Specification for the design of a new W.T.

① Purpose and type of use of the W.T.
② Speed range or Mach no. range
③ Test section area
④ Re/m range or mass flow rate / unit area.

Once the above specifications are given or decided at, the next thing to do would be to estimate the power requirement.

Power requirement of low speed W.T.

$$P = f_n(U, A, \rho, \mu, a, S)$$

P ↑ power; a ↑ speed of sound; S ↑ geometry of the tunnel

In dimensionless form

$$\frac{P}{\frac{1}{2}\rho U^3 A} = P_f = g(Re, M, S)$$

① For low speed W.T., $M \leq 0.3$

$$P_f = g(Re, S)$$

Once we consider geometrically similar tunnel; the dependence on S is also removed, and we obtain

$$P_f = g(Re).$$

Therefore, Power factor, P_f, can be obtained from the geometrically similar W.T.s if Re is maintained same.

However, no two W.Ts have been designed using the similarity approach. For this reason, W.T. design has been more of an art with agreement between different designers on some basic issues. As a result one or more of the following 3 methods have been employed to estimate the power requirements of a new W.T.

(1) Estimate the ~~power~~ losses in various components in a W.T circuit using empirical laws.

(2) Small scale (W.T. model) testing of proposed large W.T.

(3) Reference to the data on existing W.T.s.

$$P_f = \frac{\text{Power input}}{\text{R.E. on the T.S. Jet}}$$

$$= \frac{P}{\frac{1}{2}\rho U^3 A} = \frac{1}{ER}$$

P_f should be as low as possible.
ER as high as possible (3 to 9).

Power requirements

$$\text{Power factor} = \frac{\text{Power input to the driving unit}}{\text{rate of flow of K.E. at the T.S}}$$

If P is power input (i.e. the motor output)

then $$P.F. = \frac{P}{\frac{1}{2}\rho_T U_T^3 A_T} \quad \text{— (1)}$$

T stands for test section.

If η is the efficiency of the driving unit (i.e, the fan efficiency). Then, of the power P a quantity ηP is communicated to airstream, and for steady flow this quantity is equal to the sum of the losses occurring in the flow through the tunnel (and at the diffuser exit in the case of an open-circuit tunnel).

$$\therefore \quad PF = \frac{\Sigma \text{ losses}}{\eta \cdot \frac{1}{2}\rho_T U_T^3 A_T} \quad \text{— (2)}$$

Energy ratio:

$$ER = \frac{1}{PF}$$

is sometimes used as an alternative measure of the efficiency of the system

E.R. increases as the tunnel performance improves.

Power loss calculation

In the following, we will try to estimate the losses occuring in various components of a W.T. The tunnel may be conveniently broken into for this purpose in the following components.

i) Convergent cone
ii) Test section
iii) Diffusers
iv) corners (guide vanes)
v) Return circuit
vi) Honey comb
vii) Screens

Energy loss due to each component

$$\Delta E = \Delta H * A * V$$
$$= \frac{\Delta H}{q_0} * \frac{1}{2} \rho V_0^2 . A * V$$

We define head loss coefficient

$$K_0 = \frac{\Delta H}{q_0}$$; q_0 is the dynamic head in the test section.

From continuity: $A V = A_0 V_0$

$$\therefore \quad \Delta E = K_0 \cdot \frac{1}{2} \rho A_0 V_0^3$$

Total Energy loss

$$= \sum_i \Delta E_i = \frac{1}{2} \rho A_0 V_0^3 \left[K_{0_1} + K_{0_2} + K_{0_3} + \cdots \right]$$

$$K_{o_1} = \frac{\Delta H_1}{q_0} \; ; \; K_{o_2} = \frac{\Delta H_2}{q_0} \quad \ldots$$

Now this energy loss must be supplied by the motor.

If Φ is the power input (i.e. the motor output)

then $$P.F = \frac{\Phi}{\frac{1}{2}\rho U_0^3 A_0} = \frac{1}{ER}$$

If η_f is the fan efficiency

η_s " " drive shaft "

then, of the power Φ a quantity $\eta_f \eta_s \Phi$ is communicated to airstream, and for steady flow this quantity is equal to the sum of the losses occuring in the flow through the tunnel.

$$\therefore \quad P.F = \frac{\sum_i \Delta E_i}{\eta_f \eta_s \frac{1}{2}\rho V_0^3 A_0} = \frac{\frac{1}{2}\rho A_0 V_0^3 \sum_i K_{oi}}{\eta_f \eta_s \frac{1}{2}\rho U_0^3 A_0}$$

$$\boxed{P.F = \frac{\sum K_{oi}}{\eta_f \eta_s}} = \frac{1}{ER}$$

or $$ER = \frac{\eta_f \eta_s}{\sum K_{oi}}$$

You may assume $ER = \frac{1}{PF}$ independent of Reynolds number for preliminary estimation of power for the prototype. $PF)_m = PF)_p$

$$\therefore PF = \frac{1}{E.R} = \frac{\Pi}{\frac{1}{2}\rho A_0 V_0^3} \quad \text{for prototype}$$

$$\therefore \quad \Pi_p = PF)_m * \left(\tfrac{1}{2}\rho A_0 V_0^3\right)_p$$

$$= \left(\frac{\sum_i K_{oi}}{\eta_f \eta_s}\right)_m \left(\tfrac{1}{2}\rho A_0 V_0^3\right)_p$$

For a model (w.T.) losses across each component can be measured by means of precision manometers in terms of liquid column.

For example,

losses in the diffuser = 10 mm of water

$$\therefore \quad K_{o_d} = \frac{\Delta H}{q_0} = \frac{\rho_w g h_d}{q_0}$$

$$\therefore \sum_i K_{oi} = \frac{\rho_w g}{q_0}\left(\sum_i h_i\right)$$

$$\therefore \quad P_f = \frac{\Pi}{\frac{1}{2}\rho A_0 V_0^3} = \frac{\sum_i K_{oi}}{\eta_f \eta_s}$$