Chapter 4

Results and Discussions

4.1 Calculation of Precision

Before analyzing the results and comparing them with previous works. It is necessary to evaluate the precision of various measurements and calculate the % error of each group of measurement.

In the course of this study correlation in terms of dimensionless groups is in the form

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

4.1.1 Reynolds number relative the particle $Re_p = d_p \frac{T\omega\rho}{\mu}$

The physical properties of water ρ and μ are known to be exact and the temperature, diameter, T and height, H of vessel is also exact, therefore

$$\frac{\Delta Re_p}{Re_p} = \frac{\Delta d_p}{d_p} + \frac{\Delta \omega}{\omega} = \frac{\Delta d_p}{d_p} + \frac{\Delta N}{N}, \quad (\omega = 2\pi N)$$

The solid particle diameter d_p is determined from

$$d^3 = \frac{M_T}{n\frac{\pi}{6}\rho_s}$$

$$\frac{\Delta d_p}{d_p} = \frac{1}{3}\left(\frac{\Delta M_T}{M_T} + \frac{\Delta \rho_s}{\rho_s}\right)$$

$$\frac{\Delta Re_p}{Re_p} = \frac{1}{3}\left(\frac{\Delta M_T}{M_T} + \frac{\Delta \rho_s}{\rho_s}\right) + \frac{\Delta N}{N}$$

4.1.2 <u>Schmidt number</u> , $Sc = \frac{\mu}{\rho D_V}$

The following equation is used to calculate the error Schmidt number

$$\frac{\Delta Sc}{Sc} = \frac{\Delta D_V}{D_V}$$

4.1.3 <u>Sherwood Number</u> , $Sh = \frac{kd_p}{D_V}$

$$\frac{\Delta Sh}{Sh} = \frac{\Delta k}{k} + \frac{\Delta d_p}{d_p} + \frac{\Delta D_V}{D_V}$$

The mass transfer coefficient k is determined by the relation.

$$k = \frac{m}{A_m \Delta C_{ML}}$$

or

$$k = \frac{m_o - m_f}{tA_m \Delta C_{ML}}$$

$$\frac{\Delta k}{k} = \frac{\Delta(m_o - m_f)}{(m_o - m_f)} + \frac{\Delta t}{t} + \frac{\Delta A_m}{A_m} + \frac{\Delta(\Delta C_{ML})}{\Delta C_{ML}}$$

The area A_m is determined by the mean diameter , $\bar{d}_p$ and the number or particle n.

$$A_m = \bar{d}_p^{\,2} \P n$$

$$\bar{d}_p = \frac{d_{pi} + d_{pf}}{2}$$

$$\Delta\bar{d}_p = \frac{1}{2}\Delta(d_{pi} + d_{pf}) \simeq \Delta d_p$$

$$\frac{\Delta A_m}{A_m} = \frac{2\Delta\bar{d}_p}{\bar{d}_p} = \frac{2\Delta d_p}{d_p}$$

ΔC_{ML} is determined from the initial concentration C_o, the final concentration C_f and the saturated concentration C_S, by the relation

$$\Delta C_{ML} = \frac{(C_S - C_o) - (C_S - C_f)}{\ln\left(\frac{C_S - C_o}{C_S - C_f}\right)} = \frac{C_f}{\ln\frac{C_S}{C_S - C_f}}$$

$$\frac{\Delta(\Delta C_{ML})}{\Delta C_{ML}} = \frac{\Delta C_f}{C_f} + \frac{\Delta\left(\ln\frac{C_S}{C_S - C_f}\right)}{\ln\frac{C_S}{C_S - C_f}}$$

C_f, the final concentration is obtained by calculation from the initial mass m_o and the final mass m_f of solid exchange, and the total volume V of the liquid in the vessel.

$$C_f = \frac{(m_o - m_f)}{V}$$

$$\frac{\Delta C_f}{C_f} = \frac{\Delta(m_o - m_f)}{(m_o - m_f)} + \frac{\Delta V}{V}$$

