CHAPTER 3

EXPERIMENTAL

3.1 Apparatus

Agitated vessels are used as the experimental apparatus. Figure 2 and Table 2 show the dimensions of the agitated vessels used. In order to know the geometrical effect, two vessels of different diameters (15 and 20 cm.ϕ) are used. These vessels are equipped with four symmetrically located baffles of widths T/10. The impellers used are standard 6-blade turbine, 6-blade fan turbine, 4-blade pitch fan turbine, marine propeller and paddle with diameters of 0.33T , see Figure 3.

3.2 Materials

Tap water is chosen as the experimental liquid. α -napthol is selected as the experimental solid because of its low solubility, high purity and stability.

To produce solid particles having uniform characteristics. α-napthol is pelleted into modify ball shapes in a single-punch tabletting machine. No lubricating or binding agent are used in the pelleting operation. A set of punch and die is used which produced uniform sized pellets of 0.5852 cm. in diameter. The α-napthol pellets are used in determining the density and mass transfer coefficient

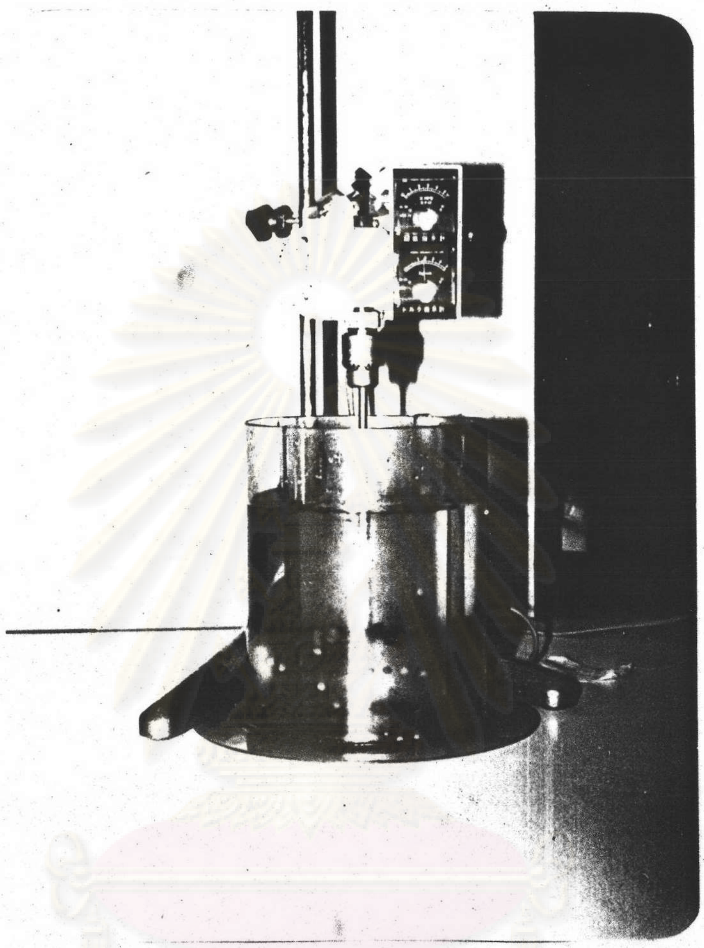
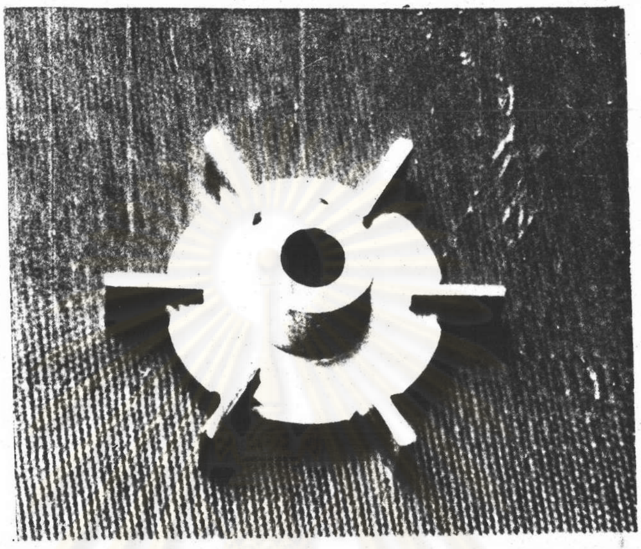
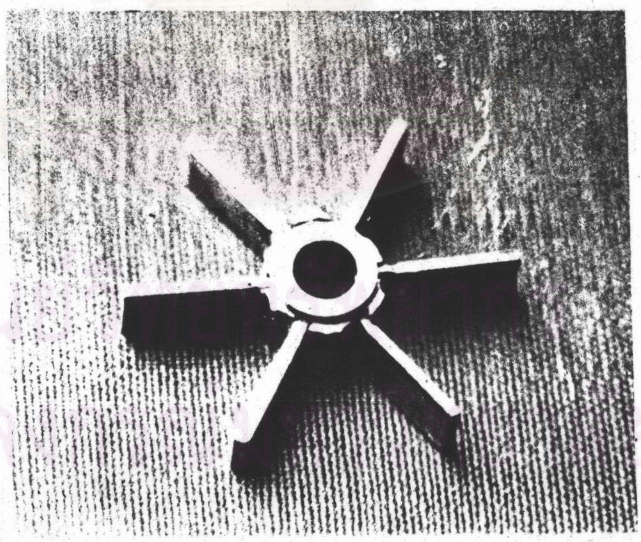


