The Installation of Testing Apparatus for Vehicle Tunnels

1. The background for necessity of testing apparatus for vehicle tunnels

In recent years the planning and construction of vehicle tunnels are increasing rapidly in many location in the world. On the hand, also the number of serious fire accidents in tunnels has increased.

The analysis of aerodynamics and smoke behavior in case of an accident in tunnels is one of the very important and urgent issues, a fact that has to be considered from the planning stage to the operation stage.

In spite of its importance, there are still some outstanding that still have to be verified in order to assure appropriate design and operation conditions. The following are the reasons for these remaining item:

- The aerodynamical environment of vehicle tunnels usually shows highly complicated phenomena, due to the different aerodynamic shape with traffic velocity and the influence by natural meteorological conditions.
- In addition, in case of emergency, the human behavior may affect the safety level of tunnels, and should therefore be well considered when setting up the basic organization system between road administrators and related agencies, Police and Fire Brigade.
- Furthermore, the design and operation should be appropriate also from the viewpoint of saving costs and energy, from the stage of construction to the stage of operation.

We believe that this testing apparatus will be an important contribution to this field, not only in Japan and Taiwan but also other countries, and we hope to be able to use the Apparatus for projects worldwide as one of the most advanced tools presently available in this field.

2. Experiment facilities

2.1 Running Apparatus

For the experiment, a running apparatus (Figure 2.1) with effective length of 18m is used. Table 2.1 gives details of the running apparatus.

Table 2.1 Details of the running apparatus

Car velocity	Any velocity in a range of 10 ~ 60km/h
Velocity measurement	Line speed meter
Effective length for measurement	3ϕ×200V×4P×3.7kW, 2 units variable velocity type
Running belt	Height: 30mm Width* 3mm Polyamide
Tracer gas release equipment	Located in the middle of the road or at both road sides at 10 mm intervals, the tracer gas is released in equivalent concentrations in the direction of the road surface (over the total length of 18,000 mm.)

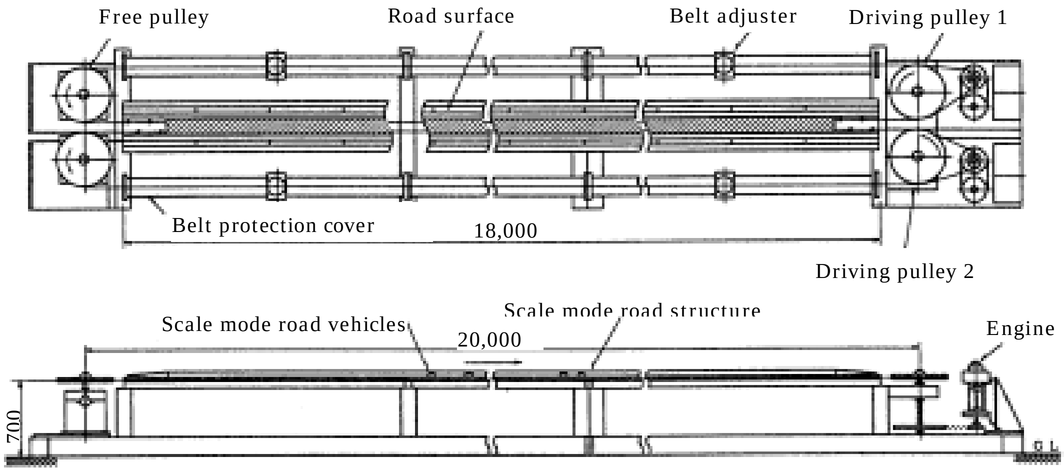


Figure 2.1 Running Apparatus

2.2 Rule of similarity

Fundamentally, the flow field needs to maintain the same features for the actual case and the scale model experiment, and makes use of the wind velocity in the roadway, the mechanical wind velocity caused by the ventilation equipment, the respiration volume and the natural wind velocity (all of dimension [m/s]).

As for the wind velocity in the roadway, with the use of wind tunnel experiments on wind velocity in roadway and the traffic conditions in actual tunnels, the similarity between features in the actual case and the scale model has sufficiently been confirmed. Also for depressed road structures, the similarity is maintained in the same way as for tunnels, and for the underlying experiment the vehicle speed, the mechanical wind velocity and the natural wind velocity have been set at the same values as for the real case. Consequently, the value of the respiration value, as well as the relation between wind velocity in the roadway, mechanical wind velocity caused by the ventilation equipment, respiration volume and natural wind velocity are consistent with reality.

The rule of similarity is as shown in Table 2.2.