Support that T the vessel diameter is exact

$$\frac{\Delta C_f}{C_f} = \frac{\Delta(m_o - m_f)}{(m_o - m_f)} + \frac{\Delta H}{H}$$

$$\text{Thus} \quad \Delta \ln \frac{C_S}{C_S - C_f} = \frac{\Delta C_f}{C_S - C_f}$$

$$\frac{\Delta(\Delta C_{ML})}{\Delta C_{ML}} = \frac{\Delta C_f}{C_f} + \frac{\Delta C_f}{C_S - C_f} \cdot \frac{1}{\ln \frac{C_S}{C_S - C_f}}$$

$$= \frac{\Delta C_f}{C_f} + \frac{\Delta C_f}{C_f(C_S - C_f)} \cdot \frac{C_f}{\ln \frac{C_f}{C_S - C_f}}$$

$$= \frac{\Delta(m_o - m_f)}{m_o - m_f} + \frac{\Delta H}{H} + \left(\frac{\Delta(m_o - m_f)}{m_o - m_f} + \frac{\Delta H}{H} \right) \frac{1}{C_S - C_f} \Delta C_{ML}$$

$$\frac{\Delta Sh}{Sh} = \frac{\Delta k}{k} + \frac{\Delta d_p}{d_p} + \frac{\Delta D_V}{D_V}$$

$$= \frac{2\Delta(m_o - m_f)}{m_o - m_f} + \frac{\Delta t}{t} + \frac{\Delta M_T}{M_T} + \frac{\Delta \rho_S}{\rho_S} + \frac{\Delta H}{H}$$

$$= \left(\frac{\Delta(m_o - m_f)}{m_o - m_f} + \frac{\Delta H}{H} \right) \frac{1}{C_S - C_f} \Delta C_{ML} + \frac{\Delta D_V}{D_V}$$

Numeric Application

The mass m_o and m_f are measured by weight balance of 1000 g. precision by using minimum value of M_T and $(m_o - m_f)$ thus

$$\frac{\Delta M_T}{M_T} = \frac{0.001 \times 100}{2.4514} \simeq 0.004\%$$

$$\text{and} \quad \frac{\Delta(m_o - m_f)}{m_o - m_f} = \frac{2\Delta M_T}{m_o - m_f} \leq \frac{0.0002 \times 100}{0.0376} \simeq 0.532\%$$

The speed of rotation measurement error take about $\pm$ 2 rpm

$$\frac{\Delta N}{N} = \frac{\Delta\omega}{\omega} \leq \frac{2 \times 100}{250} \simeq 0.8\%$$

The height of liquid measurement error in the agitated vessel take about $\pm$ 2 m.m.

$$\frac{\Delta H}{H} \leq \frac{2 \times 100}{150} \simeq 1.333\%$$

Δt is the drainage time which is about 30 sec.

$$\frac{\Delta t}{t} \leq \frac{30 \times 100}{600} \simeq 5\%$$

The error $\Delta D_V/D_V$ of diffusion coefficient is $\pm$ 7.1%

The calculated error of dimensionless group of this experiment is following

$$\frac{\Delta Re_p}{Re_p} \leq 0.27\%$$

$$\frac{\Delta Sc}{Sc} \leq 7.1\%$$

$$\frac{\Delta Sh}{Sh} \leq 16.19\%$$

4.2 General Correlation

Mass transfer coefficient of the system is conveniently expressed by the equation

$$Sh = a\ Re_p^{p}\ Sc^{q}$$

where a dimensionless group, Sh is a function of other dimensionless groups, Re_p, Sc

In this work the correlations obtained are as follows.