Figure 2 Apparatus for agitated-vessel study

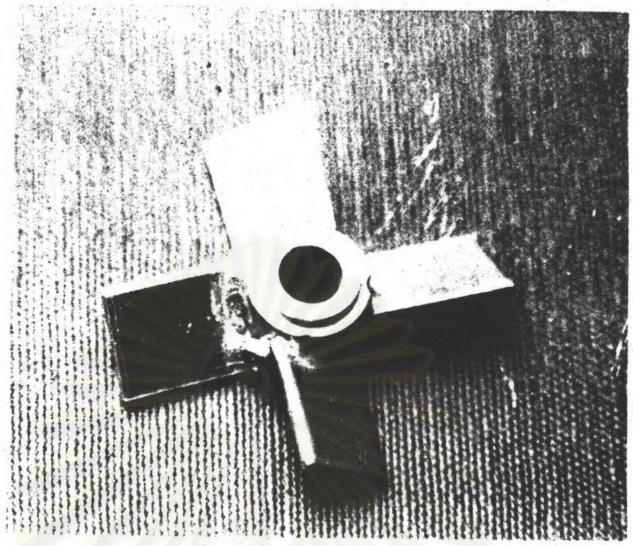
Figure 3 Types of Agitators



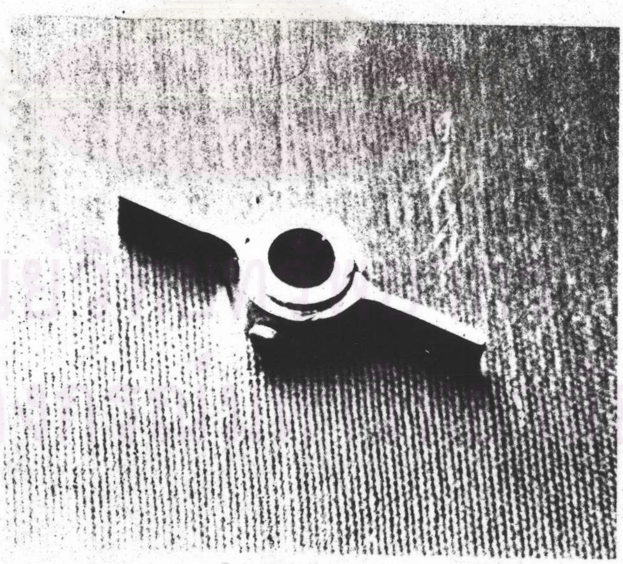
Standard 6-Blade Turbine



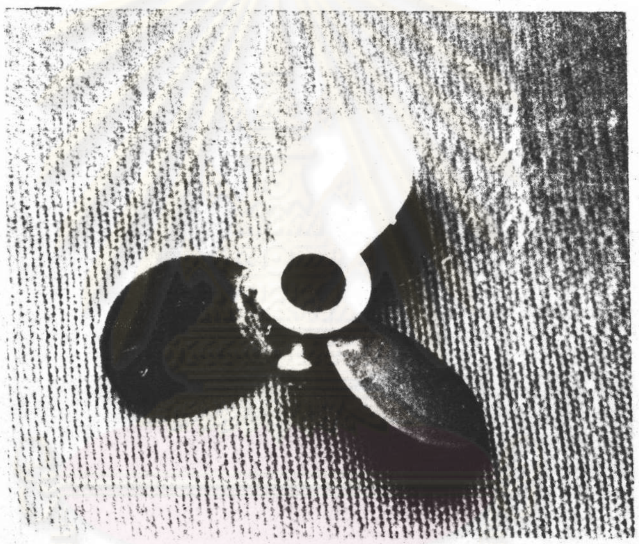
6-Blade Fan Turbine



4-Blade Pitched Fan Turbine



Paddle



Marine Propeller

TABLE 2 Dimension of Apparatus

Types of agitator	Disk Turbine	Fan turbine	Pitched Fan Turbine	Marine Propeller	Paddle
Impeller diameter(cm)	5,6.67	5	5	5	5
Impeller height from the tank bottom(cm)	5,6.67	5	5	5	5
Impeller blade width(cm)	1,1.33	1	1	1	1
Impeller blade length(cm)	1.25,1.67	1.25	1.25	1.25	1.25
Number of blades	6	6	4	3	2
Angle of blade	90^{o}	90^{o}	45^{o}	45^{o}	90^{o}
Tank diameter(cm)	15,20	15	15	15	15
Liquid height(cm)	15,20	15	15	15	15
Number of baffles	4	4	4	4	4
Flow Pattern	Radial flow	Radial flow	Axial flow	Axial flow	Radial flow

3.2.1 Determination of Mass Transfer Coefficient

The determination of mass transfer coefficient concerns the measuring of concentrations before and after diffusion.

The mass transfer coefficients are determined from the knowledge of material balance of the solid mass exchanged during the experiment. The transfer coefficients are calculated from the relation :

$$k = \frac{m}{A \, \Delta C_{ML}}$$

where m is the difference between the initial and final weights of α-napthol pellers, the weight lost which dissolved into the solution.

A is the surface area of solid particle

$$A = n \pi \bar{d}_p^2$$

n is the number of particles

$$\bar{d}_p = \frac{(d_{pi} + d_{pf})}{2}$$ is the average value of initial and final diameter of particle

$$\Delta C_{ML} = \frac{(C - C_o)}{\ln \frac{C_S - C_o}{C_S - C}}$$

3.3 Experimental Procedure

Following is an outline of the procedure followed for each run. Fill the vessel with a volume of water so that the depth of water is equal to the vessel diameter. Measure the liquid temperature and adjust the impeller speed to proper setting. A weighed amount of solid is introduced, and the stop watch is started simultaneously. After ten minutes, the solid particles are collected and dried in the oven at 40°C for 20 minutes. The dried pellets are then placed in a dessicator left at room temperature. After two hours the pellets are weighed and replaced in the dessicator again for two hours and reweighed. This procedure is repeated until a constant weight is obtained. The range of rotation speeds studied are 250 to 500 rpm.

In order to find the effect of the temperature the rotation speed is kept constant at 350 rpm. The range of temperatures studied are 15 to 40°C .

Diffusivity and saturated concentration values are obtained from results of Suvachittanont[18] Weighings are made on a Satorius automatic balance having on accuracy of ± 0.0001 g.

3.4 Dimensional Anaylsis of Mass Transfer Correlation

In solid-liquid agitation the entire mass transfer relation can be expressied by five independent variables as

$$k = f(d_p, \mu, \rho, D_V, \omega)$$

where D_V, the diffusion coefficient of a solid in liquid.

ω is the rotation speed of the agitator

In agitated solid-liquid systems, the appropriate equation is

$$\frac{kd_p}{D_V} = f\left(\frac{d_p T \omega\rho}{\mu} , \frac{\mu}{\rho D_V}\right)$$

or

$$Sh = f(Re_p , Sc)$$

where

$\frac{kd_p}{D_V}$ is the Sherwood number , Sh

$\frac{d_p T\omega\rho}{\mu}$ is the Reynold number , Re_p refers to solid particle

$\frac{\mu}{\rho D_V}$ is the Schmidt number , Sc

3.5 Influence of Reynolds number , $Re_p = \frac{d_p T\omega\rho}{\mu}$

Under isothermal condition for any particular liquid-solid system, μ, ρ and D_V are constant. So the value of Reynolds number depends on the rotation speed of the agitator, ω . Fluctuations no greather than 1 to 2 rpm. from any set speed ever occured. The variations in Re_p for five different impellers are presented in Tables 3 to 8 and they are plotted on logarithmic scales, see figures 4 to 8

TABLE 3

Vessel diameter = 15 cm.

Particle diameter , d_p = 0.5852 cm.

Schmidt number , Sc = 919.1167

STANDARD 6-BLADES TURBINE

Re x 10^{-4}	Sh_p (1)	Sh_p (2)	Sh_p (3)
2.6319	542.08	542.08	548.24
3.1583	640.64	634.48	640.64
3.6846	794.64	800.80	794.64
4.2110	964.12	967.12	967.12
4.7374	1,090.32	1,084.16	1,096.48
5.2638	1,416.80	1,416.80	1,410.64

TABLE 4

Vessel diameter = 15 cm.

Particle diameter , d_p = 0.5852 cm.

Schmidt number , Sc = 919.1167

6-BLADE FAN TURBINE

$Re \times 10^{-4}$	$Sh_p(1)$	$Sh_p(2)$	$Sh_p(3)$
2.6319	542.08	548.24	492.80
3.1583	665.28	659.12	659.12
3.6846	800.80	806.96	794.64
4.2110	911.68	887.04	887.04
4.7374	1,016.40	1,016.40	1,010.24
5.2638	1,145.76	1,151.90	1,145.75

TABLE 5

Vessel diameter = 15 cm.

Particle diameter, d_p = 0.5852 cm.

Schmidt number , Sc = 919 .1167

PADDLE

Re x 10^{-4}	$Sh_p(1)$	$Sh_p(2)$	$Sh_p(3)$
2.6319	344.96	301.84	351.12
3.1583	502.656	498.96	523.60
3.6846	614.152	616.00	628.32
4.2110	757.68	757.68	715.52
4.7374	837.76	837.76	842.92
5.2638	899.36	905.52	893.20

TABLE 6

Vessel diameter = 15 cm.
Particle diameter, d_p = 0.5852 cm.
Schmidt number, Sc = 919.1167

4-BLADES-PITCH FAN TURBINE WITH 45^{o}

Re x 10^{-4}	$Sh_p(1)$	$Sh_p(2)$	$Sh_p(3)$
2.6319	542.08	498.96	535.92
3.1583	634.48	646.80	628.32
3.6846	720.72	708.40	720.72
4.2110	856.24	850.08	893.20
4.7374	911.68	887.04	917.84
5.2638	1,028.72	1,022.56	1,028.72

TABLE 7

Vessel diameter = 15 cm.

Particle diameter, d_p = 0.5852 cm.

