References

1. Rojanapanthu, P., S. Siripaiwan, N. Yukuntapompong, N. Teerawatanasuk and S. Thongthep, "*Ocimum canum* seeds I : Mucilage separation", Mahidol Univ J Pharm Sci, **10**, 19, 1983.

2. Rojanapanthu, P., S. Siripaiwan, N. Yukuntapompong, N. Teerawatanasuk, and S. Thongthep, "*Ocimum canum* seeds II : Properties of dried mucilage", Mahidol Univ J Pharm Sci, **12**, 1, 1985.

3. Porter, H. F., G. A. Schurr, D. F. Wells and K. T. Semrau, "Solid drying and gas-solid systems", Perry's Chemical Engineers Handbook, (Perry, P. H., and D. Green, eds), pp. 70, 6th ed., McGraw Hill, New York, 1984.

4. Hetsroni, G., Handbook of Multiphase System, pp. 8-47, McGraw Hill, Washington, 1982.

5. Leva, M., and C. Y. Wen, "Elutriation", Fluidization, (Davidson, J. F. and D. Harrison, eds), pp. 627, Academic Press, New York, 1971.

6. Bird, R. S., W. E. Stewart and E. N. Lightfoot, Transport Phenomena, pp. 60, 182, John Wiley & Son, New York, 1960.

7. George, S. E., and J. R. Grace, "Entrainment of particles from aggregative fluidized beds", AIChE Symposium Series, **74** (176), 67, 1978.

8. Leva, M., "Elutriation of fines from fluidized systems", Chem Eng Prog., **47**, 39, 1951.

9. Yaki, S. and T. Aochi, "Elutriation of particles from a batch fluidized bed", Paper presented at the Society of Chemical Engineers (Japan), Spring Meeting, 1955, in Fluidization, (Davison, J. F. and D. Harrison eds), pp. 627, Academic Press, New York, 1971.

10. Thomas, W. J., P. J. Grey, and S. B.Watkins, "Effect of particle size distribution in fluidization", British Chem Eng, **6** (2), 176, 1961.

11. Kunii, D., and O. Levenspeil, Fluidization Engineering, pp. 77,100,303, John Wiley and Son, Inc., 1969.

12. Wen, C. Y., and L. H. Chen, "Fluidized bed freeboard phenomena : Entrainment and elutriation", AIChE J, **28**, 117, 1982.

13. Wen, C. Y. and L. H. Chen, "Flow model concepts of fluidized beds", Handbook of Fluid in Motion, (C. Cheremisinoff, N. P. and R. Gupta, eds.), pp. 683, Ann Arbor Science, 1983.

14. Large J. F., Y. Martinie, and M. A. Bergougnou, "Interpretative model for entrainment in large gas fluidized bed, Int Conf Powder and Bulk Solids Handling, May, 1976.

15. Mori, S., and C. Y. Wen, "Estimation of bubble diameter in gas fluidized beds", AIChE J, **21**, 109, 1975.

16. Cranfield, R. R., and D. Geldart, "Large particle fluidization", CES, **29**, 936, 1974.

17. Wen, C. Y., and Y. H. Yu, "A generalized method for predicting the minimum fluidization velocity", AIChE J, **12**, 610, 1966.

18. Zenz, F. A., and N. A. Weil, "A theoretical-empirical approch to the mechanism of particle entraiment from fluidized beds", AIChE J, **4**, 472, 1958.

19. Yate, J. G., Fundametal of Fluidized-Bed Chemical Process, pp. 9,39, Butterworths Monographs in Chemical Engineering, London, 1983.

20. Osberg, G. L., and D. H. Charlesworth, "Elutriation in a fluidized bed", Chem Eng Prog., **47**, 566, 1951.

21. Hanesian, D., and A. Rankell, "Elutriation from multisize particle fluidized beds", I &EC Fundamentals, **7** (3), 452, 1968.

22. Geldart, D., J. Cullinan, S. Georghiades, D. Giluray, and D. J. Pope, "The effect of fines on entrainment from gas fluidized beds", Transaction of I Chem E, **57**, 269, 1979.

23. Zenz, F., and D. F. Othmer, Fluidization and fluid-particle systems, Reinhold Pub. Corp., New York, 1960, in Yate, J. G., Fundametal of Fluidized-Bed Chemical Process, pp. 9,39, Butterworths Monographs in Chemical Engineering, London, 1983.

24. Tanaka, I., and H. Shinohara, "Estimation of the column height of a fluidized bed", International Chem. Eng, **18**, 276, 1978.

25. Ketusinh, O., and O. Arunlakshana, "Studies in foods and nutrition ; 2. Seeds of *Ocimum basilicum* as food and as drug", Siriraj Hospitol Gazette, **2**, (12), 593, 1950.

26. Siripaiwan, S., "Study on ocimum seed as bulk laxative drug", (unpublished)

27. ASTM Commitee E-29, Manual on Test Sieving Methods, pp. 13-, American Society for Testing and Materials, Philadephia, 1972.

28. Allen, T., Particle Size Measurement, 3rd ed., pp. 103, Chapman and Hall, London, 1981.

29. BS 2955, Glossary of Terms Relating to Powder, British Standards Institution, London, 1963.

30. BS 4359, Methods for the Determination of Specific Surface of Powders; Part 3. Calculation from the Particle Size Distribution,pp. 26-33, British Standards Institution, London, 1970.

31. Lewis, W. K., et al., "Entrainment from fluidized beds", CEP Symposium Series, **58**, 65, 1962, in Kunii, D., and O. Levenspeil, Fluidization Engineering, pp. 303, John Wiley and Son, Inc., 1969.

32. Liskin, M., Advanced dBaseIII Programming and Techniques, Osborne McGrawl Hill, California, 1986.

33. Turbo Basic Owner's Handbook, Borland International, California, 1987.

34. Miller, A. R., Turbo Basic Programs for Scientists and Engineers, Synbex, Sanfransisco, 1987.

35. Snedecor, G. W., and W. G. Cochran, Statistical Methods, 2nd ed., pp. 447, The Iowa State University Press, Iowa, 1968.

36. Mickley, H. S., T. S. Sherwood, and C. E. Reed., Applied Mathematic in Chemical Engireering, pp. 95, Tata McGraw Hill, New Delhi, 1981.

Appendix

Appendix A

A1 Specifications of anemometer, DATAMETRIC™, model 100-VT-D

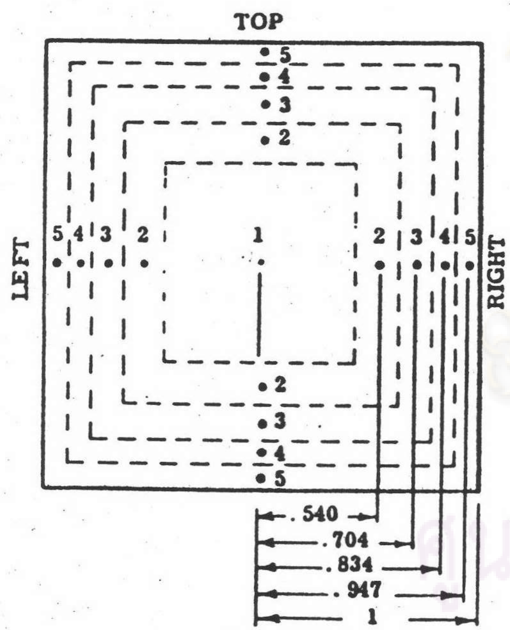
Specifications

Velocity Measurement ranges		
Low	0 to 600 FPM	0 to 3 m/sec.
High	600 to 6000 FPM	3 to 30 m/sec
Temperature Measurement range	$-50^{o}F$ to $+210^{o}F$	$-40^{o}C$ to $+100^{o}C$
Meter ambient temperature range	$+40^{o}F$ to $+150^{o}F$	$+5^{o}C$ to $+65^{o}C$
Meter size	$6\frac{1}{4}$ in. x $3\frac{3}{4}$ in.x$2\frac{3}{4}$	159 mm x 95 mm x 70 mm
Meter weight	Less than 2 lbs.	Less than 1 kg
Probe Size		
Diameter	3/8 in.	9.5 mm
Length(including sensor)	$7\frac{3}{4}$ in.	197 mm
Cable length	$7\frac{1}{2}$ ft	2.3 m

Sensor materials exposed to fluid medium	300-series stainless steel, Kel-f
Power requirements :	
Nicad battery pack: (meter input)	15 VDC 120 ma (as supplied by 100-VT's charger)
Battery charger:	115VAC or 230 VAC, 50-60Hz, depending on model. See ordering information below
Nominal time for continuous battery operation:	4 to 7 hours
Nominal time required to recharge fully discharged batteries:	4 hours

NOTE: Meter may be operated through charger during re-charging of batteries.

A2 Method for determining of air flow rate correction factor : The probe tip locations are indicated by dots



	LOCATION						
	1	2	3	4	5	SUM	AV
LEFT	1200	1200	1200	1150	700	5450	1090
RIGHT	1200	1200	1200	1140	630	5370	1074
TOP	1200	1300	1400	1220	750	5870	1174
BOTTOM	1200	1100	1000	960	420	4680	936
SUM	4800	4800	4800	4470	2500	21370	4274
AV	1200	1200	1200	1117	625	5342	1068

F_C @1200FPM $= \frac{1068}{1200} = .890$

Average velocity = F_C X Center Velocity

Appendix B

B1 Experimental data input form

ENTRAINMENT : DATA FORM Experimental No =

Particle cut size (mesh : micron)	wt. of sample and frame (grams)	wt. of frame (grams)
20-40...601.04	....	....
40-60...325.96	....	....
60-80...212.13	....	....
80-100..163.77	....	....
100-120..136.47	....	....
120-140..114.56	....	....
140-200...88.15	....	....
200-325...57.45	....	....
325- ...22.00	....	....

Superficial velocity (U) = ... m/s

Hight above fluidized bed (H) = ... m

Running time (t) = ... min

Bed hight from distributor (h) = ... m

Sample & Frame weight. __________kg. __________kg.

Frame weight __________kg. __________kg.

Sample weight : before run__________kg. after run__________kg.

B2 Report form ; results of estimation from Wen and Chen's model

Entrainment and Elutriation Rate : Experiment No. 903

Dpi	Xi	Uti	EiA1	FiA1	Fio	Fi
22.000	0.1649	0.0199781	5.72894247	0.94470264	7.84145297	1.07102103
57.450	0.0562	0.3146251	6.22933730	0.35008876	2.67246607	0.39262459
88.150	0.0231	0.4827538	5.81867447	0.13441138	1.09846912	0.15206871
114.560	0.0666	0.6273883	4.95031400	0.32969092	3.16701498	0.38165833
136.470	0.0839	0.7473785	4.02438005	0.33764547	3.98967776	0.40453478
163.770	0.0638	0.8968870	2.74921171	0.17539971	3.03386708	0.22775436
212.130	0.1764	1.1617307	0.63145943	0.11138945	8.38830994	0.26298653
325.960	0.2756	1.7851212	0.00000000	0.00000000	13.1055444	0.24003642
601.040	0.0896	3.2915978	0.00000000	0.00000000	4.26072856	0.07803797

DpMean (micron) =149.463 Surface Mean (micron) = 82.335
Free board hight (HI:m) = 1.000 Running time (T:sec) = 0
Superficial gas velocity (U:m/s) = 1.3000
Minimum fluidized velocity (Umf:m/s) = 0.0100339
Bubble diameter at bed surface (Db:m) = 0.05360
Total entrainment rate at bed surface (Fo:kg/sqr.m-s) = 47.5527760
Total elutriation rate (F:kg/sqr.m-s) = 3.2107227

Entrainment and Elutriation Rate : Experiment No. 904

Dpi	Xi	Uti	EiA1	FiA1	Fio	Fi
22.000	0.1649	0.0199781	5.26680832	0.86849672	6.67003312	0.97475556
57.450	0.0562	0.3146251	5.58006457	0.31359964	2.27323141	0.34949154
88.150	0.0231	0.4827538	5.09054503	0.11759159	0.93437089	0.13255142
114.560	0.0666	0.6273883	4.20134458	0.27980956	2.69390060	0.32402518
136.470	0.0839	0.7473785	3.28765690	0.27583440	3.39366733	0.33293951
163.770	0.0638	0.8968870	2.06776416	0.13192335	2.58064341	0.17677323
212.130	0.1764	1.1617307	0.21968118	0.03875176	7.13519615	0.16872767
325.960	0.2756	1.7851212	0.00000000	0.00000000	11.1477318	0.20417783
601.040	0.0896	3.2915978	0.00000000	0.00000000	3.62422637	0.06638002

DpMean (micron) =149.463 Surface Mean (micron) = 82.335
Free board hight (HI:m) = 1.000 Running time (T:sec) = 0
Superficial gas velocity (U:m/s) = 1.2300
Minimum fluidized velocity (Umf:m/s) = 0.0100339
Bubble diameter at bed surface (Db:m) = 0.05240
Total entrainment rate at bed surface (Fo:kg/sqr.m-s) = 40.4489560
Total elutriation rate (F:kg/sqr.m-s) = 2.7298220

Appendix C

C1 Listing of computer program : DATA.prg

```
* Program DATA.prg : Entrainment experimental data management
* -----------------------------------------------------------------------------
* EXPDATA.dbf : Source data direct measure or detected from experiment
*      INPFORM.fmt : Monitor display format for editing of experimental data
*      EXPNO.ndx   : Index for searching, key field "Experimental No.:RECNO"
* PCLEANAL.PRG : Program for particle size analysis of data in EXPDATA.dbf
*      PCLEDATA.dbf : Output result of PCLEANAL.prg and data used for
*                calculation of Eantrainment Rate
*      SIZEFORM.fmt  : Monitor display format for editing of PCLEDATA.dbf
*      VARIABLE.txt  : Sequential file tranfered from PCLEDATA.dbf,
*                which could be called by ENTRAIN.bas (.EXE)
set talk off
set echo off
do while .t.
clear all
store space(1) to A
clear
   text
                  ____________________________________________________

                       Entrainment :Experimental Data Analysis
                  ____________________________________________________


                            1. Input of Experimental Data

                            2. Edit of Experimental Data

                            3. Particle Size Analysis

                            4. Calculate Entrainment Rate

                            5. Report

                            6. Quit  ( 0 = exit program )
                  ____________________________________________________

                                  Select Choice ?
                  ____________________________________________________

   endtext
   @ 21,42 get A
   read
```

C1 (continue)

```
do case
   case A = "1"
      use b:expdata.dbf index expno
      set form to inpform.fmt
      appe
      reindex
      clos data
   case A = "2"
      EXP = 0
      use b:expdata index expno
      go top
      @ 23,18 say "* Enter Experimental No. *"
      @ 23,45 get EXP pict "###"
      read
      seek EXP
      set form to inpform
      edit
      clos data
   case A = "3"
     do a:pcleanal
   case A = "4"
     run a:entrain.exe
     use b:result.dbf index resultno
     appe from b:evadata.txt deli
     reindex
     clos data
   case A = "5"
     do report
   case A = "6"
     quit
   case A = "0"
     retu
   otherwise
     @ 22,20 say "*** Choice Error : Reentry !***"
     WAIT
     loop
  endcase
enddo
set talk on
set echo on
retu
```

C1 (continue)

```
* Program : PCLEANAL.prg
set talk off
set echo off
clear
  EXP = 0
  MEAN = 0
  Y = space(1)
  SUMLOG = 0
  REC = 0
sele 1
use b:expdata.dbf index expno
sele 2
use b:pcledata.dbf
zap
sele 1
go top
  @ 3,3 say "*** Enter Experimental No. ***" get EXP PICTURE "###"
  @ 4,3 say "*** Generated Remaining Data (Y/N)" get Y
  read
  @ 20,10 say "*** In Processing Now : Please Wait ! ***"
  seek EXP
  REC = recno()
do while .not. eof()
   SAMWT  = (SF40-F40)+(SF60-F60)+(SF80-F80)+(SF100-F100)+(SF120-F120)
            +(SF140-F140)+(SF200-F200)+(SF325-F325)+(SFRAME-FRAME)
   repl X_FR  with (SFRAME-FRAME)/SAMWT
   repl CU_FR  with X_FR*100
   repl X_325 with (SF325-F325)/SAMWT
   repl CU_325 with CU_FR+X_325*100
   repl X_200 with (SF200-F200)/SAMWT
   repl CU_200 with CU_325+X_200*100
   repl X_140 with (SF140-F140)/SAMWT
   repl CU_140 with CU_200+X_140*100
   repl X_120 with (SF120-F120)/SAMWT
   repl CU_120 with CU_140+X_120*100
   repl X_100 with (SF100-F100)/SAMWT
   repl CU_100 with CU_120+X_100*100
   repl X_80  with (SF80-F80)/SAMWT
   repl CU_80  with CU_100+X_80*100
   repl X_60  with (SF60-F60)/SAMWT
   repl CU_60  with CU_80+X_60*100
   repl X_40  with (SF40-F40)/SAMWT
   repl CU_40  with CU_60+X_40*100
```

C2 Listing of computer program : PCLEANAL.prg

```
    store LOG(SAM_40)*X_40+LOG(SAM_60)*X_60+LOG(SAM_80)*X_80
          +LOG(SAM_100)*X_100+LOG(SAM_120)*X_120+LOG(SAM_140)*X_140
          +LOG(SAM_200)*X_200+LOG(SAM_325) *X_325+LOG(SAM_FR)*X_FR to SUMLOG
    repl DPMEAN with exp(SUMLOG)
    SUMSUR =  X_40/SAM_40+X_60/SAM_60+X_80/SAM_80+X_100/SAM_100+X_120/SAM_120
             +X_140/SAM_140+X_200/SAM_200+X_325/SAM_325+X_FR/SAM_FR
    repl SURMEAN with 1/SUMSUR
@ 20,10 clear
@ 6,10 say "Experimental No. = "
@ 6,31 say EXPNO pict "###"
@ 8,10 say "SUM LOG ="
@ 8,21 say SUMLOG pict "####.####"
@ 9,10 say "Mean Particle Diameter = "
@ 9,36 say DPMEAN pict "####.####"
@ 10,10 say " Surface Mean Diameter = "
@ 10,36 say SURMEAN pict "####.####"
    sele 2
    appe blank
      repl EXPNO with expdata->EXPNO
      repl U with expdata->U
      repl HI with expdata->HI
      repl T with expdata->T
      repl H with expdata->H
      repl DPMEAN with expdata->DPMEAN
      repl SURMEAN with expdata->SURMEAN
      repl SAM_40  with expdata->SAM_40
      repl SAM_60  with expdata->SAM_60
      repl SAM_80  with expdata->SAM_80
      repl SAM_100 with expdata->SAM_100
      repl SAM_120 with expdata->SAM_120
      repl SAM_140 with expdata->SAM_140
      repl SAM_200 with expdata->SAM_200
      repl SAM_325 with expdata->SAM_325
      repl SAM_FR  with expdata->SAM_FR
      repl X_40  with expdata->X_40
      repl X_60  with expdata->X_60
      repl X_80  with expdata->X_80
      repl X_100 with expdata->X_100
      repl X_120 with expdata->X_120
      repl X_140 with expdata->X_140
      repl X_200 with expdata->X_200
      repl X_325 with expdata->X_325
      repl X_FR  with expdata->X_FR
```

C2 (continue)

```
   repl X_60  with expdata->X_60
   repl X_80  with expdata->X_80
   repl X_100 with expdata->X_100
   repl X_120 with expdata->X_120
   repl X_140 with expdata->X_140
   repl X_200 with expdata->X_200
   repl X_325 with expdata->X_325
   repl X_FR  with expdata->X_FR
   repl CU_40  with expdata->CU_40
   repl CU_60  with expdata->CU_60
   repl CU_80  with expdata->CU_80
   repl CU_100 with expdata->CU_100
   repl CU_120 with expdata->CU_120
   repl CU_140 with expdata->CU_140
   repl CU_200 with expdata->CU_200
   repl CU_325 with expdata->CU_325
   repl CU_FR  with expdata->CU_FR
  if upper(Y) <> "Y"
     exit
  endif
  sele 1
  skip
enddo
sele 2
go REC
set format to sizeform
edit
copy to b:variable deli
clos all
retu
```

C3 Listing of computer program : ENTRAIN.exe(.bas)

```
REM : ENTRAIN.exe(bas)
REM : Program for Estimation of Entrainment and Elutriation Rate
'     of Fluidized Bed
'
'     Calculation procedure was based on Wen and Chen Model:1982,1983
'     Developed by:  Nu Somjanyakul,1987-88
'_____________________________________________________________________
cls
clear
$include "b:TITLE.bas"
gosub Anykey
cls

defdbl U,D,V,R,F,E
dim X(1:9)
dim Dp(1:9)
dim CU(1:9)
dim Ut(1:9)
dim FiAl(1:9)
dim Fio(1:9)
dim Fi(1:9)
YN$ = ""
locate 1,10
input "Constant Data File Exit ! (Y/N) ";YN$
if ucase$(YN$)="N" then
  $include "b:inputcon.bas"
end if

$include "b:opencons.bas"
delay 3
cls

close #1
DEF FN ReNo(V,D) = DenP*V*D#/Vis#      'particle Renold's Number

rem :------------------------------------------Cal. Terminal velocity
open "b:VARIABLE.txt" for input as 2
input #2, ExpNo%,U,HI,t,h,_
        Dp(1),X(1),Cu(1),Dp(2),X(2),Cu(2),Dp(3),X(3),Cu(3),_
        Dp(4),X(4),Cu(4),Dp(5),X(5),Cu(5),Dp(6),X(6),Cu(6),_
        Dp(7),X(7),Cu(7),Dp(8),X(8),Cu(8),Dp(9),X(9),Cu(9),_
        SamDpMean,SamDsm
close #2
```

