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APPENDIX - A

AFBC PROGRAM FOR DESIGN F.B.C. OF FUEL

USER MANUAL DISPLAY EXAMPLE

AFBC

(ATMOSPHERIC FLUIDIZED BED COMBUSTOR)

PROGRAM FOR PRELIMINARY DESIGN

; COPYRIGHT, 1987;

BY DEPARTMENT OF CHEMICAL ENGINEER, FACULTY OF ENGINEERING

CHULALONGKORN UNIVERSITY

Press any key to continue...

AFBC

THIS PROGRAM CALCULATES CONCEPTUAL DESIGN OF

FLUIDIZED BED COMBUSTOR

Program concieved and developed by

Sutham Vanichseni
Chinnathep Benyajati
Adinun Laowongsin

Press any key to continue...

Design Approach

1. There is no water tube in combustor.
2. Fluidizing velocity in operation is 2-5 times of minimum fluidizing velocity.
3. Combustion efficiency in this system is 100% .
4. Minimum fluidizing velocity will be calculated from fuel size (in spherical shape), if there is no bed material.

Press any key to continue...

```
                              DESIGN BASIS

Fuel : rice husk : Heating value          =        3600    kcal/hr
""""             : Composition ( H:C:S ) =  4.97 : 38.7 : .1   (by weight)
                 : size diameter (as sphere)    =   .004      m
Air :   Viscosity               =     .000018     kg/(m.s)
"""     Density                 =     1.1532      kg/m^3
        Temperature             =     40          celcius
Bed material : sand             : shape factor  =  .67
                                : minimum void  =  .5
                                : density       =  1550            kg/m^3
                                : size diameter (as sphere) = .0004      m


          Do you want to change this data basis ?
             (1) Change all data       (4) Change bed material data
             (2) Change fuel data      (5) No, continue please
             (3) Change air data

          Choose the number which you want me to do next
```

INPUT DESIGN DATA

Combustion temperature (C)	=	700
Fuel feed rate (kg/hr)	=	162
% excess air	=	25
Resident time (sec)	=	3
Fluidized bed velocity is 2.5		times of Umf
Bed height (m)	=	.4

CALCULATION

Air flow rate	=	956.8605	m^3/hr
Umf	=	.3154386	m/s
Uf	=	.7885966	m/s
Cross sectional area of FBC	=	1.093158	m^2
Combustor ´s height	=	2.76579	m
Heat produced from combustion	=	583200	kcal/hr

Press ESC to design basis or any other key to continue

May I help you to do something ?