Schmidt number, Sc = 919.1167

MARINE PROPELLER

$Re \times 10^{-4}$	Sh_p	Sh_p	Sh_p
2.6319	492.80	492.80	505.12
3.1583	609.84	616.00	591.36
3.6846	665.28	665.28	659.12
4.2110	770.00	757.68	776.16
4.7374	843.92	856.24	862.40
5.2638	899.36	899.36	899.36

TABLE 8

Vessel diameter , T = 20 cm

Particle diameter , d_p = 0.6252 cm

Schmidt number , Sc= 919.1167

STANDARD 6-BLADES TURBINE

rev. (rpm)	Re x 10^{-4}	Sh_p	Sh_p	Sh_p
250	3.7491	664.6863	671.2673	658.1053
300	4.4989	835.7937	835.7937	835.7937
350	5.2487	1,046.3874	1,072.7116	1,072.7116
400	5.9985	1,210.9137	1,204.3326	1,210.9137
450	6.7483	1,382.0210	1,382.0210	1,382.0210
500	7.4981	1,618.9389	1,625.5200	1,618.9389

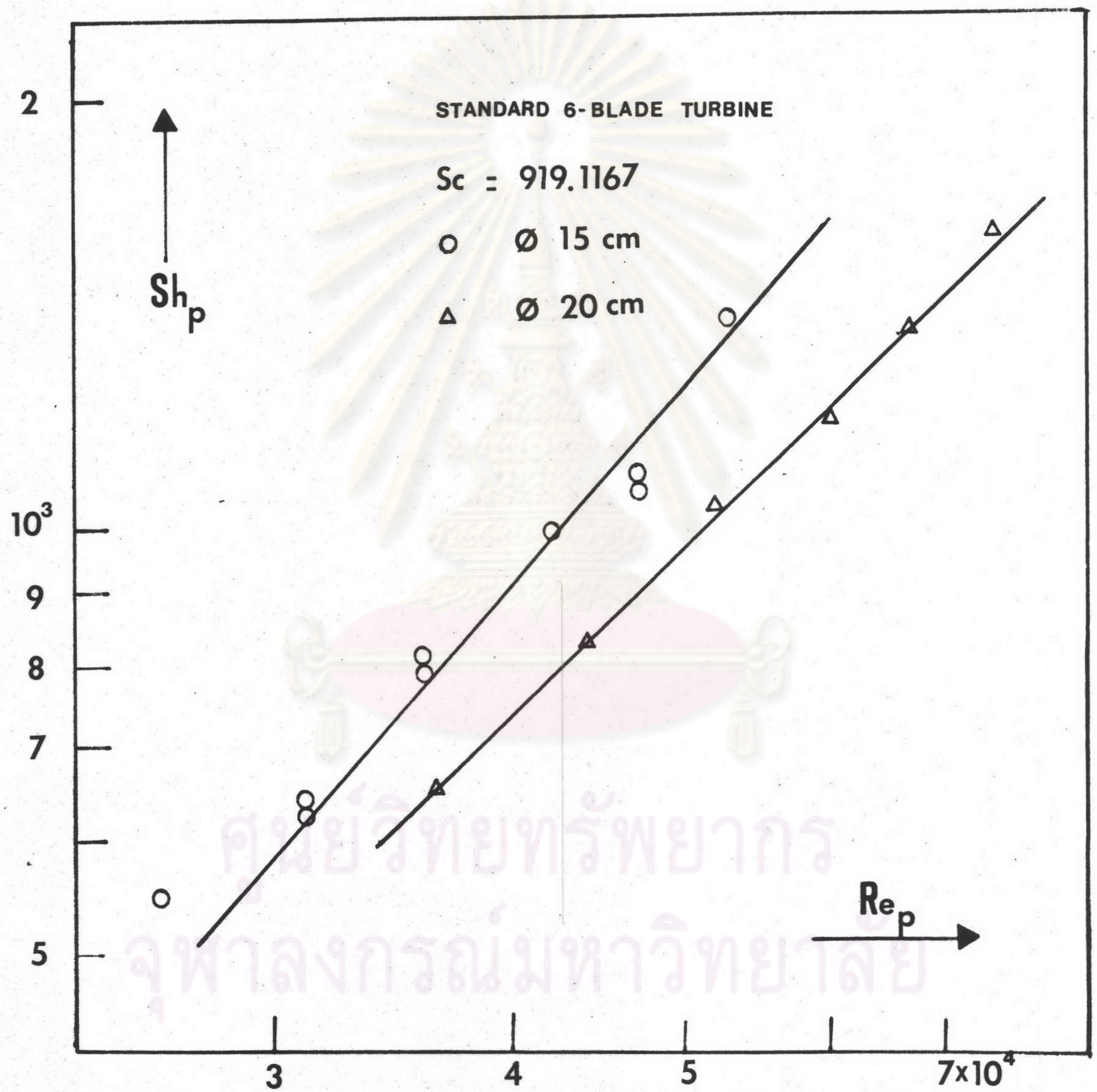


Figure 4 Plot of Sh_p as a function of Re_p

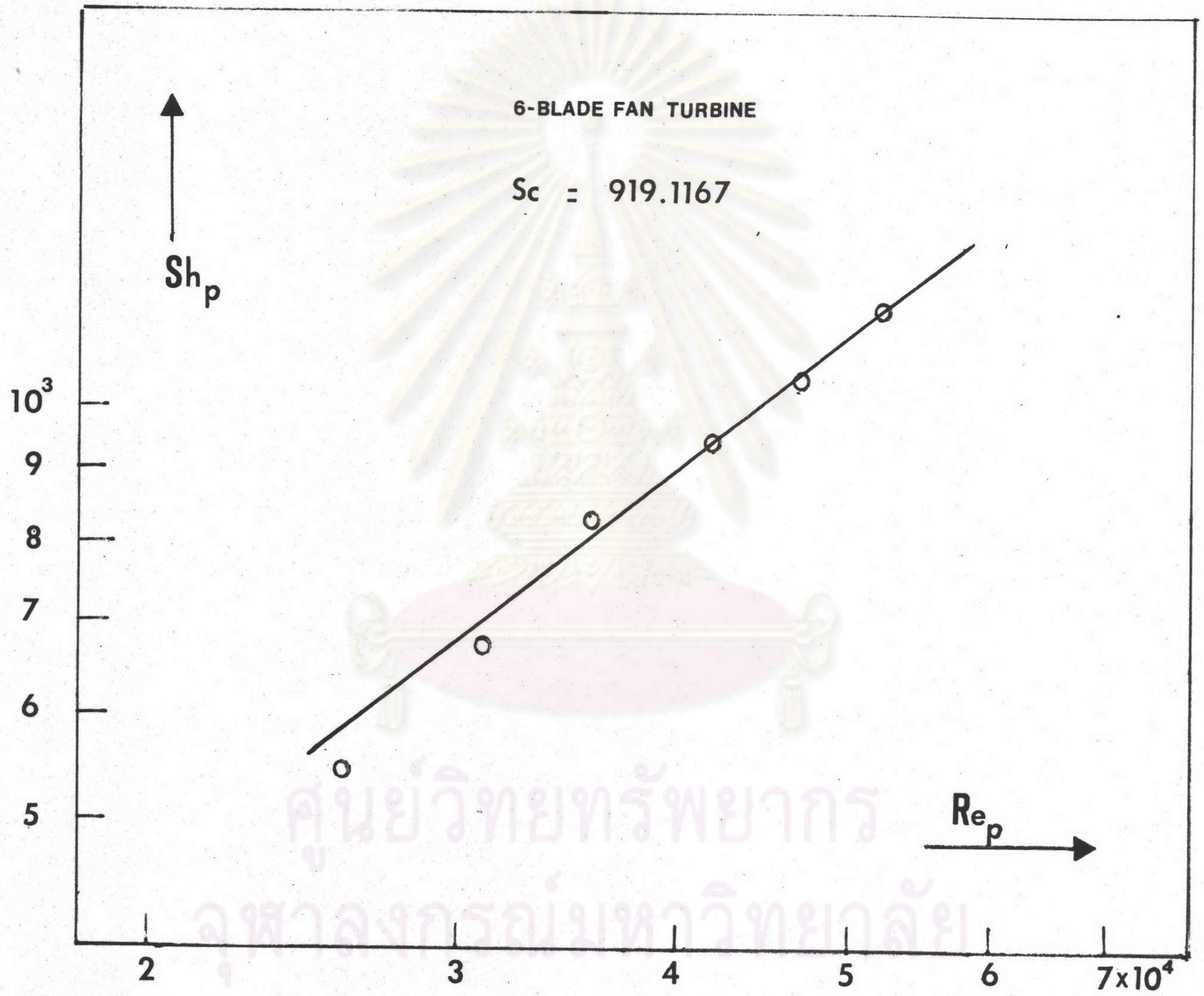


Figure 5 Plot of Sh_p as a function of Re_p

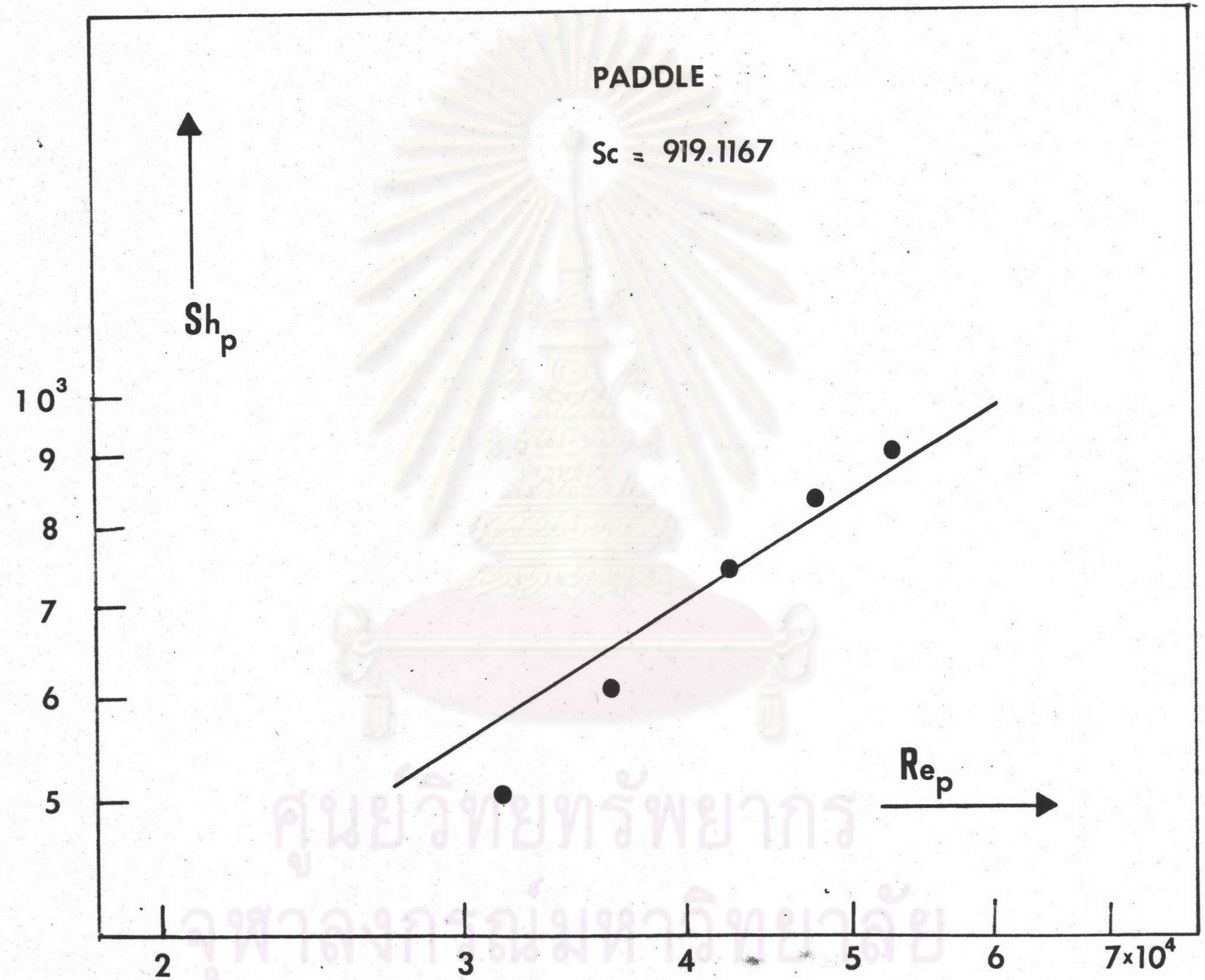


Figure 6 Plot of Sh_p as a function of Re_p

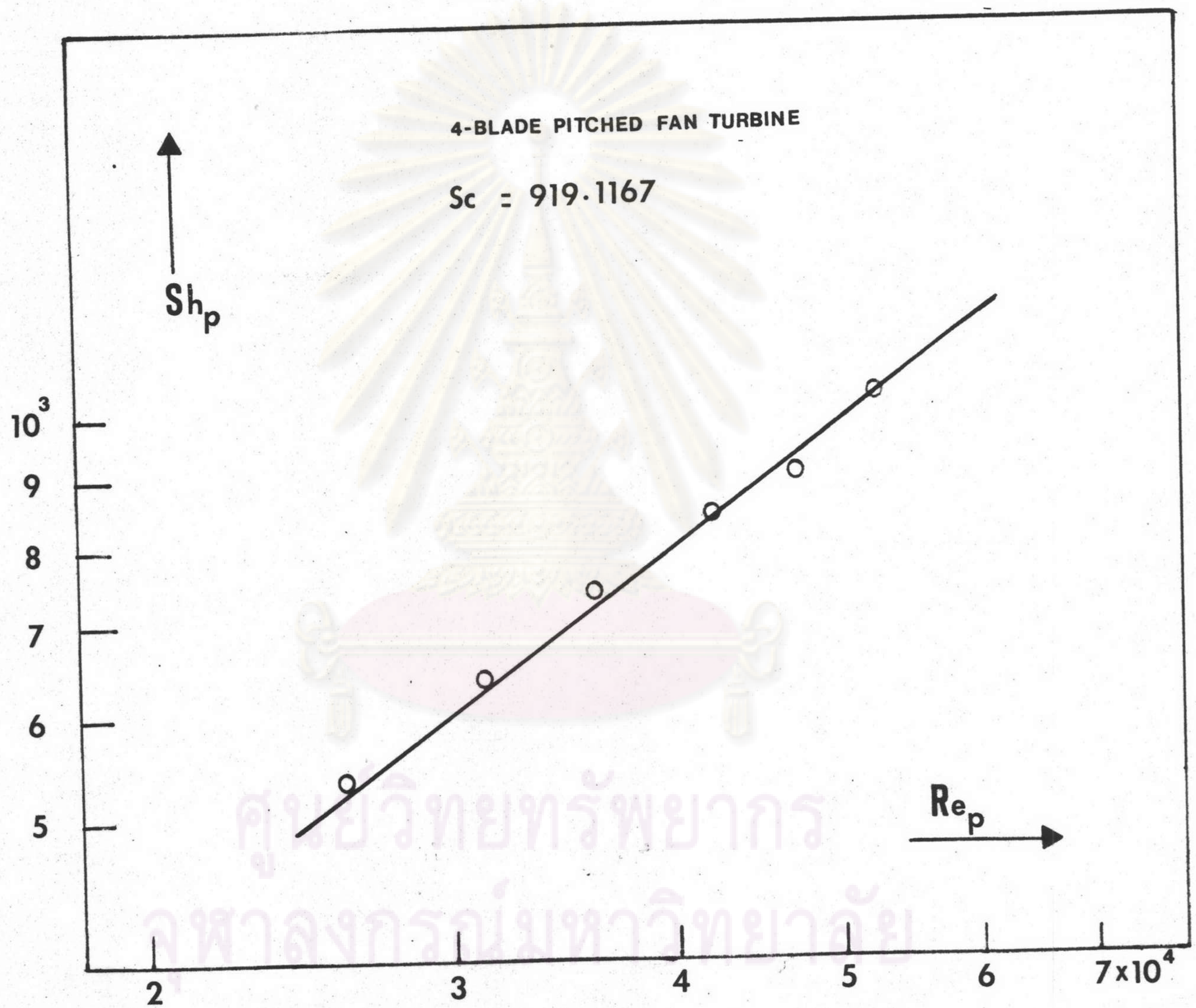


Figure 7 Plot of Sh_p as a function of Re_p

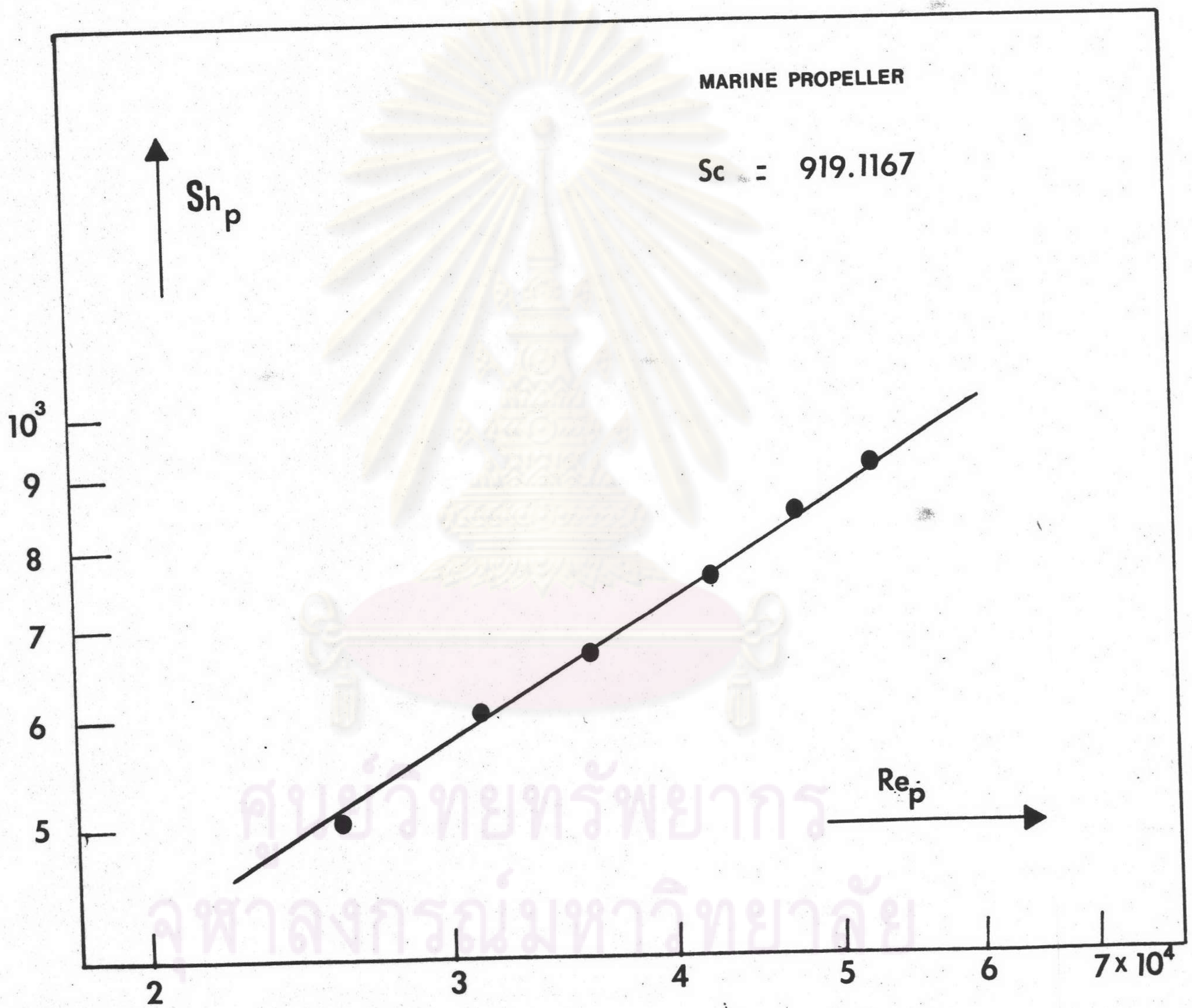


Figure 8 Plot of Sh_p as a function of Re_p

3.6 Influence of Schmidt number, $Sc = \frac{\mu}{\rho D_V}$

To determine the influence of the Schmidt number on mass transfer the temperatures are varied while the rotation speed is kept constant. Since kinematic viscosity appears in both the Reynolds number and the Schmidt number, when the Schmidt number is high the Reynolds number tends to below and vice versa. Tables 9 to 14 show the results obtained for a range of Schmidt number at the Reynolds number constant and are represented on figures 9 to 13