C3 (continue)

```
for j% = 1 to 9      'Cal. Ut  Loop--------------------------
do
Dp(j%) = Dp(j%)*10^-6     'convert to SI unit
Ut(j%) = ((3.1*(DenP-DenG)*g*Dp(j%)*Shape)/DenG)^(1/2)
Re = FNReNo(Ut(j%),Dp(j%)*Shape)
IF Re>500 THEN
   GOSUB Report
   PRINT "( 500 < Re < 200,000 ) "
   exit loop
ELSE
   Ut(j%) = ((4*(DenP-DenG)^2*g^2)/(225*DenG*Vis#))^(1/3)*Dp(j%)*Shape
   Re = FNReNo(Ut(j%),Dp(j%)*Shape)
   IF Re>.4 AND Re<=500 THEN
      GOSUB Report
      PRINT "(  0.4 < Re < 500 ) "
      exit loop
   else
      Ut(j%) = (Dp(j%)*Shape^2*(DenP-DenG)*g)/(18*Vis#)
      Re = FNReNo(Ut(j%),Dp(j%)*Shape)
      GOSUB Report
      print "( Re < 0.4 ) "
      exit loop
   end if
END IF
loop
rem

next j%    'End Cal. Ut  LOOP--------------------------------------
delay 1

   '-------------Basic Information
   Eqn$ = ""
   cls
   locate 2,3 : print "Calculation of Minimum Fluidization Velocity ( SI Unit )"
   locate 3,3 : print "------------------------------------------------------------
   locate 5,3
   print "[ 1 = Equation of Wen & Yu  or  2 = Group A Powders : Geldart's Equation ]"
   do
     locate 6,3
     input "Select Number  ( 1 or 2 ) "; Eqn$
       if Eqn$="1" or Eqn$="2" then
       exit loop
     end if
     gosub PrnErr
   loop
```

C3 (continue)

```
locate  9,3 : print "Estimation of Bubble Diameter in Gaseous Fluidied Bed"
locate 10,3 : print "Equation of Mori and Wen, (AIChE J, 21:109-115, 1975)"
locate 11,3 : print "Unit Used in The Empirical Formula : CGS
locate 12,3 : print "_______________________________________________________________
locate 14,3
print "Type of Distributor Plate [ 1 = Perforated plate, 2 = Porous plate ]"
do
  locate 15,3 : input "Select 1 or 2";Type$
  if Type$="1" or Type$="2" then
    exit loop
  end if
  gosub PrnErr
loop
'--------------------------------------Basic Information

rem :-------------Cal. Umf
DpMean# = DpMean!*10^-6
Dsm# = Dsm!*10^-6
select  case Eqn$
case = "1"
   Ga# = ((DpMean#*Shape)^3*DenG*(DenP-DenG)*g)/(Vis#^2)
   MF# = (33.7^2+(0.0408*Ga#))^(1/2)-33.7
   Umf# = (MF#*Vis#)/(DenG*(DpMean#*Shape))
case = "2"
   locate 8,3
   print "{ Group A powders : 30 < dp < 150  micron ,  Particle Density < 1,500  }"
   Umf# = (9e-4*(DenP-DenG)^0.934*g^0.934*Dsm^1.8)/(Vis#^0.87*DenG^.066)
end select

cls
open "b:VARIABLE.txt" for input as 2
open "b:EVADATA.txt" for output as 3

DO WHILE NOT EOF(2)    '========================================EOF LOOP

   input #2, ExpNo%,U,HI,t,h,_
          Dp(1),X(1),Cu(1),Dp(2),X(2),Cu(2),Dp(3),X(3),Cu(3),_
          Dp(4),X(4),Cu(4),Dp(5),X(5),Cu(5),Dp(6),X(6),Cu(6),_
          Dp(7),X(7),Cu(7),Dp(8),X(8),Cu(8),Dp(9),X(9),Cu(9),_
          SamDpMean,SamDsm
```

C3 (continue)

```
rem :----------Cal. Bubble diameter at bed surface
AAc = Ac*10^4     'covert to CGS
hh = h*100
DDc = Dc*100
UUmf = (U-Umf)*100
select case Type$
case "1"
   Dbo = 0.347*(AAc*UUUmf/Nd%)^(2/5)
case "2"
   Dbo = 0.00376*UUUmf^2
end select
Dbm = 0.652*(AAc*UUUmf)^(2/5)
Db = Dbm-(Dbm-Dbo)*EXP(-0.3*hh/DDc)
Db = Db*10^-2     'convert to SI

rem :-----------Cal. Total entrainment rate at bed surface
UUmf = U-Umf
Fo = (3.07E-9*DenG^3.5*g^.5*UUmf^2.5*Ac*Db)/Vis^2.5


cls
locate 2,2
print "Entrainment and Elutriation Rate of Experimental No. ";ExpNo%
locate 3,2
print "=============================================================================="
locate 4,2
print "  Dpi      Xi      Uti     EiAl     FiAl     Fio      Fi"
locate 5,2
print "------------------------------------------------------------------------------"

F = 0
for j% = 1 to 9     'Cal.Ent Rate------------------------ 9 DATA POINT

  Dp(j%) = Dp(j%)*10^-6

  UUt = U - Ut(j%)
  if UUt>0 then
     K# = (DenP/(Dp(j%)*Shape)^2)*(Vis#/DenG)^2.5
     Rep =DenG*UUt*Dp(j%)*Shape/Vis#
     if ( Rep<=2.38/Dc ) then
       Lamb# = 5.17*Rep^(-1.5)*Dc^2/K#
     else
       Lamb# = 12.3*Rep^(-2.5)*Dc/K#
     end if
     Epsilon# = (1+(Lamb#*UUt^2)/(2*g*Dc))^(-1/4.7)
     EiAl(j%) = DenP*(1-Epsilon#)*UUt
```

C3 (continue)

```
    else
       EiAl(j%) = 0
    end if

    FiAl(j%) = EiAl(j%)*X(j%)       '---Cal. elutriation rate of particle i

    Fio(j%) = Fo*X(j%)         '--Cal. entrainment rate of particle i (surface)

    Fi(j%) = FiAl(j%)+(Fio(j%)-FiAl(j%))*Exp(-a*HI)

    F = F + Fi(j%)

    Dp(j%) = Dp(j%)*10^6

    locate 6+j%,2  : print using "###.###";Dp(j%)
    locate 6+j%,11 : print using "#.####";X(j%)
    locate 6+j%,20 : print using "#.###^^^^";Ut(j%)
    locate 6+j%,32 : print using "#.###^^^^";EiAl(j%)
    locate 6+j%,44 : print using "#.###^^^^";FiAl(j%)
    locate 6+j%,56 : print using "#.###^^^^";Fio(j%)
    locate 6+j%,68 : print using "#.###^^^^";Fi(j%)

next j%      '---------------------------------------------- 9 DATA POINT

locate 16,2
print "----------------------------------------------------------------------------"
locate 17,2
print "                    Superficial velocity (U:m/s) = ";
print using "#.###";U
locate 18,2
print "                          Free board high (H:m) = ";
print using "#.###";HI
locate 19,2
print "             Minimum fluidized velocity (Umf:m/s) = ";
print using "##.###^^^^";Umf
locate 20,2
print "        Bubble diameter at bed Surface (Db:m) = ";
print using "##.###^^^^";Db
locate 21,2
print "Total entrainment rate at bed surface (Fo:Kg/sqr.m-s) = ";
print using "##.###^^^^";Fo
locate 22,2
print "    TOTAL ELUTRIATION RATE OF PARTICLE (F:Kg/sqr.m-s) = ";
```

C3 (continue)

```
  print using "##.###^^^^";F#
  locate 23,2
  print "____________________________________________________________"
  gosub Anykey

  write# 3, ExpNo%,U,HI,t,Umf,Db,Fo,F,SamDpMean,SamDsm,_
            Dp(1),X(1),Ut(1),EiAl(1),FiAl(1),Fio(1),Fi(1),_
            Dp(2),X(2),Ut(2),EiAl(2),FiAl(2),Fio(2),Fi(2),_
            Dp(3),X(3),Ut(3),EiAl(3),FiAl(3),Fio(3),Fi(3),_
            Dp(4),X(4),Ut(4),EiAl(4),FiAl(4),Fio(4),Fi(4),_
            Dp(5),X(5),Ut(5),EiAl(5),FiAl(5),Fio(5),Fi(5),_
            Dp(6),X(6),Ut(6),EiAl(6),FiAl(6),Fio(6),Fi(6),_
            Dp(7),X(7),Ut(7),EiAl(7),FiAl(7),Fio(7),Fi(7),_
            Dp(8),X(8),Ut(8),EiAl(8),FiAl(8),Fio(8),Fi(8),_
            Dp(9),X(9),Ut(9),EiAl(9),FiAl(9),Fio(9),Fi(9)

LOOP     '==================================================EOF LOOP

close #2
close #3

END

'_______________________________________________________

Anykey:
  locate 24,2
  print "press any key to continue !"
while  not instat
wend
Char$ = inkey$
return

'_______________________________________________________

Report:
  print j%;
  print " (Ut) = ";Ut(j%)
  print " Re = ";Re;
return

'_______________________________________________________

PrnErr:
  locate 24,2
  print "*** Data Entry Error ***"
  beep 3
  locate 24,2
  print "                              "
return
```

Appendix D

Example calculation of computer program ENTRAIN.exe

Basic information (ambient condition) :

ρ_s	=	1400	kg/m^3
ρ_g	=	1.1032	kg/m^3
μ_g	=	1.8464×10^{-5}	kg/m.s
D	=	0.254	m
g	=	9.80665	m/s^2
h	=	0.05	m
H	=	1	m
A_c	=	0.05067	m^2
N_d	=	552	-
d_p	=	149.463	μm
d_{sm}	=	82.335	μm
d_{pi}	=	22.00	μm
X_i	=	0.1649	-
a	=	4	m^{-1}
U	=	1.304	m/s

Particle terminal velocity : from equation 2.18

Stokes' law

$$U_t = \frac{d_{pi}^2 (\rho_s - \rho_g)\ g}{18\mu_g} \quad , \quad Re < 0.4$$

$$U_t = \frac{(22\times10^{-6})^2 (1400 - 1.1032)\ 9.80665}{18(1.8464 \times 10^{-5})}$$

$$= 0.0199 \quad m/s$$

$$Re = \frac{\rho_g\ U_t d_{pi}}{\mu_g}$$

$$= \frac{1.1032 \times 0.0199 \times 22\text{x}10^{-6}}{1.8464\text{x}10^{-5}}$$

$$= 0.0262 < 0.4$$

<u>Elutriation rate constant and Elutriation rate</u> : from equation 2.3, 2.15 - 2.17

$$E_{i\infty} = \rho_s\,(1 - \varepsilon_i)\,(U - U_t)$$

$$\varepsilon_i = [\,1 + \frac{\lambda(U - U_t)^2}{2gD}\,]^{-(1/4.7)}$$

$$\frac{\lambda\rho_s}{d_{pi}^2}\,\frac{\mu_g^{2.5}}{\rho_g^{2.5}} = \{\frac{(5.17Re_p^{-1.5}D^2\ ,\ Re_p \leq 2.38/D)}{(12.3Re_p^{-2.5}D\ ,\ Re_p \geq 2.38/D)}$$

$$Re_p = \frac{\rho_g(U - U_t)\,d_{pi}}{\mu_g}$$

$$= \frac{1.1032\,(1.304 - 0.0199)\,22\text{x}10\text{-}6}{1.8464\text{x}10\text{-}5}$$

$$= 1.688$$

$$\frac{2.38}{D} = \frac{2.38}{0.254}$$

$$= 9.37 \ > Re_p$$

$$\frac{\lambda\rho_s}{d_{pi}^2}\,\frac{\mu_g^{2.5}}{\rho_g^{2.5}} = 5.17\ Re_p^{-1.5}\,D^2$$

$$\frac{\lambda 1400}{(22\text{x}10^{-6})^2}\,\frac{(1.8464\text{x}10^{-5})^{2.5}}{1.1032^{2.5}} = (5.17)\ (1.686)^{-1.5}\ (0.254)^2$$

$$\lambda = 0.04588$$

$$\varepsilon_i = \left[1 + \frac{(0.04588)(1.304 - 0.0199)^2}{2 \times 9.80665 \times 0.254}\right]^{-(1/4.7)}$$

$$= 0.9968$$

$$E_{i\infty} = (1400)\ (1 - 0.9968)\ (1.304 - 0.0199)$$

$$= 5.74 \qquad \text{kg/m}^2\text{.s}$$

$$F_{ci} = E_{i\infty} X_i$$

$$= 5.74 \times 0.1649$$

$$= 0.94 \quad kg/m^2.s$$

Minimum fluidized velociy and Entrainment rate : from equation 2.9 - 2.14

$$\frac{F_o}{A_c D_b} = 3.07 \times 10^{-9} \frac{\rho_g^{3.5} g^{0.5}}{\mu^{2.5}} (U - U_{mf})^{2.5}$$

$$F_{oi} = F_o X_i$$

$$\frac{D_{bm} - D_b}{D_{bm} - D_{bo}} = \exp(-0.3h/D)$$

$$D_{bm} = 0.625 \left[A_c (U - U_{mf}) \right]^{2/5}$$

$$D_{bo} = 0.347 \left[\frac{A_c (U - U_{mf})}{N_d} \right]^{2/5}$$

$$Re_{mf} = \left[(33.7)^2 + 0.0408\, G_a \right]^{1/2} - 33.7$$

where $$Re_{mf} = \frac{U_{mf} d_{pi} \rho_g}{\mu_g}$$

and $$G_a = \frac{d_{pi}^3 \rho_g (\rho_s - \rho_g) g}{\mu_g^2}$$

$$G_a = \frac{(149.463 \times 10^{-6})^3 1.1032 (1400 - 1.1032) 9.80665}{(1.8464 \times 10^{-5})^2}$$

$$= 148.221$$

$$Re_{mf} = \frac{U_{mf} (149.463 \times 10^{-6}) (1.1032)}{1.8464 \times 10^{-5}}$$

$$= 8.93\, U_{mf}$$

$$Re_{mf} = \left[(33.7)^2 + (0.0408)(148.221) \right]^{1/2} - 33.7$$

$$U_{mf} = \frac{\left[(33.7)^2 + (0.0408)\,(148.221)\right]^{1/2} - 33.7}{8.93}$$

$$= 0.01 \quad m/s$$

Empirical correlation for calculating bubble diameter is in cgs unit

$$D_{bm} = 0.625\left[(506.74)\,(130.4 - 1)\right]^{2/5}$$

$$= 55.071 \quad cm$$

$$D_{bo} = 0.347\left[\frac{(506.7)\,(130.4 - 1)}{552}\right]^{2/5}$$

$$= 2.345 \quad cm$$

$$D_b = 5.37 \quad cm$$

$$\frac{F_o}{(0.0506)\,(0.0537)} = 3.07 \times 10^{-9}\,\frac{(1.1032)^{3.5}\,(9.80665)^{0.5}}{(1.8464 \times 10^{-5})^{2.5}}\,(1.304 - 0.01)^{2.5}$$

$$= 47.966 \quad kg/m^2s$$

$$F_{oi} = F_o X_{io}$$

$$= 47.966 \times .1649$$

$$= 7.91 \quad kg/m^2s$$

Appendix E

A sample worksheet of non linear regression analysis for curve fitting

Regression analysis : $Y = A + B\exp(kX)$

in form of $Y = a+bX1+cX2$

		X=time	Y= Xi/Xio	Xo	X1	X2	y (Y-Yave)	x1 (X1-X1ave)	x2 (X2-X2ave)	x1*x2	x1^2	x2^2	x1*y	x2*y
first approx=	**0.039** (6 point)	0	1.00000	1.0000	1.0000	0.0000	0.802	0.828	-0.178	-0.148	0.685	0.032	0.664	-0.143
suggest=	0.033	1	0.06317	1.0000	0.0330	1.0000	-0.135	-0.139	0.822	-0.115	0.019	0.675	0.019	-0.111
		2	0.03933	1.0000	0.0011	0.0660	-0.159	-0.171	-0.112	0.019	0.029	0.013	0.027	0.018
test value =	0.033	3	0.02741	1.0000	0.0000	0.0033	-0.171	-0.172	-0.175	0.030	0.030	0.031	0.029	0.030
		4	0.03218	1.0000	0.0000	0.0001	-0.166	-0.172	-0.178	0.031	0.030	0.032	0.029	0.030
coeff of det. =	0.9999	5	0.02741	1.0000	0.0000	0.0000	-0.171	-0.172	-0.178	0.031	0.030	0.032	0.029	0.030
Sum =		15.000	1.190	6.000	1.034	1.069	0.000	0.000	0.000	-0.151	0.823	0.814	0.797	-0.146
mean =		2.500	0.198		0.172	0.178								

D =	*0.6467*
A =	0.0312
B =	0.9688
k =	-3.4112
Coeff of det. =	0.999897
C =	0.0005
z =	0.9999

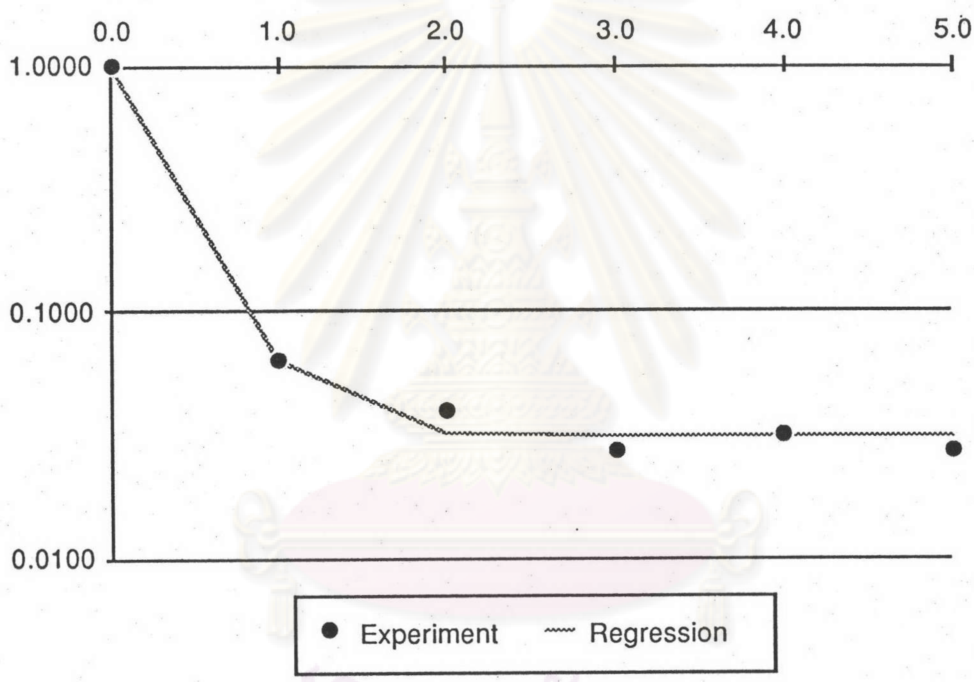
Compared Yexp & Ycal

	Experiment	Regression	Calculate	y^2	Yreg^2
0.0	1.0000	1.0000	1.0000	0.643	0.643
1.0	0.0632	0.0636	0.0632	0.018	0.018
2.0	0.0393	0.0323	0.0323	0.025	0.028
3.0	0.0274	0.0312	0.0312	0.029	0.028
4.0	0.0322	0.0312	0.0312	0.028	0.028
5.0	0.0274	0.0312	0.0312	0.029	0.028

