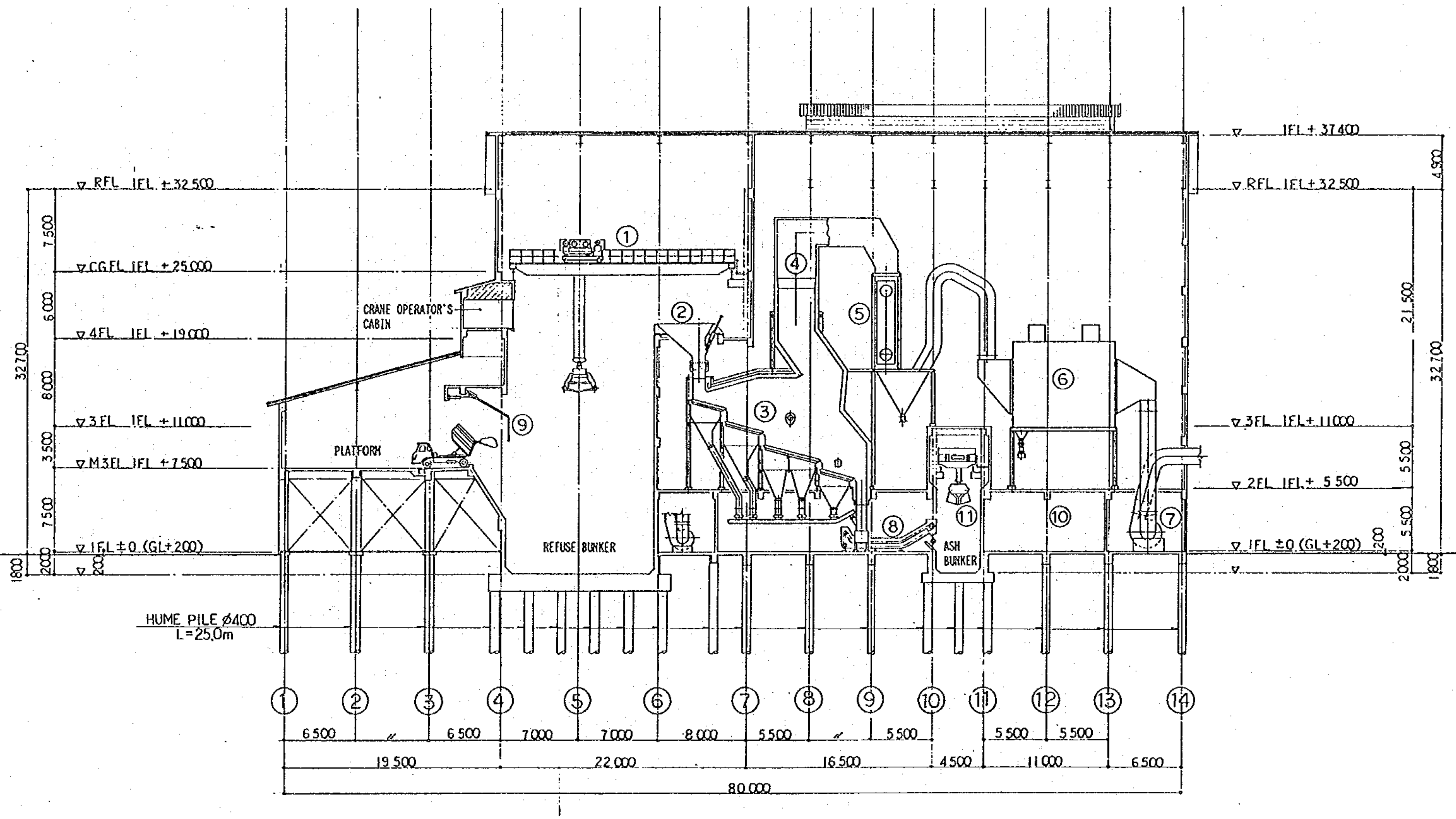


① REFUSE CRANE
② CHARGING HOPPER
③ FURNACE
④ GAS COOLER
⑤ GAS AIR HEATER
⑥ ELECTROSTATIC PRECIPITATOR
⑦ INDUCED DRAFT FAN
⑧ ASH CONVEYOR
⑨ DAMPING DOOR
⑩ WASTE WATER TREATMENT PLANT
⑪ ASH CRANE