(1) Printout design basis, input data and result of calculation

(2) Printout input data and result of calculation

(3) Goto design basis in program and calculate again

(4) Goto input data and calculate again

(5) No, thank you and quit this program

Choose any number which you want me to do next

APPENDIX – B

DRAWING OF SYSTEM

Plate 1 - F.B.C. System

Plate 2 - 3 - Detailed Drawing of Combustor

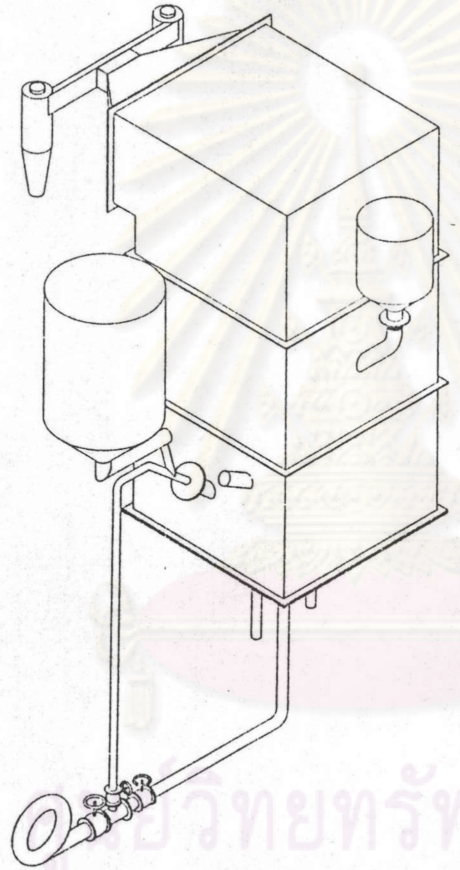
Plate 4 - Nozzle Stand Pipe

Plate 5 - Distributor

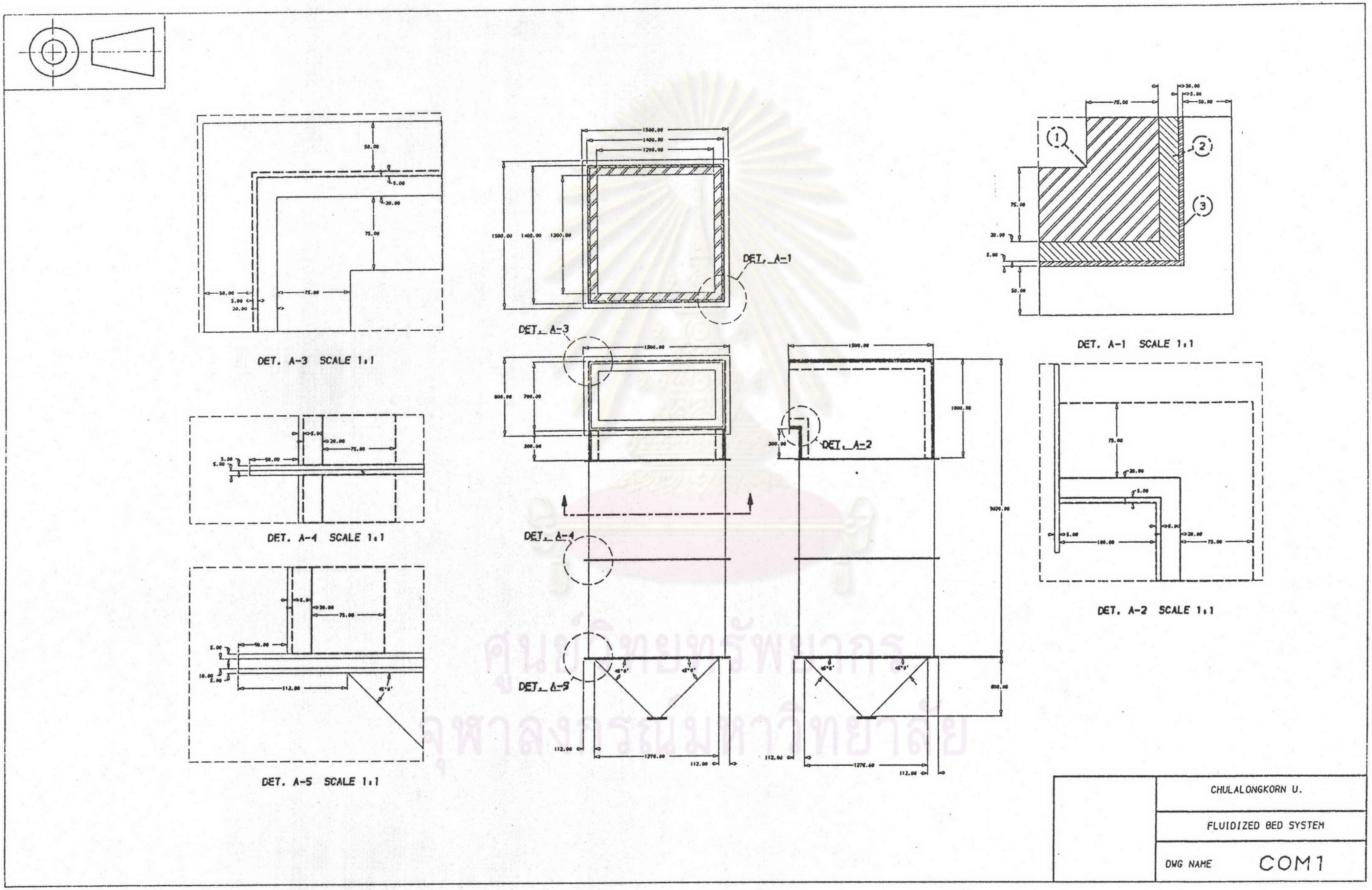
Plate 6 - Thermocouple Location in System