Note : Yreg = Ycal-Yave

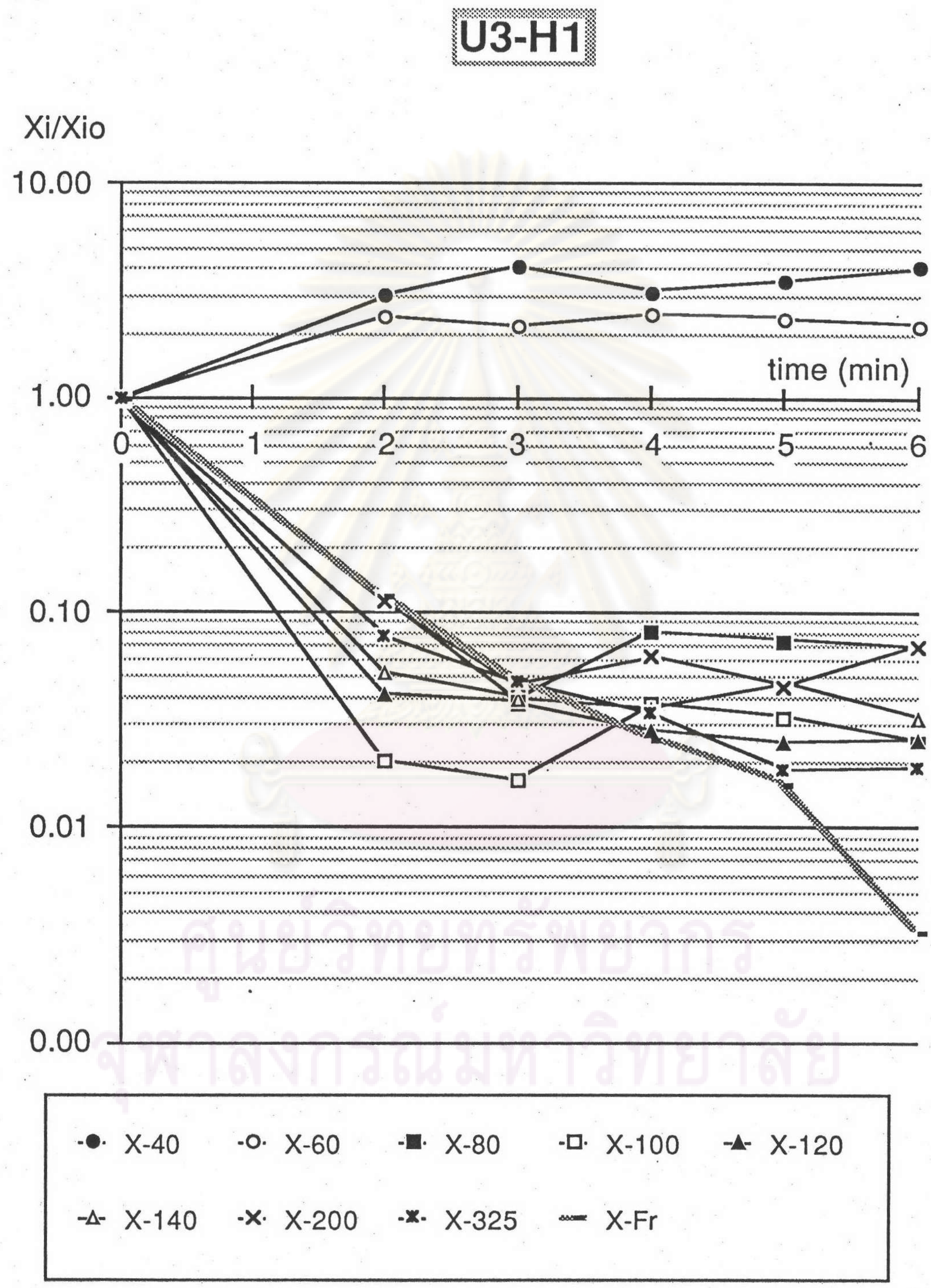
Calculate = a + bx1 + cx2

An example resulting cuvre from regression analysis

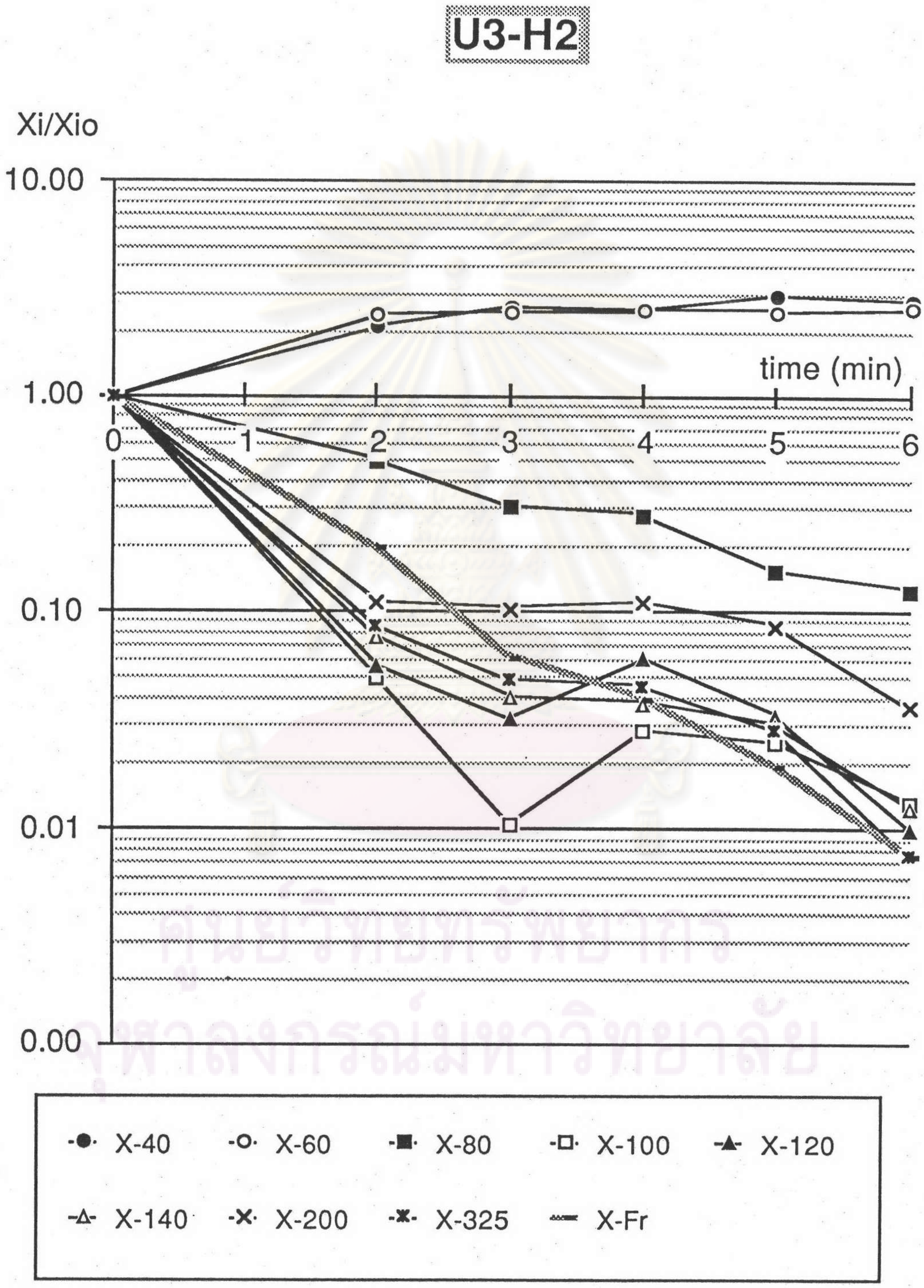


Appendix F

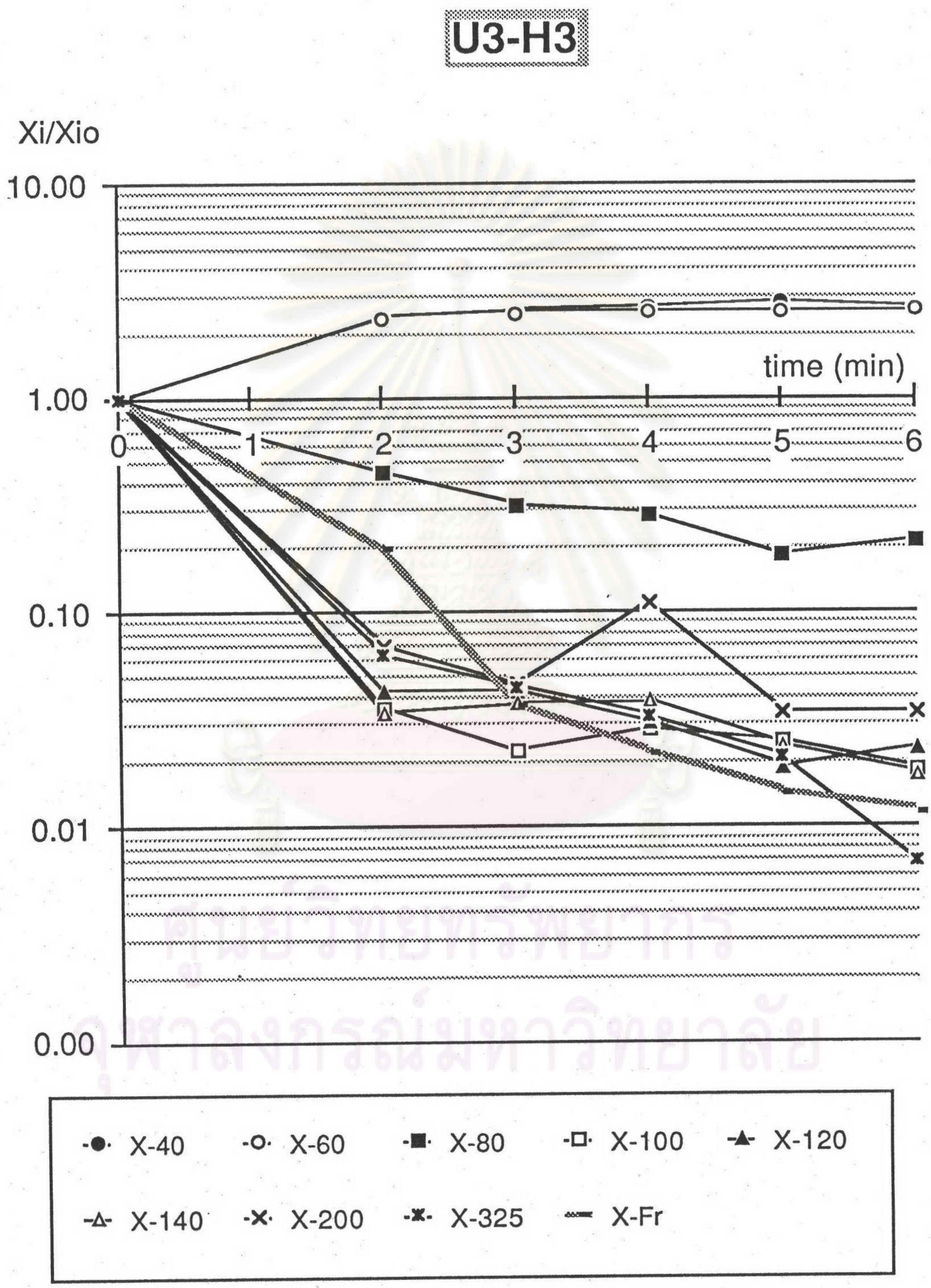
F1.1 Plot of X_i/X_{io} versus time from experimental data set U3H1



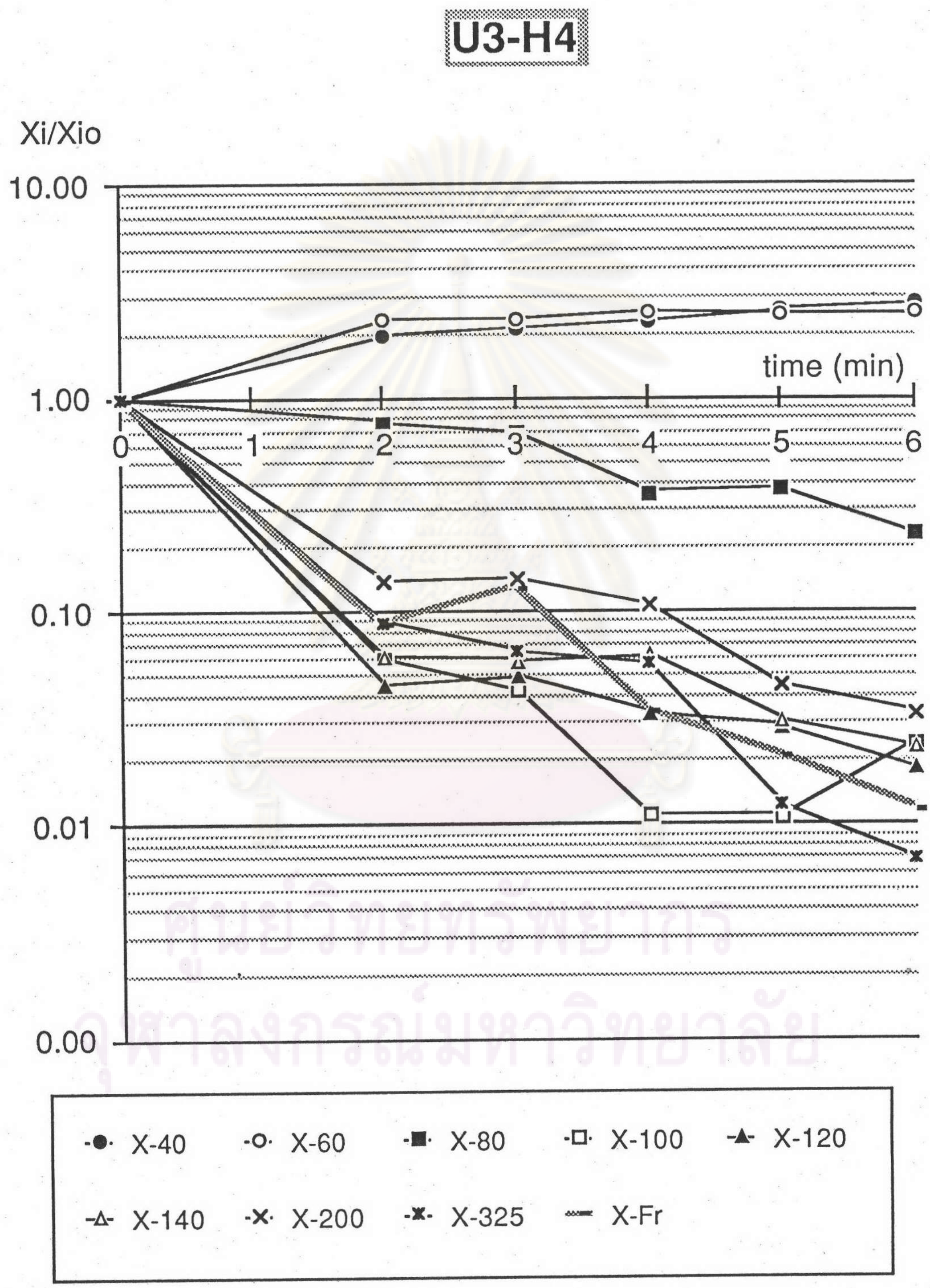
F1.2 Plot of X_i/X_{io} versus time from experimental data set U3H2



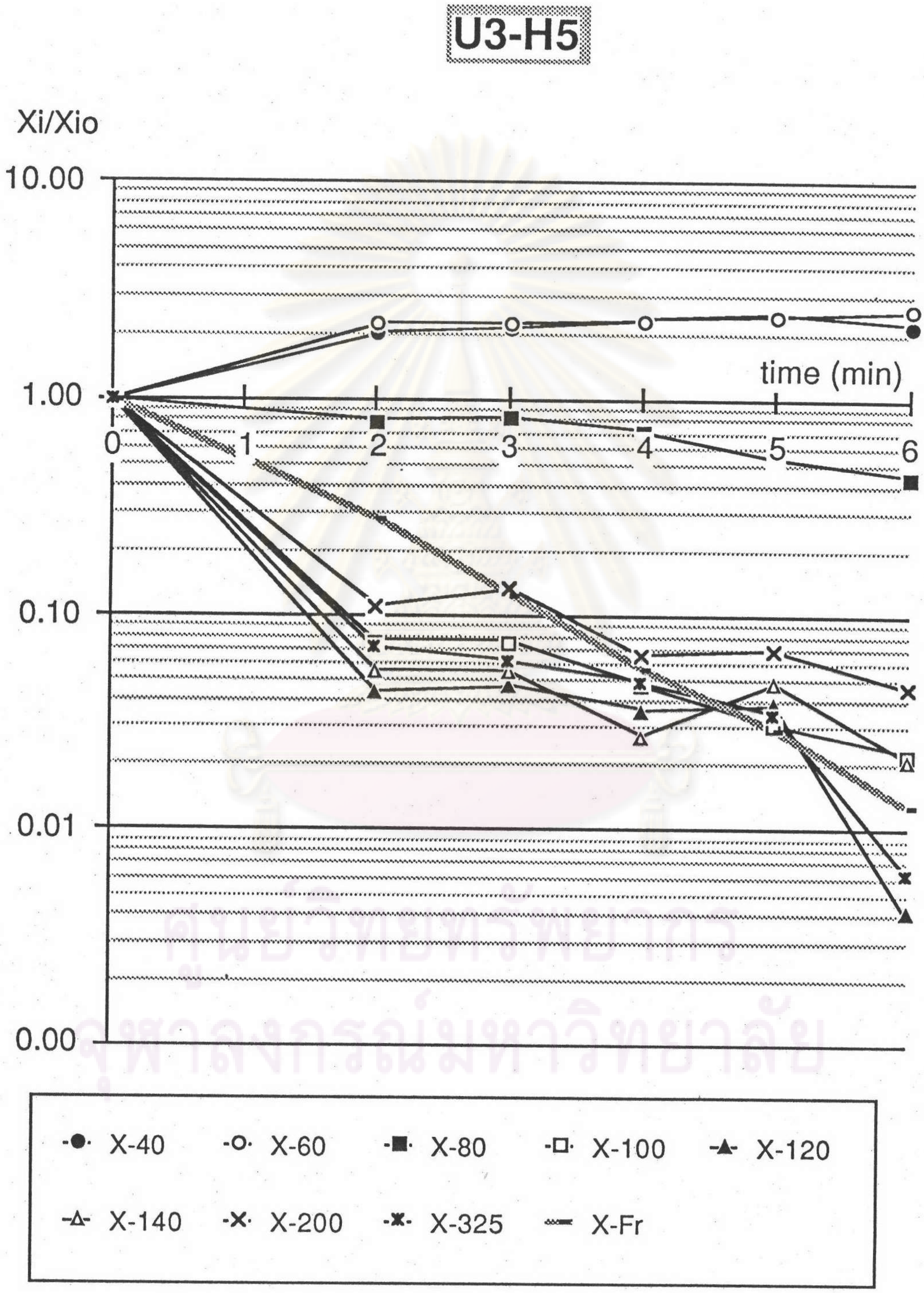
F1.3 Plot of X_i/X_{io} versus time from experimental data set U3H3



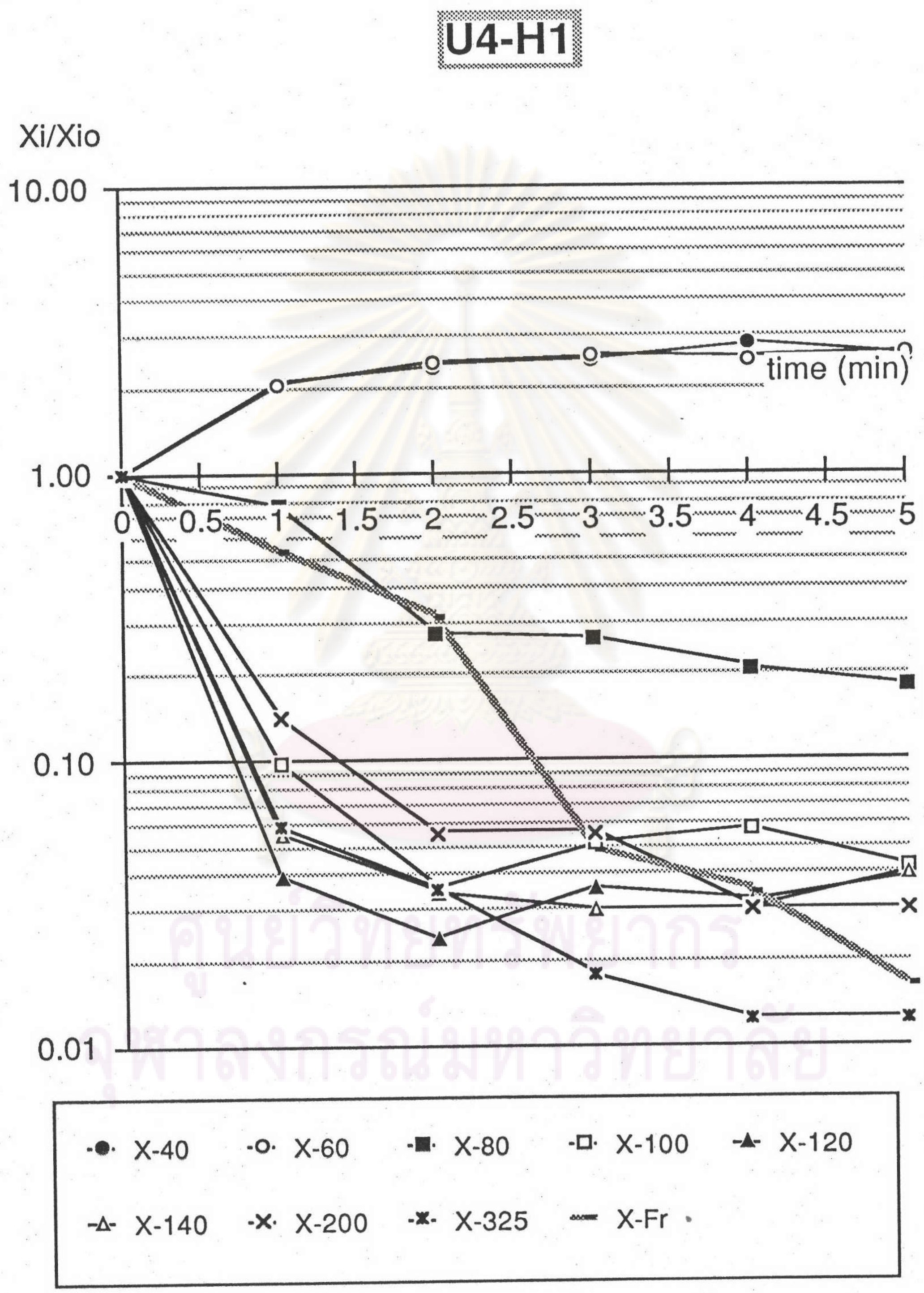
F1.4 Plot of X_i/X_{io} versus time from experimental data set U3H4



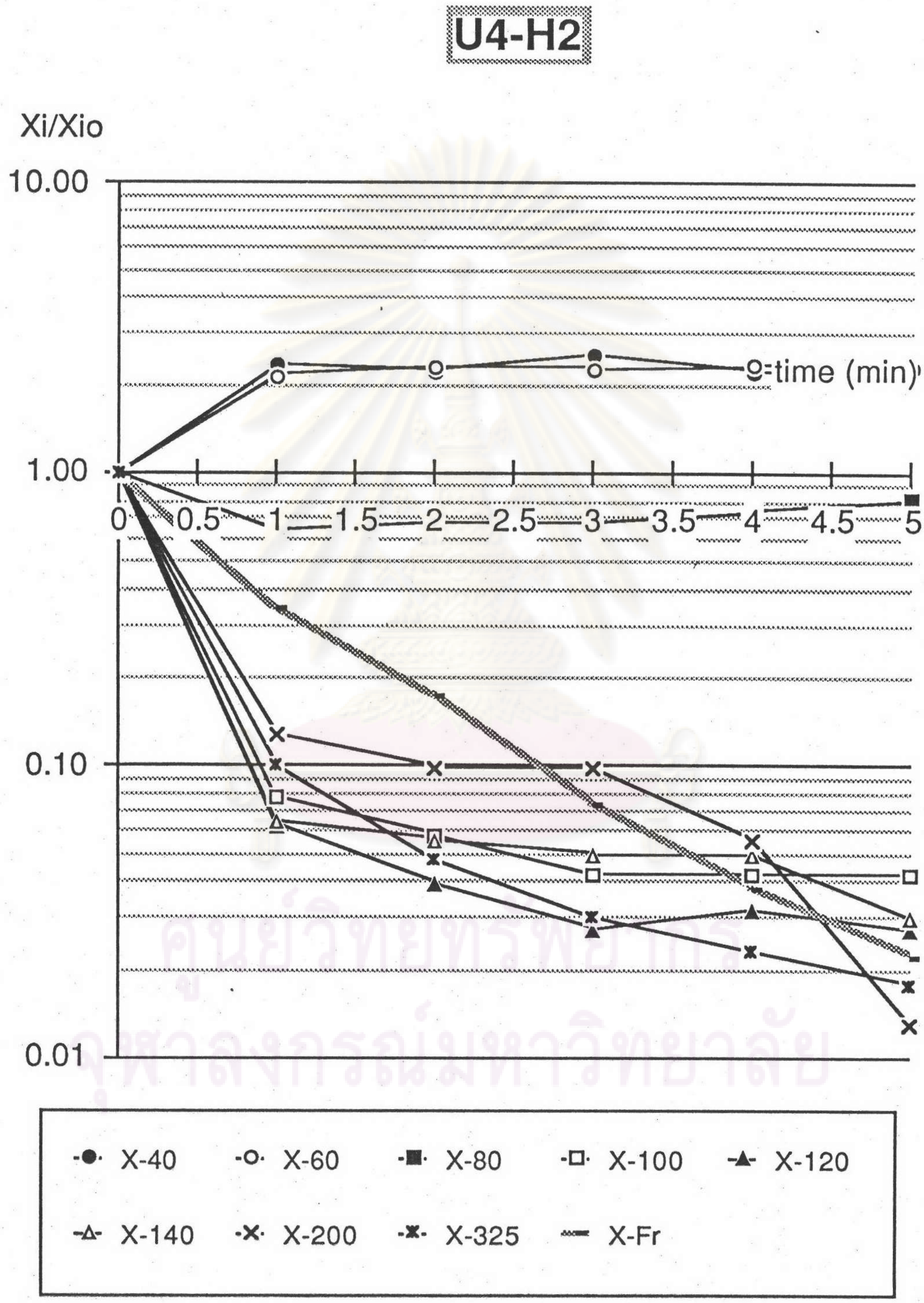
F1.5 Plot of X_i/X_{io} versus time from experimental data set U3H5