Table 2.2 Rule of similarity

	Actual phenomenon	Example of Scale model	Remark
Geometrical structure	1	1/200	
Traffic conditions	1	1/200	Time is equal for real situation and scale model
Vehicle speed	1	1	
Flow volume in roadway space	1	$(1/200)^2$= 1/40,000	
Mechanical wind velocity	1	1	
Natural wind velocity	1	1	Consistent in case of no wind

2.3 Scale model

1) Scale

In order to satisfy the requirements of similarity, it is necessary to carry out the scale model experiment in the same flow field as in reality. According to the Moody diagram (figure 2.2), in order to gain a fully rough zone, the Reynolds number should be at least 1.0×10^4. When we consider the Reynolds (Re) for a scale of 1/200, we obtain.

(3.1) $Re = (Vt\times L) / v = (1{,}667\times0.93) / 0.150 = 1.03\times10^4$

where Vt: vehicle velocity 60km/h=1,667cm/s

L: representative vehicle length 185cm

$L = (1-\varepsilon)\times Ds + \varepsilon\times Db$

where ε: large size vehicle mix rate: 40%(0.4)

Ds: representative length passenger car: 141cm

Db: representative length large size car: 250cm

v: kinetic viscosity coefficient $0.150\text{cm}^2/\text{s}$

(in case of 20° atmospheric temperature)

We can conclude that a model scale of around 1/200 is a minimum in order to create a fully rough zone. On the other hand, a scale of more than 1/100 results in problems in the actual installation of model vehicles (weight etc.) . Therefore, a scale of between 1/100 ~ 1/200 is generally used in experiments with a running apparatus.

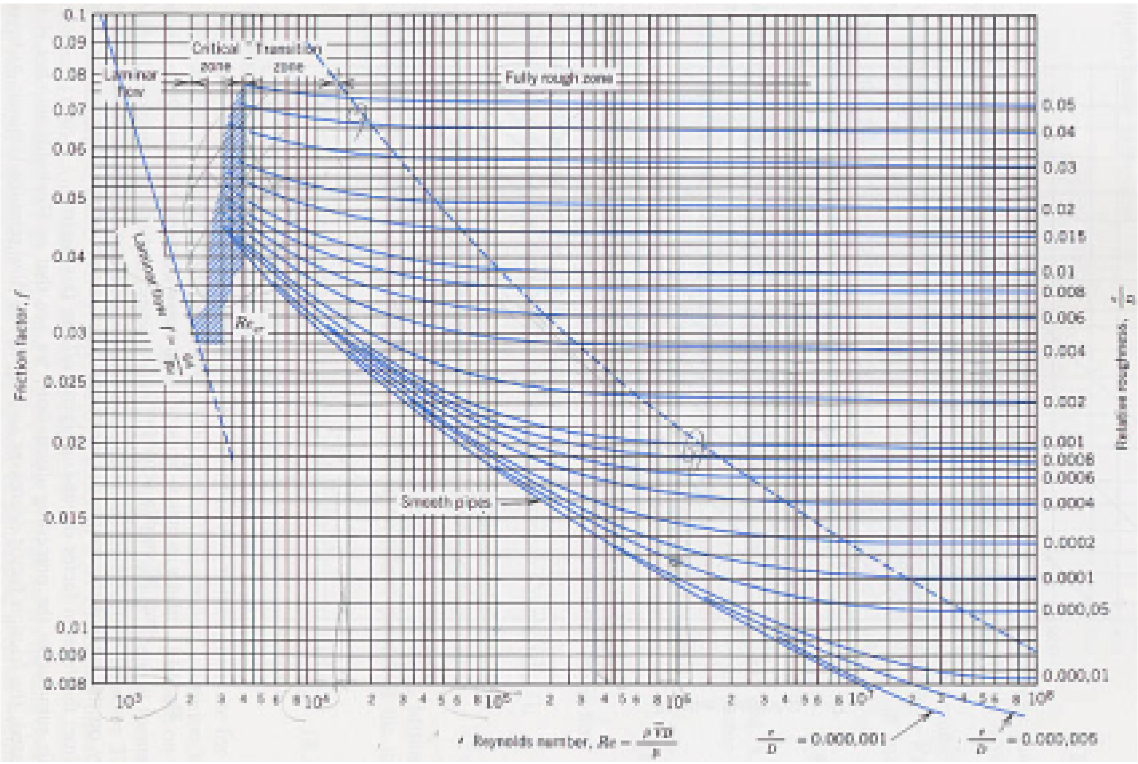


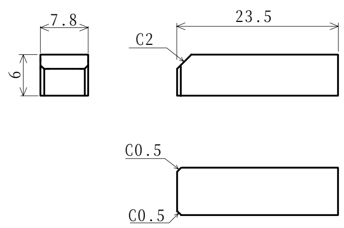
Figure 2.2 Moody diagram

2) Scale model vehicles

Figure 2.3 shows the scale model vehicles (polyurethane, scale 1/200). The small vehicles

represent passenger cars of the 2000cc class, and the large vehicles represent large size trucks (7.75 ton). Since the friction coefficient is different for small Reynolds numbers, the scale model vehicles are shaped rectangular. This shape has been determined by wind tunnel experiments to verify measurements on wind velocity in the roadway and traffic conditions in actual tunnels, and the best correlation was obtained.
As a whole, the running apparatus and scale model vehicles possess extremely good properties to simulate aerodynamic features and the shape of the scale model vehicles possess extremely good properties to simulate aerodynamic features and shape of the scale model vehicles are appropriate, also in aerodynamic sense.