Impellers types	Correlations
Standard 6-blade turbine	$Sh_p = 1.2186 \times 10^{-5} Re_p^{1.492} Sc^{0.336}$
6-blade fan turbine	$Sh_p = 0.0025\ Re_p^{1.0025}\ Sc^{0.227}$
Paddle	$Sh_p = 0.0377\ Re_p^{0.803}\ Sc^{0.197}$
4-blade pitch fan turbine	$Sh_p = 0.0135\ Re_p^{0.957}\ Sc^{0.123}$
Marine propeller	$Sh_p = 0.0191\ Re_p^{0.866}\ Sc^{0.212}$
For vessel diameter = 20 cm	
Standard 6-blade turbine	$Sh_p = 4.395 \times 10^{-5}\ Re_p^{1.269}\ Sc^{0.465}$

The limits of variation of various dimensionless groups :

$$2.6 \times 10^{4} < Re_p < 7.5 \times 10^{4}$$

$$572 < Sc < 1570$$

4.3 Comparison of The Experimental Results with Others

In this present work, experimental mass transfer coefficient of α-napthol in water are obtained at several rotation speeds of agitator; temperatures of water, and types of impeller. No previous work has been reported for the mass transfer coefficient of α-napthol in water, therefore the mass transfer coefficient of α-napthol in water is compared with the mass transfer coefficient of the other substance and they are all measured in agitated vessel.

4.3.1 Influence of various variables

The number and the constitution of the dimensionless group proposed by various, researchers are different therefore, it is difficult to carry out a complete comparisons. However, there are three important variables, Reynolds number, Schmidt number, and type of impeller with are in common.

In table 15 , the exponent obtained for various variables of the other researches are compared.

It is seen that the range of exponent value for standard 6-blade turbine

$0.28 < Re_p < 0.83$

$0.30 < Sc < 0.5$

6-blade fan turbine

$0.55 < Re_p < 0.62$, $0.3 < Sc < 0.33$

Table 15 Comparison of the exponents obtained for various variables

Author	Ref	Expenent of Re_p	Exponent of S_c	System of agitator utilize
Hixson and Baum	1	0.62,1.40	0.5	Turbine incurved with 45^{o} Marine propeller
Barker and Treybal	3	0.83	0.5	Standard 6-blade turbine
Horriott	10	0.3 ,0.5	0.33	Standard 6-blade turbine
Keey and Glen	13	0.8	0.5	Paddle
Weinspach	27	0.15	0.56	Paddle
Nagata et al	2	0.2, 0.67	0.5	Marine propeller
Levins	19	0.5, 0.62	0.38,0.36	6-blade turbine Marine propeller
Miller	14	0.65	0.33	4-blade turbine
Askew and Beckmann	12	0.55	0.30	6-blade turbine
		0.67	0.30	Marine propeller
Boon-Long	15	0.28	0.461	Standard 6-blade turbine
This work		1.49,1.27	0.336,0.465	Standard 6-blade turbine
		1.06	0.227	6-blade fan trubine
		0.8	0.197	Paddle
		0.96	0.123	4-blade pitch fan turbine
		0.87	0.212	Marine propeller

marine propeller

$0.2 < Re_p < 1.40$

$0.3 < Sc < 0.5$

paddle

$0.15 < Re_p < 0.8$

$0.5 < Sc < 0.56$

our exponents value lie within the range above

4.3.2 Comparison of results with other investigation

The results obtained in this work are compared with other correlations in term of experimental Sherwood number versus calculable Sherwood number by substituting experimental data from Table 3 to 7 in the correlations obtained :

Figure 15 and 16 show the comparison of this report with five correlations [1,3,11,12] for standard 6-blade turbine.

Figure 17 shows the comparison of this work with two correlations [1,12] for marine propeller.

Figure 18 shows the comparison of this work with Keey and Colen's correlation [13] for paddle.