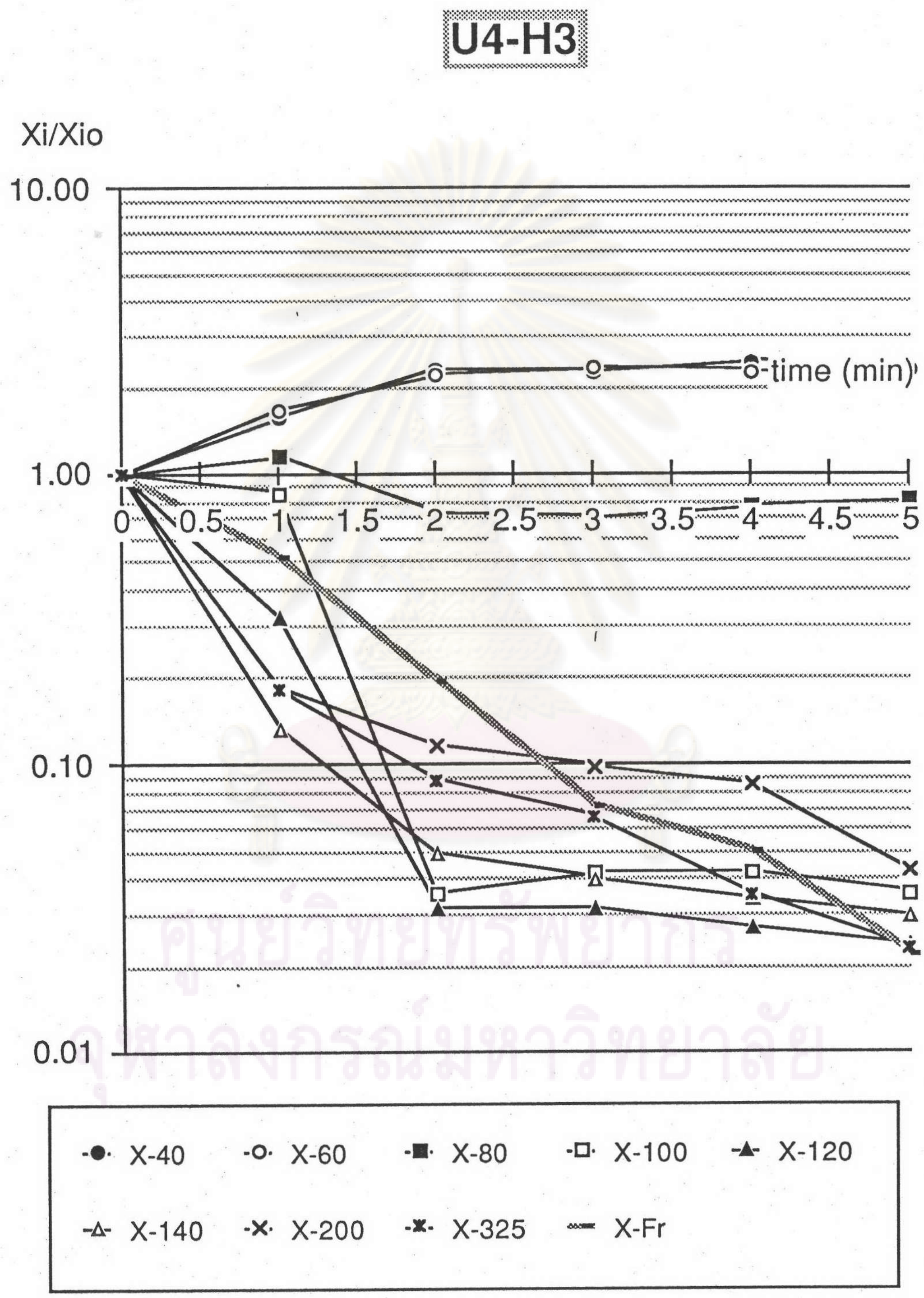
F2.1 Plot of X_i/X_{io} versus time from experimental data set U4H1



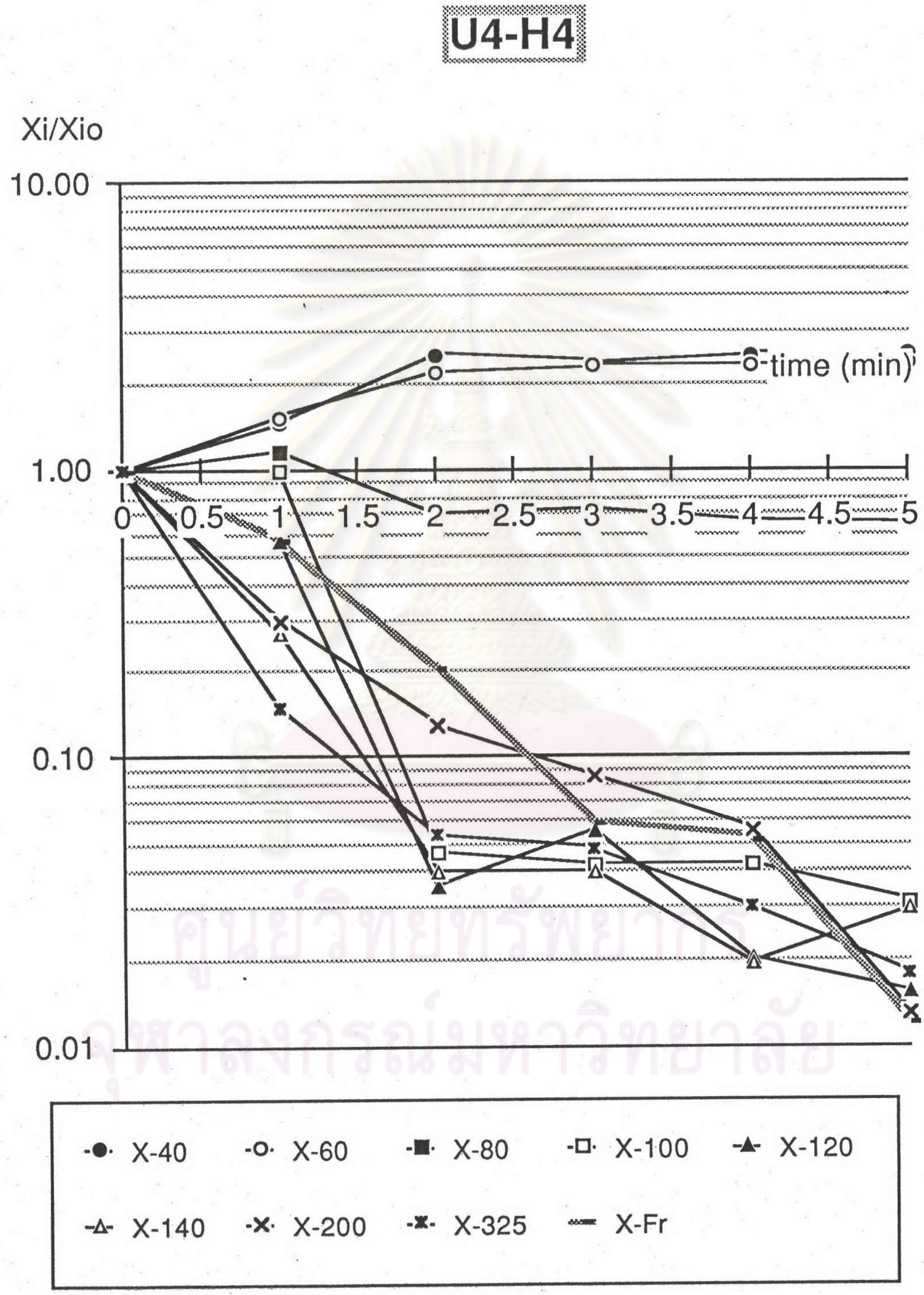
F2.2 Plot of X_i/X_{io} versus time from experimental data set U4H2



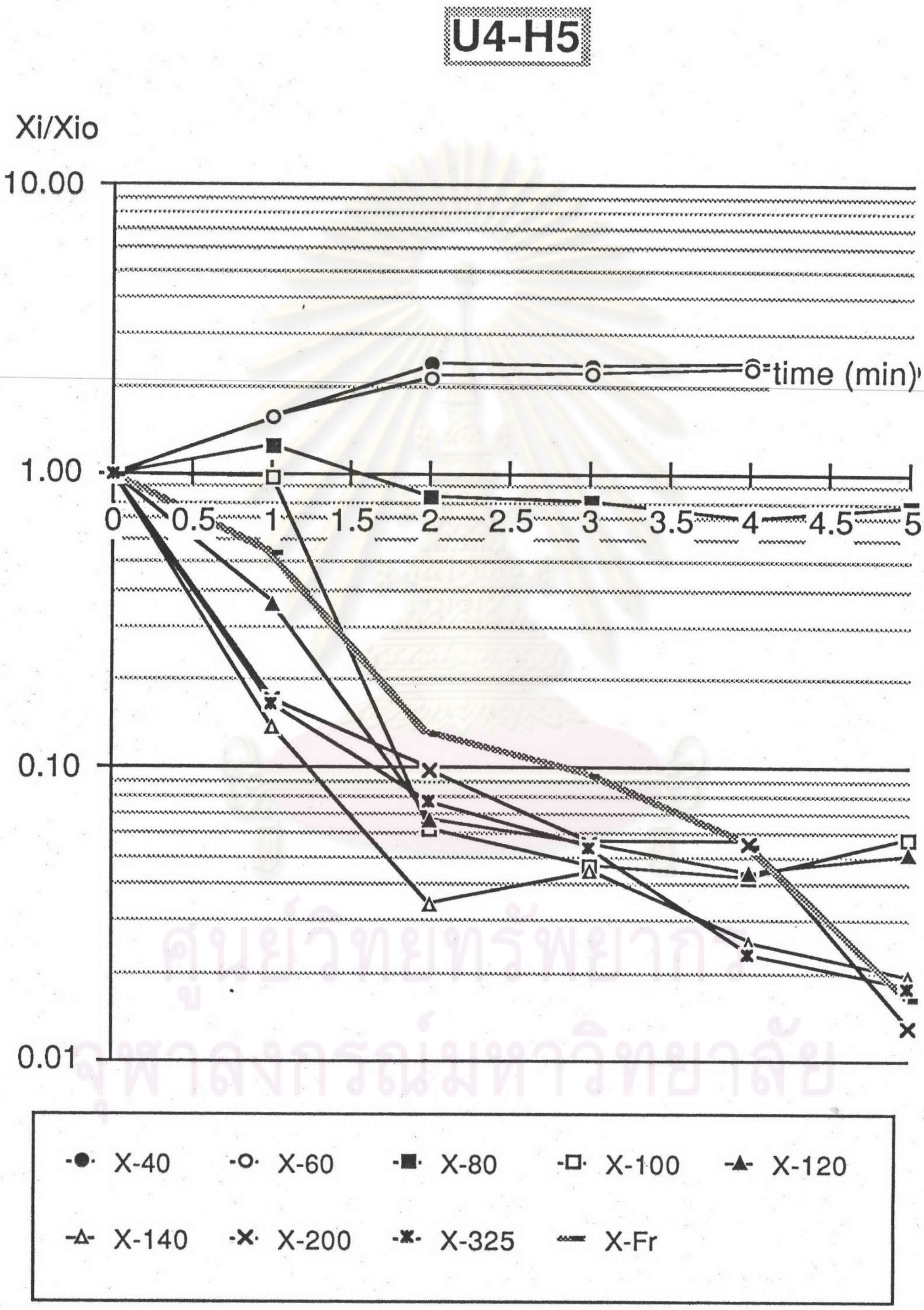
F2.3 Plot of X_i/X_{io} versus time from experimental data set U4H3



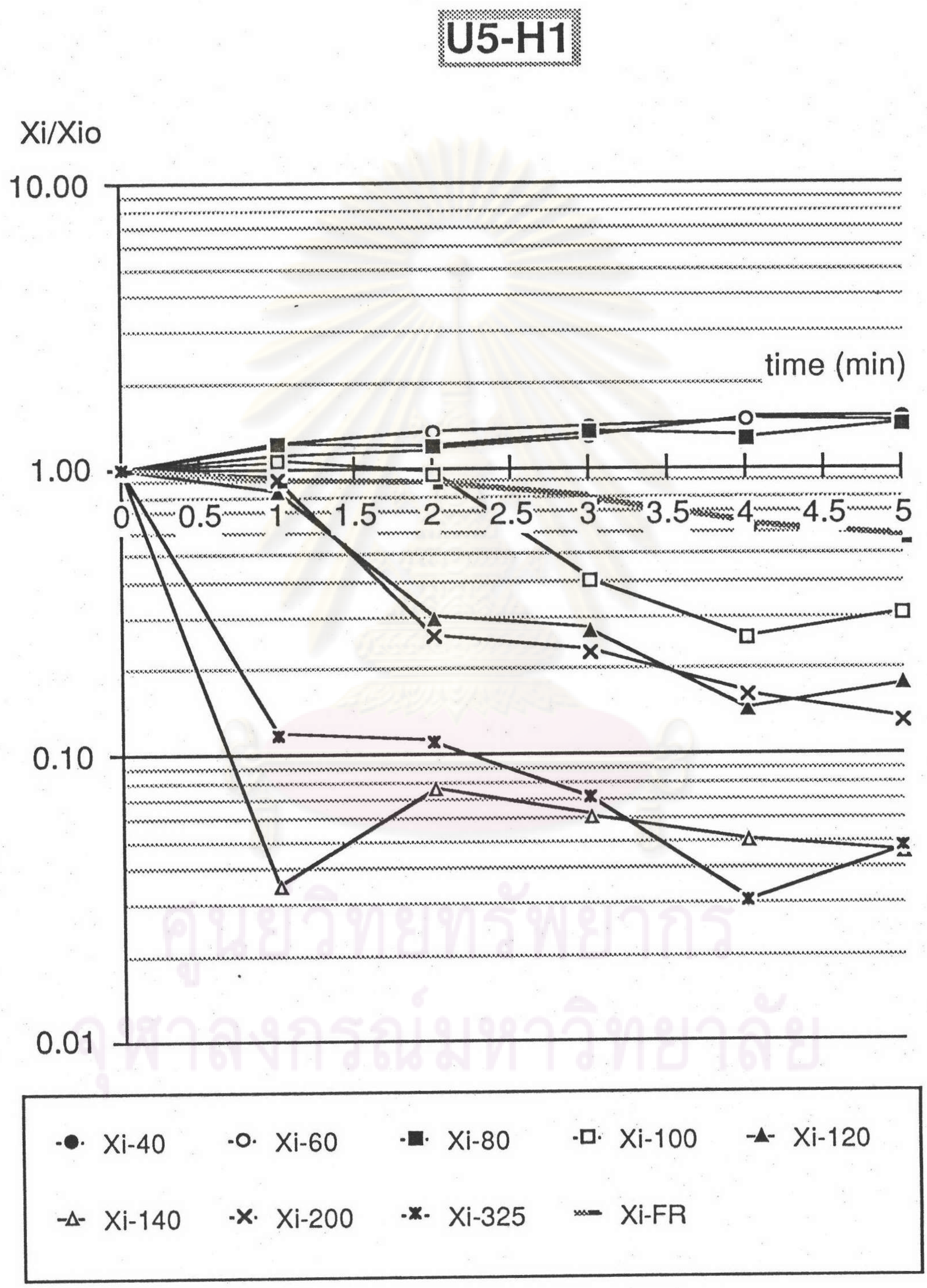
F2.4 Plot of X_i/X_{io} versus time from experimental data set U4H4



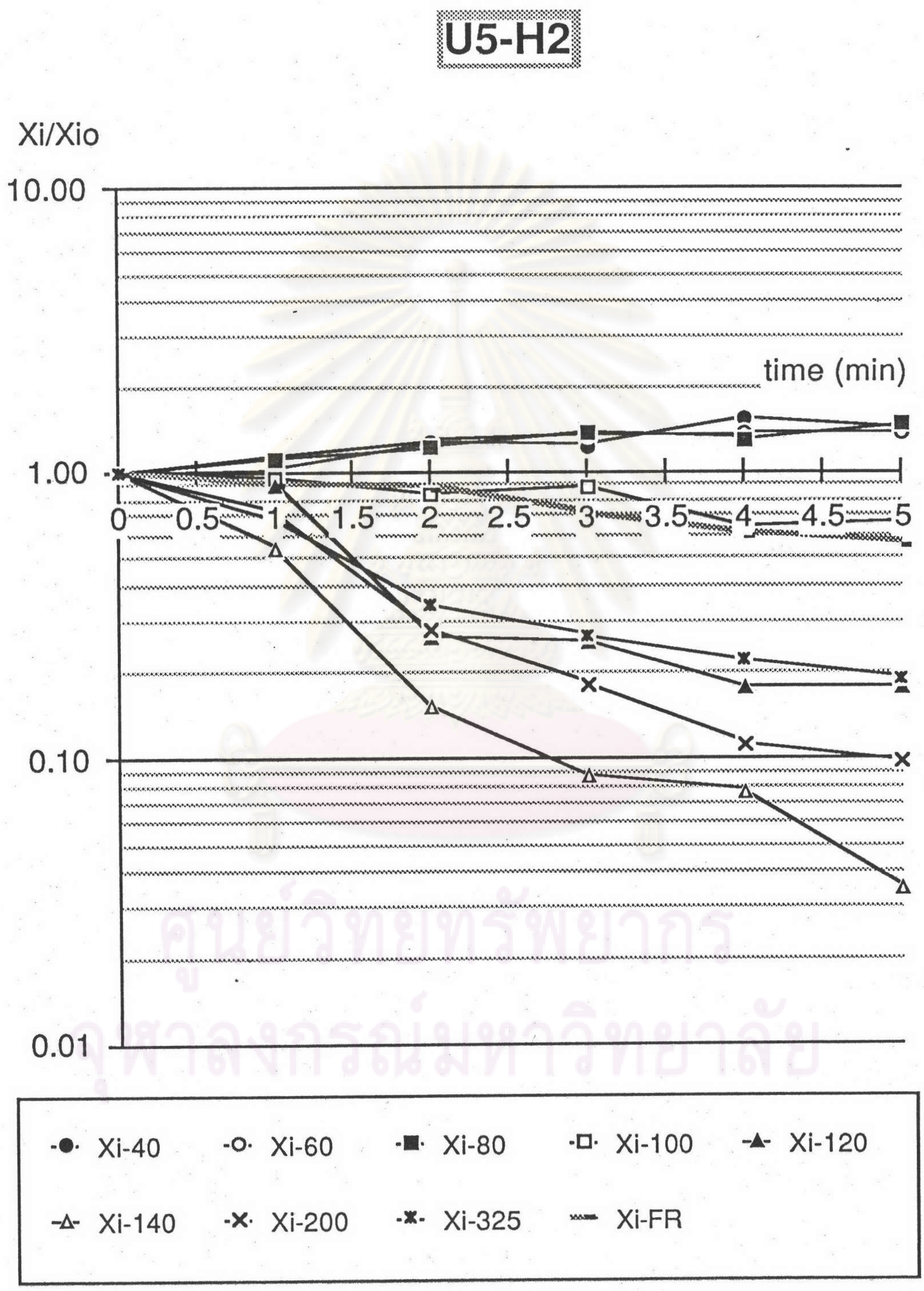
F2.5 Plot of X_i/X_{io} versus time from experimental data set U4H5



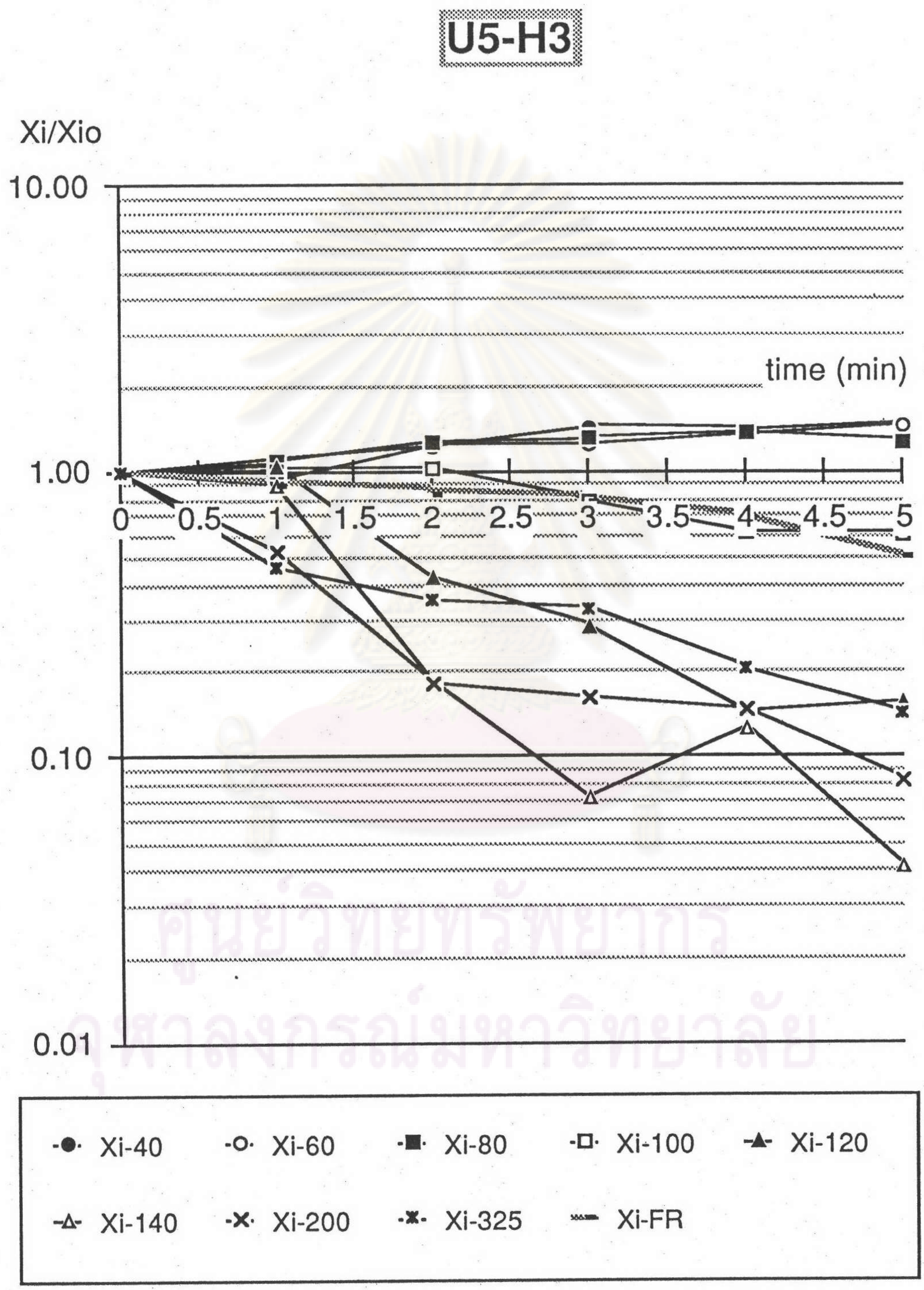
F3.1 Plot of X_i/X_{io} versus time from experimental data set U5H1



