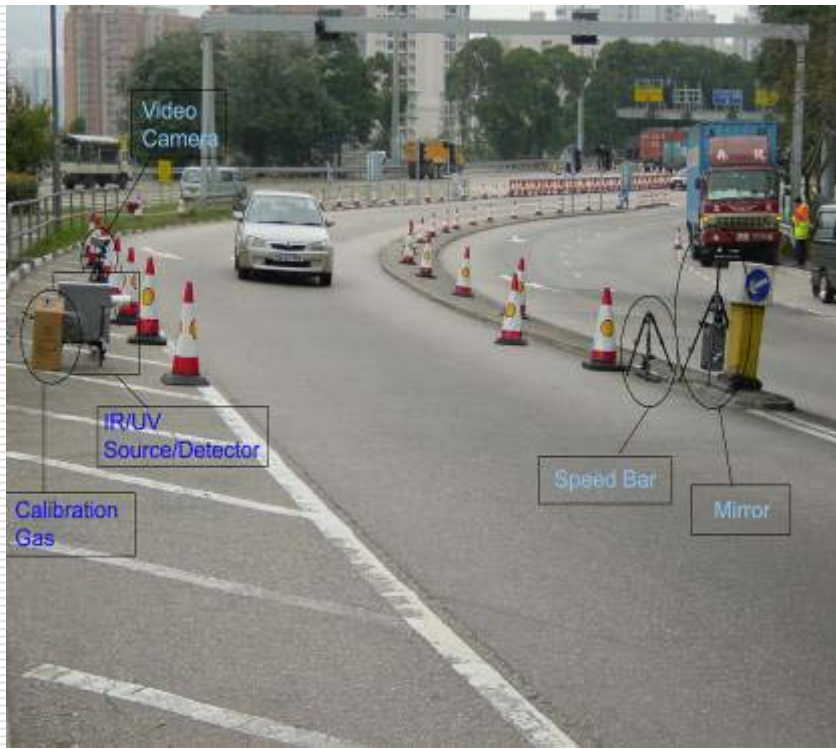
RSD 3000



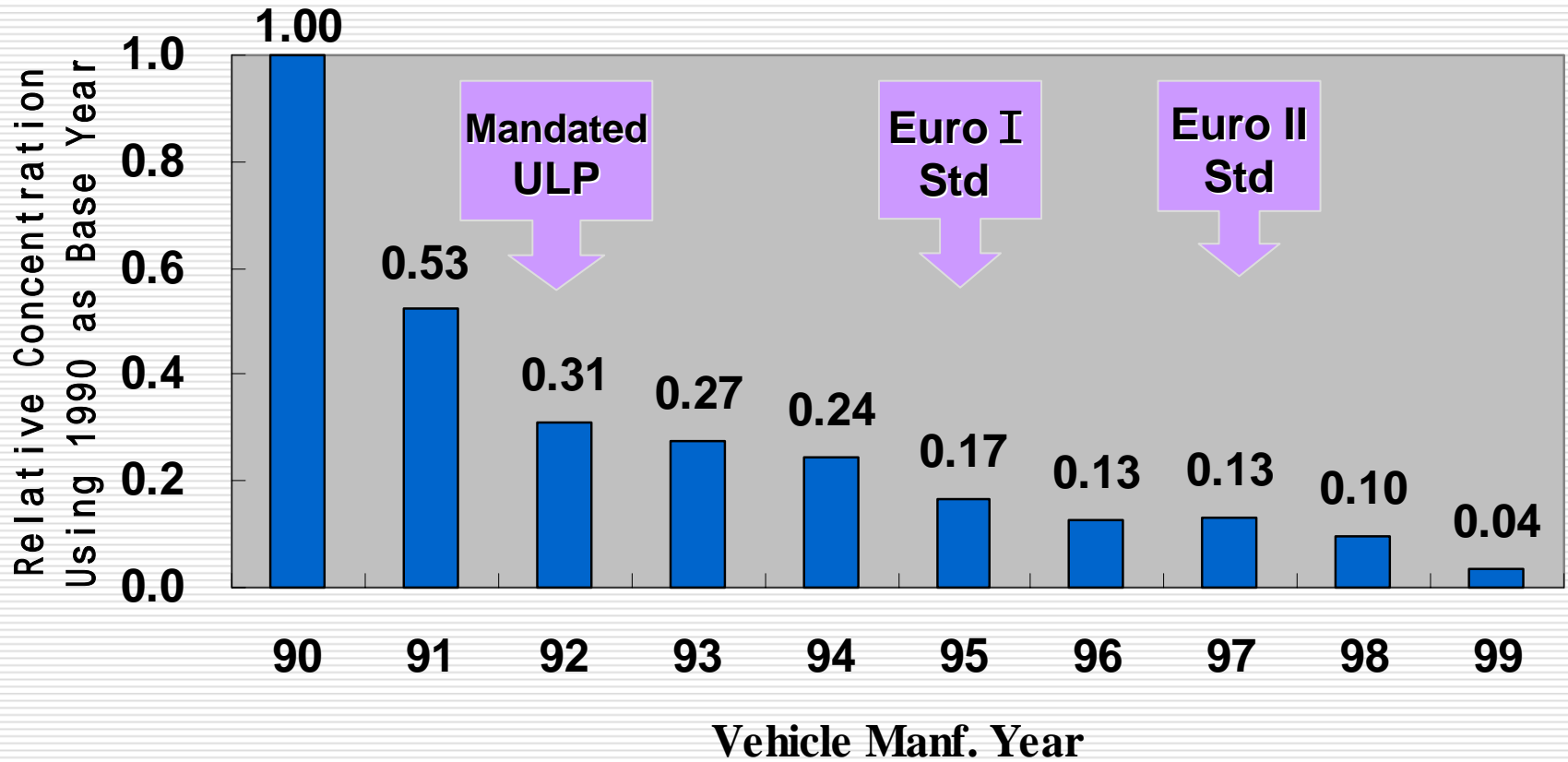
RSD 4500/4600

# A Typical Set up of RSD (Single & Dual Units Deployment)

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# Typical Emission Profile (CO Concentration)



## 2. Advantages & Limitations

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### □ Advantages

- Mobile set up
- No interruption of traffic flow, no interaction with drivers & vehicles
- Capture Large quantity of emission data
- Effective emission measurement tool

### □ Limitations:

- Snapshot of emission in ½ Second
  - Dry Weather Technology
  - Single lane with positive gradient
  - Skilled operator required
  - Site constraints (capture rate, safety, space restrictions)
  - No standard QC procedure on equipment
  - Need to develop data screening and management technique
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# 3. Equipment QA/QC and Site Selection (1)

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## 3.1 Selected Suitable RSD with QC measures

- to suit intended vehicles fleet (petrol & LPG);
    - Hydrocarbon species measurement is problematic
    - Equipment supplier needs to match with intended the vehicle fleet and their fuel specifications to be measured;
    - Equipment supplier to provide Shop test certificate
    - To request new RSD must meet stringent performance requirements (such as BAR) with certificate. If not, conduct local test to confirm compliance
-



# RSD's Performance Tests



# 3. Equipment QA/QC and Site Selection (2)

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## 3.2 Testing the Characteristic of RSD Measurement

- ❑ On-road testing of petrol and LPG vehicles
  - ❑ Use of dynamometer with transient cycles
  - ❑ Compare the emission data between RSD and on board 5-gas analyser
-

# On-road Testing of RS vs On-board Analyser

- ❑ Diesel, petrol & LPG vehicles were used;
- ❑ Tested both carburetor and injection petrol cars;
- ❑ Attached 5-gas analyser to vehicle ;
- ❑ Tried different speeds and accel./decel modes



# Findings

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- ❑ Diesel car - cannot provide exact concentration because of assumption of stoichiometric combustion
  - ❑ Petrol/LPG car – observed significant variations, higher RS reading is of concern
  - ❑ Carburetor car – lower variation but still no match
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# Comparison of RS & 5-gas Analyser Data for Transient Test on Dynamometer

- ❑ Modified RSD to continuous measurement mode (50ms sampling)
- ❑ Used petrol & LPG vehicles on dynamometer with transient cycle
- ❑ Use of gas chamber for vehicle exhaust measurement by both RSD & 5-gas analyser
- ❑ Recorded readings from transient cycles on both equipment