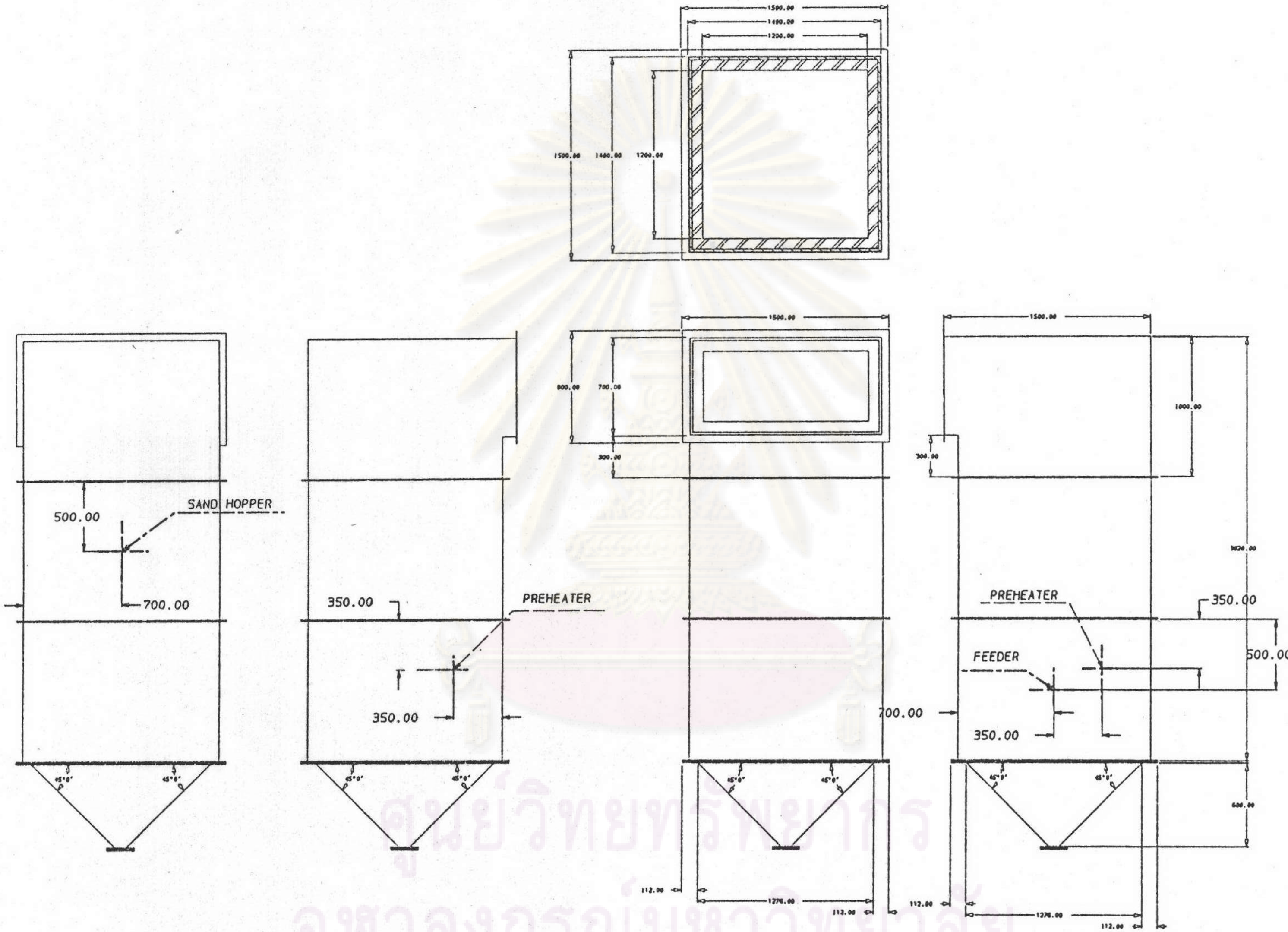
Plate 7 - Diagrame of Temp. Measurement

Plate 7 - 9 - Orifice Plate and Location



	CHULALONGKORN U.
	FLUIDIZED BED SYSTEM
	DWG NAME SYS

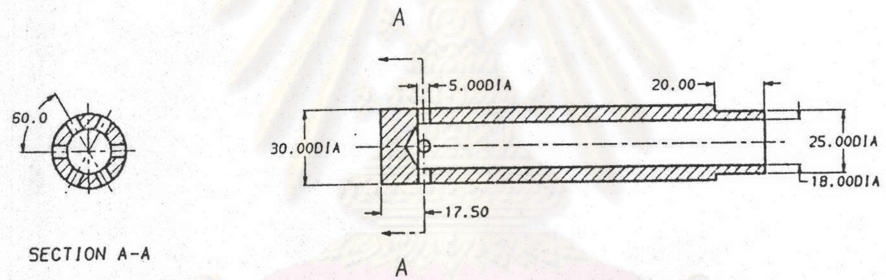

DET. A-3 SCALE 1:1
DET. A-4 SCALE 1:1
DET. A-5 SCALE 1:1
DET. A-1
DET. A-3
DET. A-2
DET. A-4
DET. A-5
DET. A-1 SCALE 1:1
DET. A-2 SCALE 1:1
1500.00
1400.00