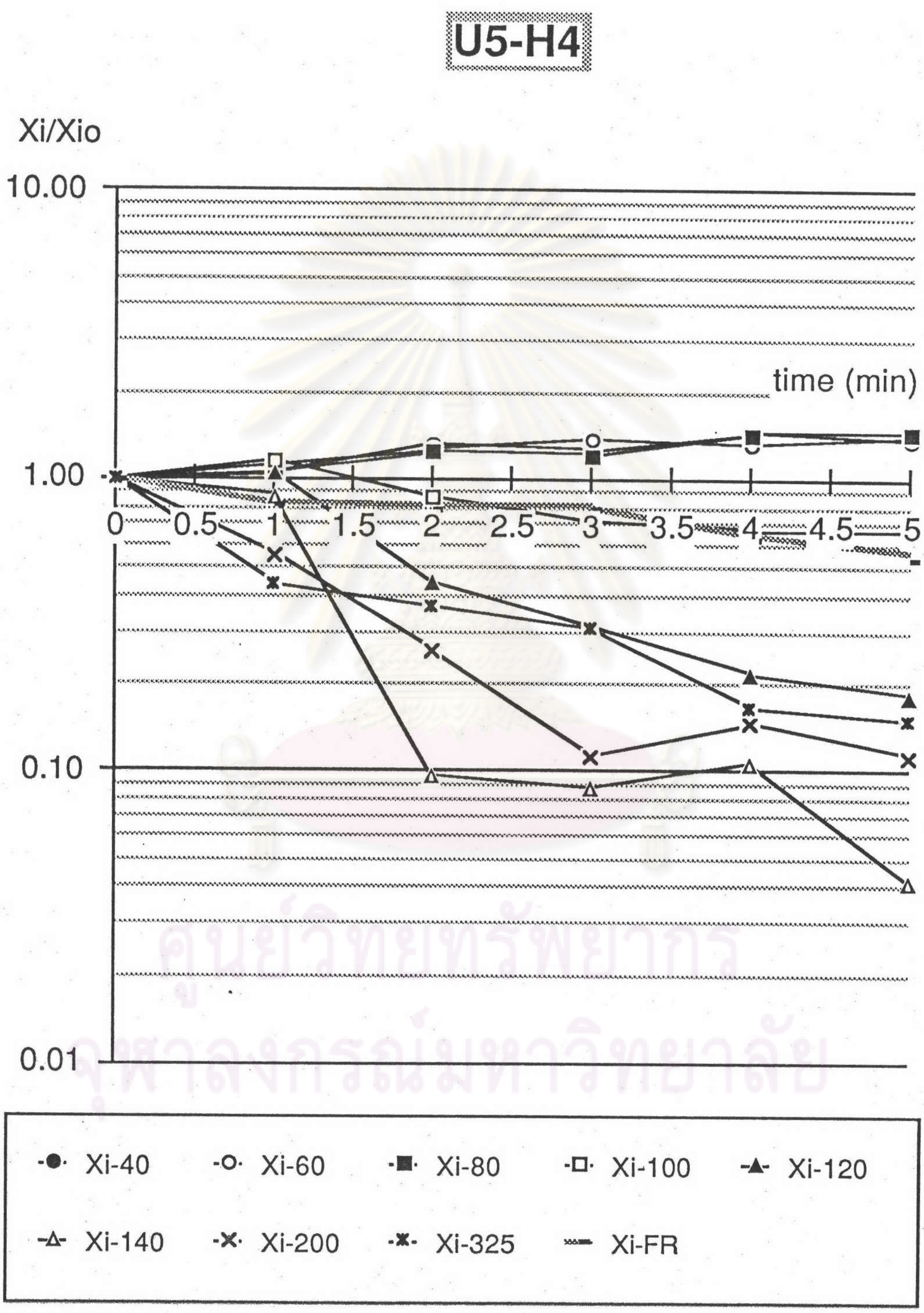
F3.2 Plot of X_i/X_{io} versus time from experimental data set U5H2



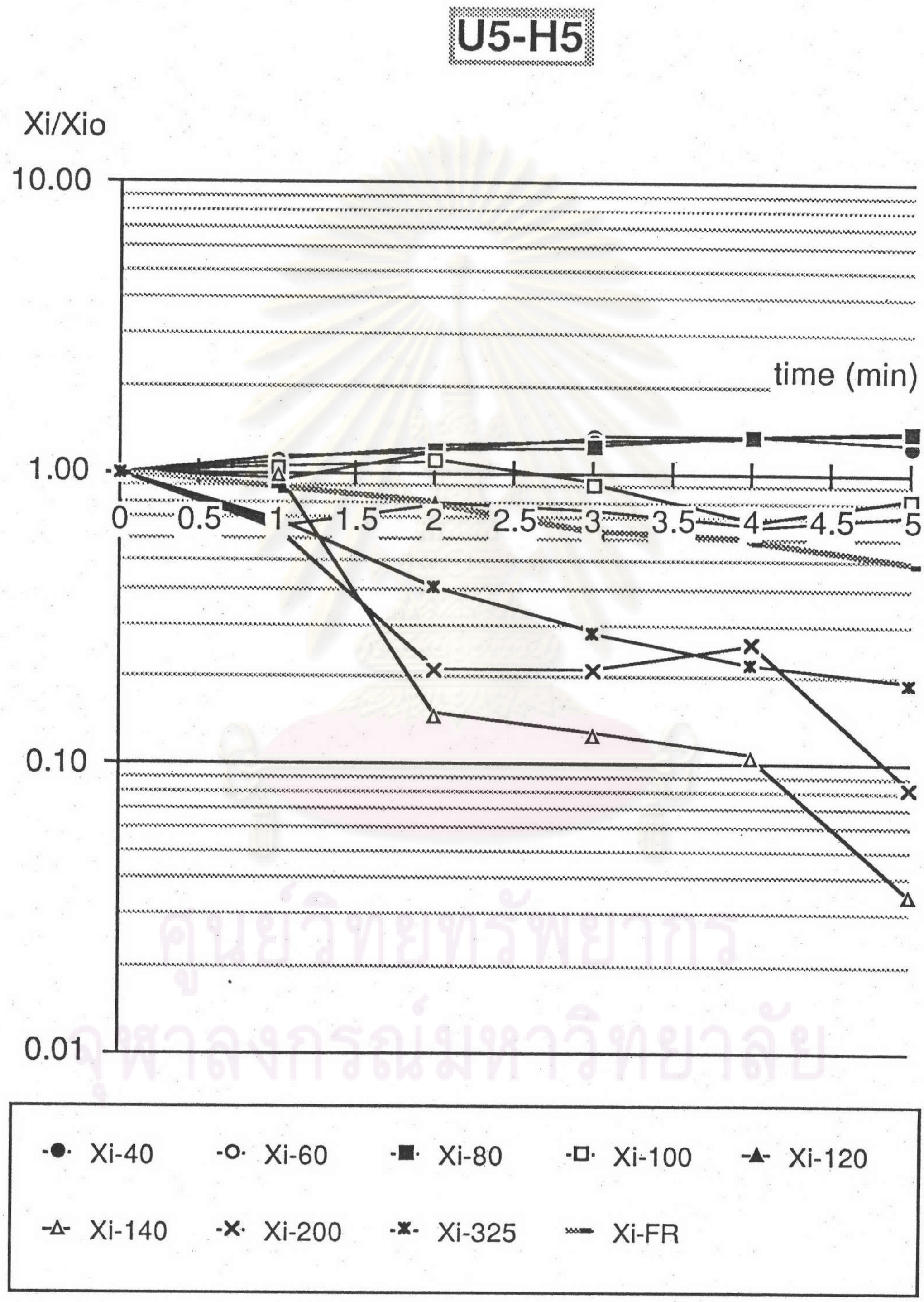
F3.3 Plot of X_i/X_{io} versus time from experimental data set U5H3



F3.4 Plot of X_i/X_{io} versus time from experimental data set U5H4

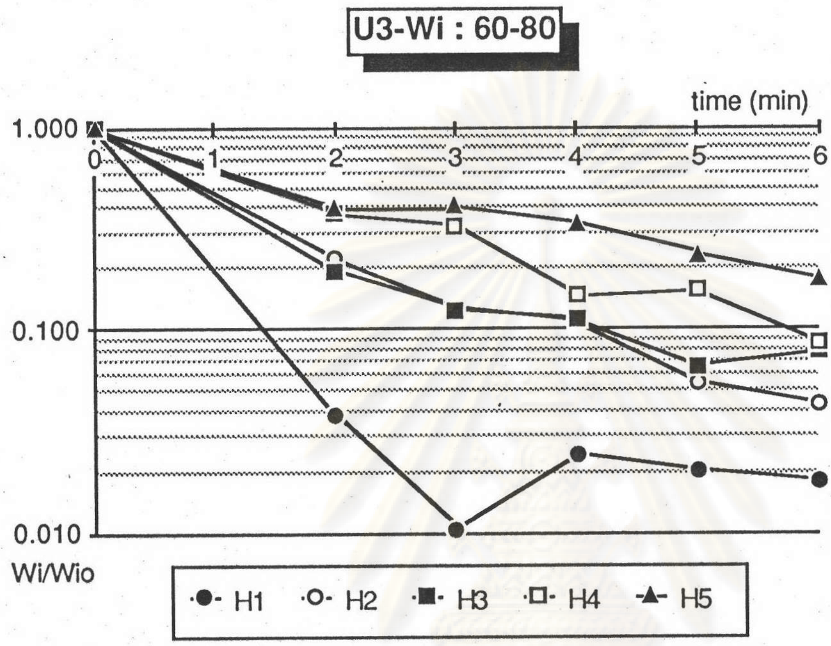


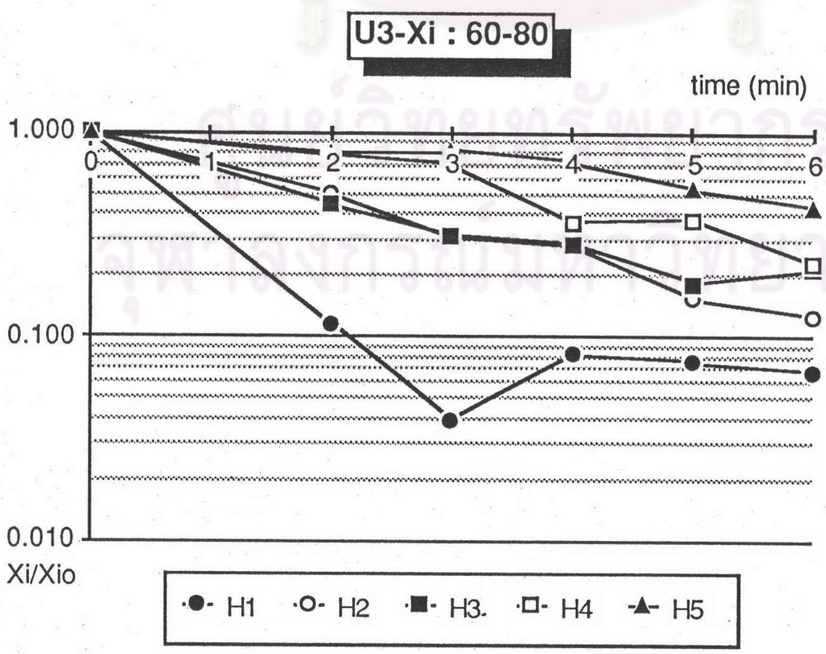
F3.5 Plot of X_i/X_{io} versus time from experimental data set U5H5



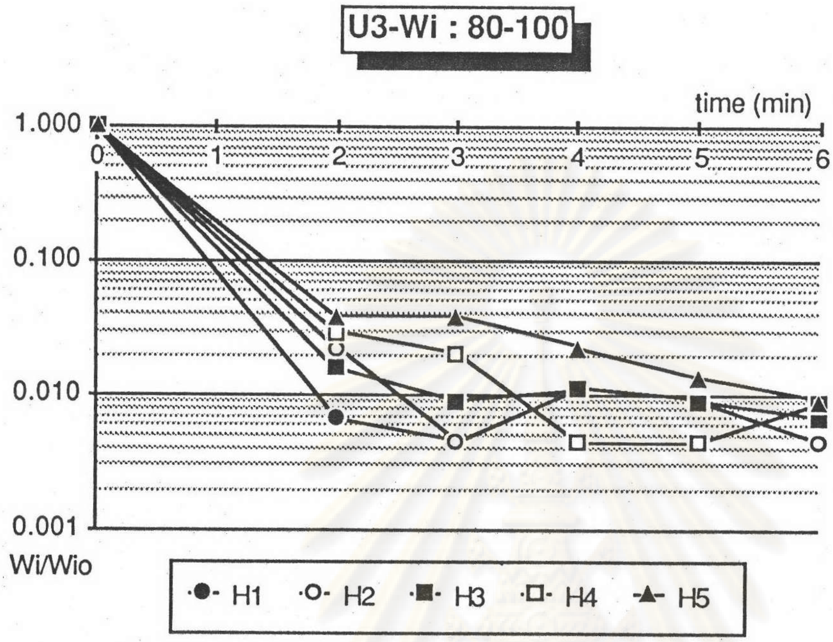
Appendix G

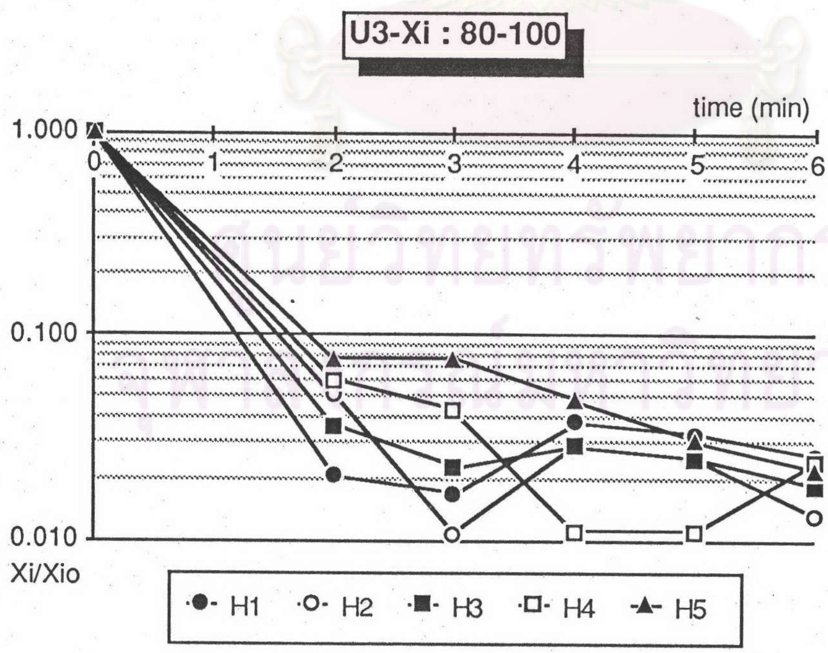
G1.1 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 60-80 mesh (212 μm) in U3 series



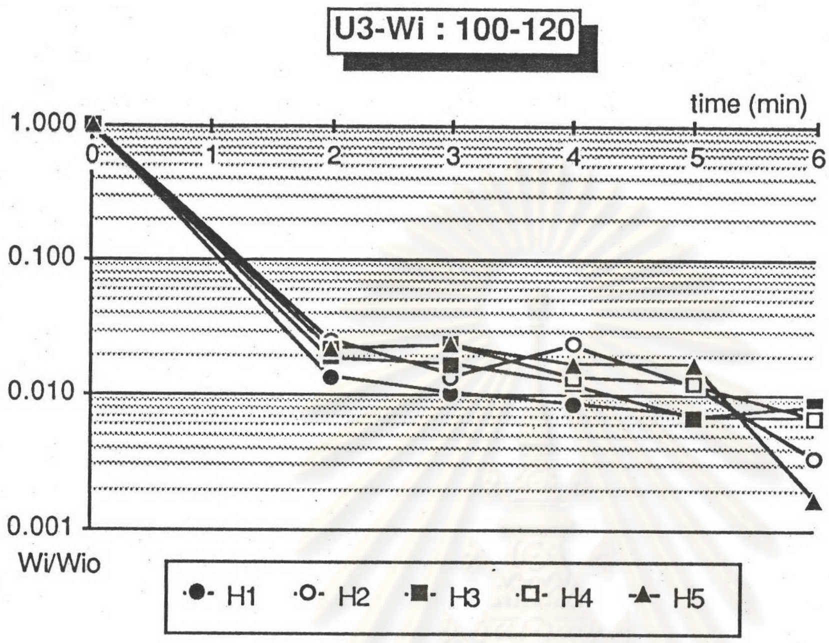


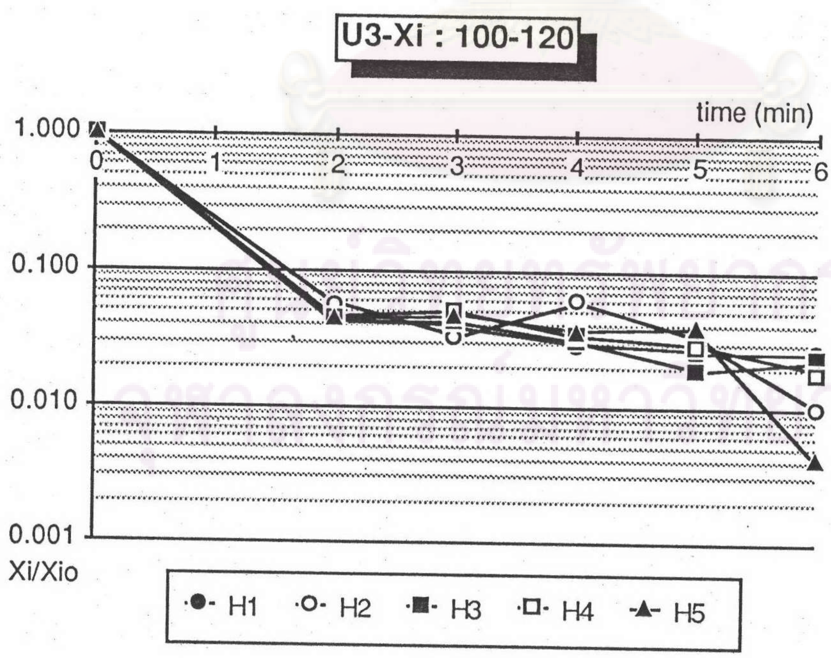
G1.2 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 80-100 mesh (164 μm) in U3 series



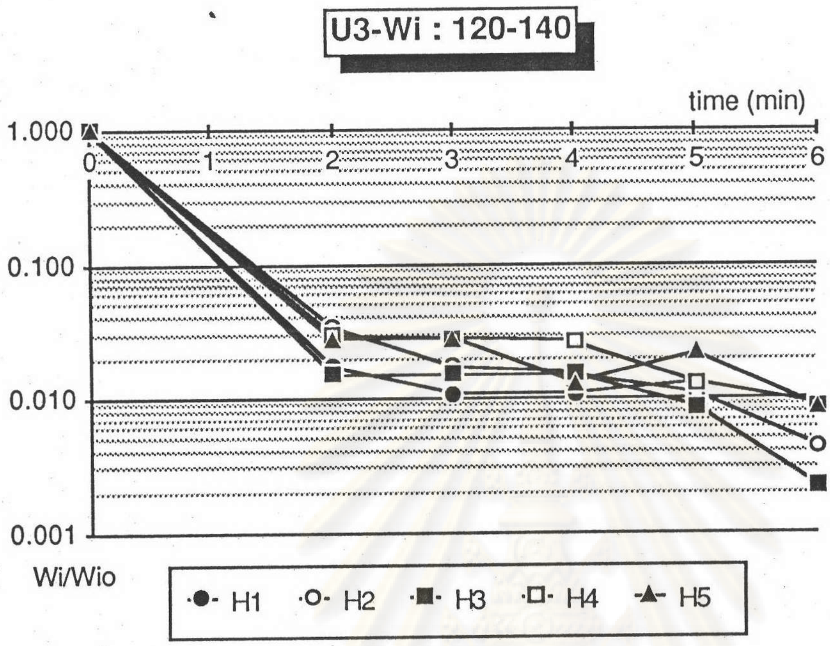


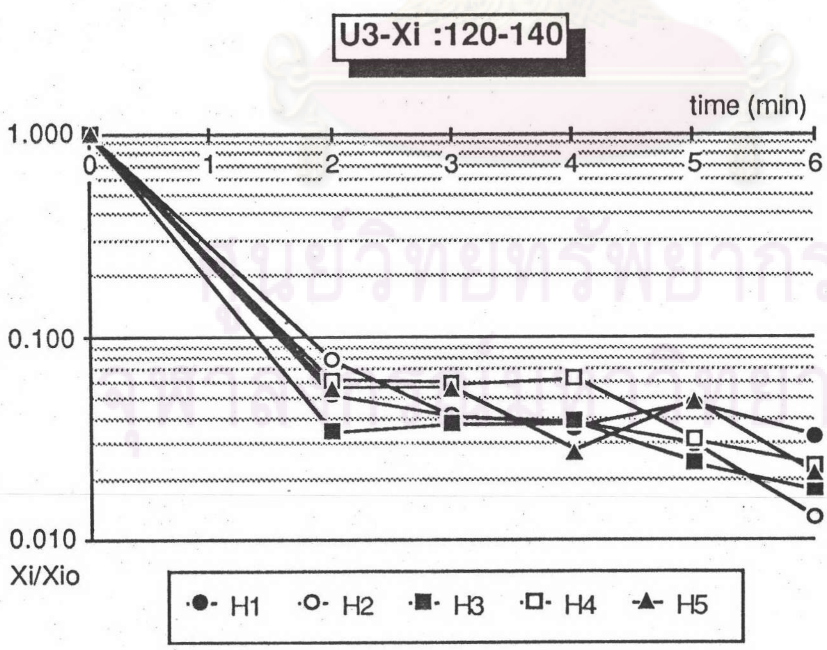
G1.3 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 100-120 mesh (136 μm) in U3 series



