DEVELOPMENT OF THE CEILING TYPE ELECTROSTATIC PRECIPITATION SYSTEM (SECOND REPORT)

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ABSTRUCT

Performance of new EP station composed of four EP-fan units on ceiling boad was investigated experimentally. Loss distribution in flow passage varies with the number of the running unit.
Direction of discharge flow is downwards, which is concerned for interference with motorbike riders. Flow arround EP station was verified in model test.
Experimental results were compared totally with other models presented in the last symposium in Brighton.

NOMENCLATURE

Cp : Pressure coefficient $[=PS(x)/(1/2 \cdot \rho \cdot Vr^2)]$
PS : Static pressure
V : Velocity
ΔP : Pressure difference
ΔCp: Pressure difference coefficient $[=\Delta P/(1/2 \cdot \rho \cdot Vr^2)]$
ν : Kinematic viscousity
ρ : density

subscripts
ep : Electrostatic precipitator
r : Tunnel

INTRODUCTION

Ventilation duct on tunnel ceiling has been applied to vehicle tunnels in Japan. Electric power as well as construction of the duct costs comparatively high because of the duct loss. Longtitudinal ventilation sysytem with electrostatic precipitator (EP) shown in Fig.1 has been becoming current one, in which polluted air is extracted into bypass tunnel. Air filtered by EP is fed back to the traffic tunnel. Both civil and running cost are reduced with this system. More than 20 ventilation systems with EP has been constructed since 1977 in Japan. However, it is impossible to construct the bypass tunnel in case of the tubular tunnel running through the muddy soil such as Tokyo Bay.

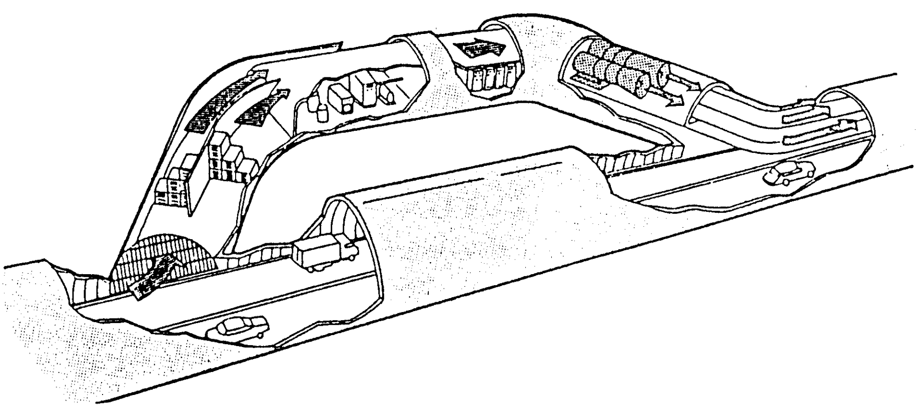

Fig.1. Existing Type EP Station

Ventilation committee for Trans-Tokyo Bay Undersea Tunnel has been investigated the new ventilation system in which EPs, fans are installed on ceiling space of the vehicle tunnel as shown in Fig.2. Authors have investigated the ceiling type EP system and clarified the relation between internal flow and configuration [1],[2],[3],[4].
Experiments were carried out in a model tunnel with the size of 1/20 and length of 35 m considering flow similarity. Flow in EP station was measured three dimensionally. Numerical analysis was carried out applying finite element method on viscous and three

dimensional flow field. Experimental and numerical analysis results of the EP layout were published in the proceedings of the seventh international sysmposium [5].
Ventilation committee for Trans-Tokyo Bay Undersea Tunnel had decided to develop the new EP station in 1991. The new EP station was composed of four EP-fan units. Experimental results showed good velocity profile for EP. Booster characteristics of EP station itself was measured precisely in order to design the optimum fan system. At the final stage of the investigation all type of EP station were compared.