1200.00
800.00
700.00
300.00
1000.00
3020.00
800.00
1276.00
112.00
CHULALONGKORN U.
FLUIDIZED BED SYSTEM
DWG NAME COM1



CHULALONGKORN U.

FLUIDIZED BED SYSTEM

DWG NAME COM2



SECTION A-A

SCALE 1:1

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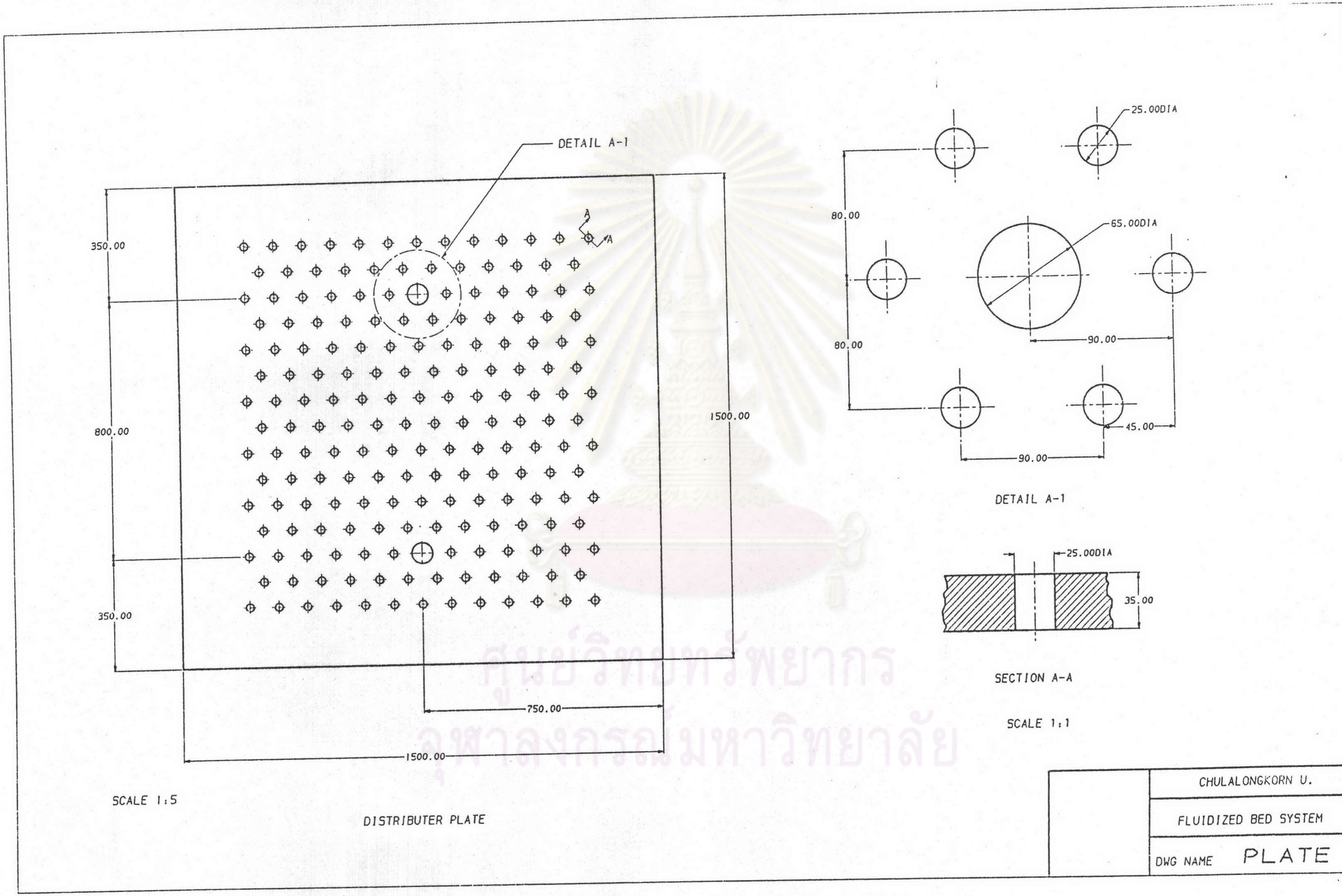
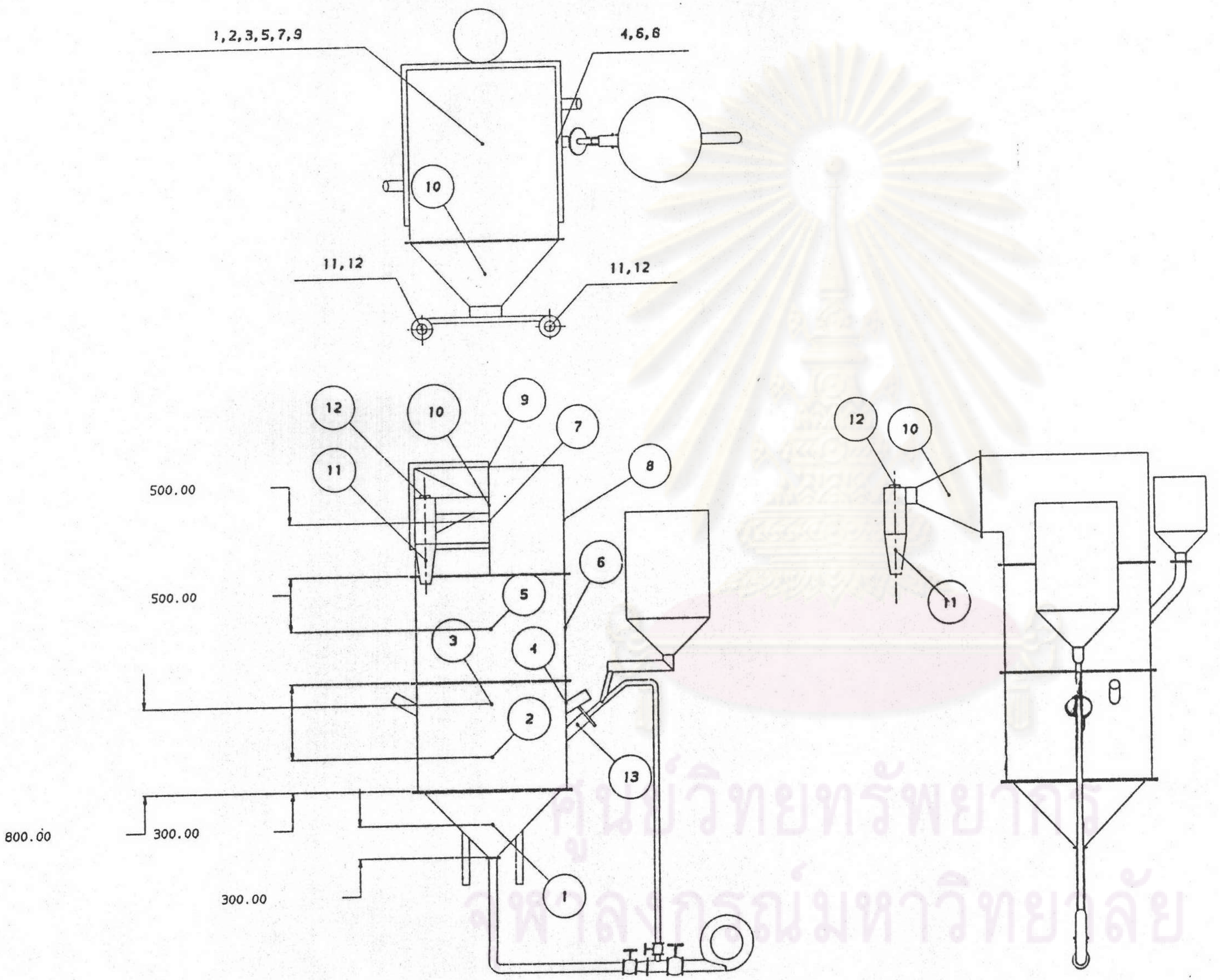
	FLUIDIZED BED SYSTEM
	DWG NAME NOZZLE