3.7 Influence of Impeller Type

It is seen from figure 14 that as the fluid circulation pattern in the vessel changes from radial to axial the mass transfer also changes in the same manner, ie. the mass transfer coefficient decreases. A transition reagion is noted with all five impellers which coincides with part of the transition region by other investigator[12] In this region the flow is fully turbulent with N = 350 to 500 rpm.

3.8 Influence of Vessel Size

Table 2 shows the correlation for geometrically similar agitator vessels (diameter 15 and 20 cm) with standard six blade turbine and having four baffles of 0.10 T width. These correlation show almost the same results. Larger vessel gives smaller mass transfer coefficient at the same Reynolds number.

TABLE 9

Vessel diameter , T = 15 cm

Particle diameter, d_p = 0.5852 cm

Reynolds number, Re_p = 3.6846×10^4

STANDARD 6-BLADES TURBINE

t ^oC	Sc	Sh_p (1)	Sh_p (2)	Sh_p (3)
40	572.5239	743.1111	738.2222	733.3333
35	719.8895	799.4832	794.0446	810.3606
30	858.8409	841.8873	841.8873	841.8873
25	989.7321	866.2500	859.8333	866.2500
20	1,350.7053	986.2921	980.4685	978.9863
15	1,570.8110	1,040.3556	1,032.2278	1,048.4833

TABLE 10

Vessel diameter , T = 15 cm

Particle diameter , d_p = 0.5852 cm

Reynolds number , Re_p = 3.6846×10^4