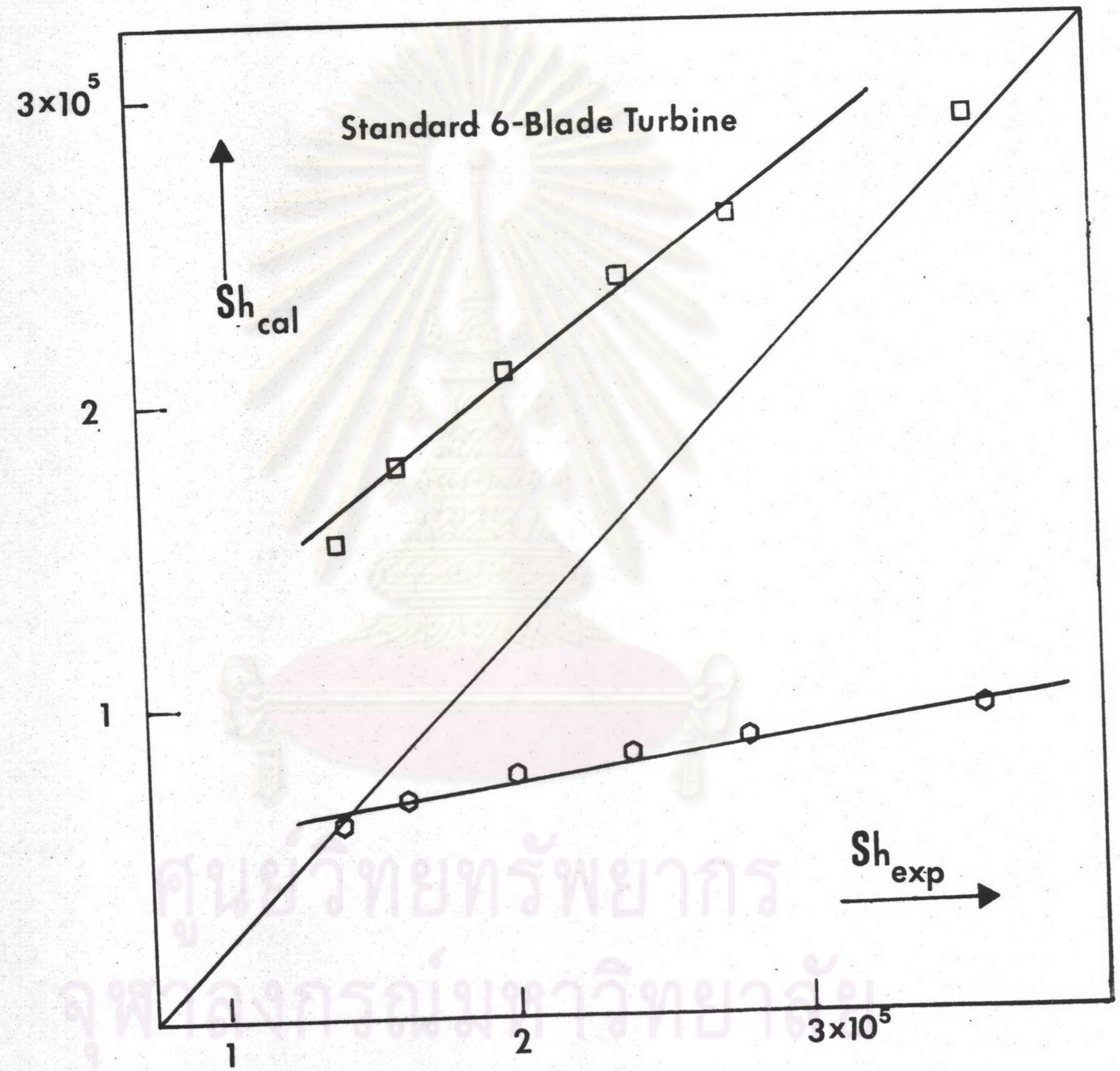

Figure 15 Comparison with other investigations