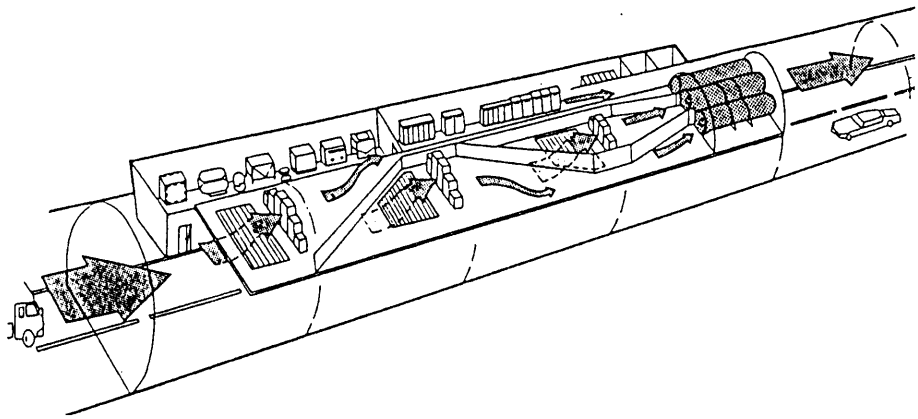

Fig.2. Ceiling Type EP Station

REVIEW OF ELECTROSTATIC PRECIPITATOR (EP) LAYOUT

Maintenance space for EP is required both in front and the rear of EP itself. Cylindrical wall on the top of tunnel also restricts the EP layout. Uniformity of flow with optimum velocity are most important condition for efficiently precipitating.

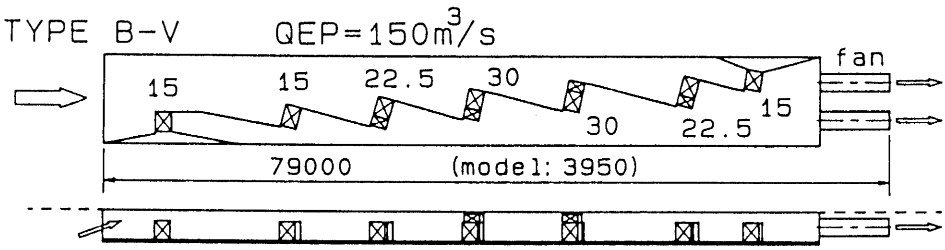

Fig.3. Layout Type B

Fig.3 shows layout Type B composed of seven EPs. Total EP flow runs through an intake in front of the station. Each EP is set aslant. Both layout of EP and the configuration of the wall control the flow and velocity distribution. Pressure loss of EP itself amounts approximately 150 Pa. Two fans feed the required flow.
Fig.4 shows layout Type C, which is composed of three independent channels with an intake, an EP and a fan. Approach flow direction is horizontally in EP1 and vertically at EP2 and EP3. Type C-V was developed with the combined concept of Type B and Type C-II; three intakes and EPs are fed air flow by two fans.