6-BLADES FAN TURBINE

t ^{o}C	Sc	Sh_p	Sh_p	Sh_p
40	572.5239	679.5556	679.5556	660.0000
35	719.8895	685.2714	690.7100	685.2713
30	858.8409	706.4789	760.4789	706.4789
25	989.7321	712.2500	705.8333	712.2500
20	1,350.7053	796.3396	803.6454	796.3396
15	1,570.8110	845.2889	845.2889	837.1611

TABLE 11

Vessel diameter , T = 15 cm

Particle diameter , d_p= 0.5852 cm

Reynolds number , Re_p = 3.6846 x 10^4

PADDLE

t ^oC	Sc	Sh_p	Sh_p	Sh_p
40	572,5339	635.5556	645.3333	630.6667
35	719.8895	679.8327	674.3940	679.8377
30	858.8409	700.5915	706.4789	700.5915
25	989.7321	731.5000	725.0833	731.5000
20	1,350.7053	752.5042	759.8102	752.5042
15	1,570.8110	788.3944	788.3944	780.2667

TABLE 12

Vessel diameter , T = 15 cm

Particle diameter , d_p = 0.5852 cm

Reynolds number , Re_p = 3.6846×10^4

4-BLADES PITCH FAN TURBINE

t ^oC	Sc	Sh_p	Sh_p	Sh_p
40	572.5239	762.6667	757.7778	767.5556
35	719.8895	783.1673	788.6059	783.1673
30	858.8409	794.7887	800.6760	800.6760
25	989.7321	821.3333	814.9167	821.3333
20	1,350.7053	847.4806	847.4806	840.1747
15	1,570.8110	861.5444	861.5444	869.6788

TABLE 13

Vessel diameter , T = 15 cm

Particle diameter , d_p = 0.5852 cm

Reynolds number , Re_p = 3.6846×10^4

MARINE PROPELLER

t °C	Sc	Sh_p	Sh_p	Sh_p
40	572.5239	640.4444	635.5560	644.2302
35	719.8895	674.3940	668.9554	674.3940
30	858.8409	706.4789	718.2535	706.4789
25	989.7321	712.2500	725.0833	712.2500
20	1,350.7053	752.5044	737.8926	759.8102
15	1,570.8110	796.7222	796.7222	792.7222