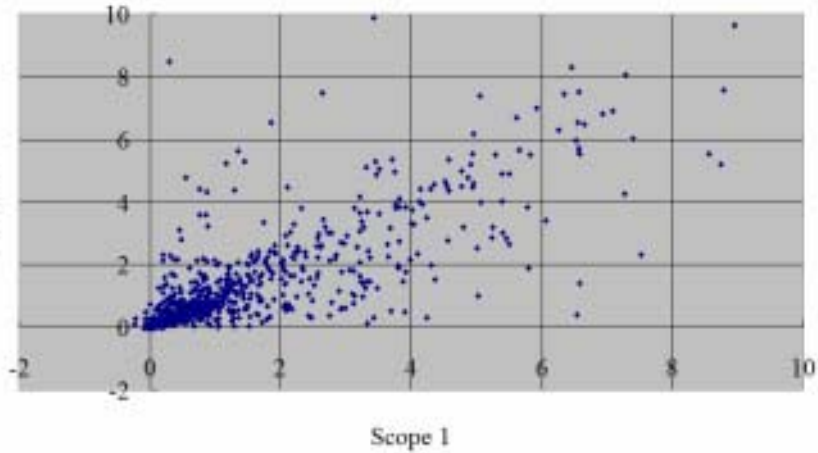


# Findings

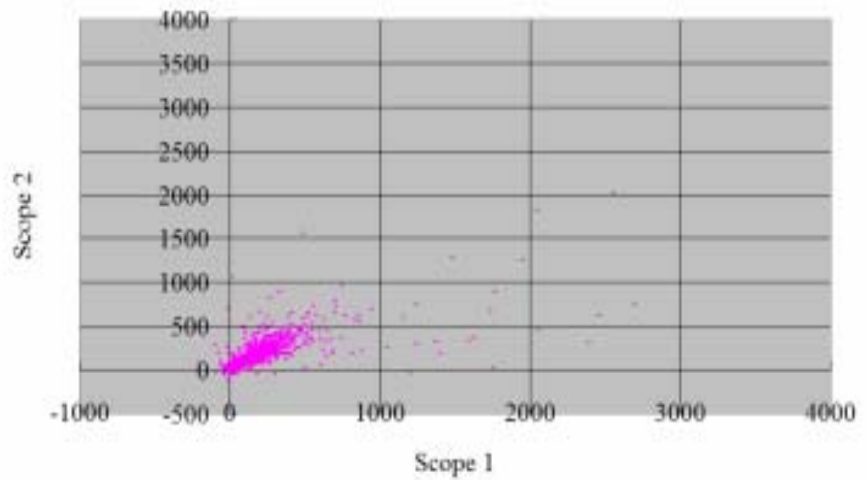
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- ❑ RS capable of capturing the high transient mode of emissions (down to 20 samples/sec) while on-board equipment cannot capture because of 1 second average reading of sampling was given.
  - ❑ Use of 2 or more RSDs to verify if readings are due to transient captured by RS, i.e. look for consistent high readings as true high readings. [see charts]
  - ❑ Combustion equation of both data set was verified from stoichiometric ( $\text{Lambda} = 1$ ) to rich ( $\text{Lambda} < 1$ ) range. Correction factor for LPG vehicles due to different C/H ratio than that of petrol need to be applied. [see 5-gas Lambda charts]
-

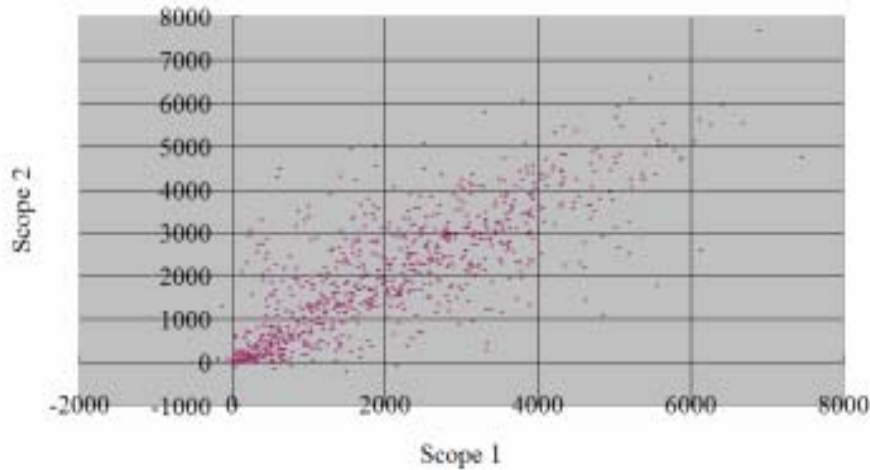
CO (%)



HC (ppm)



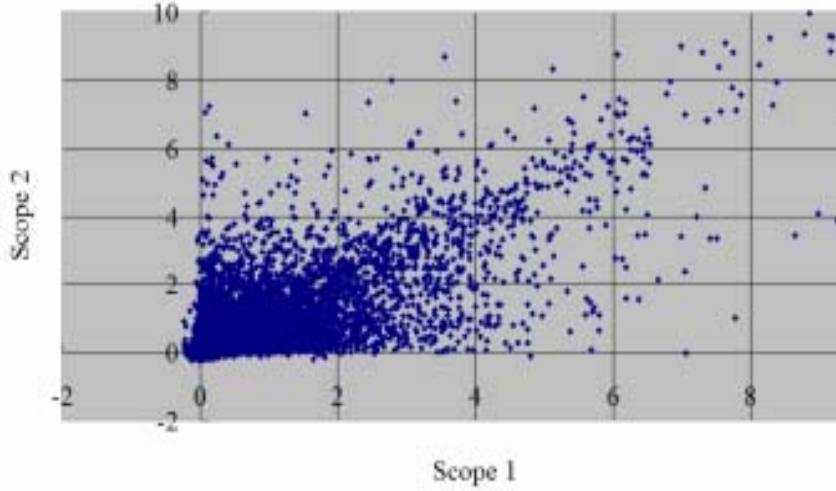
Nox (ppm)



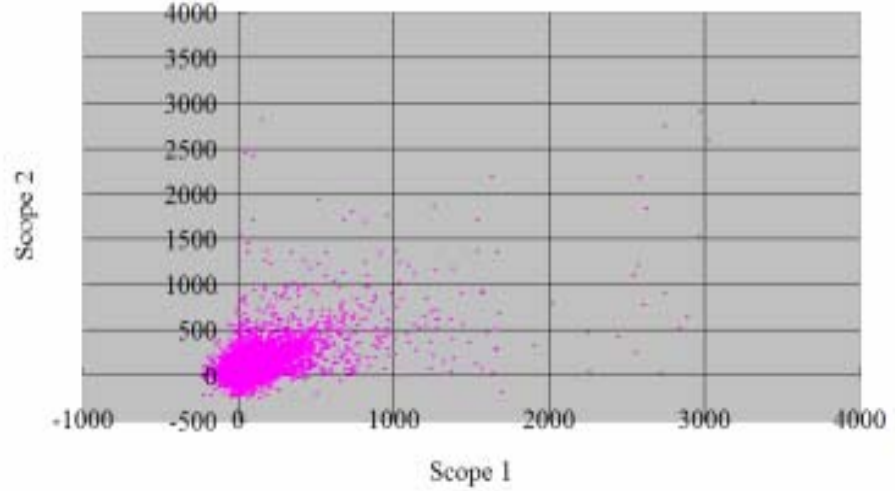
Charts of scattered  
2 scope emissions –  
Petrol Carburetor  
Cars

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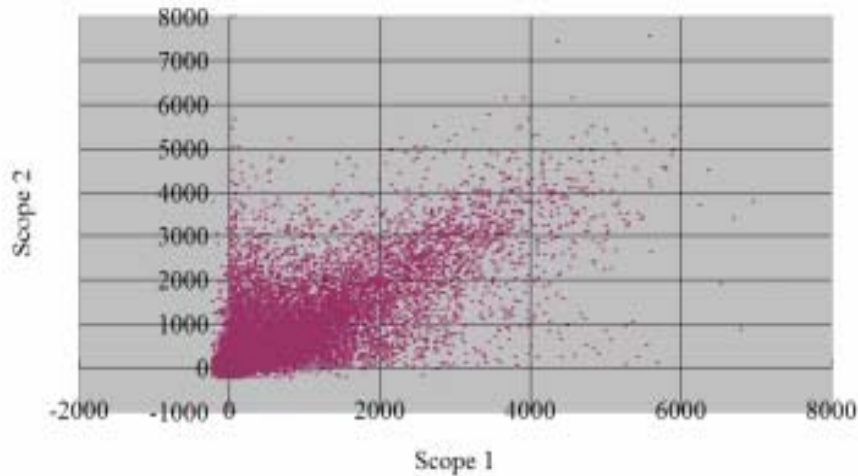
CO (%)



HC (ppm)



Nox (ppm)

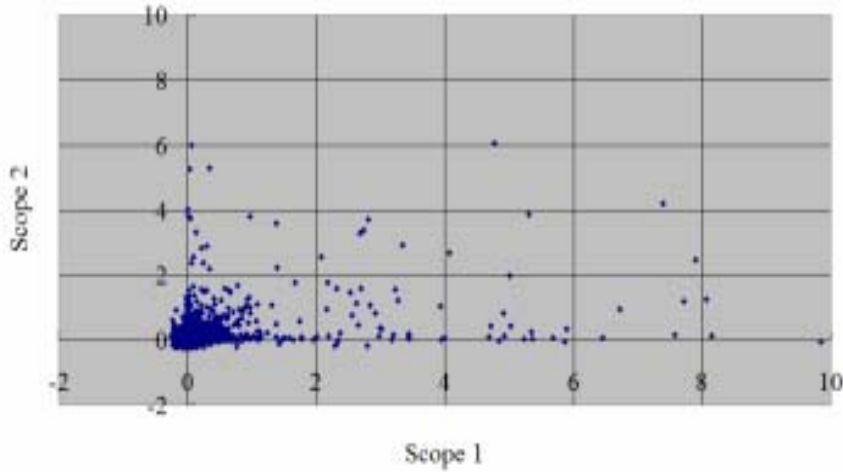


Charts of scattered  
2 scope emissions –  
Petrol Cars  
(TWC/Injection)