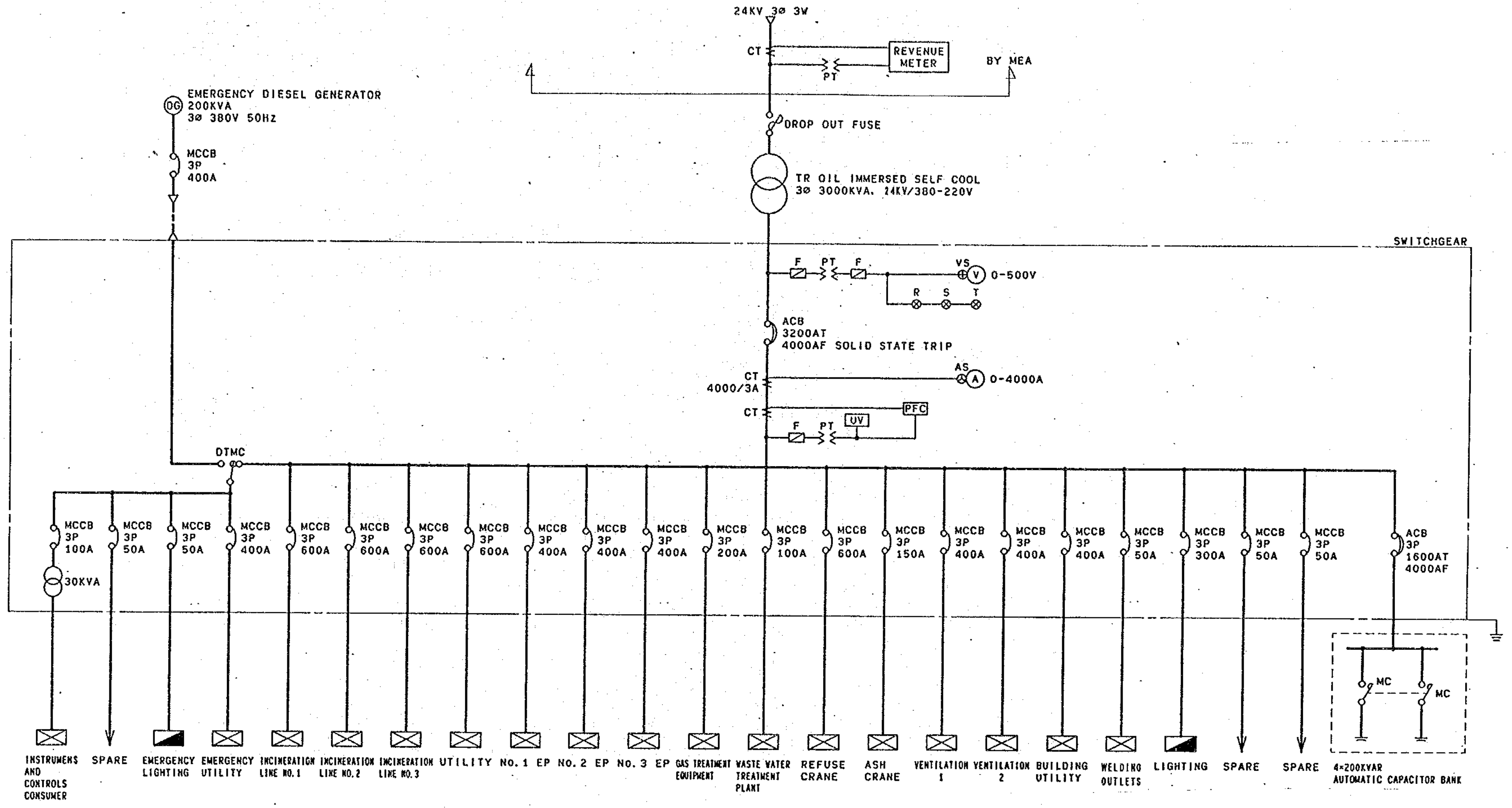
ON NUT INCINERATION PLANT

EQUIPMENT LAYOUT SECTION

| SCALE | DRAWING NO. | DATE |
|---|---|---|
| As shown | I-7 | 15/12/1990 |

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



ON NUT INCINERATION PLANT

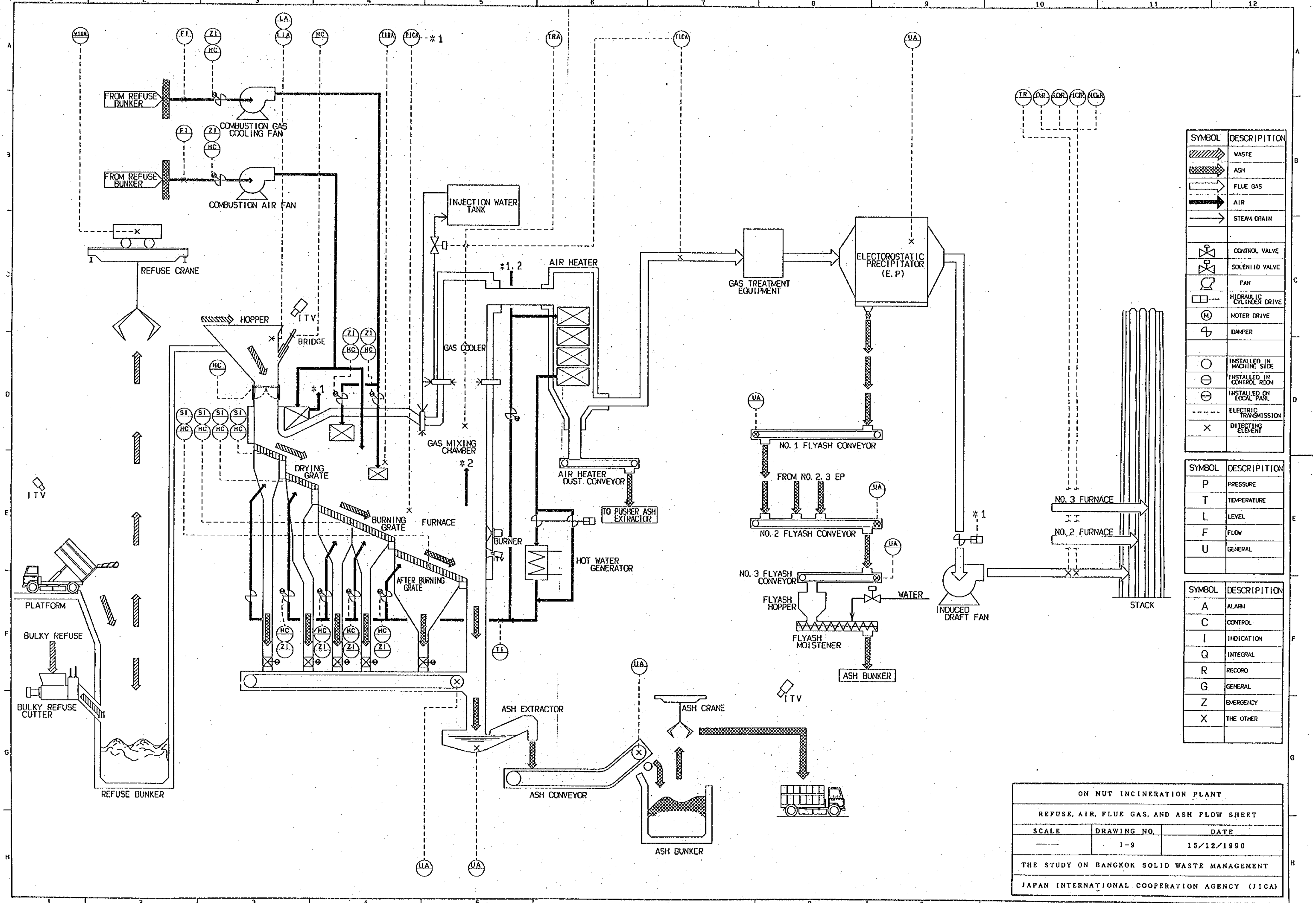
SINGLE LINE DIAGRAM

| SCALE | DRAWING NO. | DATE |
|---|---|---|
| ——— | I-8 | 15/12/1990 |

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

EQ7543- 1.A2



| SYMBOL | DESCRIPITION |
|---|---|
| ▨ | WASTE |
| ▩ | ASH |
| ⇨ | FLUE GAS |
| ➡ | AIR |
| → | STEAM DRAIN |
|  |  |
|  | CONTROL VALVE |
|  | SOLENIID VALVE |
|  | FAN |
|  | HIDRAULIC CYLINDER DRIVE |
| Ⓜ | MOTER DRIVE |
|  | DAMPER |
|  |  |
| ○ | INSTALLED IN MACHINE SIDE |
| ⊖ | INSTALLED IN CONTROL ROOM |
| ⊜ | INSTALLED ON LOCAL PANL |
| ------ | ELECTRIC TRANSMISSION |
| × | DITECTING ELEMENT |

| SYMBOL | DESCRIPITION |
|---|---|
| P | PRESSURE |
| T | TEMPERATURE |
| L | LEVEL |
| F | FLOW |
| U | GENERAL |

| SYMBOL | DESCRIPITION |
|---|---|
| A | ALARM |
| C | CONTROL |
| I | INDICATION |
| Q | INTEGRAL |
| R | RECORD |
| G | GENERAL |
| Z | EMERGENCY |
| X | THE OTHER |