TABLE 14

Vessel diameter, T = 20 cm

Particle diameter, d_p = 0.6252 cm

Reynolds number Re_p = 5.2486 x 10^4

STANDARD 6-BLADES TURBINE

t (^oC)	Sc	Sh_p (2)	Sh_p (2)	Sh_p (3)
40	572.5239	1,055.0576	1,049.8345	1,034.1654
35	719.8895	1,144.6505	1,144.6505	1,150.4609
30	858.8409	1,239.0784	1,239.0784	1,239.0784
25	989.7321	1,343.6315	1,343.6315	1,343.6315
20	1,350.7053	1,529.8277	1,522.0244	1,522.0225
15	1,570.8110	1,693.2500	1,667.2000	1,684.5667

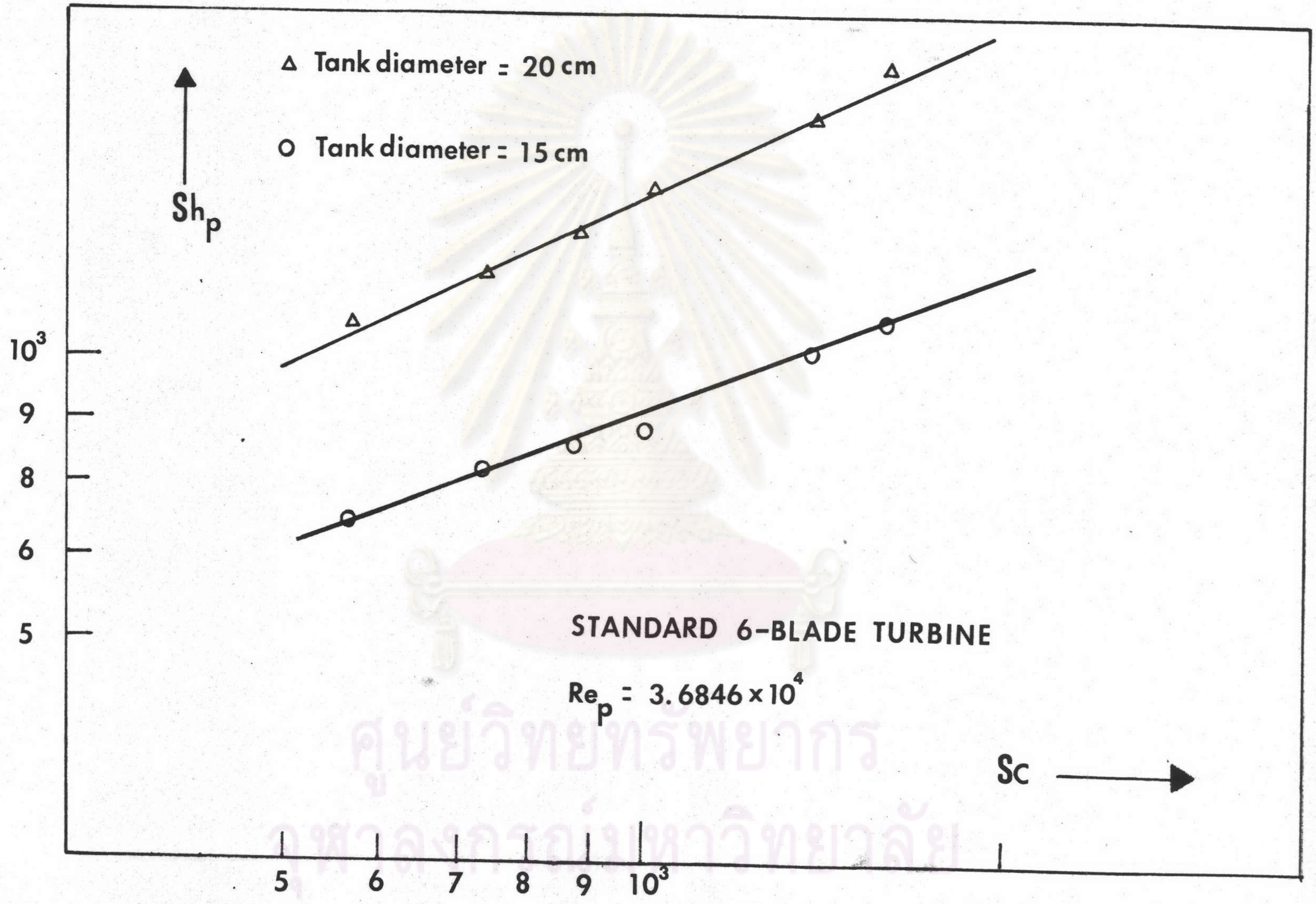


Figure 9 Plot of Sh_p as a function of Sc

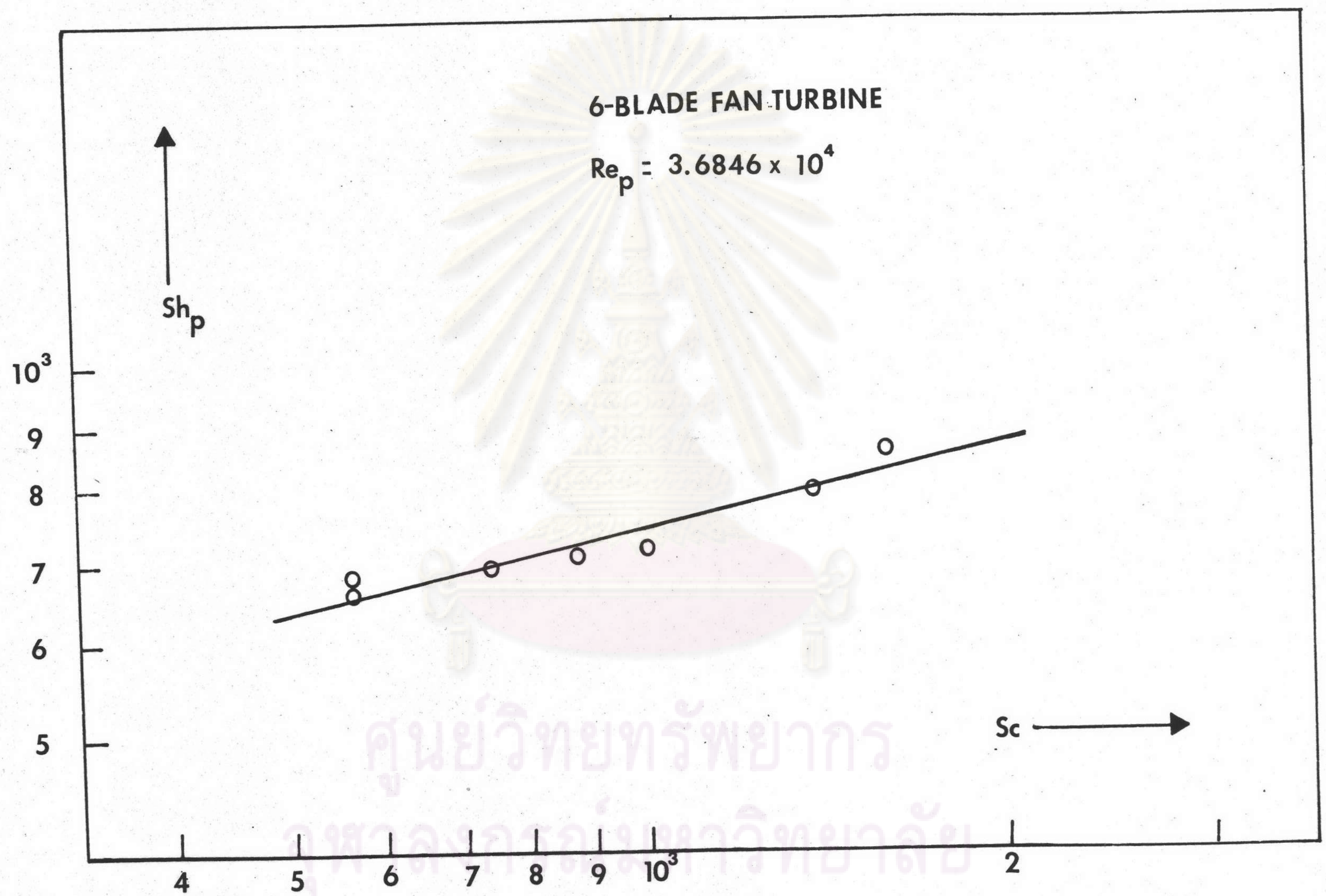


Figure 10 Plot of Sh_p as a function of Sc