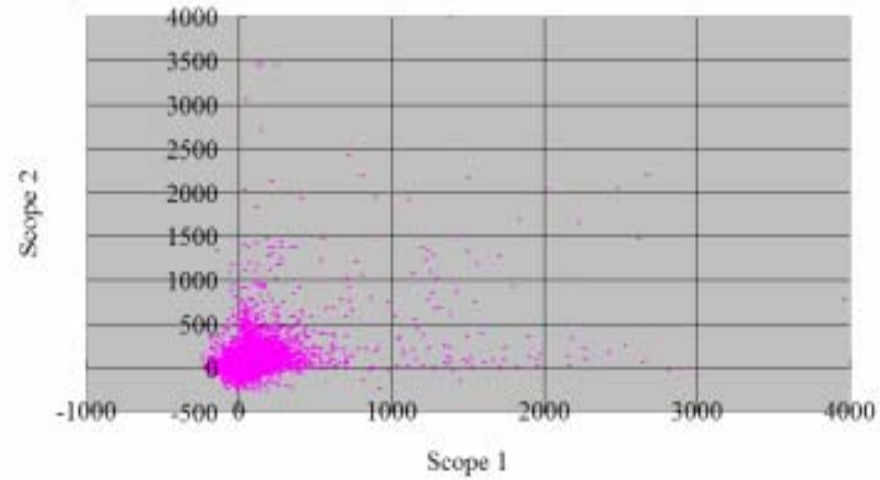
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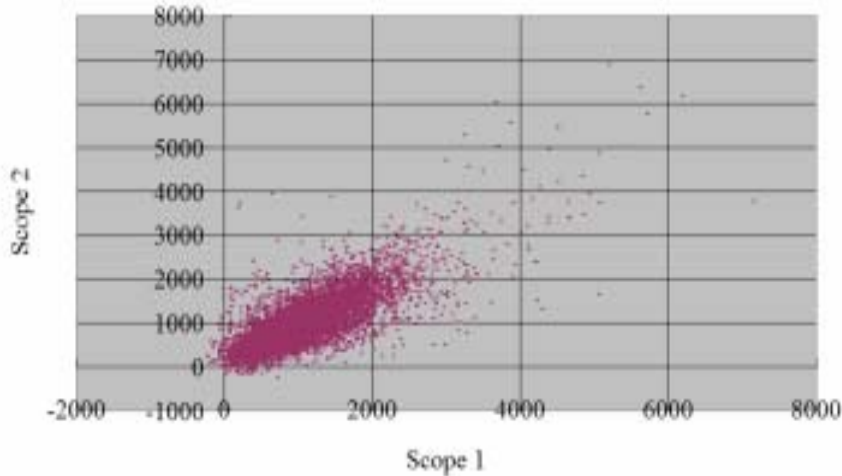
CO (%)



HC (ppm)



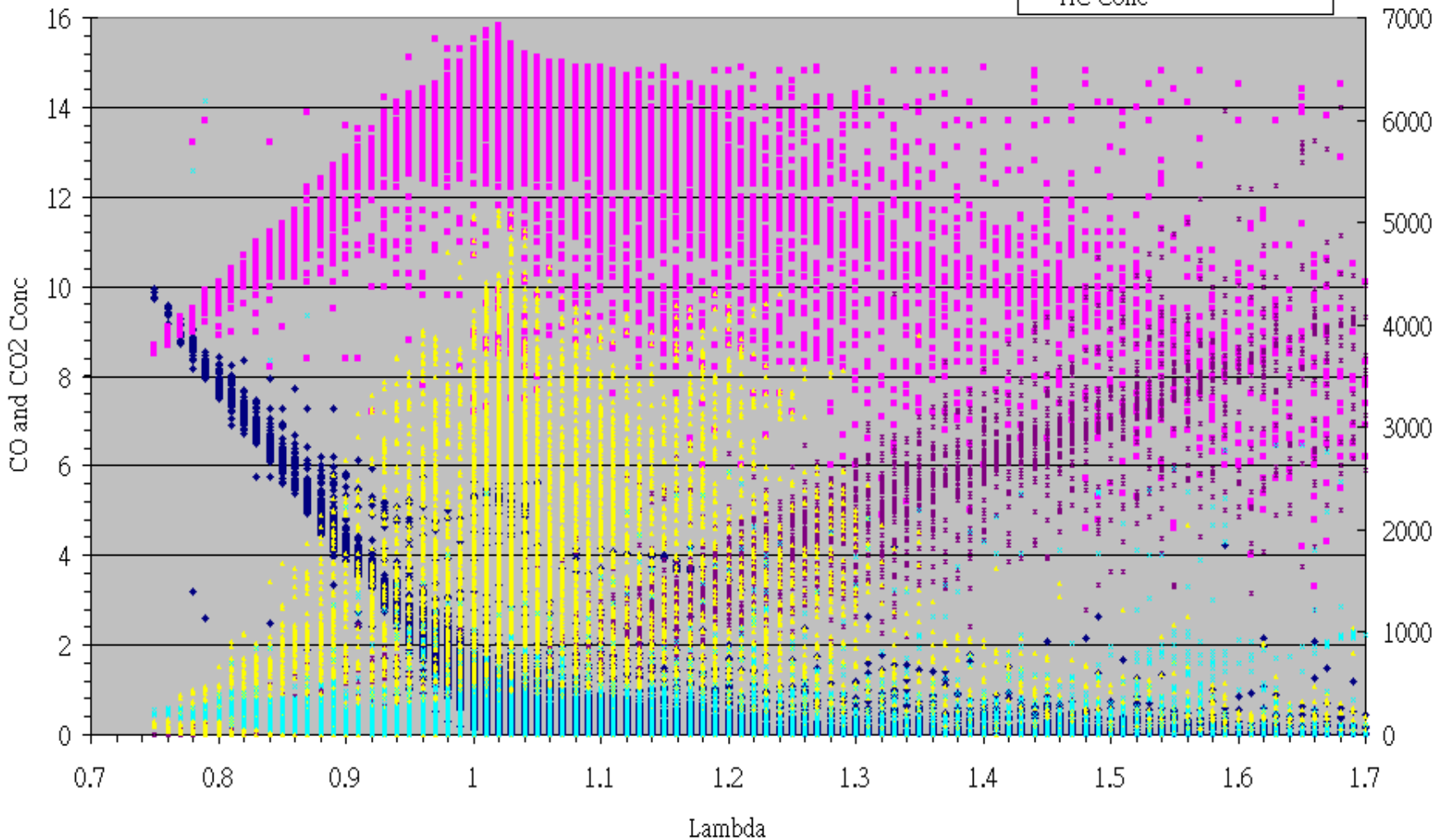
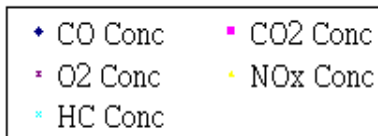
Nox (ppm)



Charts of scattered  
2 scope  
emissions – Diesel  
Vehicles

# GAS CONC VS LAMBDA

5 Gas Data (Petrol) (from dyno) vs Lambda



# Key considerations for successful RS data collection

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- ❑ RS does not measure like traditional I&M analyzer
  - ❑ RS readings can be affected by very short transient emission (e.g. engine Lambda switching) and pressure/temperature correction of the sample
  - ❑ Low plume (exhaust volume) is a challenge for small size cars
  - ❑ High specific engine emission at specific engine operation mode (e.g. high CO at standing start, high HC during deceleration)
-

# 3. Equipment QA/QC and Site Selection (3)

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## 3.3 Site Selection

- Site Survey :-
    - to obtain detail of road, traffic conditions, gradient, road width & place for operator/equipment
    - Identify the location on road with reference points with photo
  
  - Vital to ensure:-
    - consistent loading conditions
    - high capture rate and high accuracy
    - avoid capturing unrepresentative emission data (e.g. road bend, cold start)
    - clear road conditions downstream of traffic
    - it is safe for operation personal and equipment
-

## 3. Equipment QA/QC and Site Selection (4)

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### 3.4 Skilled Operator

- Vital to ensure: -
    - Equipment are setup and operate properly
    - Choosing a right point at the site for measure
    - Able to observe abnormal equipment performance
    - Able to fix mirror performance/operation/setup problems
  