DETAIL A-1
A
A
350.00
800.00
350.00
1500.00
750.00
1500.00
SCALE 1:5
DISTRIBUTER PLATE
25.00DIA
65.00DIA
80.00
80.00
90.00
45.00
90.00
DETAIL A-1
25.00DIA
35.00
SECTION A-A
SCALE 1:1
CHULALONGKORN U.
FLUIDIZED BED SYSTEM
DWG NAME PLATE



	CHULALONGKORN U.
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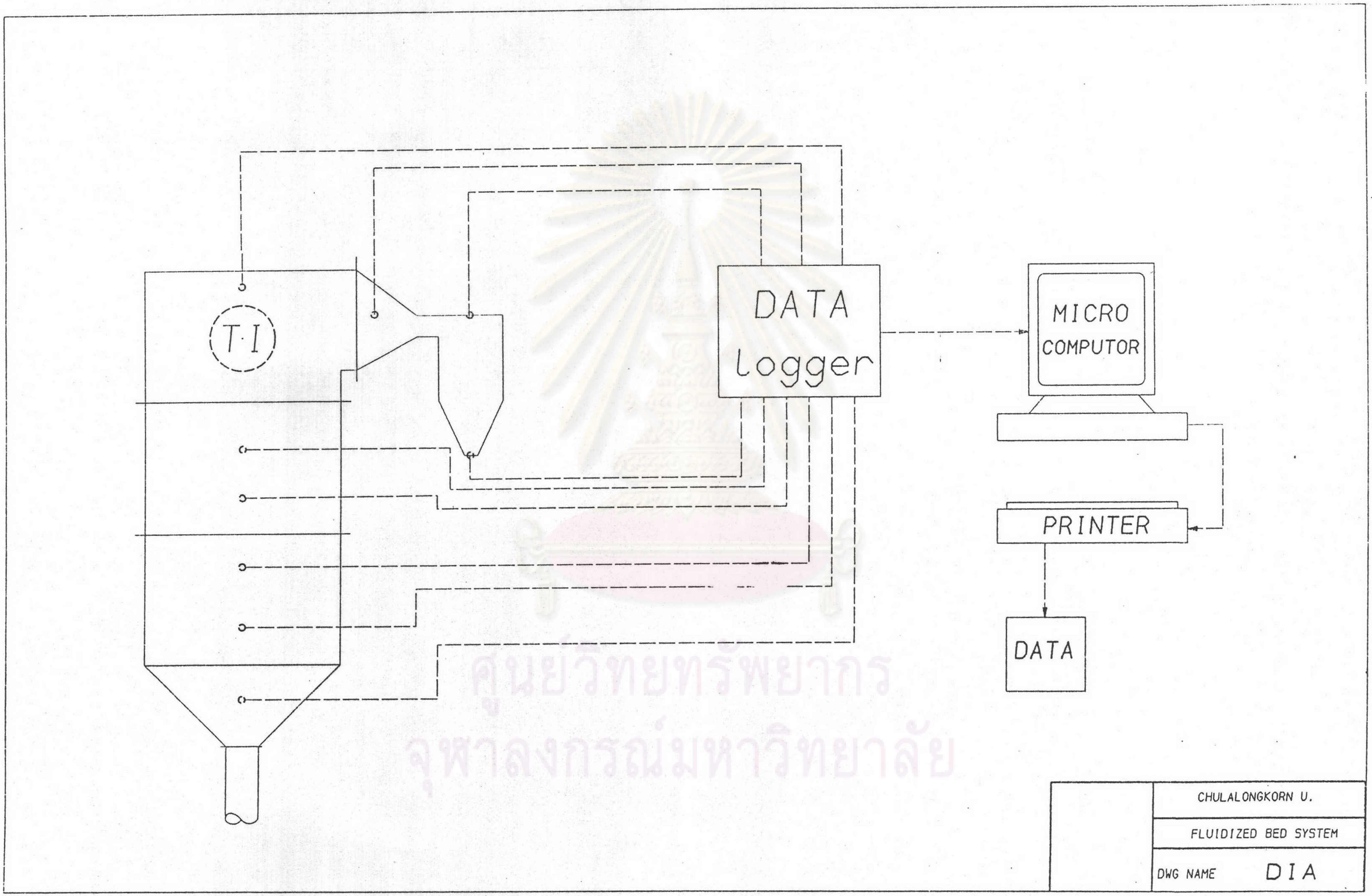
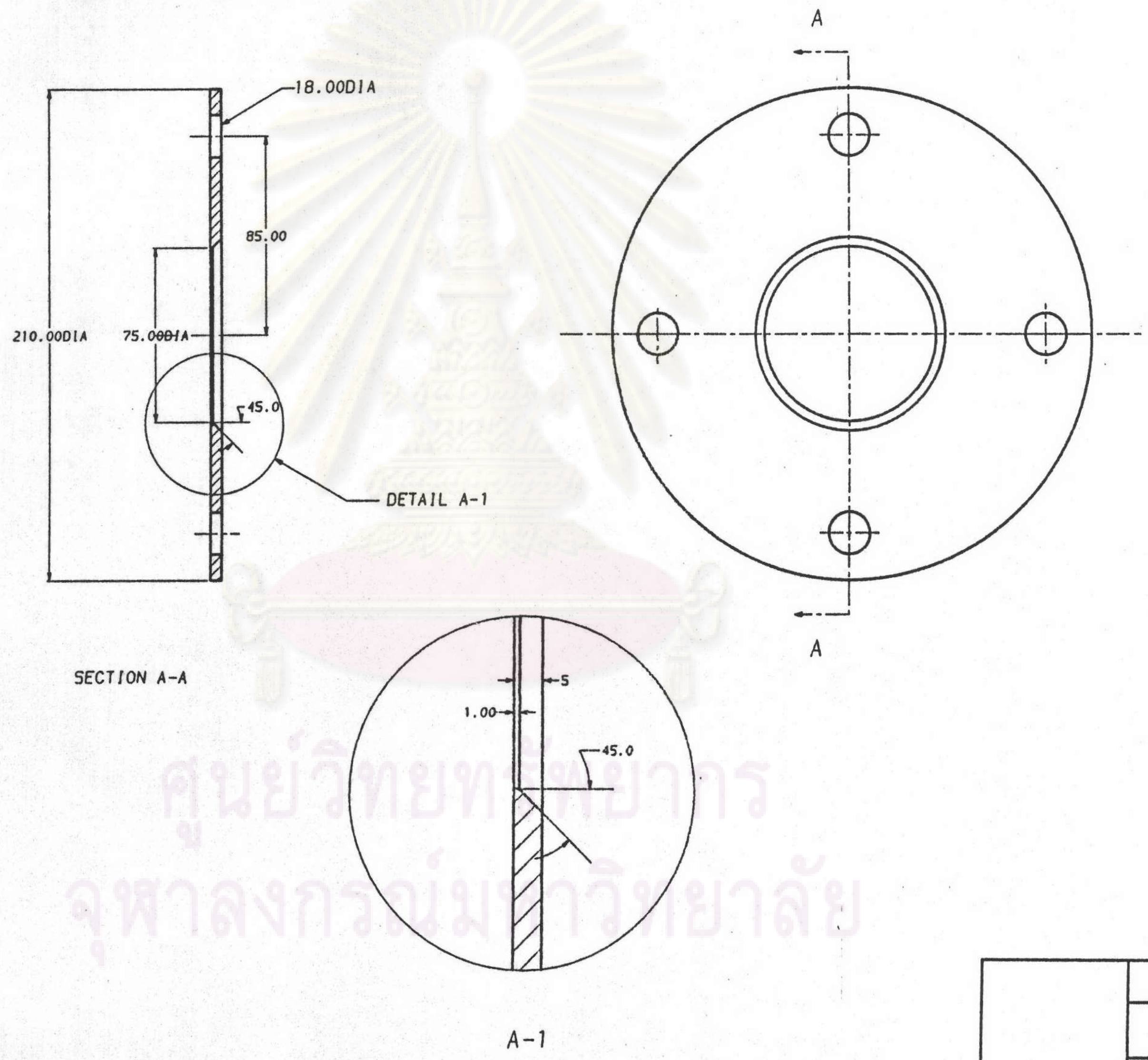
	DWG NAME THERMOC