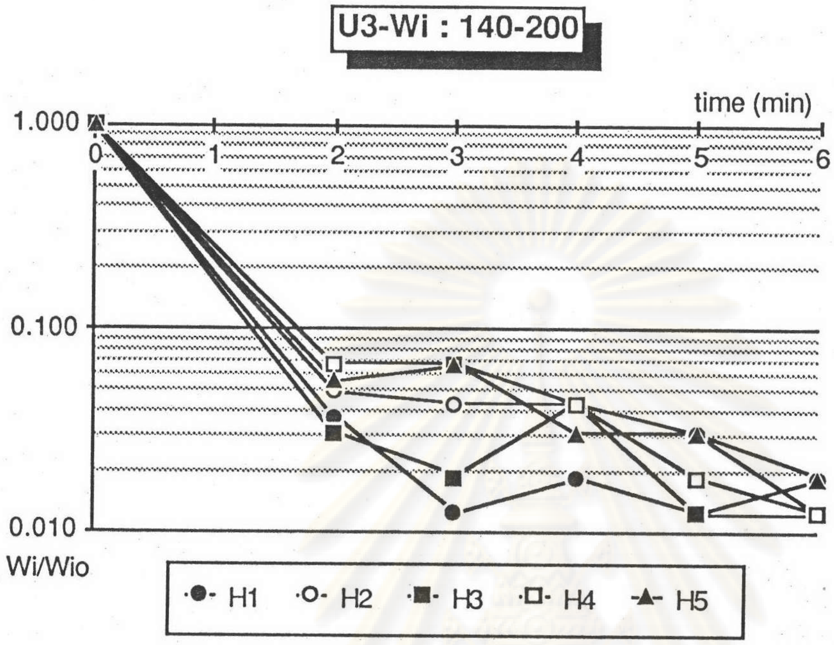


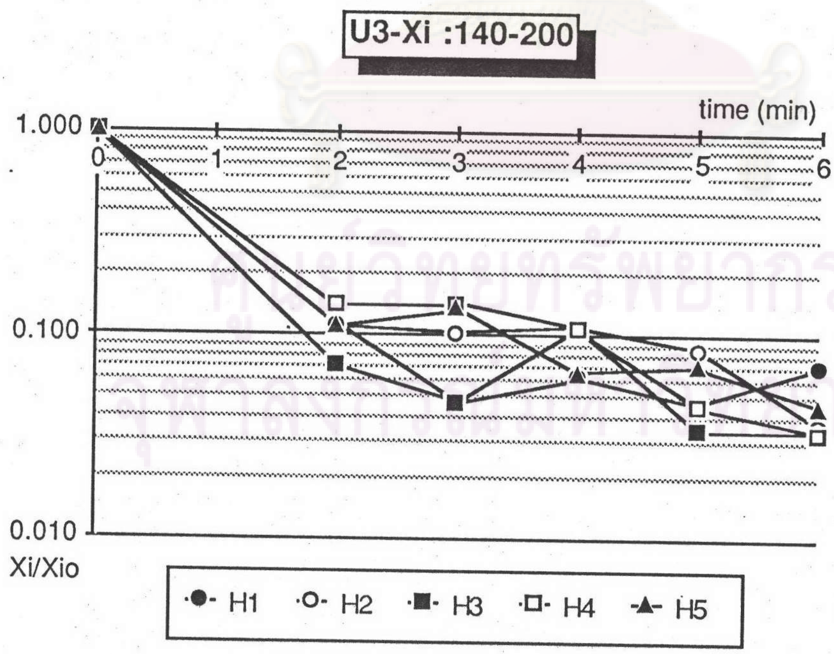
G1.4 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 120-140 mesh (115 μm) in U3 series



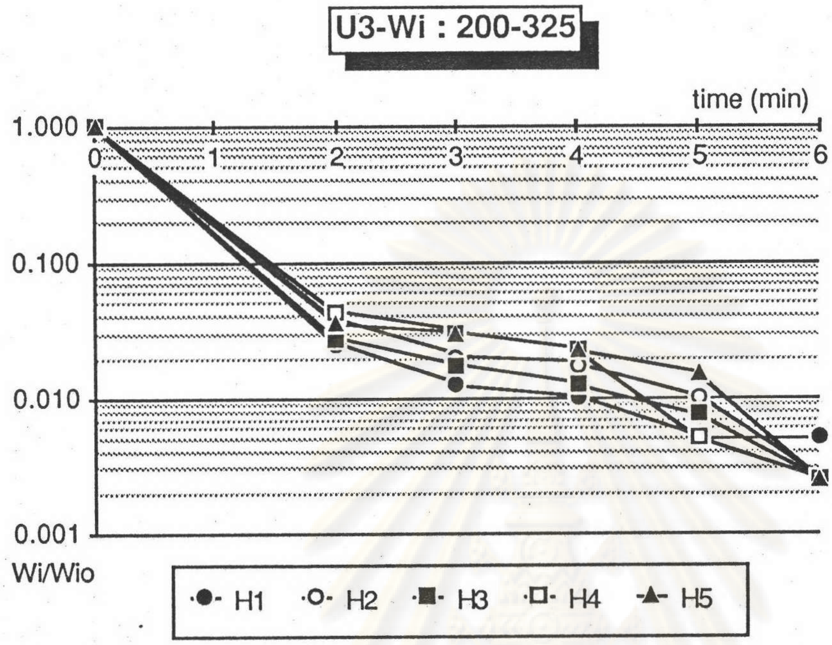


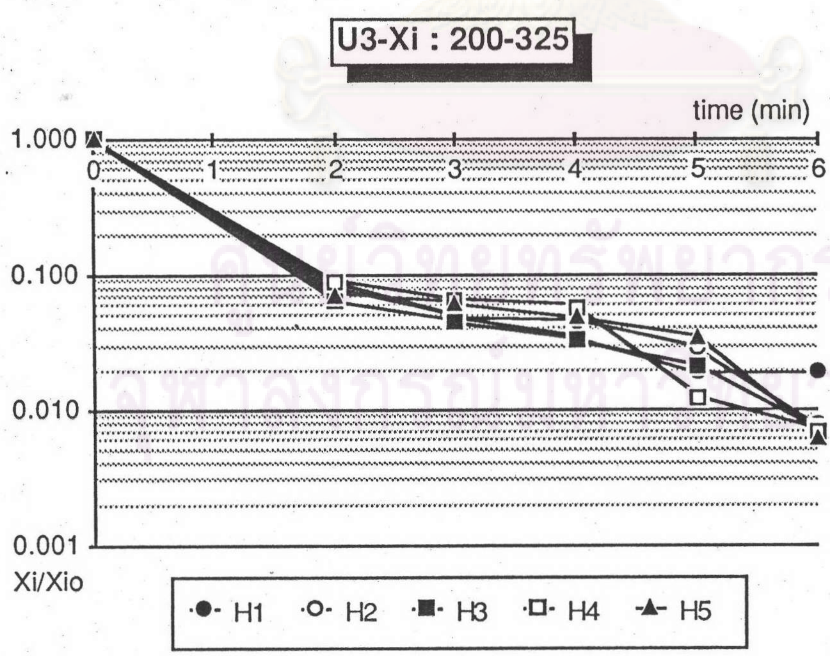
G1.5 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 140-200 mesh (88 μm) in U3 series



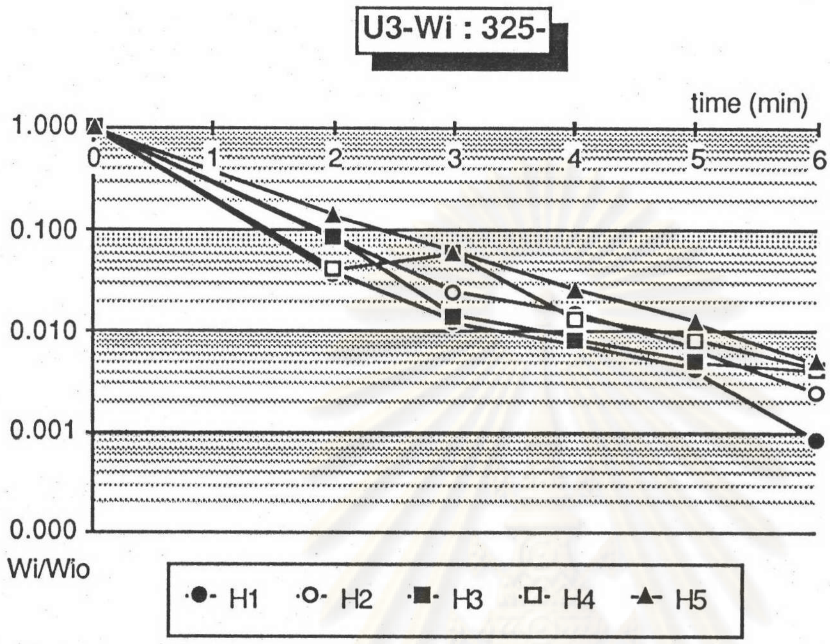


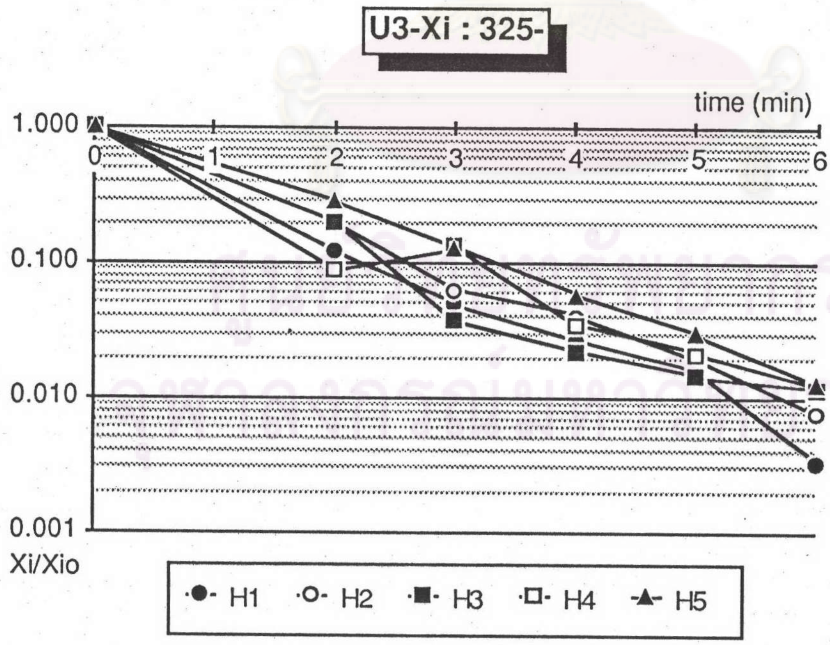
G1.6 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 200-325 mesh (57 μm) in U3 series



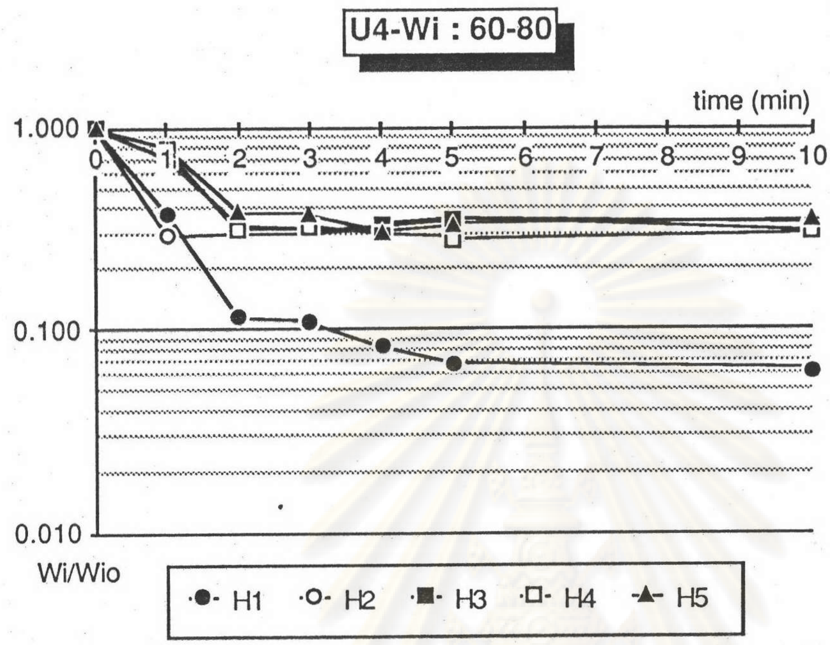


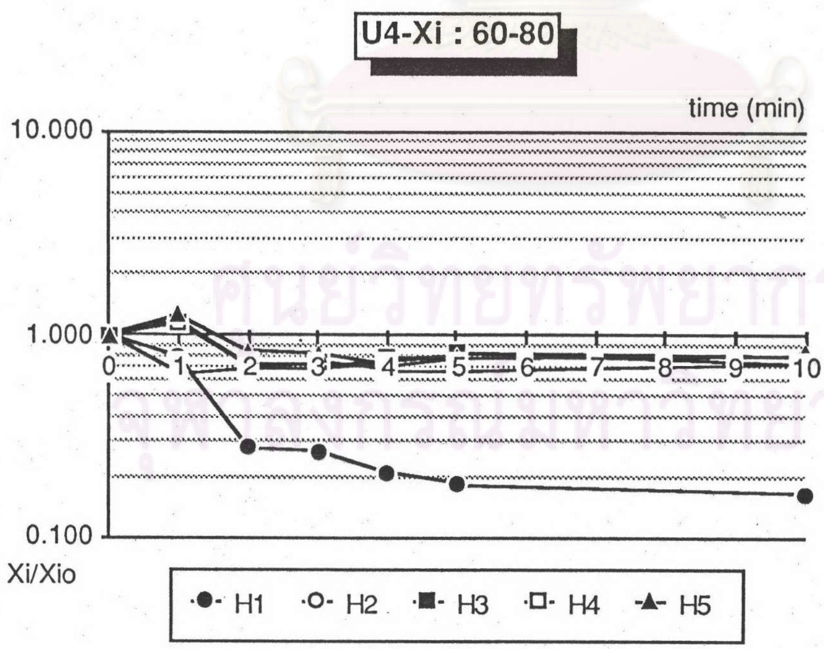
G1.7 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 325- mesh (22 μm) in U3 series



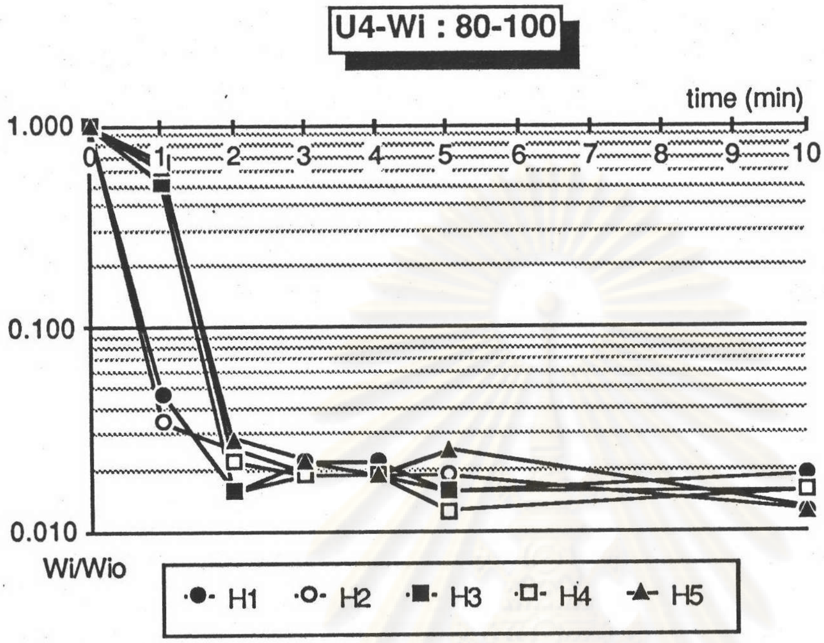


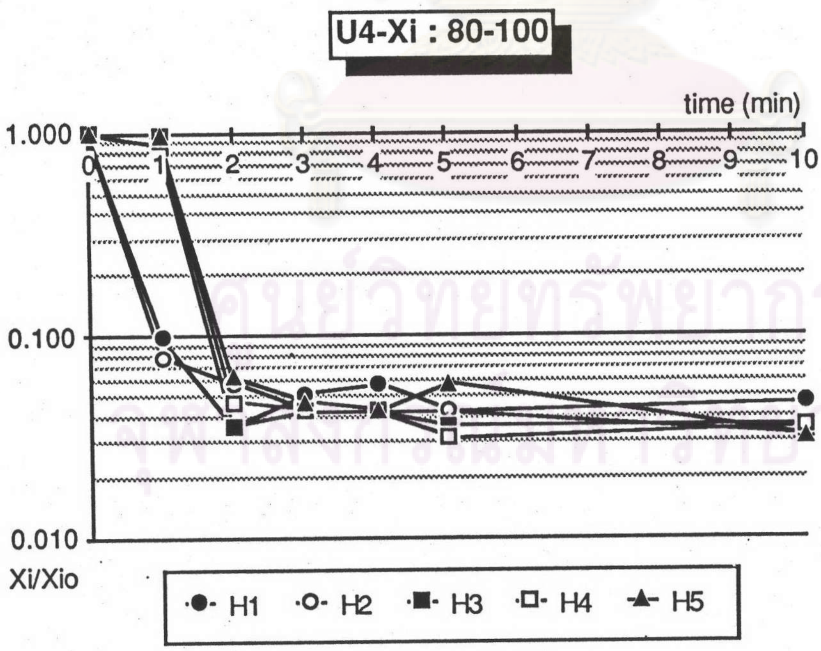
G2.1 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 60-80 mesh (212 μm) in U4 series



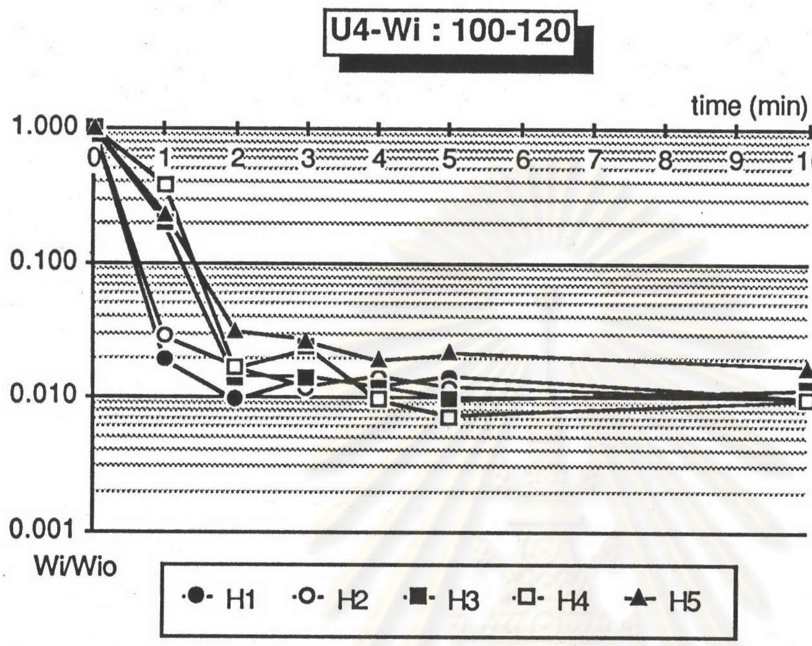


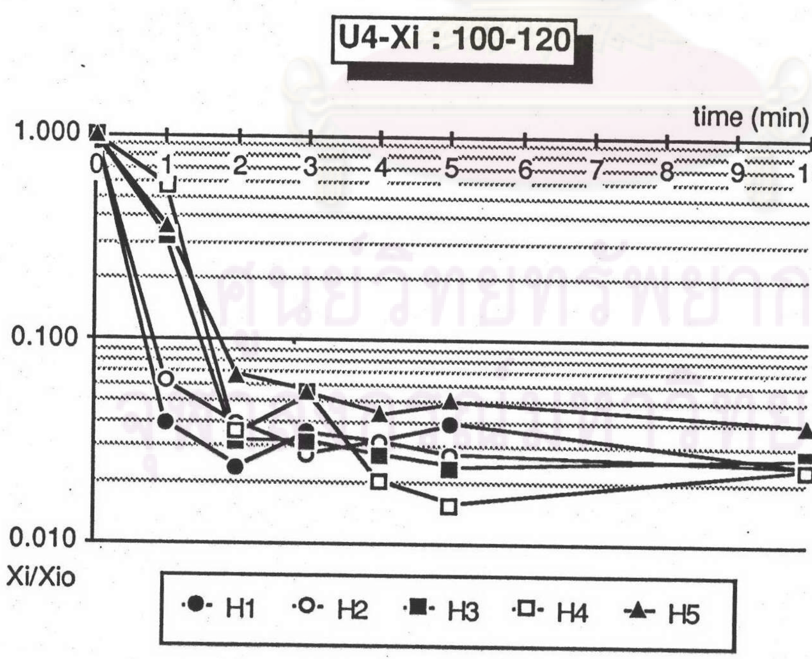
G2.2 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 80-100 mesh (164 μm) in U4 series