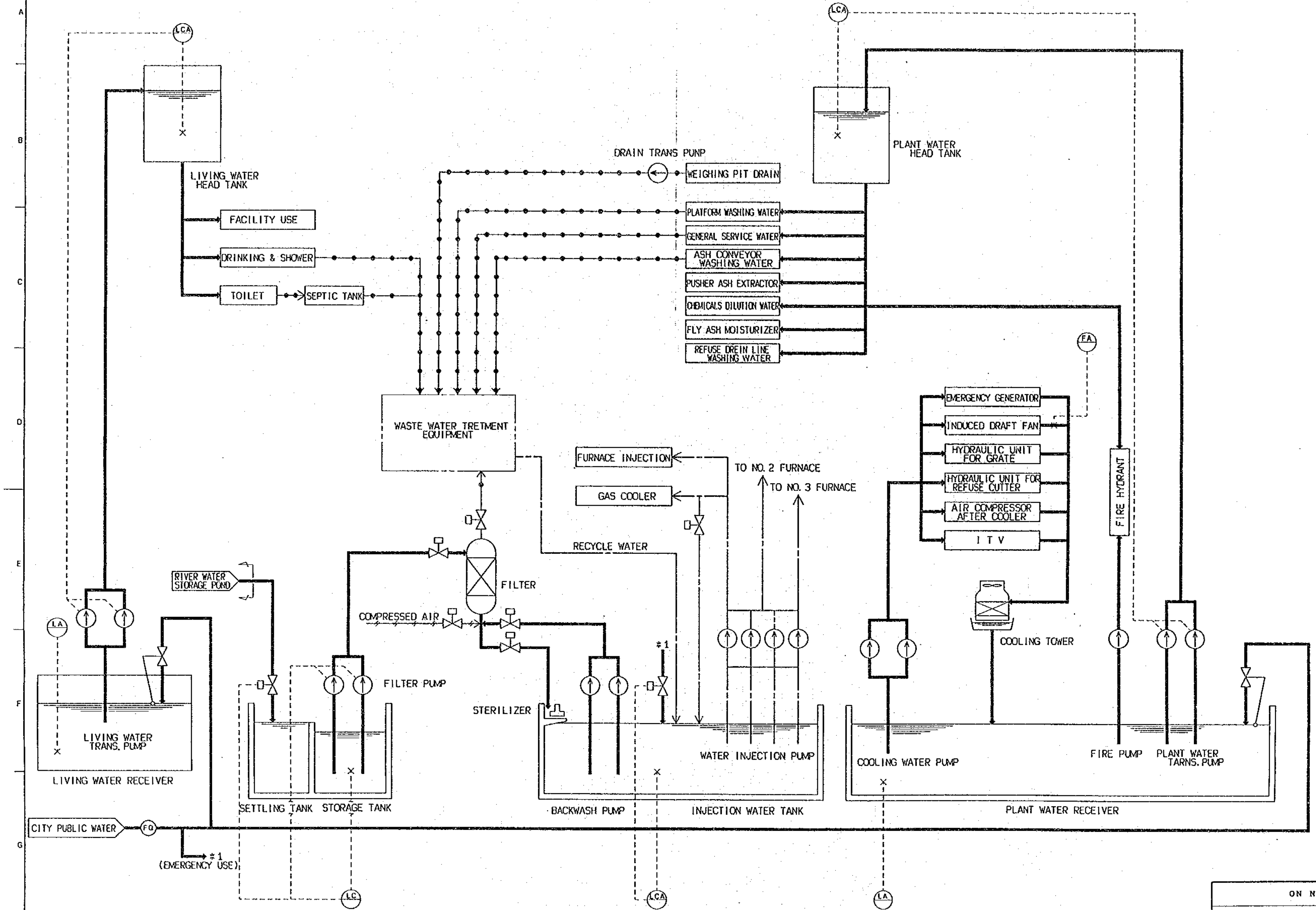
ON NUT INCINERATION PLANT

REFUSE, AIR, FLUE GAS, AND ASH FLOW SHEET

| SCALE | DRAWING NO. | DATE |
|---|---|---|
| —— | I-9 | 15/12/1990 |

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



| SYMBOL | DESCRIPITION |
|---|---|
| ━━━> | FRESH WATER |
| -●-●-●-> | WASTE WATER |
| - - - -> | RECYCLE WATER |
| | |
| | |
| | |
| ⋈ | SOLENIID VALVE |
| ⋈○ | BALL TAP VALVE |
| ⊖ | PUMP |
| | |
| | |
| ○ | INSTALLED IN MACHINE SIDE |
| ⊖ | INSTALLED IN CONTROL ROOM |
| ⊜ | INSTALLED ON LOCAL PANL |
| - - - - - | ELECTRIC TRANSMISSION |
| × | DITECTING ELEMENT |
| | |

| SYMBOL | DESCRIPITION |
|---|---|
| P | PRESSURE |
| T | TEMPERATURE |
| L | LEVEL |
| F | FLOW |
| U | GENERAL |
| | |

| SYMBOL | DESCRIPITION |
|---|---|
| A | ALARM |
| C | CONTROL |
| I | INDICATION |
| Q | INTEGRAL |
| R | RECORD |
| G | GENERAL |
| Z | EMERGENCY |
| X | THE OTHER |
| | |