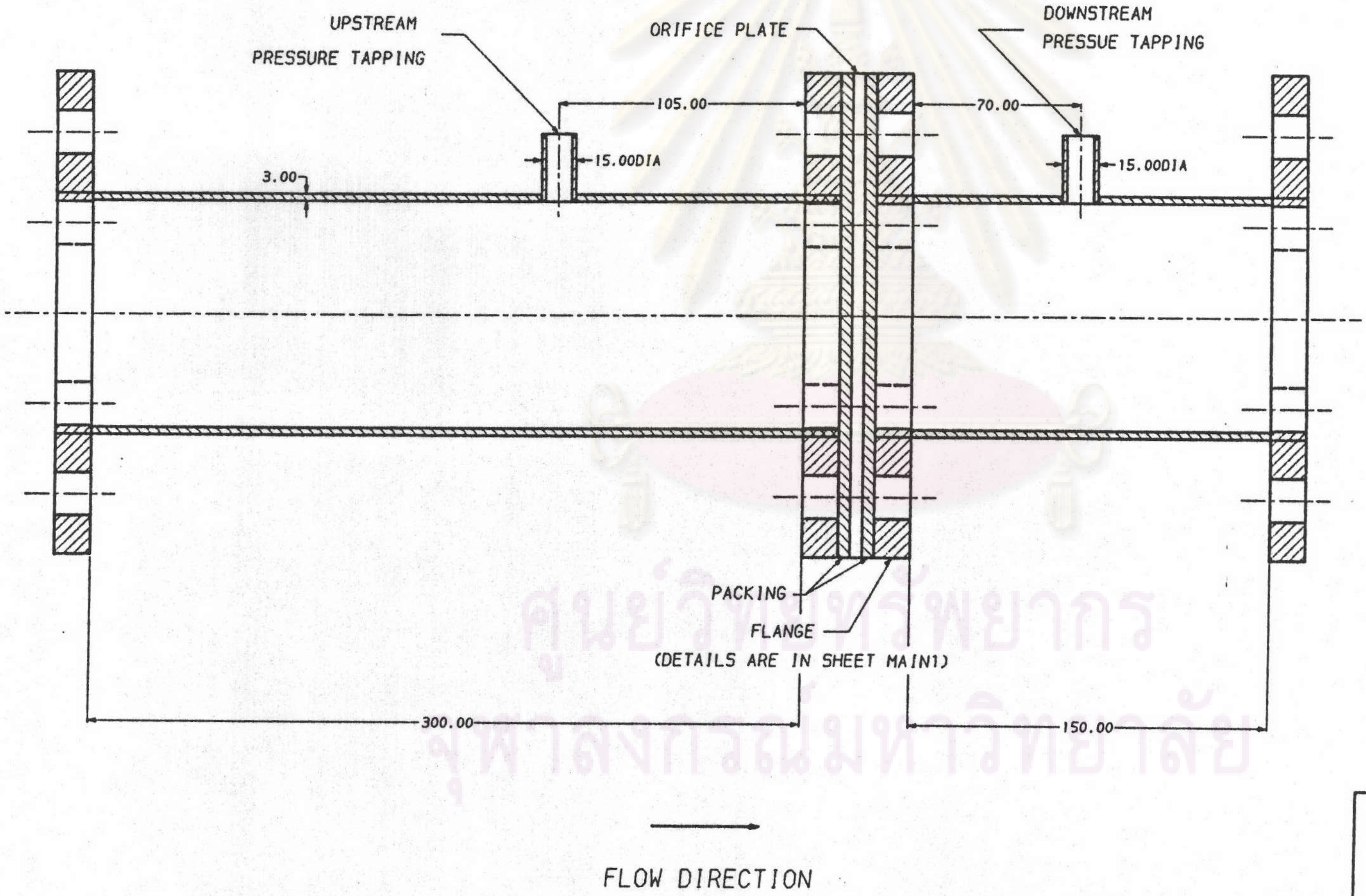

T·I
DATA
Logger
MICRO
COMPUTOR
PRINTER
DATA
CHULALONGKORN U.
FLUIDIZED BED SYSTEM
DWG NAME
DIA



CHULALONGKORN U.

FLUIDIZED BED SYSTEM

DWG NAME ORIFICE1



SCALE 1:1	CHULALONGKORN U.
	FLUIDIZED BED SYSTEM
	DWG NAME ORIFICE2

APPENDIX – C

Detailed Design Calculation of Cyclone

CYCLONE DESIGN

Volumetric Flowrate $Q := 1.944$ m3/s

Selected velocity $U := 100$ m/s

Given

$$a \cdot b = \frac{Q}{U}$$

$$\frac{a}{b} = 2.5$$

$$\begin{bmatrix} a \\ b \end{bmatrix} := \mathrm{Find}(a,b)$$

Solve the above equations yields;

$a = 0.22$ m. inlet height

$b = 0.088$ m. inlet width

For Stairmand Configuration

$D := 2 \cdot a$	$D = 0.441$	m.	body diameter
$S := a$	$S = 0.22$	m.	outlet length
$De := a$	$De = 0.22$	m.	outlet diameter
$h := 3 \cdot a$	$h = 0.661$	m.	cylinder height
$H := 8\ a$	$H = 1.764$	m.	overall hieght
$B := 0.375 \cdot D$	$B = 0.165$	m.	dust outlet diameter
$l := 2.48 \cdot D$	$l = 1.093$	m.	natural length
$N := 6.4 \cdot D$	$N = 2.822$		No.of velocity head

Calculate Grade efficiency

· find n $\qquad T := 1000 \ \mathrm{K}$ (design temperature)

$$n := 1 - \left[1 - 0.67 \cdot \left[D^{0.14}\right]\right] \cdot \left[\frac{T}{283}\right]^{0.3}$$

We have;

$$n = 0.412$$

find C

First compare l with (H-S)

$$l := 2.3 \cdot De \cdot \left[\frac{D^2}{a \cdot b}\right]^{\frac{1}{3}}$$

$$l = 1.092 \qquad\qquad H - S = 1.543$$

If l<(H-S),V=Vnl and if l>(H-S),V=VH

$$VH := \pi \cdot \frac{D^2}{4} \cdot (h - S) + \pi \cdot \frac{D^2}{4} \cdot \frac{H - h}{3} \cdot \left[1 + \left[\frac{B}{D}\right] + \left[\frac{B}{D}\right]^2\right] - \pi \cdot \frac{De^2}{4} \cdot (H - S)$$

$$d := D - (D - B) \cdot \left[\frac{S + l - h}{H - h}\right]$$

$$Vnl := \pi \cdot \frac{D^2}{4} \cdot (h - S) + \pi \cdot \frac{D^2}{4} \cdot \frac{l + S - h}{3} \cdot \left[1 + \left[\frac{d}{D}\right] + \left[\frac{d}{D}\right]^2\right] - \pi \cdot De^2 \cdot \frac{l}{4}$$