  - Training of operator
    - Should be provided by equipment supplier
-

## 3. Equipment QA/QC and Site Selection (5)

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### 3.5 On-site Calibration of RSD

- Allow ample time to order certified gases
    - Gases need time to be prepared and stabilized
  
  - Use of Certified Standard Gases :-
    - To calibrate Equipment before data taking
    - After reposition of equipment
    - Hourly or any frequency as needed to ensure accuracy performance
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## 3. Equipment QA/QC and Site Selection (6)

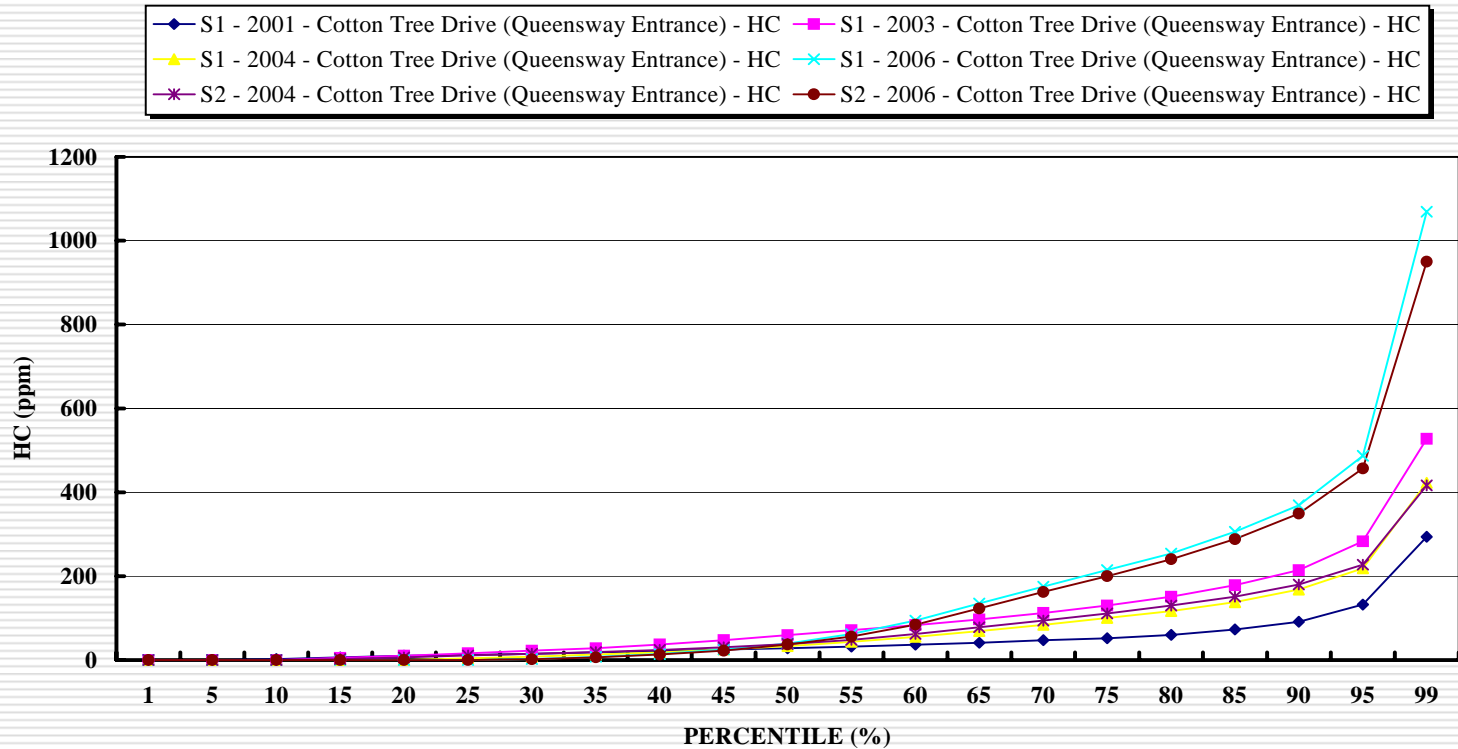
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### 3.6 Built individual Site Emission Profile and Database

- To counter check the accuracy of emission profile for new data collected
  - To keep track of the vehicle speed and acceleration profiles
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# Build up Emission Profile and DataBase for Individual Site (HC Profiles)

COTTON TREE DRIVE - HC





# 4. Factors that Affect RS Data Accuracy

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## 4.1 Weather Conditions

- Rain and snow
    - Obstruct beams passage ways and scatter beams
  
  - Strong wind
    - Affect plume dispersion
    - Safety concern for equipment & personnel on site
  
  - Hence, no operation under those conditions
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# 4. Factors that Affect RS Data Accuracy

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## 4.2 Road Conditions

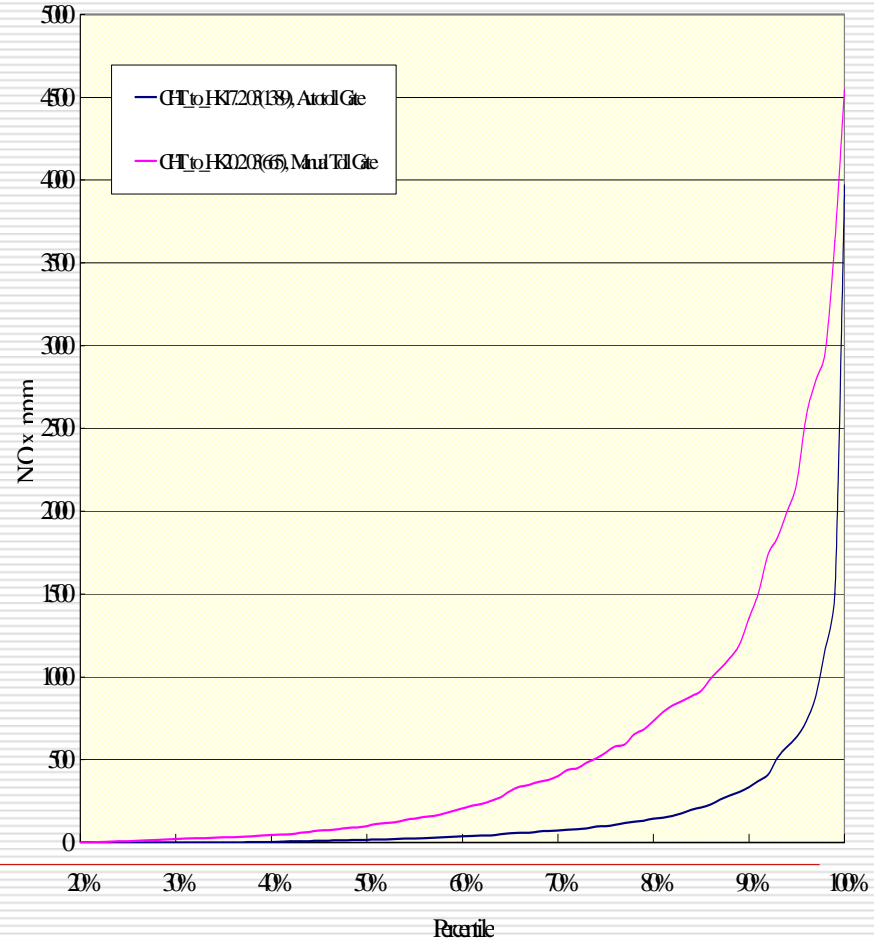
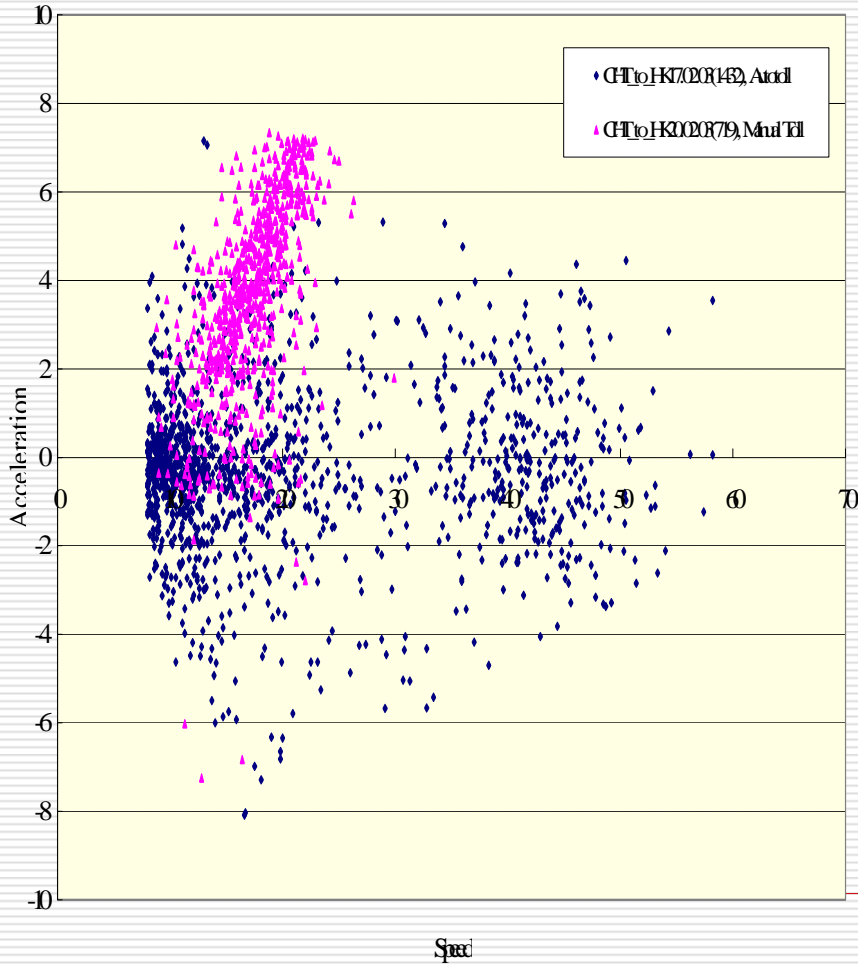
- ❑ Vehicle tends to decelerate when approaching bends or anticipating slow traffic ahead – low plume/ low capture rate and abnormal high HC
  - ❑ Straight road – vehicles passing freely
  - ❑ Traffic light/Paytoll – vehicles stop or and accelerate during start up
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## 4.2 Road Conditions (Road Bend & Entrance of Upslope)