ON NUT INCINERATION PLANT

WATER SUPPLY & DRAINAGE SYSTEM FLOW SHEET

| SCALE | DRAWING NO. | DATE |
|---|---|---|
| —— | I-10 | 15/12/1990 |

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

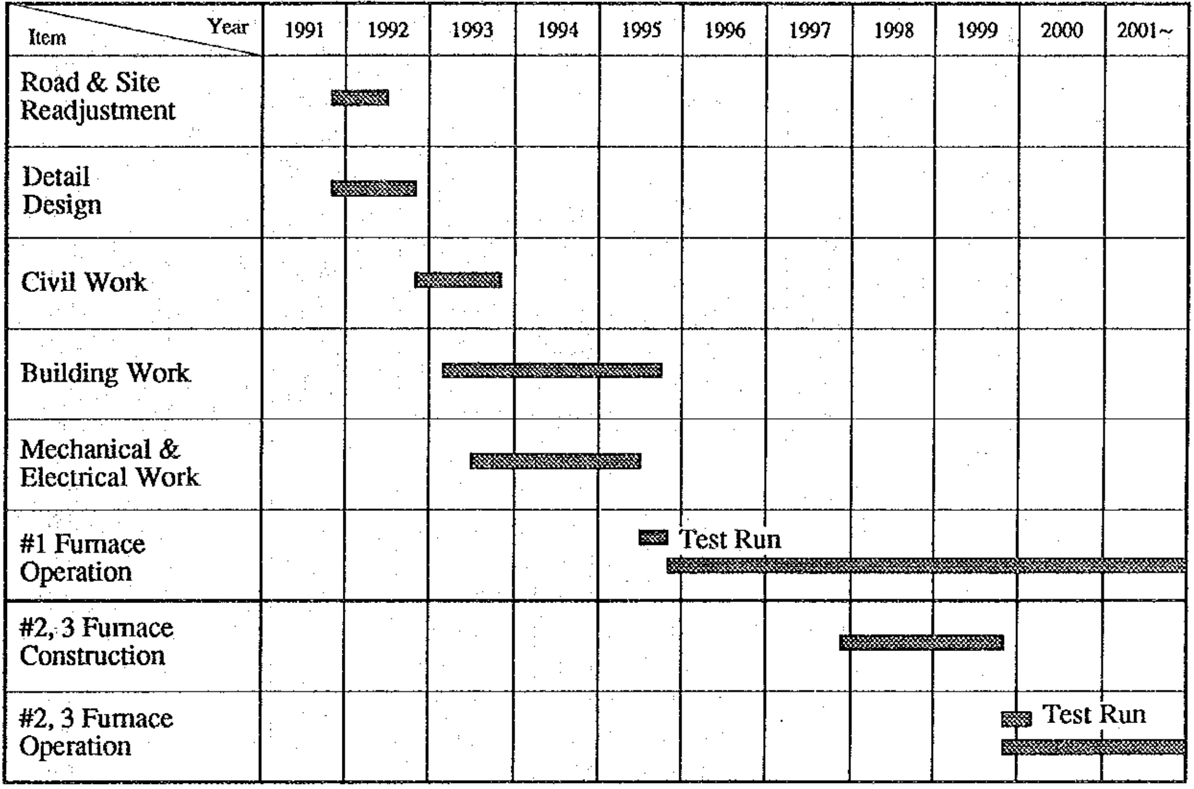
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

A1

## 10.4 Financial Expenditure of On Nut Incineration Plant

Table 10.4-1 Schedule of Construction

Real Year



Note: #1 Furnace including Pit, Stack, Water Treatment Facility for #2 and 3 will be constructed 1996. Then after #1 furnace, 2000 #2 and #3 will be constructed by 2 phase step.