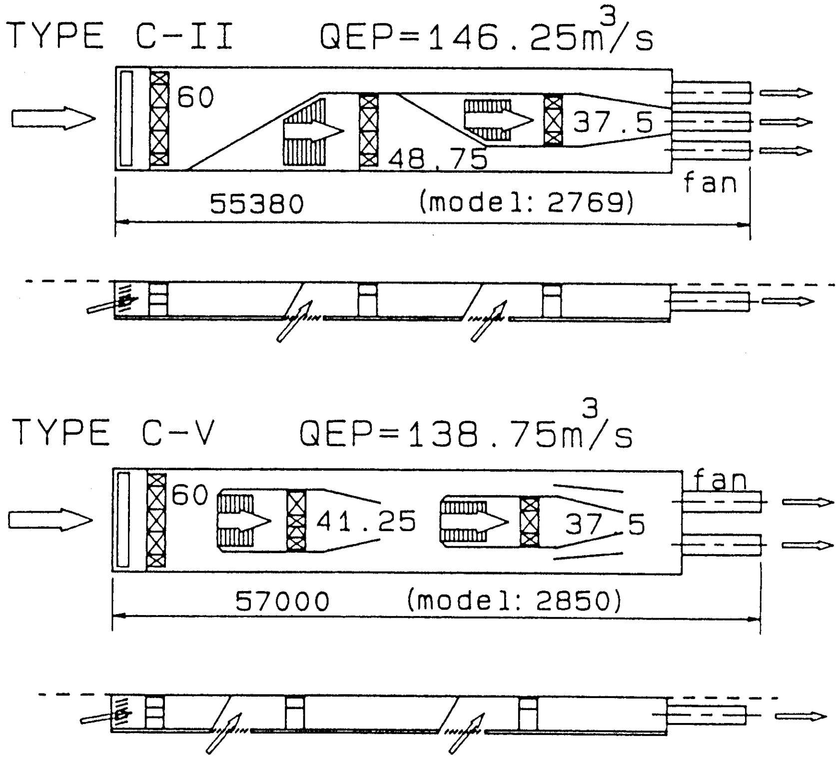

Fig.4. Layout Type C

LAYOUT OF EP WITH NEW CONCEPT

New layout Type D is composed of four EP-fan units as shown in Fig.5. Total flow is extracted through the intake in front of the station. Flow to be filtered runs into the each EP-fan unit horizontally. With such a concept flow into the each EP can be adjusted without any element, which contributes to a compact layout. Flow direction of filtered air is downwards. Discharge velocity is designed less than 15 m/s not to obstruct motorbike traffic. Wall plate at the end of the EP station is set obliquely to reduce the station loss.

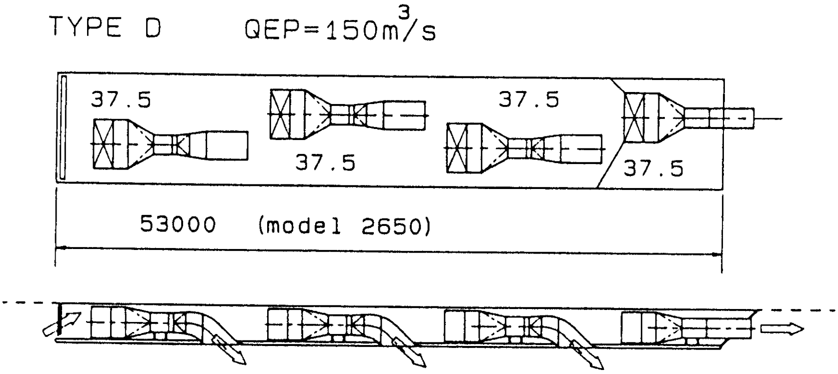

Fig.5. Layout Type D

EXPERIMENTAL APPARATUS

Model Tunnel

Velocity measurement was carried out with model EP station installed in middle of the model tunnel as shown in Fig.6. The model tunnel was made of vinyl chloride and its length is 65 times the hydraulic diameter. Flow similarity in jet mixing as well as approach flow were kept in model tunnel with sufficient length.

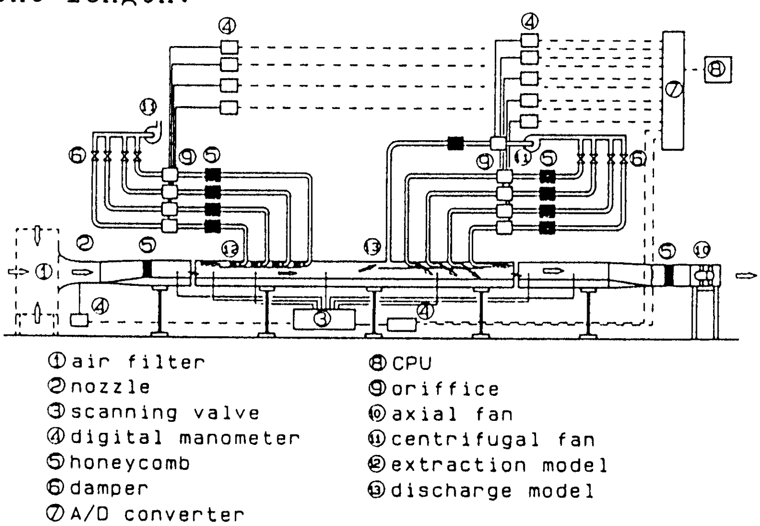

Fig.6. Experimental Apparatus

Model Station

Flow measurement was main experiment in present study. Blockage effect of probe for velocity measurement was planned to be less than 1 % which corresponds the scale of 1/20. Five-hole pitot probe was adopted for velocity measurement. Pressure on the pitot probe was measured by digital manometer and its output were acquiredby a computer 100 times through an A/D converter.

The model EP station was made of transparent acrylic plastics for flow observation. Experiment was carried out with two model stations; extraction model and discharge model because it is highly complicated system if both extraction and discharge flow are controlled simultaneously. Extraction model was tested at first. Discharge model tested afterward also extract the sameflow in order to simulate the pressure distribution upstream the EP station.

Test velocity was adjusted to the same value as the actual tunnel (8 m/s), which corresponds to tunnel Reynolds number of 2.5×10^5.