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# 4.2 Road Conditions (Effect of Auto and paytoll)



# 4. Factors that Affect RS Data Accuracy

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## 4.3 Driver's Responses

- Natural Reaction - to avoid test
  - Human nature - Curiosity
  - Suddenly change of Driving Mode
  
  - Therefore, avoid too many operators on sites and conceal equipment would yield better result
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# 4.2 Driver Responses

(Attract Attention)

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Road Too Open



Operators

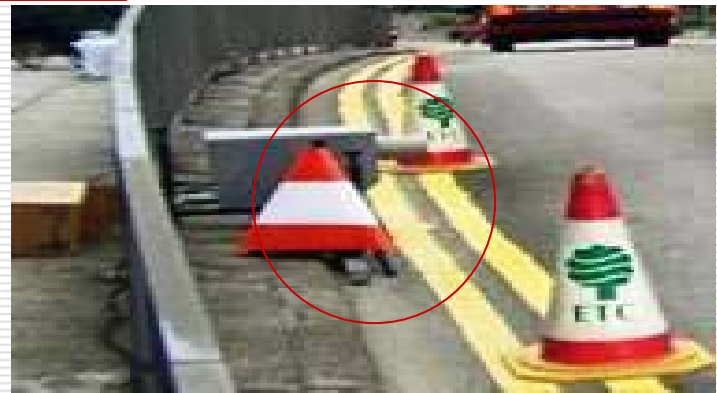
# 4.3 Driver Responses

(Covert Operation-Equipment / Operators)

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Covert Operation



Hiding Equipment



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Remote Control

# 4. Factors that Affect RS Data Accuracy

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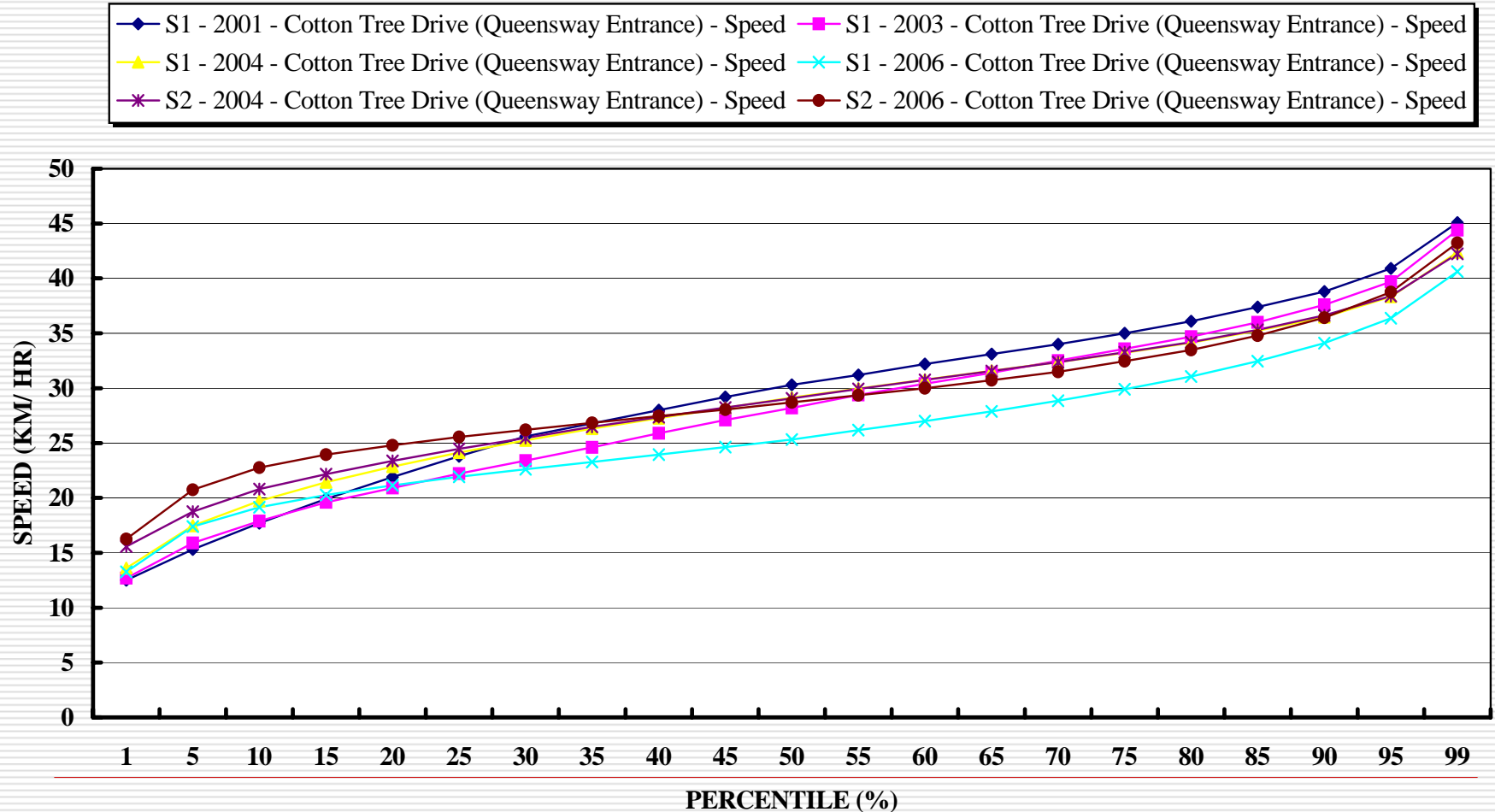
## 4.4 Equipment Malfunctioning and Inexperience Operator