Table 10.4-2 Cost Required

(Million Baht) in 1990 price

| Fiscal Year | Parts& Repair | Emolu-ment | Utility | O/M Total | Construc-tion | Total | Waste Amount (t/d) |
|---|---|---|---|---|---|---|---|
| 1991 | | | | | | | |
| 1992 | | | | | | | |
| 1993 | | 0.61 | | 0.61 | 490.00 | | |
| 1994 | | 0.63 | | 0.63 | 490.00 | | |
| 1995 | | 3.90 | | 3.90 | 229.00 | | |
| 1996 | 4.00 | 6.20 | 15.04 | 25.24 | | | 150 |
| 1997 | 4.08 | 6.38 | 15.04 | 25.50 | | | 150 |
| 1998 | 10.91 | 6.58 | 14.81 | 32.30 | 280.00 | | 150 |
| 1999 | 42.00 | 10.10 | 14.80 | 66.90 | 280.00 | | 150 |
| 2000 | 19.50 | 13.12 | 30.45 | 63.07 | 73.00 | | 470 |
| 2001 | 21.27 | 13.52 | 29.75 | 64.54 | | | 470 |
| 2002 | 36.68 | 13.93 | 29.59 | 80.20 | | | 470 |
| 2003 | 152.41 | 14.34 | 29.14 | 195.89 | | | 470 |
| 2004 | 36.59 | 14.77 | 29.93 | 81.29 | | | 470 |
| 2005 | 41.22 | 15.22 | 29.74 | 86.18 | | | 470 |
| 2006 | 47.15 | 15.67 | 29.74 | 92.56 | | | 470 |
| 2007 | 217.81 | 16.14 | 29.74 | 263.69 | | | 470 |
| 2008 | 42.24 | 16.63 | 29.74 | 88.61 | | | 470 |
| 2009 | 47.13 | 17.13 | 29.74 | 94.00 | | | 470 |
| 2010 | 52.97 | 17.64 | 29.74 | 100.35 | | | 470 |
| 2011 | 250.16 | 18.17 | 29.74 | 298.07 | | | 470 |
| 2012 | 45.52 | 18.71 | 29.74 | 93.97 | | | 470 |
| 2013 | 52.97 | 19.28 | 29.20 | 101.45 | | | 450 |
| 2014 | 57.30 | 19.85 | 29.20 | 106.35 | | | 450 |
| Total | 1,181.91<br>31% | 278.52<br>7% | 504.87<br>13% | 1,965.30 | 1,842.00<br>48% | 3,807<br>100% | 2,777,650 t |
| Unit cost of incineration | 1,371 Baht/t | | | | | | |

Table 10.4-3 Financial Expenditure

(Million Baht) in 1990 price

| Items | Fiscal Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | Total |
| Construction | 490 | 490 | 229 | - | - | 280 | 280 | 73 | 1,842 |
| Operation & Maintenance | | | | | | | | | |
| Emolument | 0.61 | 0.63 | 3.90 | 6.20 | 6.38 | 6.58 | 10.10 | 13.12 | 47.52 |
| Utility | | | | 15.04 | 15.04 | 14.81 | 14.80 | 30.45 | 90.14 |
| Parts *1 | | | | 0.36 | 0.44 | 1.82 | 2.00 | 2.80 | 7.42 |
| Repair *2 | | | | 3.64 | 3.64 | 9.09 | 40.00 | 16.70 | 73.07 |
| Subtotal | 0.61 | 0.63 | 3.90 | 25.24 | 25.50 | 32.30 | 66.90 | 63.07 | 218.15 |
| Total | 491 | 491 | 233 | 25 | 26 | 312 | 347 | 136 | 2,061 |

Note: (1) Electricity : 2.7 B/kWh
(2) Fuel : 8.0 B/l
(3) Water : 4.0 B/m3
(4) Emolument 1990 price Engineer : 180,000 B/y/person
Skilled : 120,000 B/y/person
Worker : 60,000 B/y/person
3% of increase every year estimated
(5) Total of Construction Cost : 1,842 Million Baht

*1: Parts include materials and equipment used for operation and maintenance.

*2: Repair means mainly overhaul which will be done by a contractor. Cost of minor repair to be done by the BMA is also included.

Table 10.4-4 Construction Cost in one step totally #1, 2, 3

(Million Baht) in 1990 price

| Items | Foreign portion | Local portion | Total |
|---|---|---|---|
| 1. Mechanical and Electrical Work (including Engineering fee, Supervising fee, Inspection fee and other fees) | | | |
| 1.1 Equipment | | | |
| 1) Waste Reception System | 138.82 | 4.25 | 143.07 |
| 2) Incineration System | 144.52 | 68.80 | 213.32 |
| 3) Gas Cooling System | 13.00 | 5.34 | 18.34 |
| 4) Gas Treatment System | 65.78 | 0.36 | 66.14 |
| 5) Water Supply System | 15.98 | 3.16 | 19.14 |
| 6) Waste Water Treatment System | 18.84 | 0 | 18.84 |
| 7) Heat Utilization System | 1.66 | 0.38 | 2.04 |
| 8) Air Preheating System | 63.54 | 21.13 | 84.67 |
| 9) Ash Handling System | 51.00 | 0.85 | 51.85 |
| 10) Electrical Equipment | 53.14 | 0 | 53.14 |
| 11) Measuring and Control System | 57.20 | 0 | 57.20 |
| 12) Auxiliary Equipment | 4.72 | 0 | 4.72 |
| Sub Total | 628.20 | 104.27 | 732.47 |
| 1.2 Freightage | 44.94 | 0 | 44.94 |
| 1.3 Installation Work (including Painting, Insulating, Refractory lining, Piping and Wiring) | 0 | 186.43 | 186.43 |
| 2. Civil and Building Work | | | |
| 1) Civil Work | 0 | 5.60 | 5.60 |
| 2) Building | 77.16 | 551.27 | 628.43 |
| 3) Stack | 5.38 | 38.51 | 43.89 |
| Sub Total | 82.54 | 595.38 | 677.92 |
| 3. Supplementary Work (Parking lot, Canal Water Inlet Facility, Gate and Fence, Plantation, Lighting, Rainwater Drainage, Water Spray Equipment and Pavement of Sub-area) | 0 | 2.45 | 2.45 |
| 4. Insurance | 0.90 | 18.00 | 18.90 |
| Intermediate Total | 756.58 | 906.53 | 1,663.11 |
| 5. Tax | | | |
| 1) Custom | 35.90 | 0 | 35.90 |
| 2) Business & Stamp Tax (3.3 + 0.1%) | 27.89 | 32.93 | 60.82 |
| 3) Labor Tax (3% on local portion) | 0 | 29.06 | 29.06 |
| Sub Total | 63.79 | 61.99 | 125.78 |
| Total | 820.37 | 968.52 | 1,788.89 |