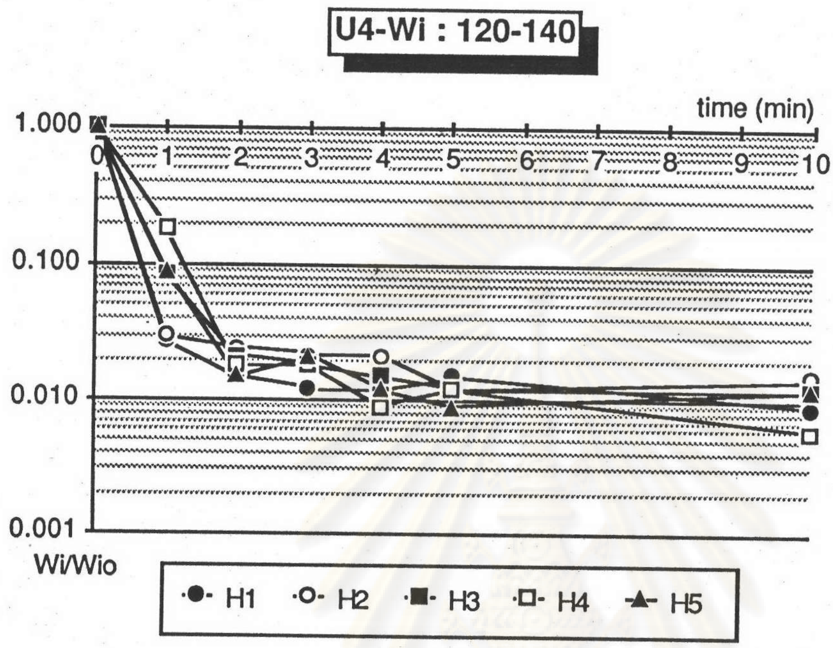


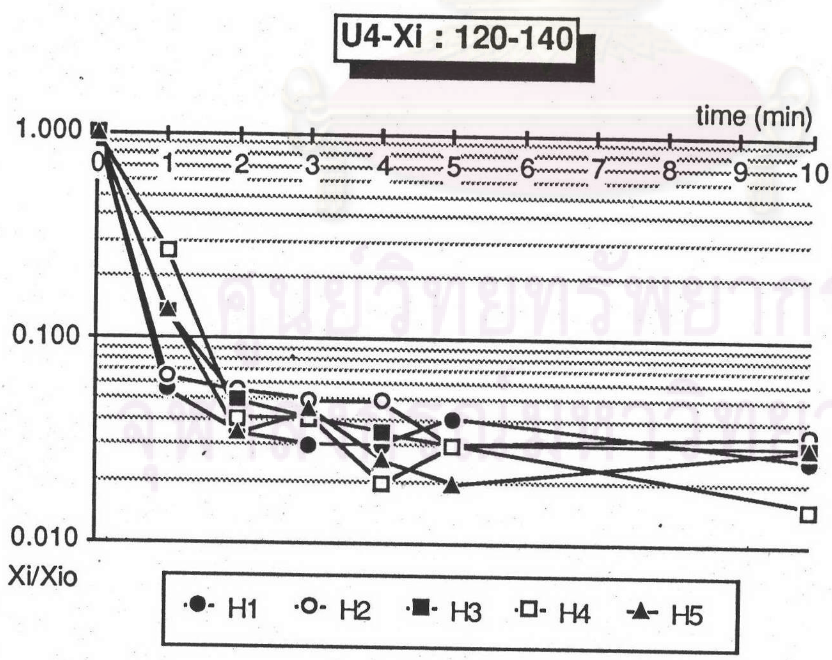
G2.3 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 100-120 mesh (136 μm) in U4 series



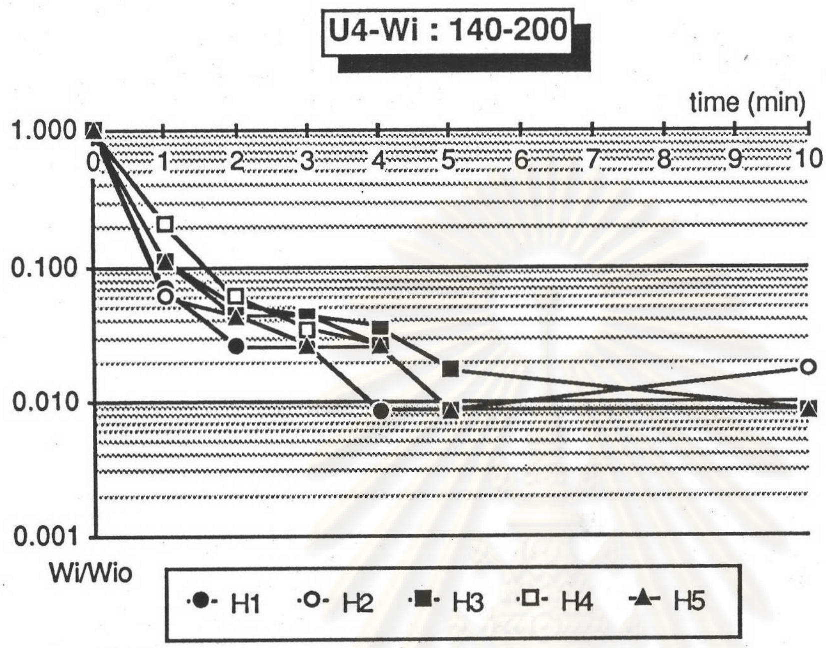


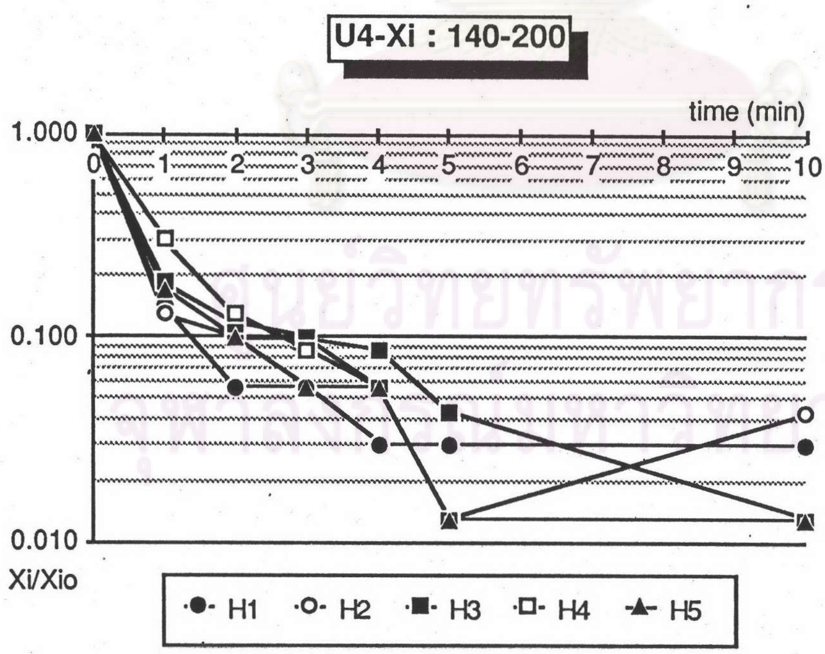
G2.4 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 120-140 mesh (115 μm) in U4 series



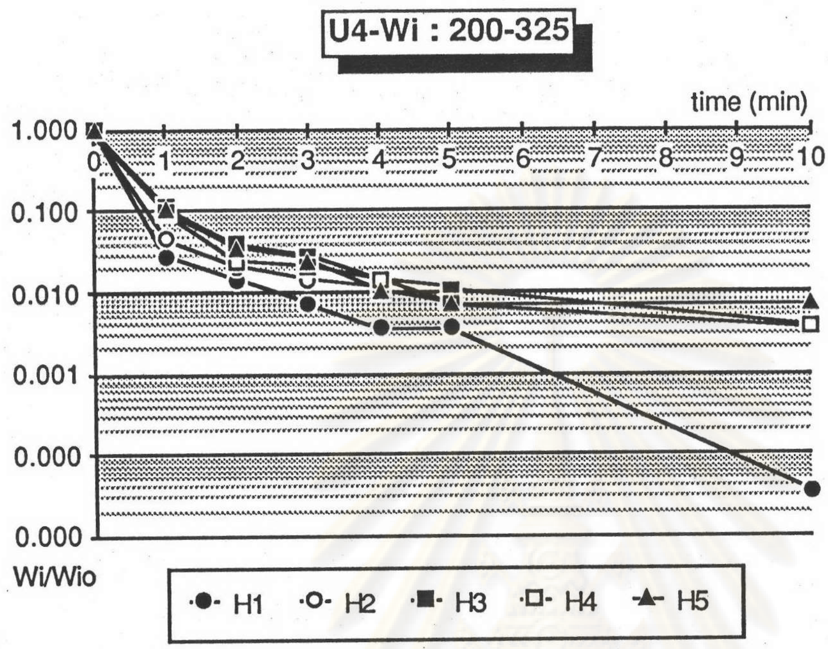


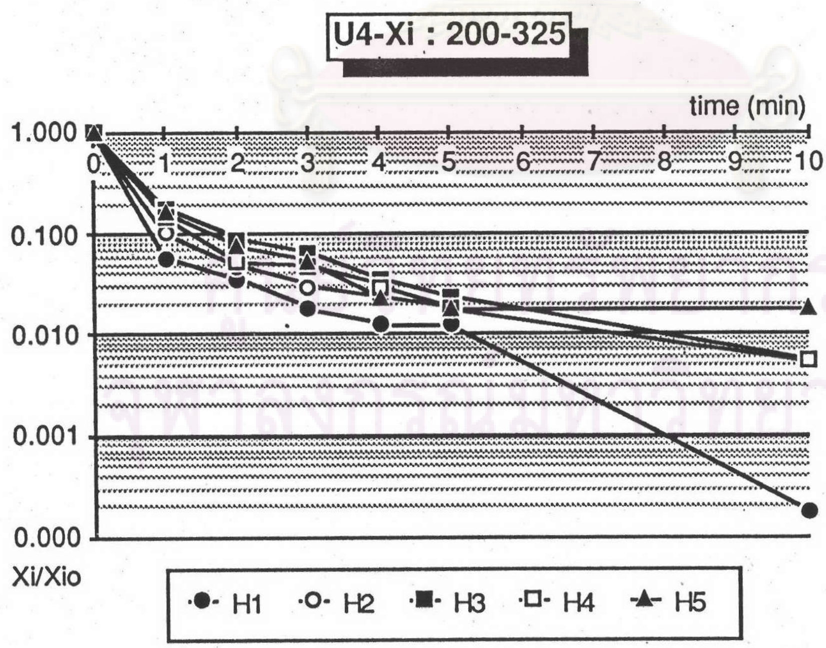
G2.5 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 140-200 mesh (88 μm) in U4 series



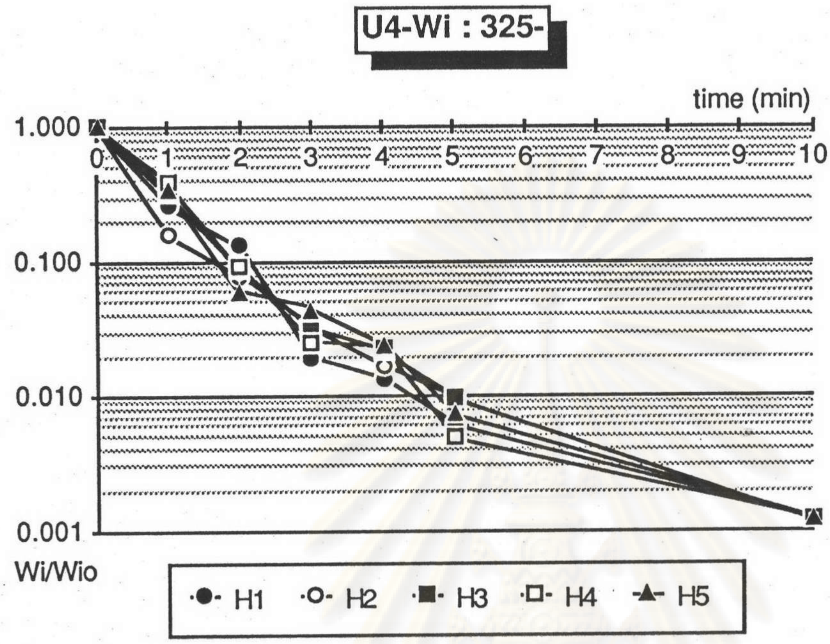


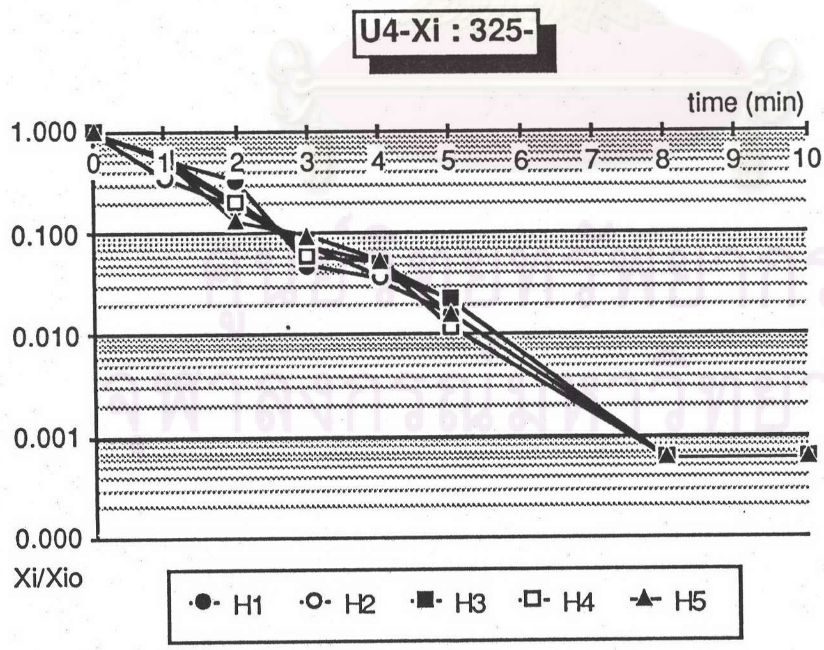
G2.6 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 200-325 mesh (57 μm) in U4 series



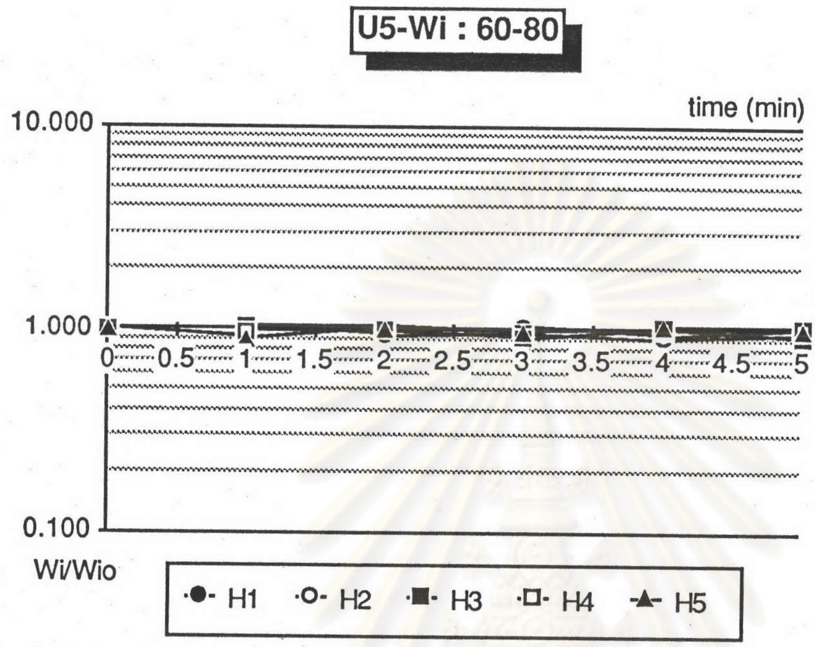


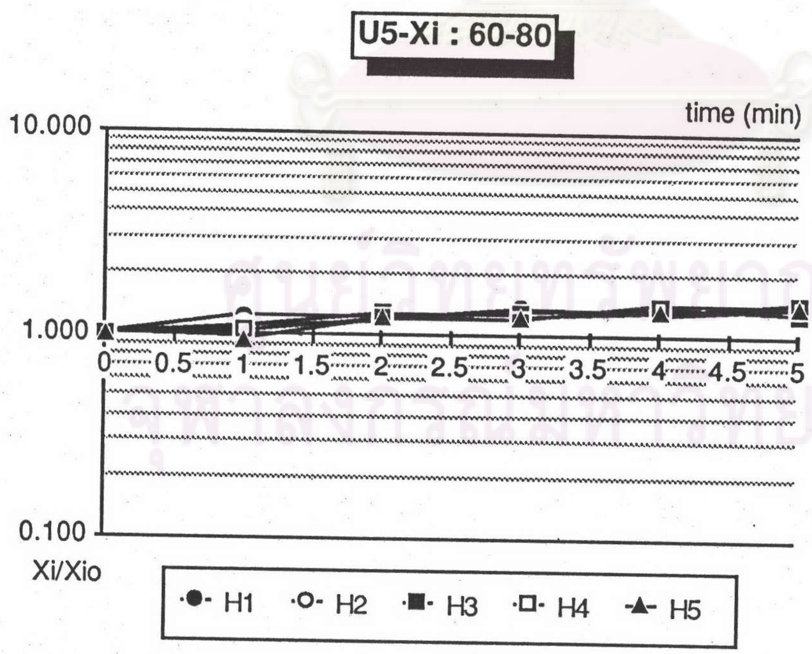
G2.7 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 325- mesh (22 μm) in U4 series



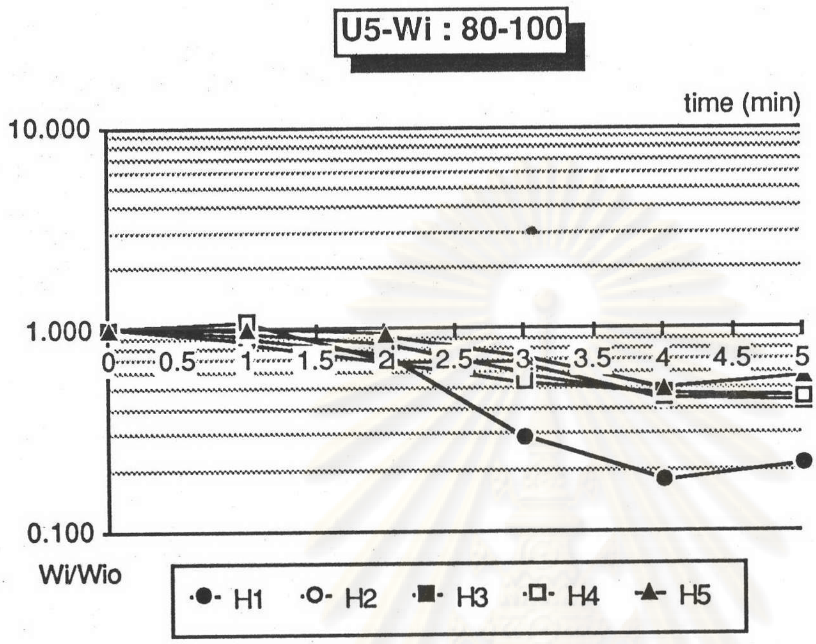


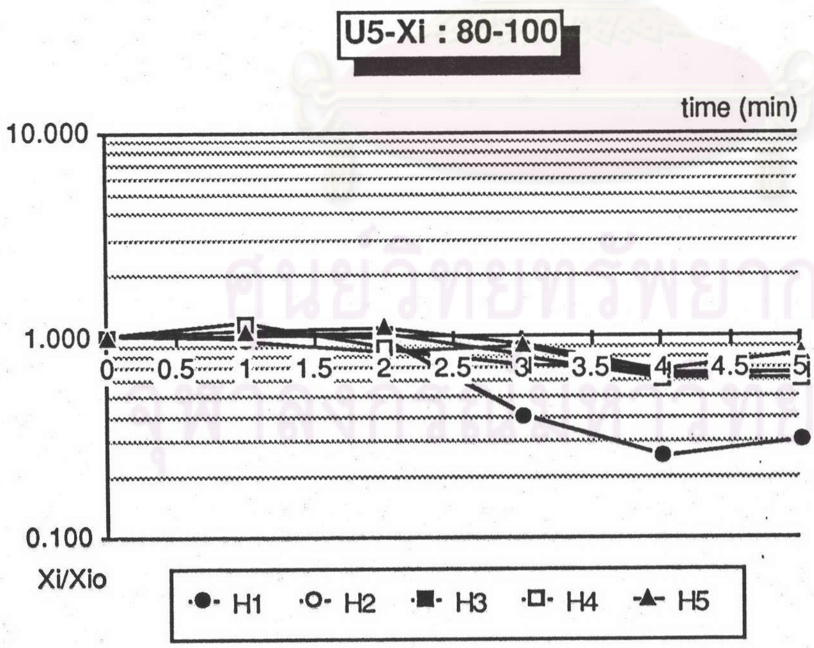
G3.1 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 60-80 mesh (212 μm) in U5 series