$$V := \mathrm{if}(l \le (H - S), Vnl, VH)$$

$$V = 0.093$$

find ψ

particle density $\rho := 1500$ kg/m3

gas viscosity $\mu := 0.000037$ kg/m.s

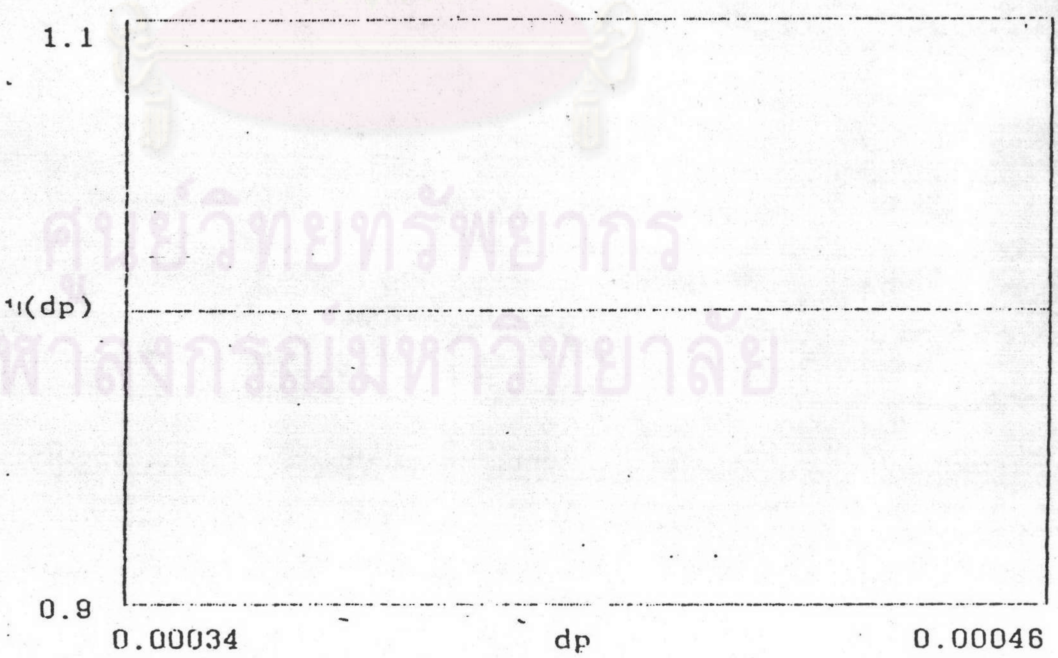
particle size distribution dp := 0.00034,0.00035 ..0.00046

$$\psi(dp) := \rho \cdot dp^{2} \cdot U \cdot \frac{n+1}{18 \cdot \mu \cdot D}$$

Now we can find the grade efficiency; from the values of C,ψ,n

$$\eta(dp) := 1 - \exp\left[-2 \cdot (C \cdot \psi(dp))^{\frac{1}{2 \cdot n+2}}\right]$$

GRADE EFFICIENCY CURVE



calculate Kc

From $$Vs := \pi \cdot \left[S - \frac{a}{2}\right] \cdot \frac{D^2 - De^2}{4}$$ then;

$$Kc := \frac{Vs + \frac{V}{2}}{D^3}$$

$Kc = 0.689$

$Ka := \frac{a}{D}$ $Ka = 0.5$

$Kb := \frac{b}{D}$ $Kb = 0.2$

We have;