□ HUMPHREY and VAN NESS

○ HIXSON and BAUM

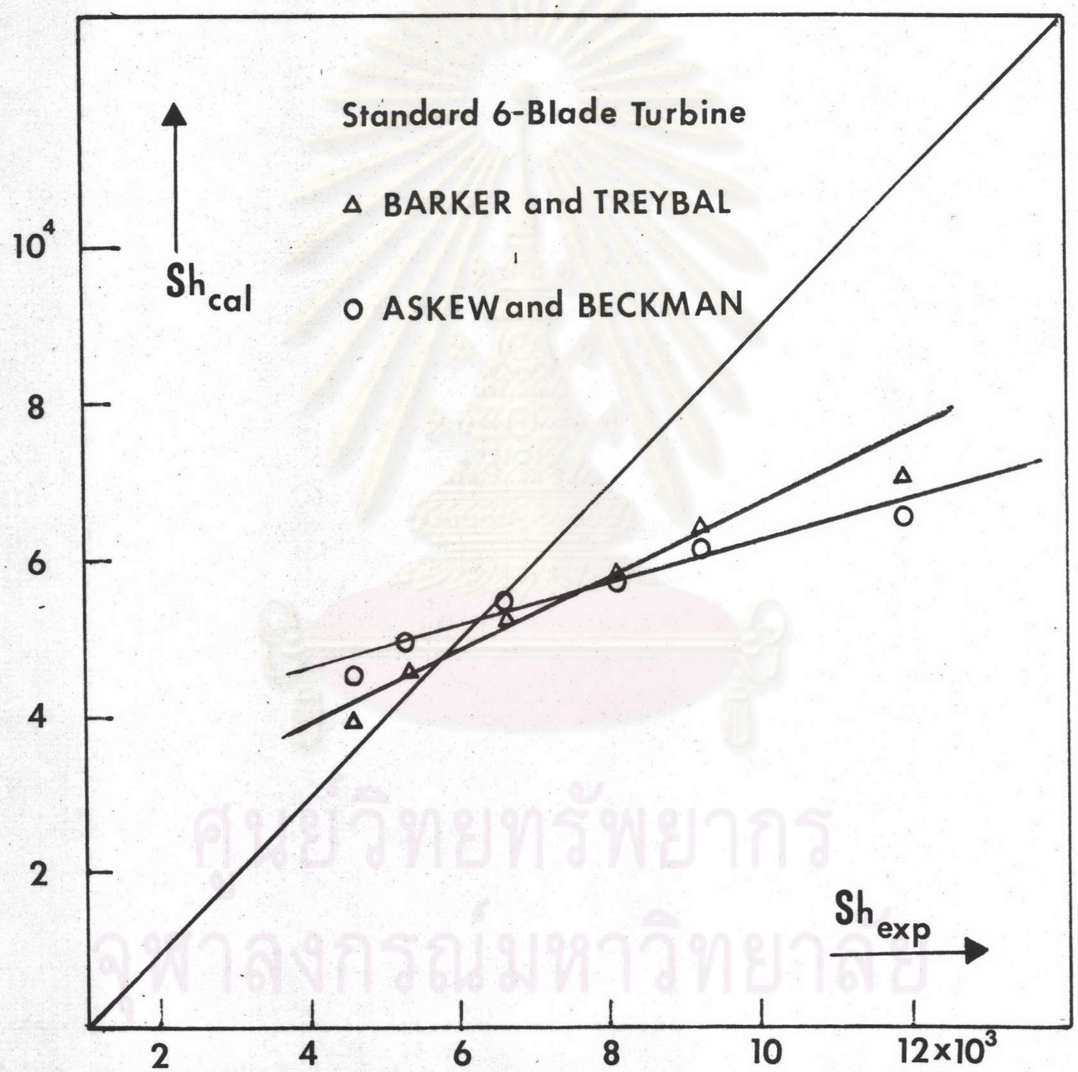

Figure 16 Comparison