EXPERIMENTAL RESULTS AND DISCUSSION

Flow in Type D

Velocity distributions in Type D are shown in Fig.7. Flow in front of EP was verified to be distorted. However, axial velocity distribute almost uniformly, which is preferable condition for high efficient precipitation as shown in Fig.7. Flow processed in Type D was controlled by changing the number of EP-fan units. Velocity measeurement was performed under eight operating conditions. Velocity plofile was good also in other conditions. Total pressure distribution in EP station also varies as operating condition. The wind passage loss is the highest when first EP-fan unit stops and the others operate.

Flow in Tunnel

Velocity distributions below the EP station are shown in Fig.8. The high velocity is distributed on the level higher than 3 m above the road surface. No dangerous flow for the motorbike riders was observed.

Booster Characteristics

Outlet flow of the EP station is expected to accelrate the tunnel ventilation flow such as jet fan. Booster characteristics was obtained by measuring the wall pressure distribution in Fig.9 and Fig.10. Pressure rise performance is not so high comparing Type B or Type C.

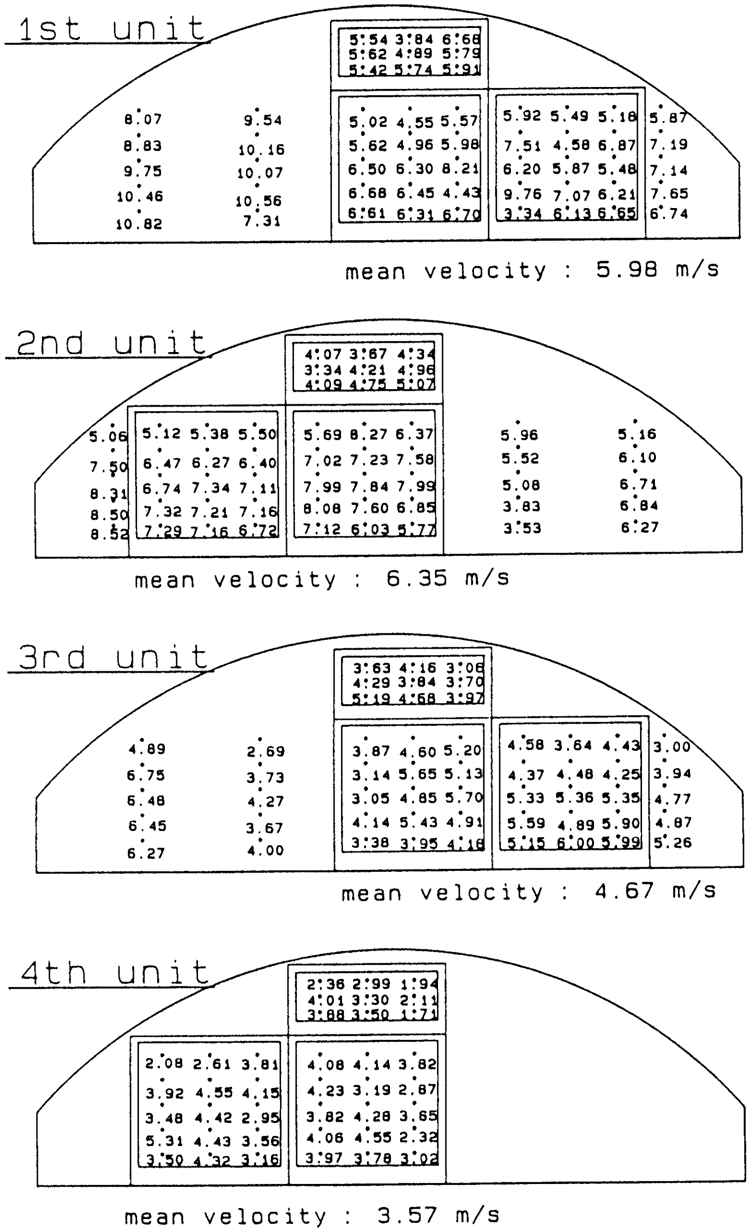

Fig.7. Axial velocity distribution in Type D

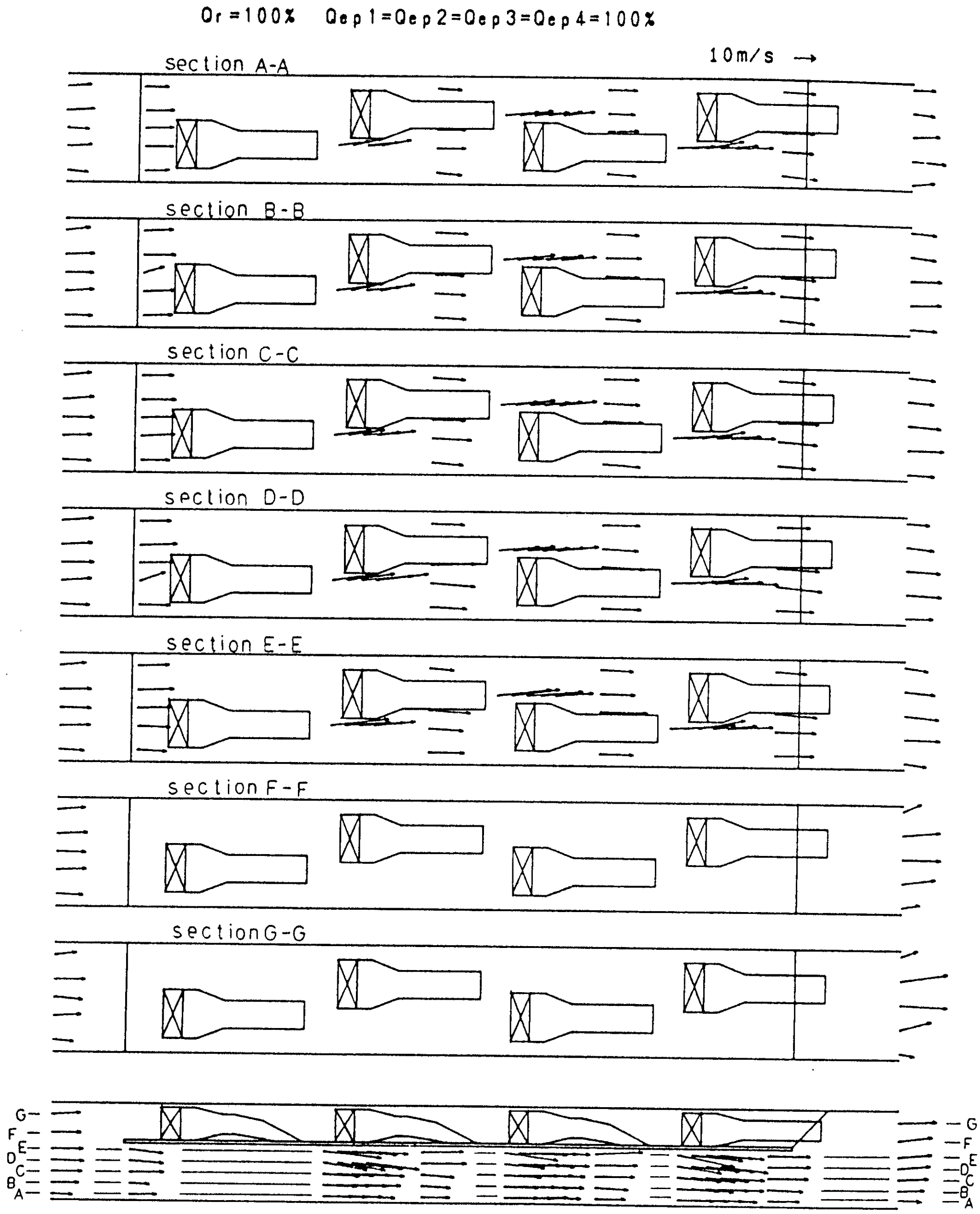

Fig.8. Velocity distribution in tunnel

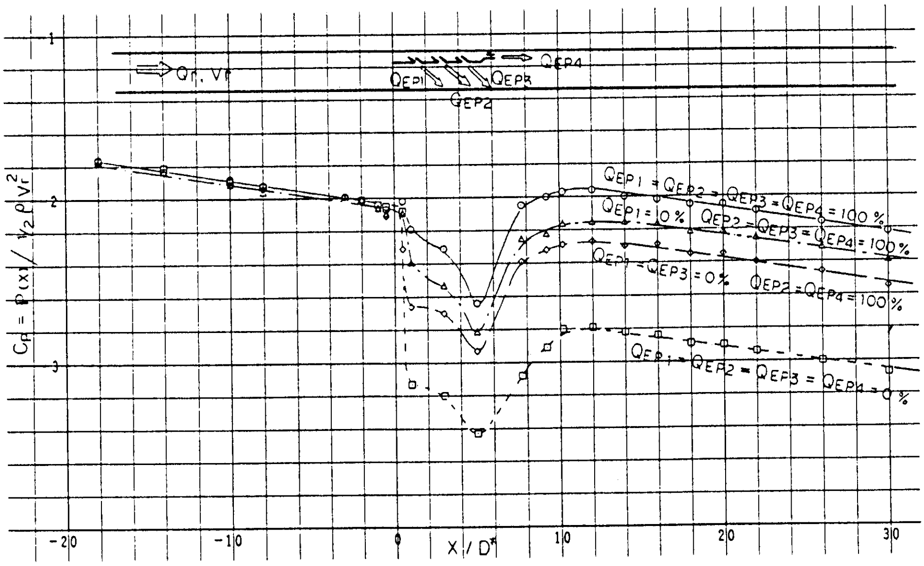

Fig. 9. Pressure distribution in tunnel

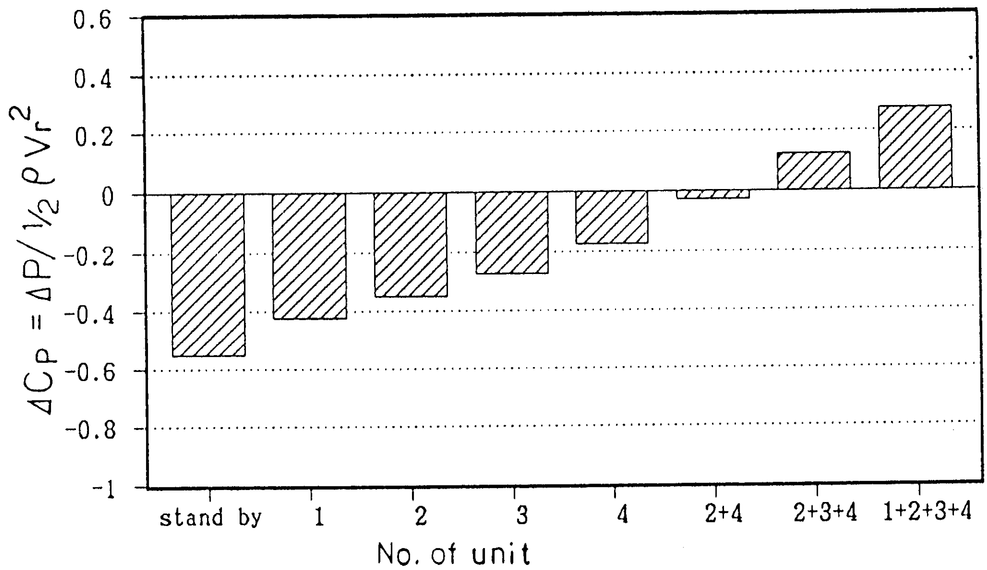

Fig. 10. Booster characteristics

CONCLUSION

Layout Type B-V, Type C-II, Type C-V and Type D were compared. Type D showed attractive features;

(1) Installation
The EP-fan unit of Type D is manufactured in factory, which makes it easy to install the EP station.

(2) Maintenance
There is no wall in Type D and access to EP and fan isthe simplest.

(3) Right weight
Type D shows the rightest weight, appealing the construction engineer

However, booster characteristics was the important specification for Trans-Tokyo Bay undersea tunnel. Type C-II showed the best performance as the total ventilation system including the vertical shaft fans and jet fans (Table 1). Type C-II saves the almost 40 jet fans and their electric power.

Table 1. Total comparison of EP station

	Type B-V	Type C-II	Type C-V	Type D
1. Treatment Flow (one EP station)	150.0 m³/s	146.25 m³/s	138.75 m³/s	150.0 m³/s
2. Fan Size	φ1800 × 2	φ1800 × 1 φ1600 × 2	φ1800 × 2	φ1600 × 4
3. Station Length	79 m	55 m	57 m	53 m
4. Station Weight	209.5 ton	154.5 ton	158.3 ton	148.6 ton
5. Number of Station	14	15	15	14
6. Total Cost (30 years)	110 %	100 %	103 %	112 %

※ Total cost is calculated for Trans-Tokyo Bay Undersea Tunnel.

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