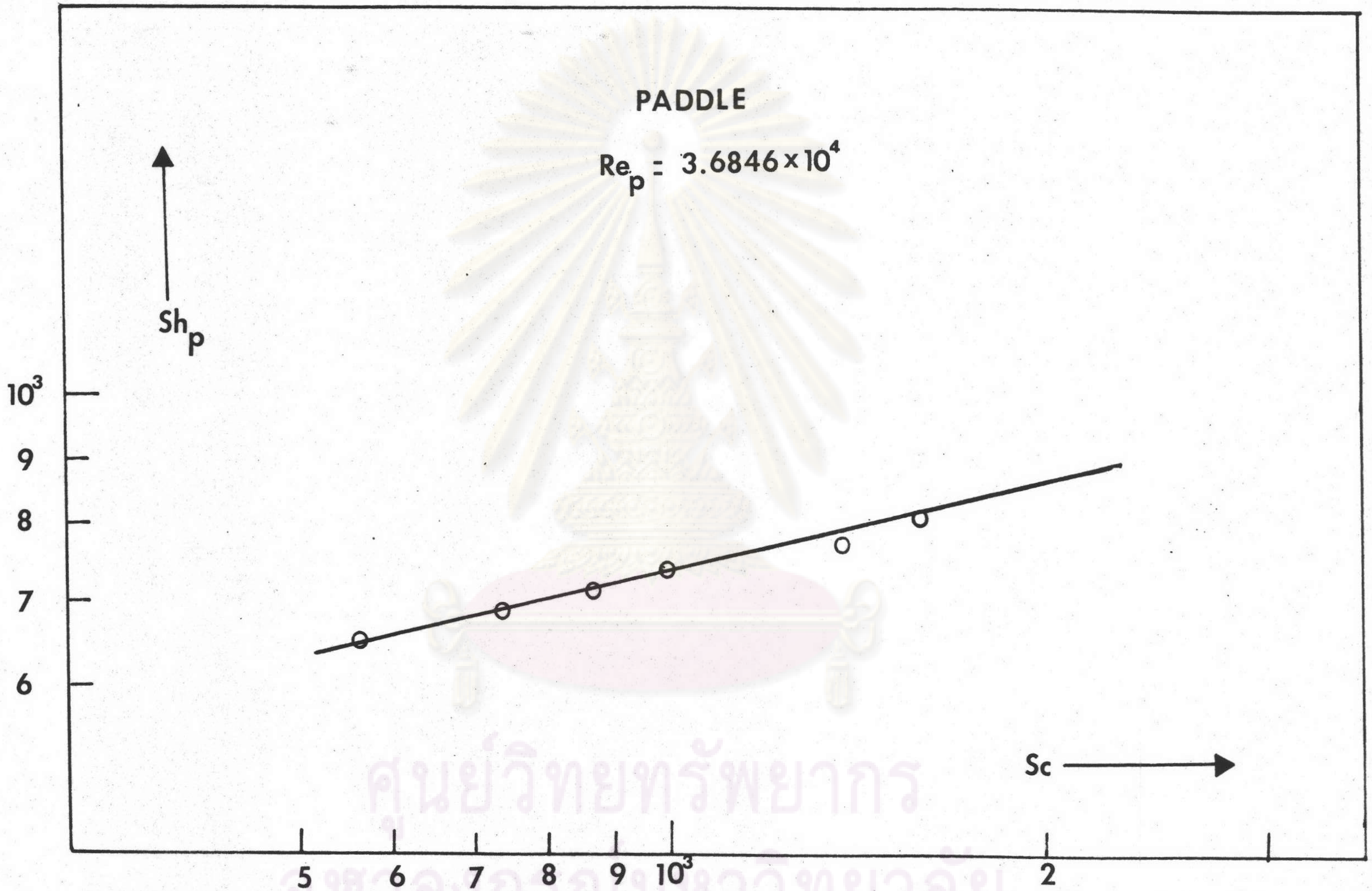


FIGURE 11 Plot of Sh_p as a function of Sc

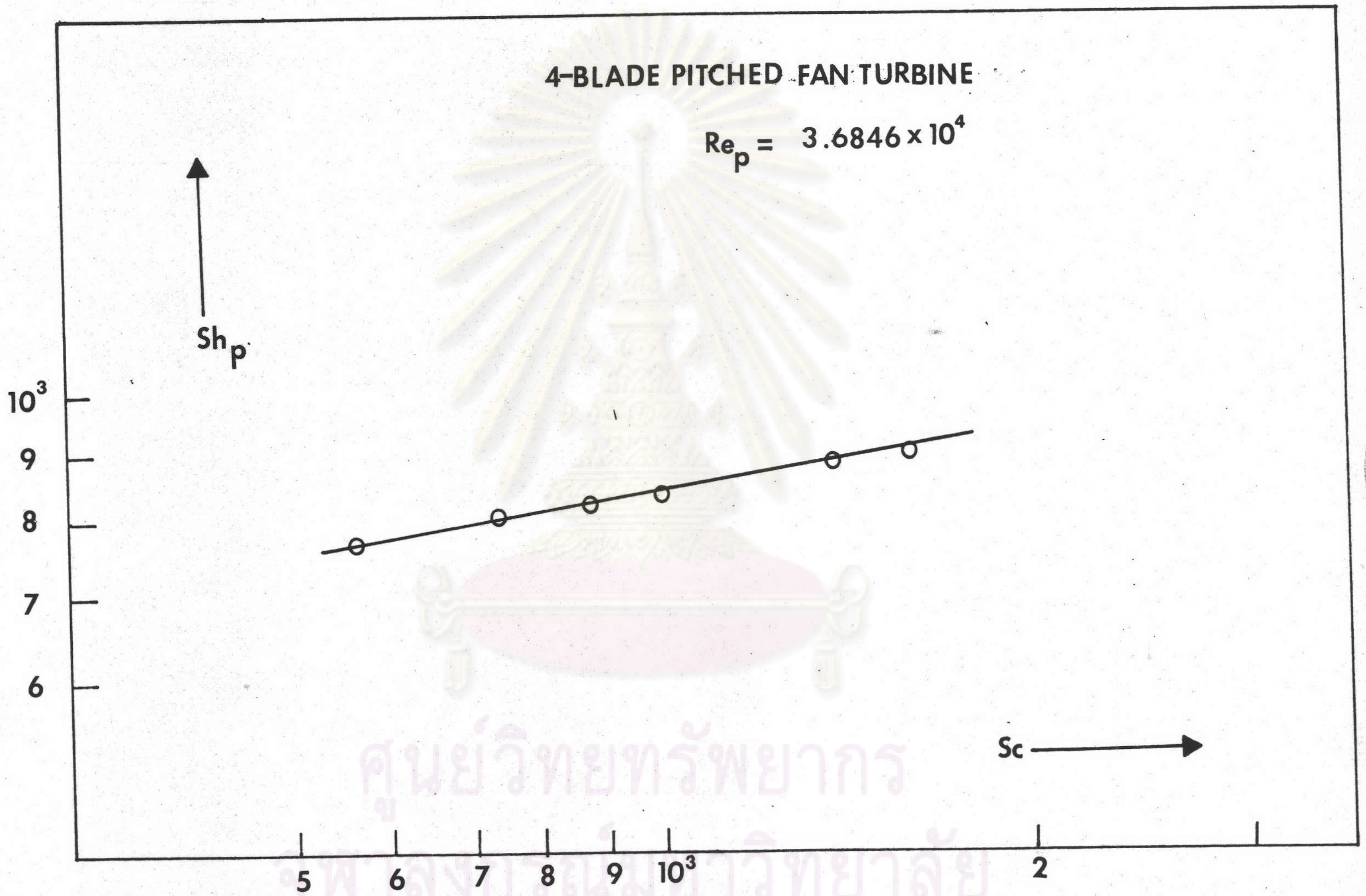


Figure 12 Plot of Sh_p as a function of Sc

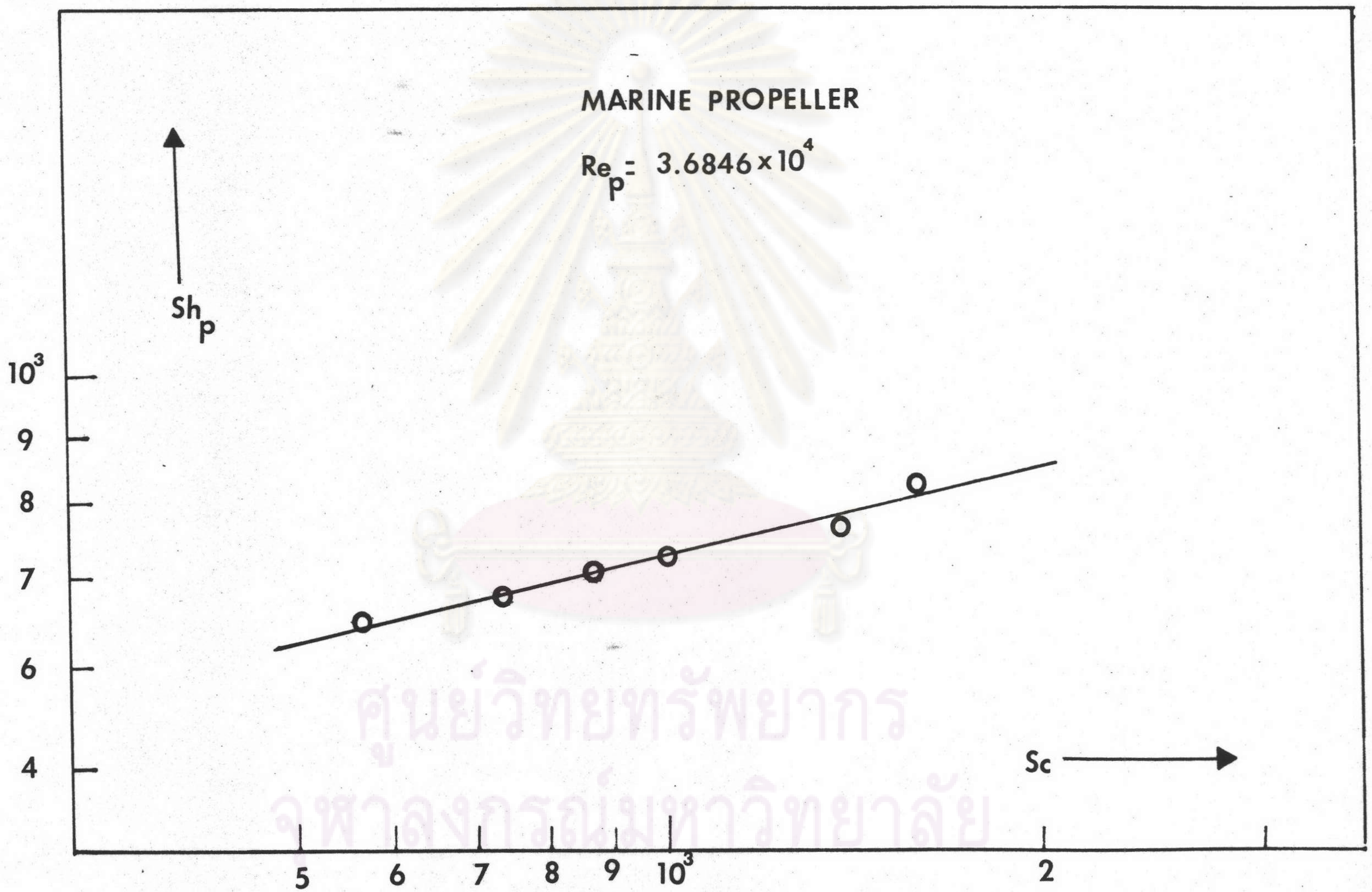


Figure 13 Plot of Sh_p as a function of Sc

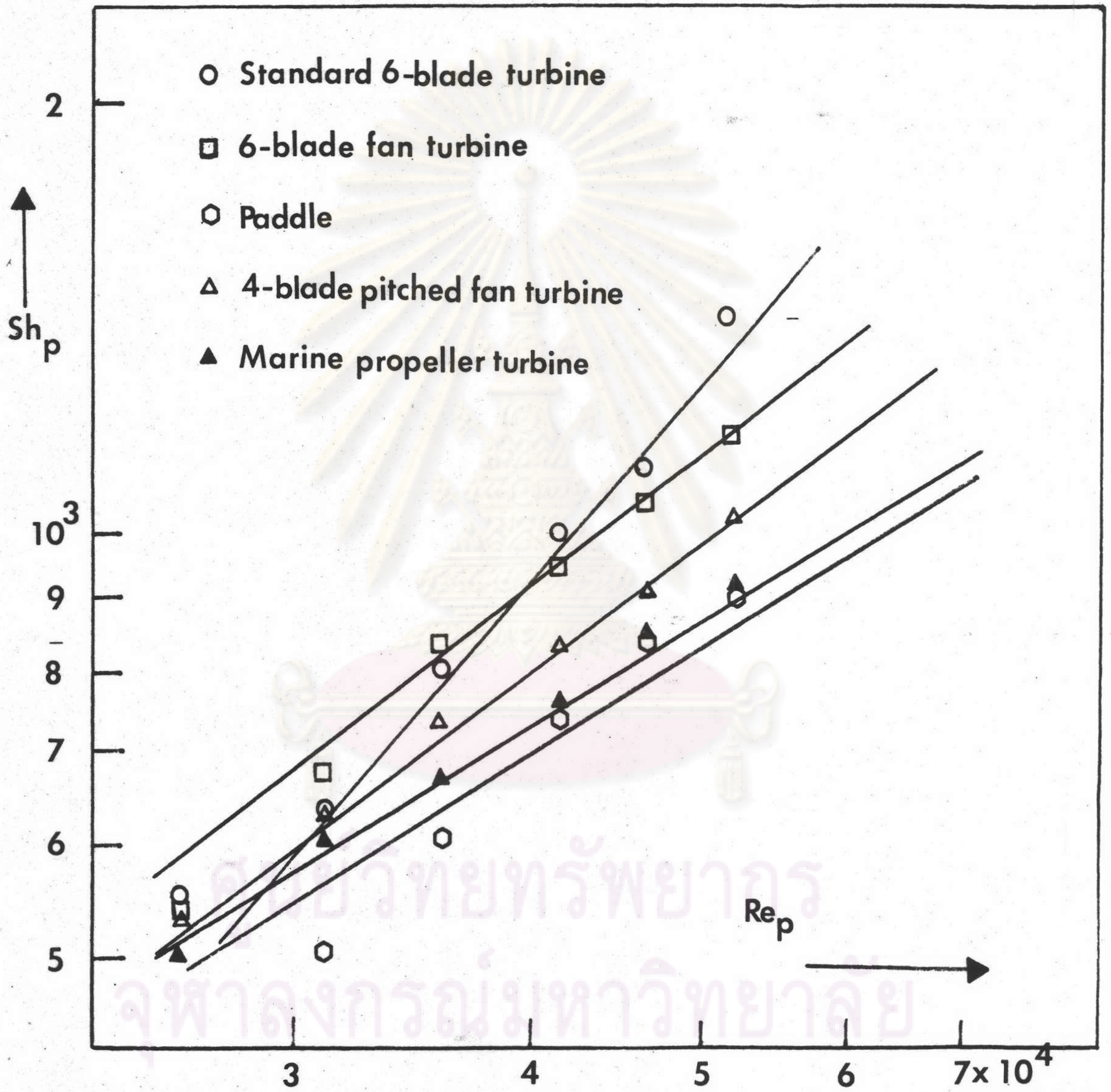


Figure 14 Influence of impeller types