(Baht)

| | | | | |
|---|---|---|---|---|
| Civil Work | | | | |
| Piling | ø300 x 107 Pile (x 25 m) | @ 9,000 | 1,500 | 1,123,500 |
| | ø350 x 78 pile (x 25 m) | @ 12,000 | 2,000 | 1,092,000 |
| | ø400 x 174 Pile (x 25 m) | @ 14,500 | 2,500 | 2,958,000 |
| | | Sub Total | | 5,173,500 |
| Ground Work (Pond, Rearrangement, Road) | | | | |
| | Pond | 200 $m^2$ | @ 500 | 100,000 |
| | Rearrangement | 1,000 $m^2$ | @ 300 | 300,000 |
| | Road | 100 $m^2$ | @ 300 | 30,000 |
| | | Sub Total | | 430,000 |
| | | Total | | 5,603,000 |
| | | | | 560 million B |

| | | |
|---|---|---|
| Supplementary Work | | |
| Parking Lot, 150 m2 @ 200 | | 30,000 |
| Canal Water Inlet Facility (1.5 km piping pump station) | | 2,251,000 |
| Gate & Fence | | 50,000 |
| Plantation | | 20,000 |
| Lighting | | 15,000 |
| Rain Water Drainage | | 65,000 |
| Water Spray | | 10,000 |
| Pavement | | 10,000 |
| | Total | 2,451,000 |
| | | 2.45 million B |

Tax

Custom [(Mechanical & Electrical Equipment - Engineering Fee, ...) x 50%
+ Freightage] x 10%
= (628.20 x 0.5 + 44.94) x 0.1 = 35.90 million B

| | | |
|---|---|---|
| Business Tax | Total x 3.3% | |
| Stamp Tax | Total 0.1% | |
| | Total x 3.4% | = 820.37 x 0.034 = 27.89 million B |
| Labor Tax | Local Total x 3.0% | = 968.52 x 0.03 = 29.06 million B |

Note)

1. The price is the current price as of 1990.
2. The equipment cost includes design fee, supervisory fee and other related cost.
3. Following exchange rate is used for cost estimation.
   5 Yen = 1 Baht
4. Followings are out of our scope of work:
   1) General
      1 Items not described on this quotation
   2) Temporary work
      1 Countermeasure work against grade settlement
   3) Civil and Building work
      1 Special dewatering
      2 Furniture
      3 External work and Landscaping
   4) Building Service facilities
      1 Temporary electrical work for construction and permanent electrical work outside of construction site
      2 Telephone wiring work outside of construction site
      3 Expense for regular inspection

Table 10.4-5 Construction Cost in Steps

(Million Baht) in 1990 price

| Items<br>Construction Schedule | #1 Furnace<br>1993-1995 | #2,3 Furnace<br>1998-2000FY | Total |
|---|---|---|---|
| 1. Mechanical and Electrical Work | | | |
| 1.1 Equipment | | | |
| 1) Waste Reception System | 124.00 | 20.00 | 144.00 |
| 2) Incineration System | 74.00 | 140.00 | 214.00 |
| 3) Gas Cooling System | 9.00 | 10.00 | 19.00 |
| 4) Gas Treatment System | 30.00 | 37.00 | 67.00 |
| 5) Water Supply System | 10.00 | 10.00 | 20.00 |
| 6) Waste Water Treatment System | 15.00 | 4.00 | 19.00 |
| 7) Heat Utilization System | 1.00 | 1.00 | 2.00 |
| 8) Air Preheating System | 35.00 | 50.00 | 85.00 |
| 9) Ash Handling System | 32.00 | 20.00 | 52.00 |
| 10) Electrical Equipment | 34.00 | 20.00 | 54.00 |
| 11) Measuring and Control System | 28.00 | 30.00 | 58.00 |
| 12) Auxiliary Equipment | 4.00 | 1.00 | 5.00 |
| Sub Total | 396.00 | 343.00 | 739.00 |
| 1.2 Freightage | 20.00 | 25.00 | 45.00 |
| 1.3 Installation Work | 100.00 | 115.00 | 215.00 |
| 2. Civil and Building Work | | | |
| 1) Civil Work | 5.00 | 1.00 | 6.00 |
| 2) Building | 547.00 | 94.00 | 641.00 |
| 3) Stack | 44.00 | 0 | 44.00 |
| Sub Total | 596.00 | 95.00 | 691.00 |
| 3. Supplementary Work (Parking lot, Canal Water Inlet Facility, Gate and Fence, Plantation, Lighting, Rainwater Drainage, Water Spray Equipment and Pavement of Sub-area) | 2.00 | 1.00 | 3.00 |
| 4. Insurance | 15.00 | 6.00 | 21.00 |
| Intermediate Total | 1,129.00 | 585.00 | 1,714.00 |
| 5. Tax | | | |
| 1) Custom | 19.00 | 17.00 | 36.00 |
| 2) Business & Stamp Tax (3.3 + 0.1%) | 41.00 | 22.00 | 63.00 |
| 3) Labor Tax (3% on local portion) | 20.00 | 9.00 | 29.00 |
| Sub Total | 80.00 | 48.00 | 128.00 |
| Total | 1,209.00 | 633.00 | 1,842.00 |