with other investigations

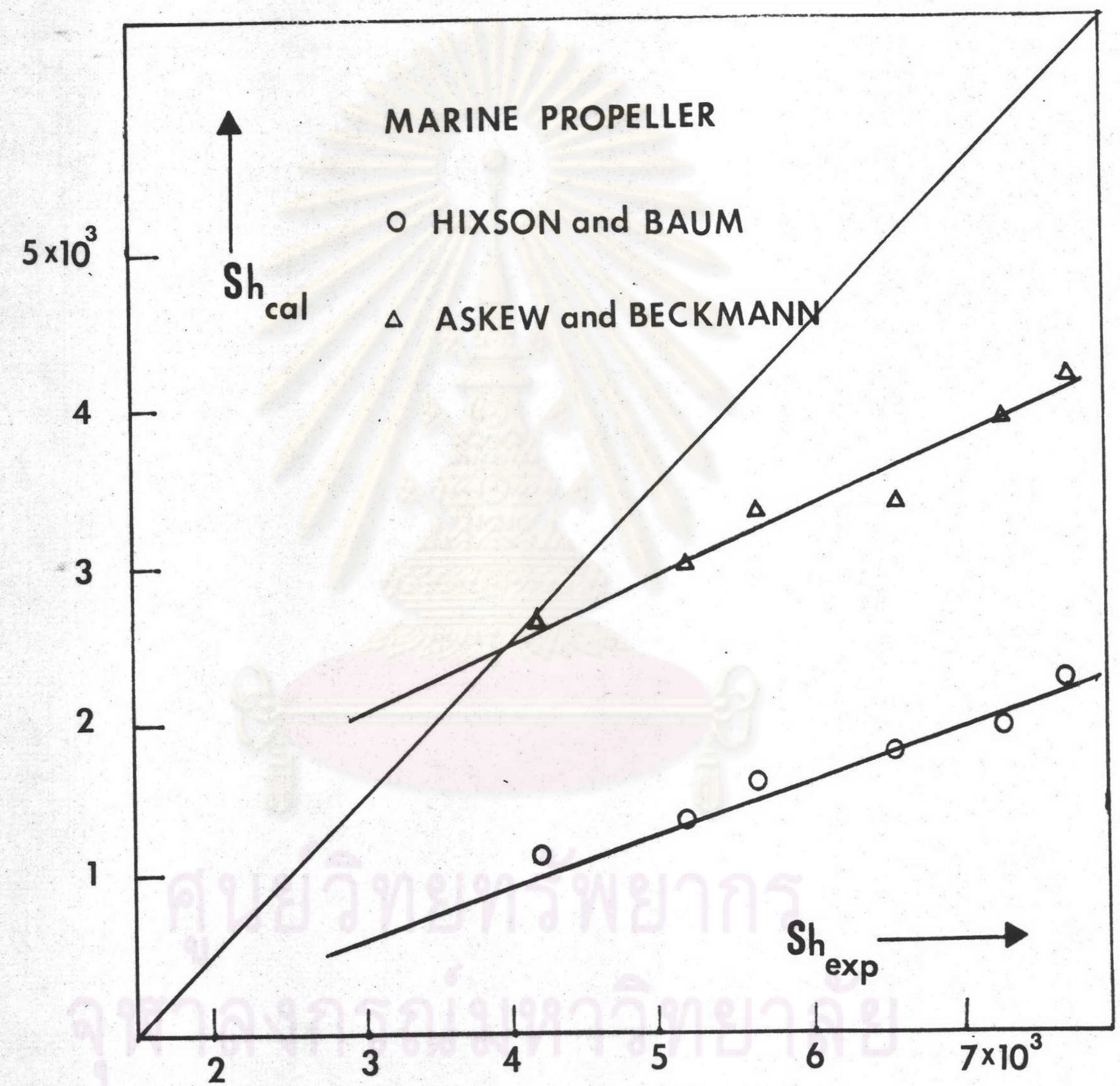

Figure 17 Comparison with other