$$C := 8 \cdot \frac{Kc}{Ka \cdot Kb}$$

$C = 55.122$

Calculate pressure drop;P

density of gas-particle stream $\rho g := 0.0000058$ g/cm3

Number of inlet velocity head $N = 2.822$

$$P := 5.12 \cdot \rho g \cdot U^2 \cdot N$$ cm. water gauge

$P = 0.838$ cm. water gauge

$$P \cdot 0.01 \cdot \frac{760}{10.33} = 0.617$$ mm.Hg

APPENDIX – D

ORIFICE PROGRAM FOR CALCULATION MASS FLOWRATE

MANUAL DISPLAY AND RESULT

```
     ENTER DATA AT ROOM TEMPERTURE [FOR OLD DATA PRESS RETURN]
     IF YOU HAVE DATA OF DIAAMETER AT WORKING TEMPERATURE PRESS RETURN
PIPE DIAMETER (M)? .1
ORIFICE DIAMETER (M)? .075

ROOM TEMPERTURE (C)? 30
WORKING TEMPERTURE (C)? 35
COEFICIENT OF LINEAR EXPANSION (/K)? .00009

SELECT TYPE OF ORIFICE [FOR OLD DATA PRESS RETURN]
[ENTER 0 FOR SQUARE-EDGE, 1 FOR CORNICAL-EDGE]? 0

SELECT TYPE OF TAPPING [FOR OLD DATA PRESS RETURN]
[ENTER 0 FOR CORNER, 1 FOR D AND D/2, 2 FOR FLANGE TAPPING]? 1

ANY CORRECTION [0 FOR NO, 1 FOR YES]? 0

ENTER TYPE OF FLUID (EXAMPLE WATER, OIL, STEAM, AIR ETC)
[***FOR OLD DATA ENTER `X´ ***]? AIR

    [FOR OLD DATA PRESS RETURN]

UPSTEAM FLOWING FLUID TEMPERTURE (C)? 30
```

```
FLOWING FLUID DENSITY (KG/CU M)
[FOR IDEL GAS JUST PRESS RETURN]?

FLOWING FLUID VISCOSITY (P.S)? .00018

ISENTROPIC EXPONENT [ENTER 0 FOR LIQUID]?

ANY CORRECTION [ 0 FOR NO, 1 FOR YES]? 0

     ***PRESSURE DROP ACROSS ORIFICE***

DO YOU WANT INPUT `MANOMETER READING (m.m.)´ OR `PRESSURE DIFFERENT (Pa.)´ DIREC
TLY
[ENTER 0 FOR MANOMETER READING, 1 FOR PRESSURE DIFFERENT]? 0

     FOR OLD DATA PRESS RETURN

ENTER MANOMETER FLUID DENSITY AT ROOM TEMPERATURE (KG/CU M)
(MAY USE RECOMMENED VALUE OF 13600 KG/CU M FOR MERCURY )? 13600

ENTER FLOWING FLUID DENSITY AT ROOM TEMPERATURE (KG/CU M)
(MAY USE RECOMMENED VALUE OF 1.1532 KG/CU M FOR AIR)? 1.1532

MANOMETER READING ACROSS ORIFICE (m.m.)? 40
```

```
ENTER MANOMETER FLUID DENSITY AT ROOM TEMPERATURE (KG/CU M)
(MAY USE RECOMMENED VALUE OF 13600 KG/CU M FOR MERCURY )? 13600

ENTER FLOWING FLUID DENSITY AT ROOM TEMPERATURE (KG/CU M)
(MAY USE RECOMMENED VALUE OF 1.1532 KG/CU M FOR AIR)? 1.1532

MANOMETER READING ACROSS ORIFICE (m.m.)? 40

       ***UPSTEAM PRESSURE***

DO YOU WANT INPUT `MANOMETER READING (m.m.)´ OR `PRESSURE (Pa.)´ DIRECTLY
[ENTER 0 FOR MANOMETER READING, 1 FOR PRESSURE ]? 0

     FOR OLD DATA PRESS RETURN

ENTER MANOMETER FLUID DENSITY AT ROOM TEMPERATURE (KG/CU M)
(MAY USE RECOMMENED VALUE OF 13600 KG/CU M FOR MERCURY )? 13600

ENTER FLOWING FLUID DENSITY AT ROOM TEMPERATURE (KG/CU M)
(MAY USE RECOMMENED VALUE OF 1.1532 KG/CU M FOR AIR)? 1.1532

MANOMETER READING at upsteam (m.m.)? 200

ANY CORRECTION [ 0 FOR NO , 1 FOR YES ]?
```

```
        ORIFICE DIAMETER (M) at room temperater..............= .075
        ROOM TEMPERATER (C)..................................= 30
        WORKING TEMPERATURE (C)..............................= 35
        TYPE OFF ORIFICE.....................................: SQUARE-EDGE
        TYPE OFF TAPPING ....................................: D AND D/2 TAPPING

GROUP 2
        TYPE OF FLUID.......................................: AIR
        UPSTEAM FLOWING FLUID TEMPERATER (C).................= 30
        FLOWING FLUID DENSITY (KG/CU M)......................= 0
        FLOWING FLUID VISCOSITY (P.S)........................= .00018
        ISENTROPIC EXPONENT .................................= 0

GROUP 3
             *PRESS DROP ACROSS ORIFICE*
        MANOMETER FLUID DENSITY at room temperater (KG/CU M).= 13600
        FLOWING FLUID DENSITY at room temprater (KG/CU M)....= 1.1532
        MANOMETER READING across orifice ((M.M.).............= 40
             *UPSTEAM PRESSURE*
        MANOMETER FLUID DENSITY at room temperater (KG/CU M).= 13600
        FLOWING FLUID DENSITY at room temprater (KG/CU M)....= 1.1532
        MANOMETER READING at upsteam (M.M.)..................= 200

ANY CORRECTION [ 0 FOR NO, 1 FOR YES ]?
```

```
FOR SQUARE-EDGED ORIFICE
LIMITS OF USES :
       D AND D/2 TAPPING
     .2000000 <= BETA <=  .75
     .0709069   <= RE <=   1E08

              MEASURED DATA :

PRESSURE DIFFERNCE (PA) =  5334.806       ( 40 MM OF MANOMETER LIQUID)
UPSTREAM PRESSURE (PA)= 26674.03          ( 200 MM OF MANOMETER LIQUID)
FLUID TEMPERATURE (C) =................................ 30

          FLOWING FLUID PROPERTIES :

DENSITY (KG/CU M)=..................................... 1.164958
VISCOSITY (PA.S) =..................................... .00018
EXPANSION FACTOR =..................................... 1

         MANOMETER FLUID PROPERTIES :

ORIFICE MANOMETER FLUID DENSITY (KG/CU M) = ........... 13600
UPSTREAM PRESSURE MANOMETER FLUID DENSITY (KG/CU M) =.. 13600

TO CONTINUE PRESS RETURN ?
```

MANOMETER FLUID PROPERTIES :

ORIFICE MANOMETER FLUID DENSITY (KG/CU M) = ... 13600
UPSTREAM PRESSURE MANOMETER FLUID DENSITY (KG/CU M) =.. 13600

TO CONTINUE PRESS RETURN ?

GEOMETRIC FACTORS :

ORIFICE DIAMETER (M) =................................ 7.503376E-02
PIPE DIAMETER (M) = ... .100045
ORIFICE TO PIPE DIAMETER RAITIO = ... .75
VELOCITY OF APPROACH FACTOR = ... 1.209486

CALCULATED RESULTS :

DISCHARGE COEFFICIENT = ... .6306855
REYNOLD'S NUMBER = ... 25294.56
FLOWRATE (KG/S) = ... .3578983
FLOWRATE (CU M /S) = ... .30722
PRESSURE RATIO (P2/P1 SHOULD EXCEED 0.75) =........... .8

DOU YOU WANT PRINTOUT RESULT (Y/N)?

FOR SQUARE-EDGED ORIFICE
LIMITS OF USES :
D AND D/2 TAPPING
.2000000 <= BETA <= .75
.0709069 <= RE <= 1E08

MEASURED DATA :

PRESSURE DIFFERNCE (PA) = 5334.806 (40 MM OF MANOMETER LIQUID)
UPSTREAM PRESSURE (PA)= 26674.03 (200 MM OF MANOMETER LIQUID)
FLUID TEMPERATURE (C) =.............................. 30

FLOWING FLUID PROPERTIES :

TYPE OF FLUID...AIR
DENSITY (KG/CU M)=................................... 1.164958
VISCOSITY (PA.S) =................................... .00018
EXPANSION FACTOR =................................... 1

MANOMETER FLUID PROPERTIES :

ORIFICE MANOMETER FLUID DENSITY (KG/CU M) = ... 13600
UPSTREAM PRESSURE MANOMETER FLUID DENSITY (KG/CU M) =.. 13600

GEOMETRIC FACTORS :

ORIFICE DIAMETER (M) =............................. 7.503376E-02
PIPE DIAMETER (M) = ... .100045
ORIFICE TO PIPE DIAMETER RAITIO = ... .75
VELOCITY OF APPROACH FACTOR = ... 1.209486

CALCULATED RESULTS :

DISCHARGE COEFFICIENT = ... .6306855
REYNOLD'S NUMBER = ... 25294.56
FLOWRATE (KG/S) = ... .3578983
FLOWRATE (CU M /S) = ... .30722
PRESSURE RATIO (P2/P1 SHOULD EXCEED 0.75) =........... .8

Bibliography

Mr. Adinun Laowongsin was born in July 25 ,1961 in Bangkok, Thailand, He attended Wat Ratcha - O - Rot High school in Bangkok and graduated in 1980 .He recieved his Bachelor degree in Engineering Chemical from the Department of Chemical Technology, Faculty of Science, Chulalongkorn University in 1984. He continued his Master's study at Faculty of Engineering at Chulalongkorn University in 1985 and granted the degree in October 1990