① Passenger car (200 cc class) ② Truck (7.75 ton class)



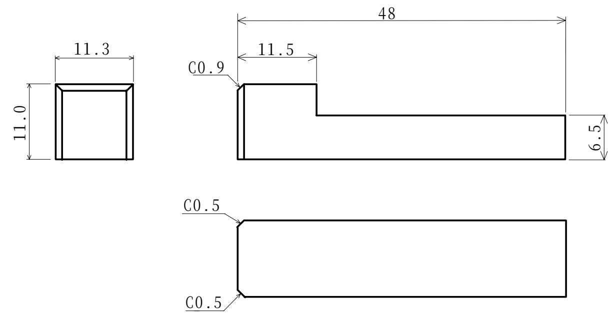


Figure 2.3 Scale model vehicles (1/200)

2.4 Measuring system

1) Measuring equipment
Table 2.3 gives details of the measuring equipment.

Table 2.3 Measuring equipment

Purpose	Name
Concentration measurement	Fluid switch box
	CO2 gas analyzer
Flow volume control	Mass flow controller
	Flow meter
Data processing	A/D converter
	I/O interface
	Personal computer
	Measurement program
Velocity measurement	Line speed meter

2) Measurement method
Figure 2.4 shows the concentration measurement system.
The scale model is placed on top of the running apparatus, and with the use of the fluid switch

box the meters and analyzers are placed.

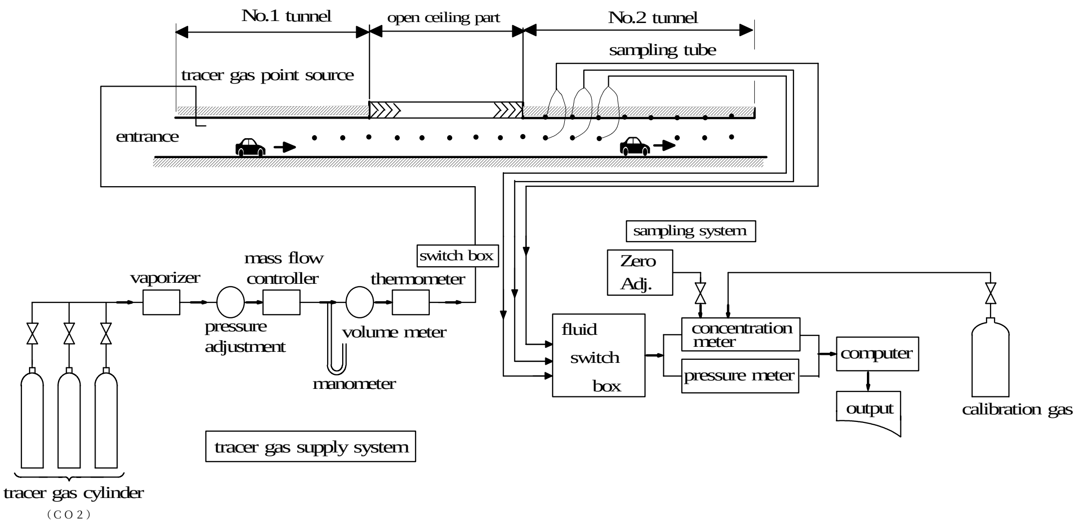


Figure 2.4　Concentration measurement system

3)　Tracer gas

Highly pure carbon dioxide will be used as tracer gas.

The tracer gas is released from the line sources and the sample gas that is brought from the valves fro concentration measurement through the fluid switch box to the analyzer and the concentration is measured.　Change of the measurement points is carried out by switching the fluid switch box.

The flow volume of the tracer gas is controlled by the mass flow controller and after that measured with the flow meter.

During the time of measuring the concentration in the roadway, the concentration of carbon dioxide gas is measured at several points as background concentration.

2.5 Data processing

Per case, the data are processed in the following way.

a)　Measurement of wind velocity in traffic space.

b)　Calculation of concentration (non-dimensional) and production of distribution diagram for concentration in roadway (in the direction of the road axis).　The non-dimensional concentration is defined as follows:

$\overline{C} = (Cr \cdot Vt \cdot L) / \omega$

where　Cr:　measured concentration in road way

Vt:　vehicle speed

L:　representative length

ω　emission volume of tracer gas or pollutant substance per unit length