investigations

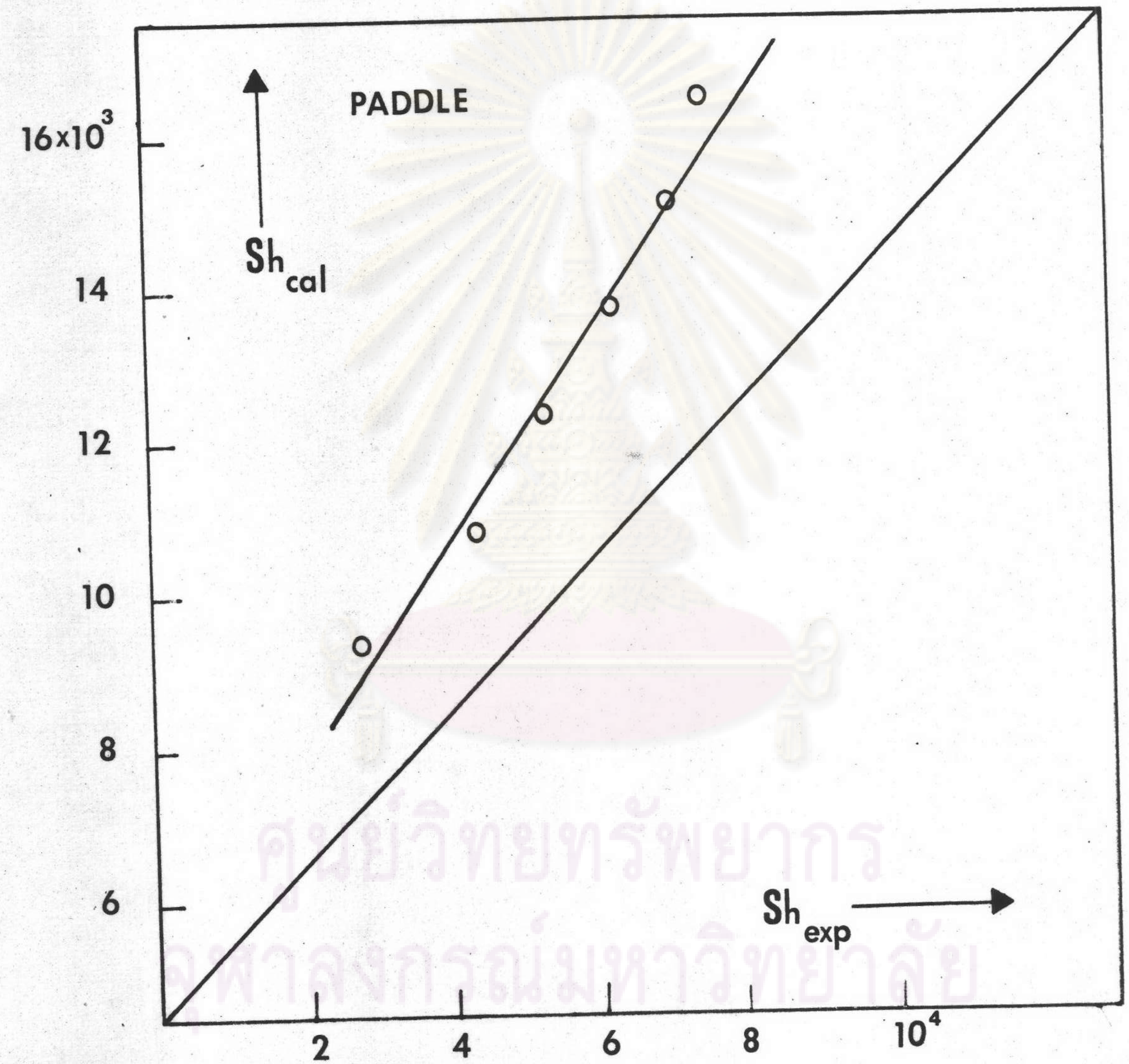

Figure 18 Comparison with KEEY and GLEN