- ❑ Any of emission measurement channel may be malfunctioning
  - ❑ Speed/Acceleration Equipment or camera unit may be mal-functioned
  - ❑ Equipment mis-alignment
  - ❑ Poor measurement location
  - ❑ Operator fails to take proper action and allows measurement to be continued
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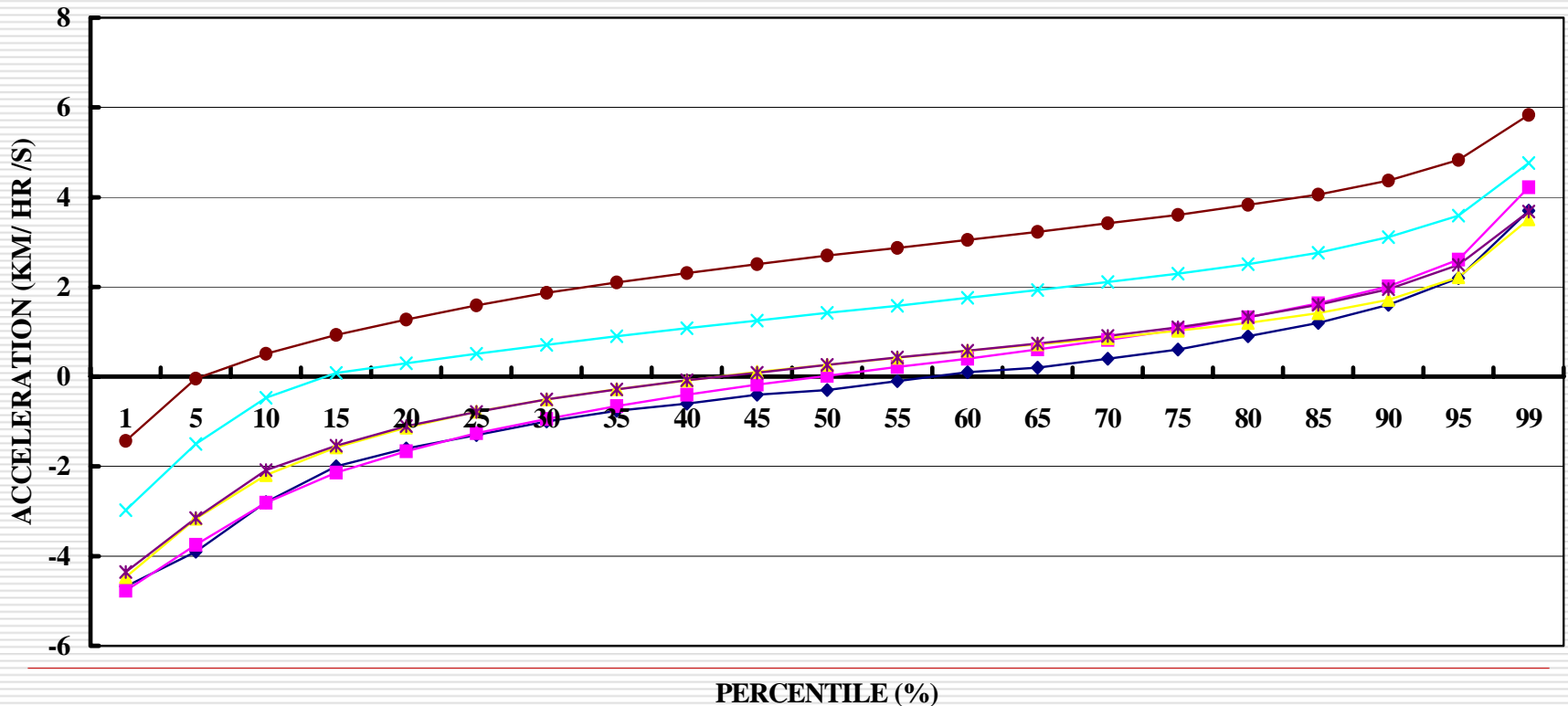
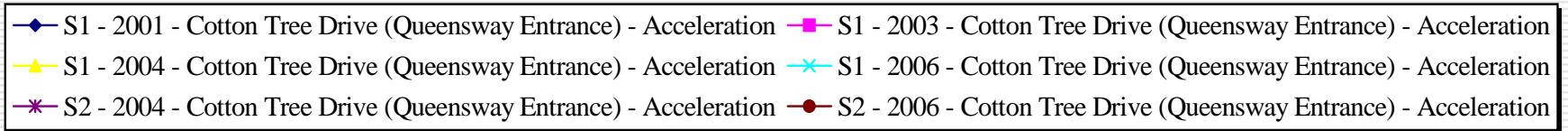
# 4.4 Equipment Malfunctioning and Inexperience Operator (Speed/Accel Bar Malfunctioning)

COTTON TREE DRIVE - SPEED



# 4.4 Equipment Malfunctioning and Inexperience Operator (Speed/Accel Bar Malfunctioning)

COTTON TREE DRIVE - ACCELERATION



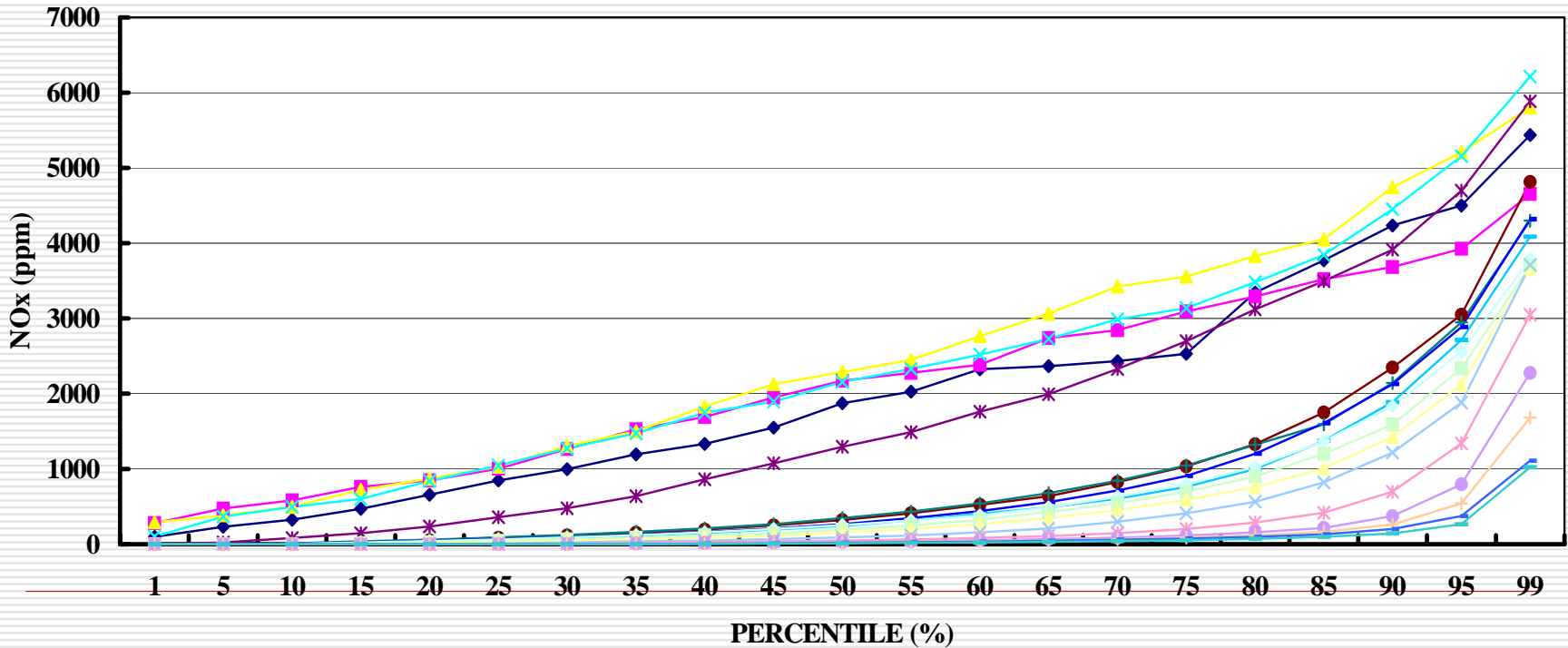
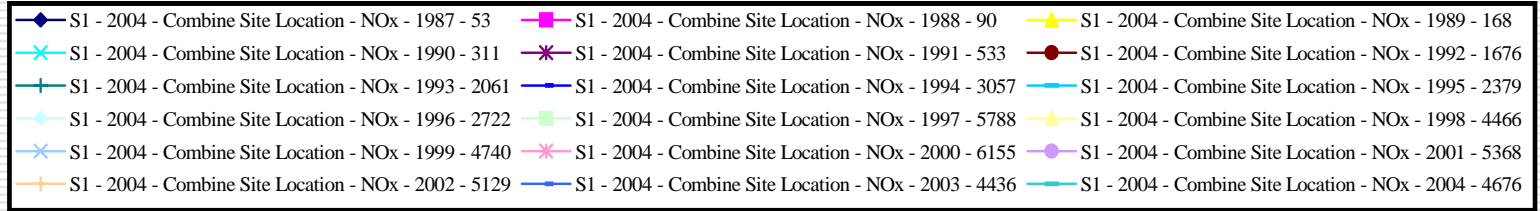
## 5. The application of RS Technology in Hong Kong

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- Fleet Monitoring – need to combine all variables as discussed and form profiles of the fleet [see emission profile charts]
  - Baseline and trend – isolate specific information and monitor the trend e.g. gross emitter percentage [see taxi and petrol multi sighting charts]
  - Gross Polluter Control Programme in petrol & LPG vehicles – combine with transient dynamometer drive cycle
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# EMISSION PROFILES