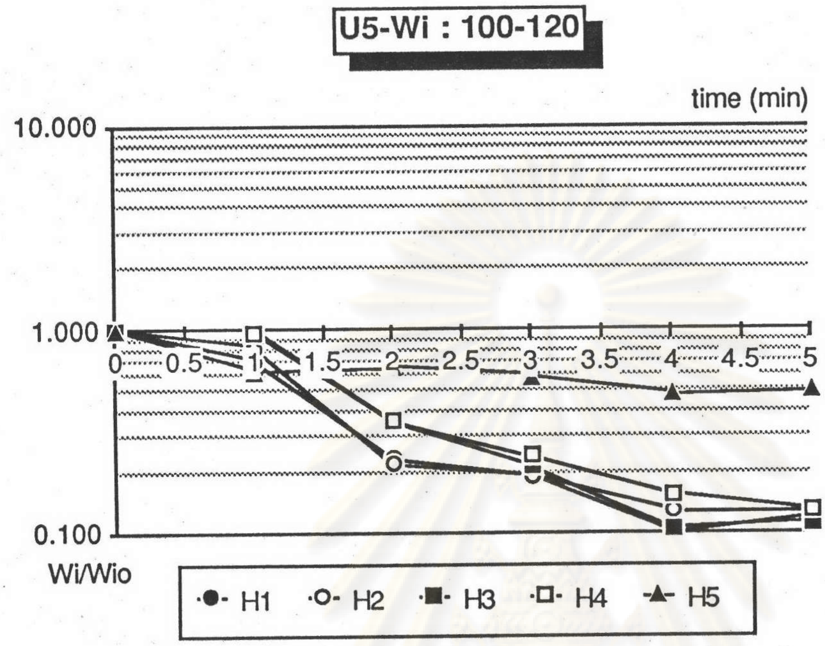


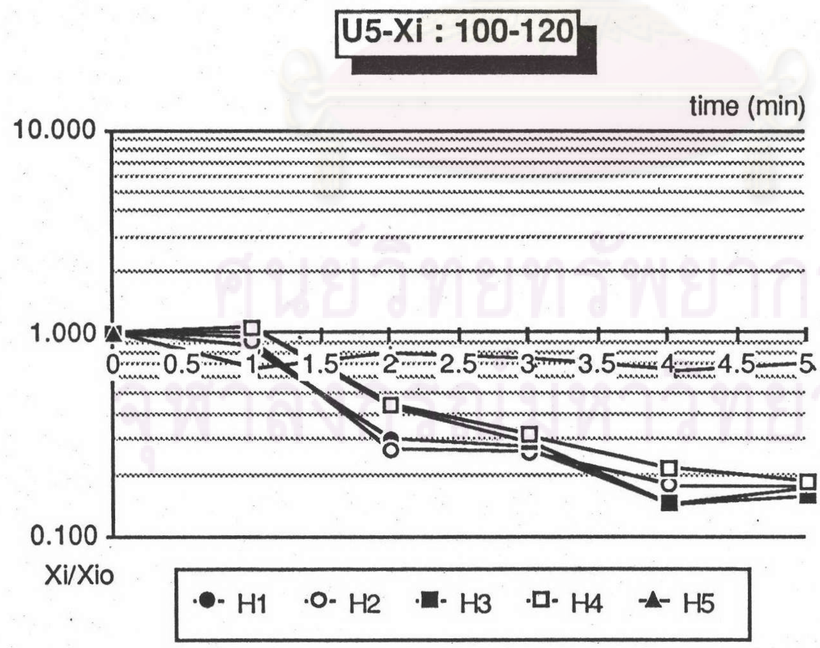
G3.2 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 80-100 mesh (164 μm) in U5 series



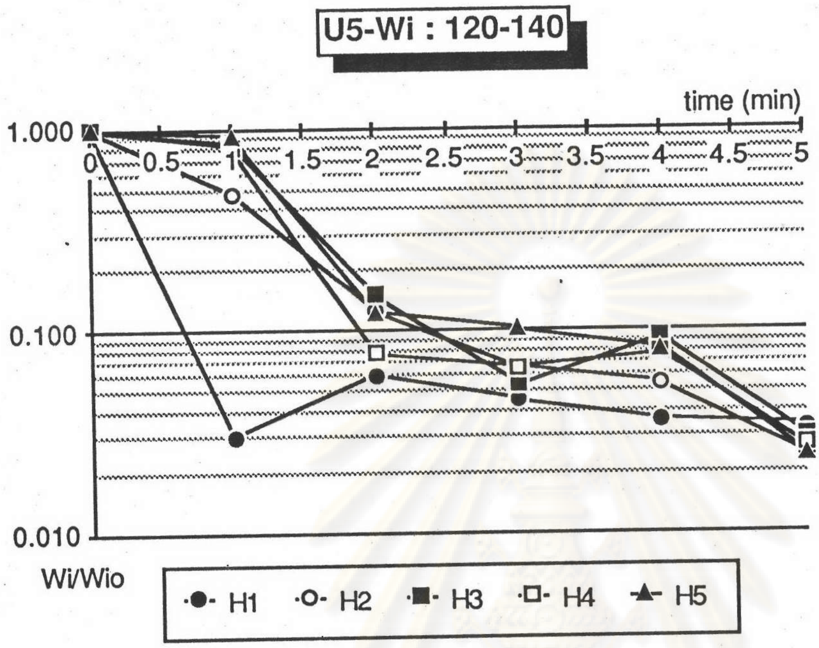


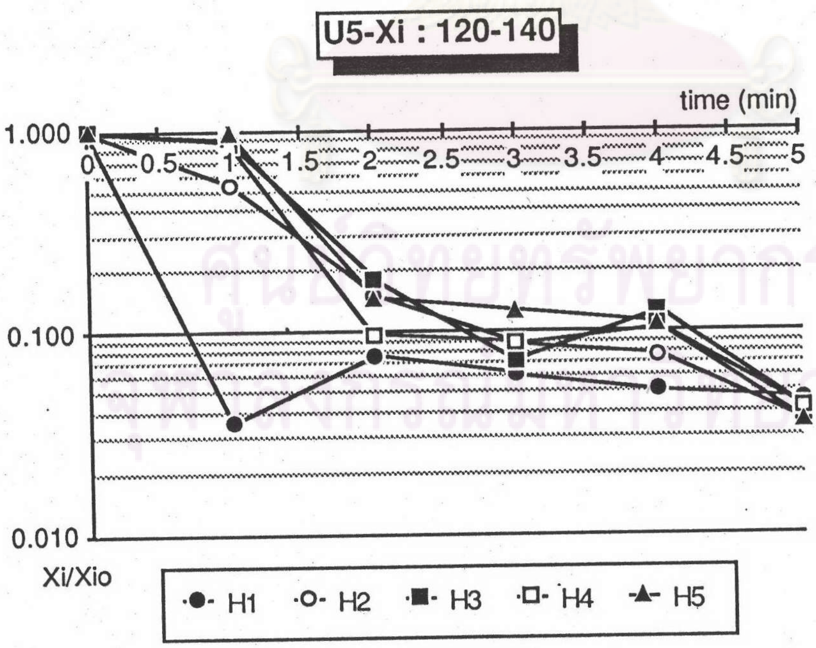
G3.3 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 100-120 mesh (136 μm) in U5 series



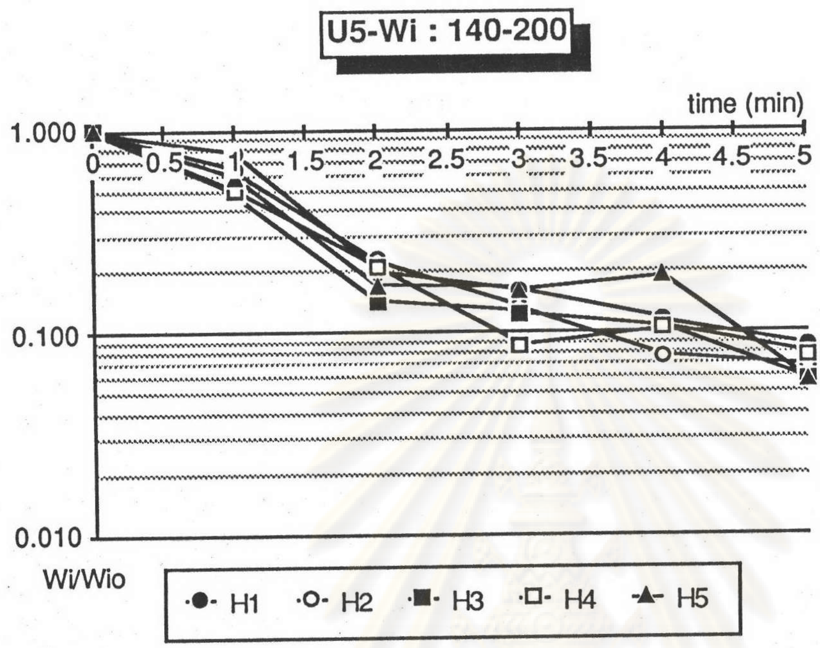


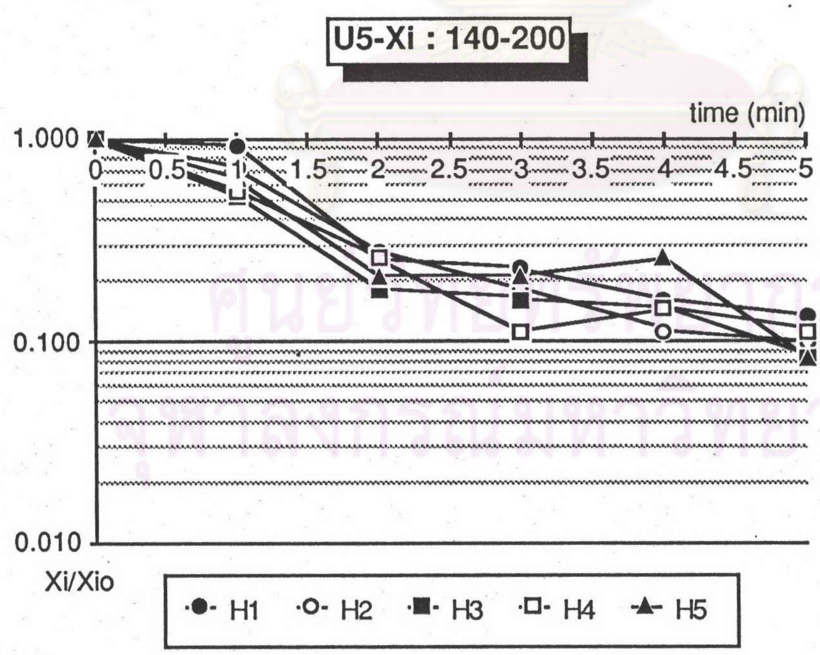
G3.4 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 120-140 mesh (115 μm) in U5 series



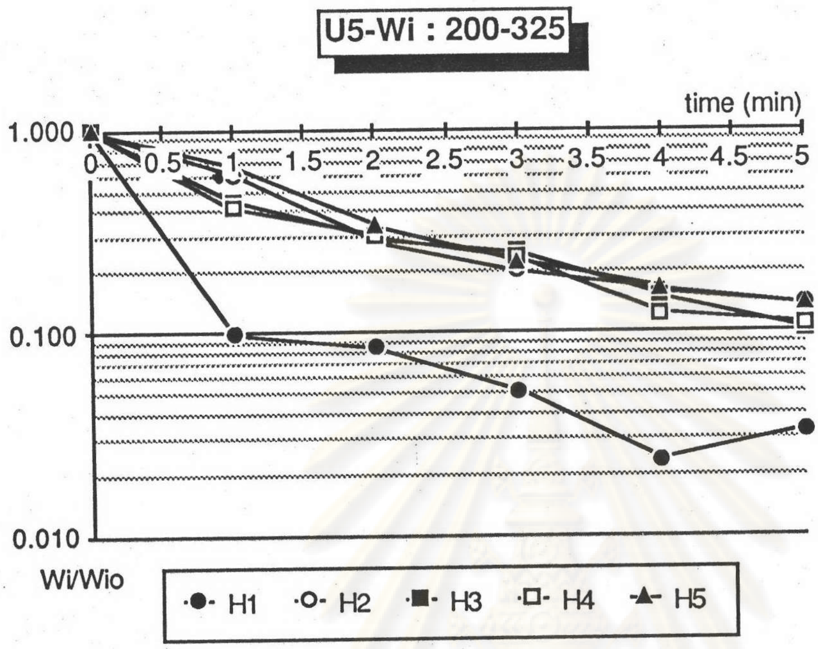


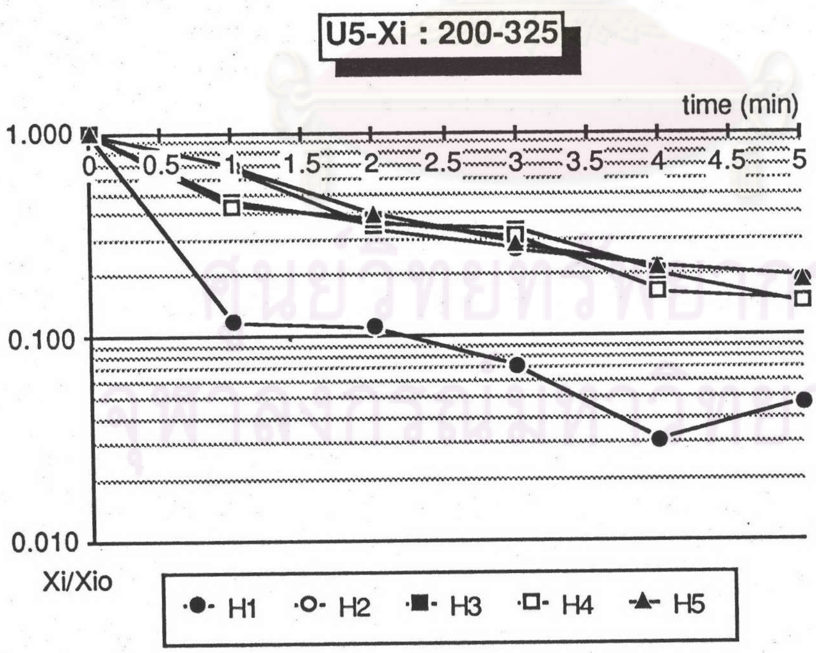
G3.5 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 140-200 mesh (88 μm) in U5 series



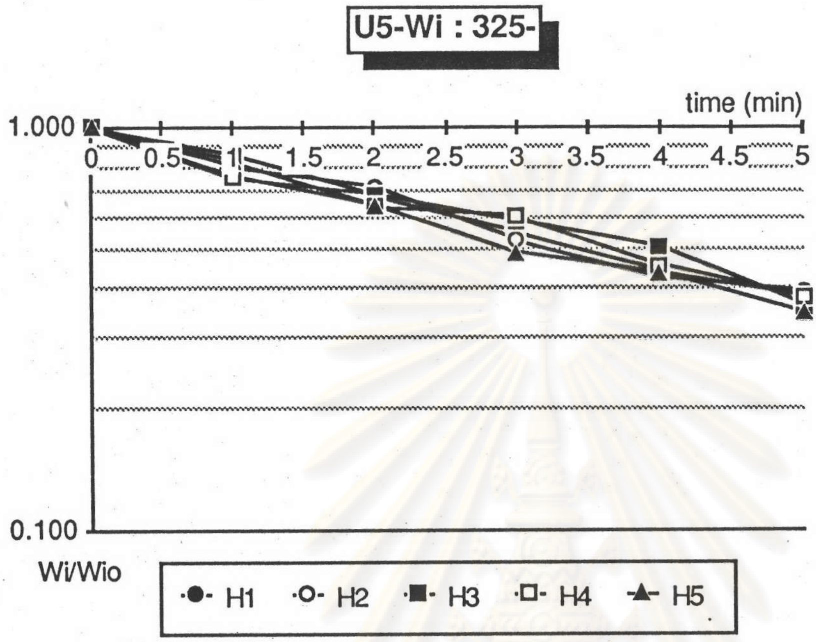


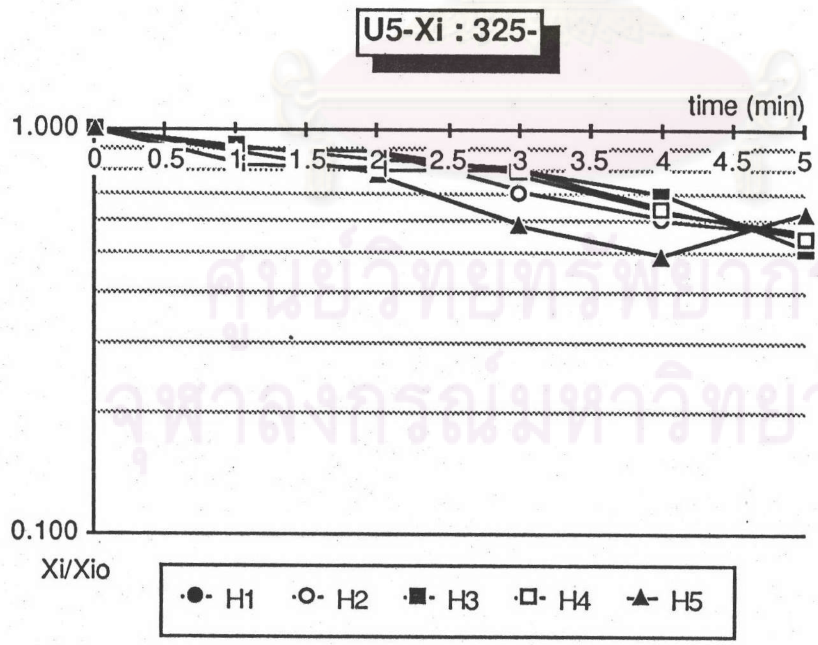
G3.6 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 200-325 mesh (57 μm) in U5 series





G3.7 Comparison of elutriation rate between W_i/W_{io} and X_i/X_{io} of particle class 325- mesh (22 μm) in U5 series





Appendix H

Calculation of efficiency, operating time and energy consumption for ocimum seed powder classification

Efficiency :

The collecting ocimum particles in this study consist of 136-601 μm cut size (20-120 mesh), from Table 3.5, total mass fraction for this size range is 0.6893. The initial weight for each batch of operation is 0.5 kg, thus total quantity of particles expected to be collected (W_o) is

$$W_o = (0.0896+0.2756+0.1764+0.0638+0.0839)x0.5$$

$$= 0.6893 \times 0.5$$

$$= 0.3446 \quad kg$$

From Appendix G3.2 and G3.3, it is shown that elutriation of 80-100 and 100-120 particle classes were terminated within a few minutes, and from Table 5.1c about 50 % of these particles were removed. The actual collection of required particles (W_t) is then determined from the remaning weight fraction ;

$$W_t = (0.0896+0.2756+0.1764)x0.5 + (0.0638+0.0839)(1 - 0.5)x\ 0.5$$

$$= 0.3077 \quad kg$$

$$\text{The classification efficiency} = \frac{W_t}{W_o} \times 100$$

$$= 89.29 \quad \%$$

Operating time :

According to the system of ocimum seed powder, elutriation rate of finest particle was considered as rate determinating step, from Table 5.3 (U5 and H5 of

325- particle group), the elutriation velocity constant, k or ß, of this particle class is -0.126 min^{-1}. Thus, time required for operation could be calculated form ;

$$t_{total} = \frac{1}{|-0.126|}$$

$$= 7.9 \quad \text{minutes}$$

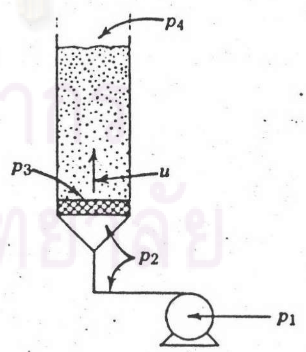
Practically, however, to ensure that fine particles were all removed, operation was performed with about 5-10 minutes additional time. Furthermore, in preliminary study of combined sizing and drying process, it took about 30 minutes time to complete the process.

Energy consumption :

Power consumption is calculated via equation derived from mechanical energy balance (following the method in "Fluidization Engineering", Kunii and Levenspiel, pp 100) (11) ;

$$\frac{-W_{si}}{hr} = \frac{\gamma}{\gamma - 1} p_2V_2 \left[1 - \left(\frac{p_1}{p_2}\right)^{(\gamma - 1)/\gamma} \right]$$

for air; $\gamma = 1.4$, p_1 = 1 atm



$$\frac{\gamma}{\gamma - 1} = \frac{1.4}{(1.4 - 1)}$$

$$= 3.5$$

$$\frac{\gamma - 1}{\gamma} = \frac{1}{3.5}$$

$$= 0.2857$$

$$\frac{-W_{si}}{hr} = 3.5\, p_2V_2 (1 - p_2^{-0.2857})$$

$$p_3 - p_4 = H(1 - \varepsilon)(\rho_s - \rho_g)\frac{g}{g_c}$$

volume of solid $= \frac{(500\ g)}{(1.4\ g/cm^3)}$

$= 357.14 \quad cm^3$

volume of bulk solid $= A_c h$

$= (506.71\ cm^3)\ (6\ cm)$

$= 3040.245 \quad cm^3$

$$\varepsilon = \frac{3040.245 - 357.14}{3040.245}$$

$= 0.8825$

$$p_3 - p_4 = \frac{(150)\ (1 - 0.8825)\ (1.4 - .001)}{1033}$$

$= 0.02388 \quad atm$

the pressure drop through distributor is approximately 10 % of the pressure drop through the bed

$p_2 - p_3 = 0.1 \times 0.02388$

$= 0.0024 \quad atm$

$p_2 = 1 + 0.02388 + 0.0024$

$= 1.026 \quad atm$

$$V_2 = UA_c \frac{p_3}{p_2}$$

$$= (115)(506.71)\left[\frac{(1.026 - 0.0024)}{1.026}\right]$$

$= 58135.34 \quad cm^3/sec$

$= 58.13 \quad lit/s$

$$\frac{-W_{si}}{hr} = (3.5)(1.026)(58.13)(1 - 1.026^{-0.2857})(0.1359)$$

$$= 0.021 \quad hp$$

assumed that blower efficiency is 60 %;

$$\text{power consumption} = \frac{0.21}{0.6}$$

$$= 0.35 \quad hp$$

$$= 0.35 \times 746 \quad watt/hr$$

$$= 261 \quad watt$$

$$\text{energy consumption} = 0.261 \times 0.5$$

$$= 0.13 \quad kwatt\text{-}hr$$

Vita

Mr. Nu Somjanyakul was born in Bangkok on February 25, 1955. He received his Bachelor Degree of Science in Pharmacy, Faculty of Pharmacy, Mahidol University, in 1978.

In 1980, he joined as a researcher in the project of "Development Strategies for Medicinal Plants in Thailand". This project which was prepared for The Office of National Economic and Social Development Board, was carried out by Faculty of Pharmacy, Mahidol University. He is also staff of the research team in the project "The Pharmaceutical Industry in Thailand" that has been carried on since 1982 by the Faculty of Pharmacy. This Project was set up and financially supported by UNIDO.

At present, he is the lecturer at the Department of Manufacturing Pharmacy, Faculty of Pharmacy, Mahidol University and also officially conducting the "Development of Ocimum Seeds as a Bulk Laxative Drug Project".