## RS2004 - NO<sub>x</sub>

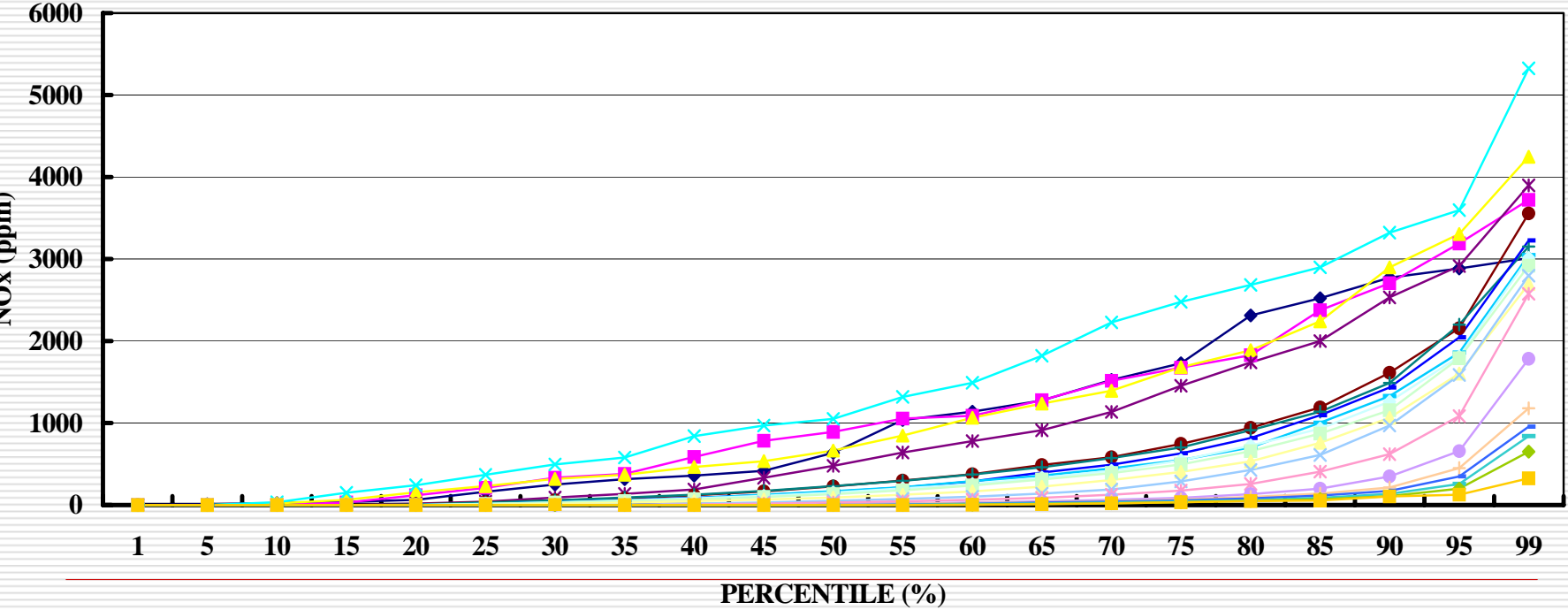
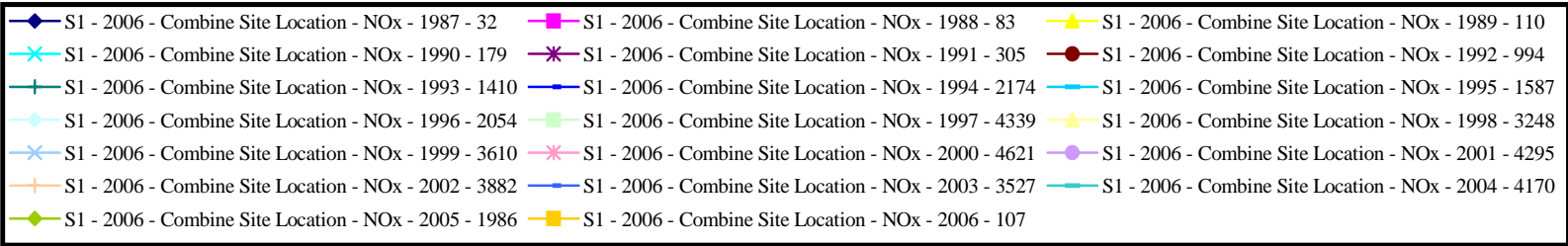






# EMISSION PROFILES

## RS2006 - NO<sub>x</sub>









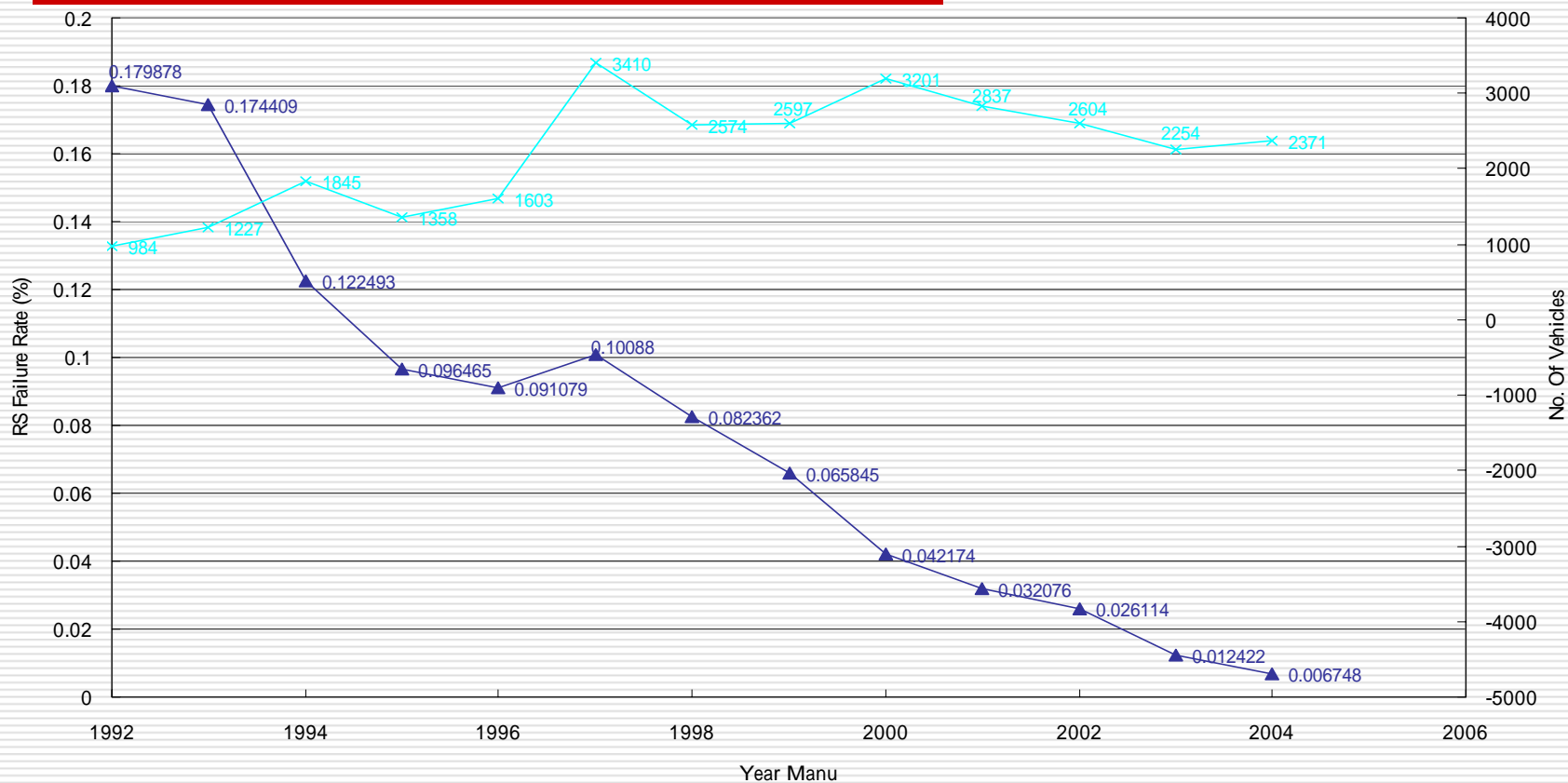
# GROSS EMITTER PROFILE

(Using Arbitrary Cutpoints for Analysis)

RS 2004 Petrol Cars Failure Rate

▲ Petrol Private Car (2004) Failure

× No. of Vehicles (Petrol PC 2004)



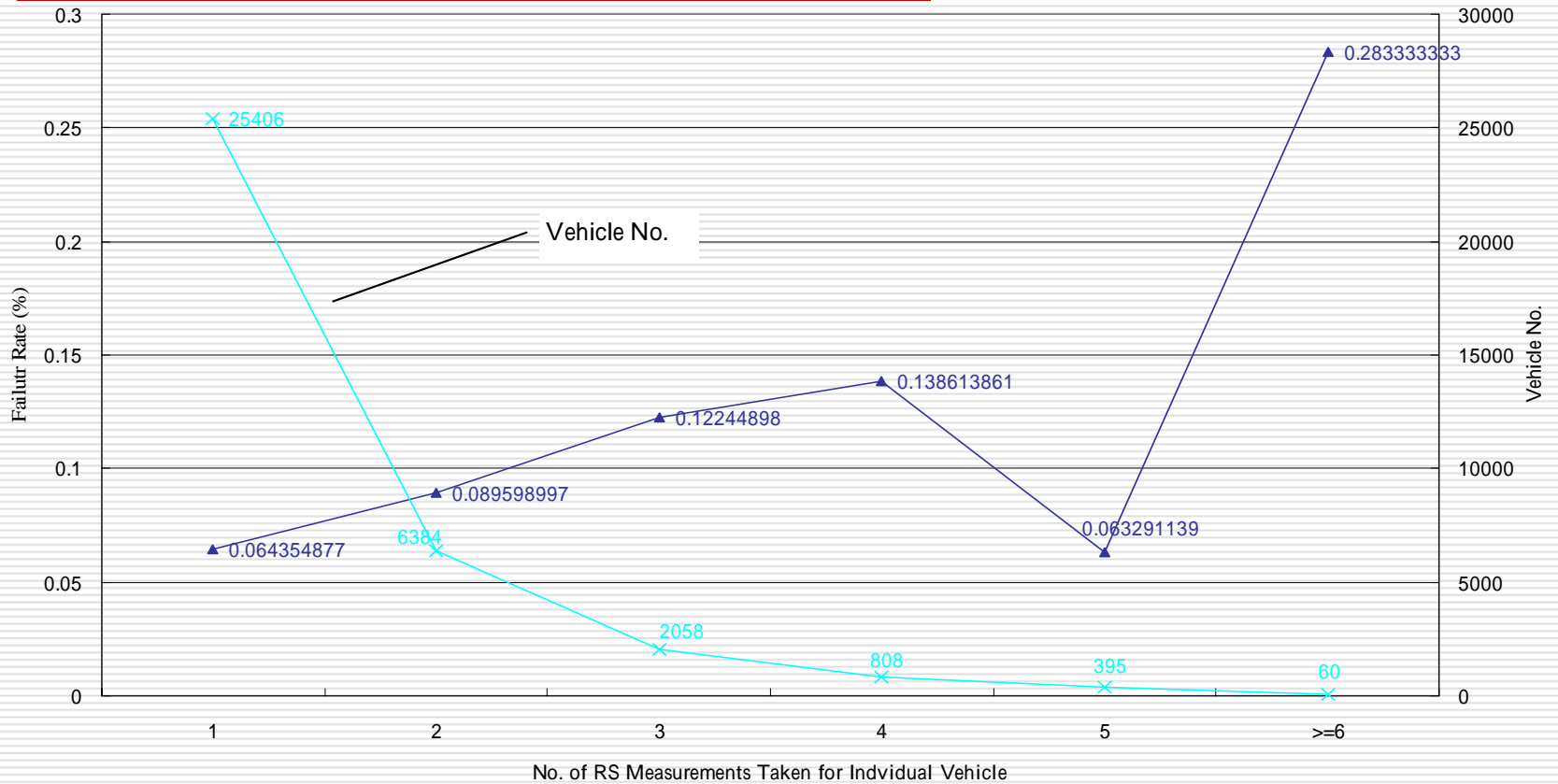
# GROSS EMITTER PROFILE

(Using Arbitrary Cutpoints for Analysis)

RS 2004 Petrol Car Failure Rate

▲ Petrol Private Car (2004) Failure

× No. of Vehicles (Petrol PC 2004)



# GROSS EMITTER PROFILE

(Using Arbitrary Cutpoints for Analysis)

RS 2004 Tax Failure Rate

—▲— LPG Taxi (2004) Failure

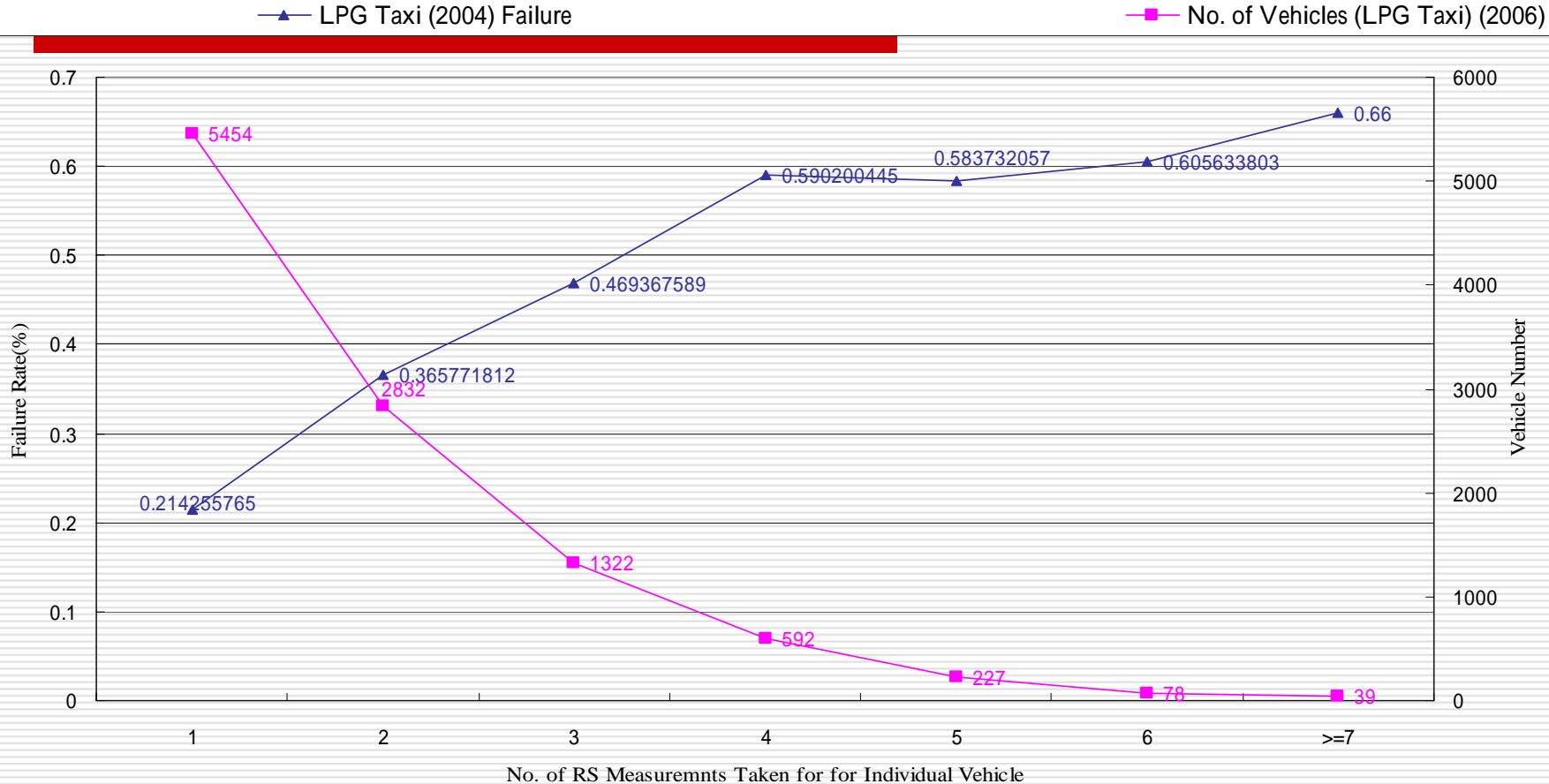
—×— No. of Vehicles (LPG Taxi 2004)



# GROSS EMITTER PROFILE

(Using Arbitrary Cutpoints for Analysis)

RS 2004 Taxi Failure Rate



# Concept of Gross Polluter Control using RS and Dynamometer

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- Dynamometer cycle gm/km determined by transient emission during acceleration
  - Find out the corresponding concentration limits from dynamometer test data making reference to the gm/km results and technology classes
  - Assume all RS measurements (true high readings using two RS devices in series) are under transient driving mode
  - Our study on 34 vehicles shows no error of commission
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## 6. Good Remote Sensing Equipment

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- ❑ High valid percentage - gas, speed /acceleration, photo
  - ❑ Good productivity – quick setup, easy calibration and audit even during heavy traffic, night mode operation
  - ❑ Lower detection limits for NO<sub>x</sub> – for newer and future vehicles
  - ❑ Improve value for money – provide data for intended use of equipment and adoptable to specific programmes
-

# 7. Preferable Future Model of RS

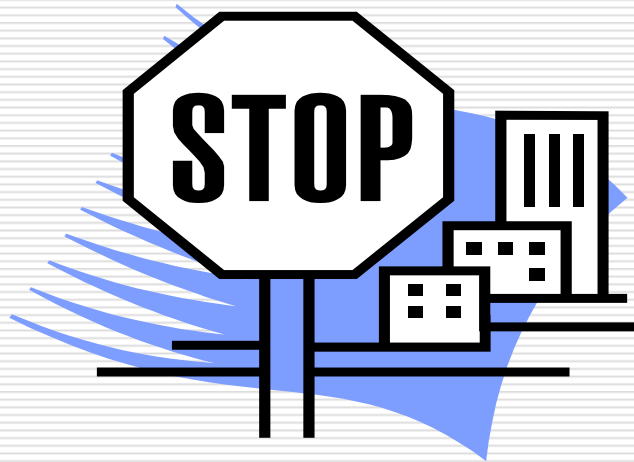
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- Compact in Size
  - Ease of setup
  - Ease of Calibration
  - Automated procedures and real time check of key operation parameters
  - Less Connection Cables
  - Battery-operated
  - Remote Control Function
  - Incorporated ALPRS system if practicable
  - Possible to detect cold catalytic converter
-



# THANK YOU !

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