Table 10.4-6 Emolument

(Million Baht) in 1990 price

| Manpower | Fiscal Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
| Manager | 0.20 | 0.21 | 0.21 | 0.22 | 0.23 | 0.23 | 0.24 | 0.25 | 0.26 |
| Engineer | | | | | | | | | |
| Mechanical | 0.20 | 0.21 | 0.21 | 0.22 | 0.23 | 0.23 | 0.24 | 0.25 | 0.26 |
| Electric | 0.20 | 0.21 | 0.21 | 0.22 | 0.23 | 0.23 | 0.24 | 0.25 | 0.26 |
| Equip. controller | | | 0.11 | 0.15 | 0.15 | 0.16 | 0.16 | 0.33 | 0.34 |
| Operator | | | | | | | | | |
| Crane | | | 0.96 | 1.18 | 1.22 | 1.25 | 1.82 | 1.99 | 2.05 |
| Incinerator | | | 0.96 | 1.18 | 1.22 | 1.25 | 1.82 | 1.99 | 2.05 |
| Weigh Bridge | | | 0.29 | 0.59 | 0.61 | 0.63 | 1.18 | 1.33 | 1.37 |
| Maintenance Crew | | | 0.76 | 1.18 | 1.22 | 1.25 | 3.02 | 3.99 | 4.11 |
| Cleansing Men | | | | 0.30 | 0.30 | 0.31 | 0.32 | 0.50 | 0.50 |
| Guardmen | | | | 0.59 | 0.61 | 0.63 | 0.65 | 1.00 | 1.03 |
| Clerk Chief | | | 0.17 | 0.22 | 0.23 | 0.23 | 0.24 | 0.25 | 0.26 |
| Clerk Sub | | | | 0.15 | 0.15 | 0.16 | 0.16 | 0.50 | 0.51 |
| Total | 0.61 | 0.63 | 3.90 | 6.20 | 6.38 | 6.58 | 10.10 | 13.12 | 13.52 |

Table 10.4-7 Manpower List

(Unit: person)

| Manpower | Unit of Emolument | Fiscal Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| Manager | 180,000 B/y | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Engineer | | | | | | | | | |
| Mechanical | 180,000 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| Electric | 180,000 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| Equip. controller | 120,000 | | | 0.8 | 1 | 1 | 1 | 1 | 2 |
| Operator | | | | | | | | | |
| Crane | 120,000 | | | 6.7 | 8 | 8 | 8 | 11.3 | 12 |
| Incinerator | 120,000 | | | 6.7 | 8 | 8 | 8 | 11.3 | 12 |
| Weigh Bridge | 120,000 | | | 2 | 4 | 4 | 4 | 7.3 | 8 |
| Maintenance Crew | 20,000 | | | 5.3 | 8 | 8 | 8 | 18.7 | 24 |
| Cleansing Men | 60,000 | | | | 4 | 4 | 4 | 4 | 6 |
| Guardmen | 60,000 | | | | 8 | 8 | 8 | 8 | 12 |
| Clerk Chief | 180,000 | | | 0.8 | 1 | 1 | 1 | 1 | 1 |
| Clerk Sub | 120,000 | | | | 1 | 1 | 1 | 1 | 3 |
| Total | | 3 | 3 | 25 | 46 | 46 | 46 | 67 | 85 |

Operators of crane (8 persons), incinerator (8 persons), and Equipment Controller (1 person) will have trainings during 10 months 1995, and 4 months 1999 for new operators.

Weigh Bridge operators will have trainings 6 months and 4 months 1999.

Maintenance Crew will have also trainings 8 months 1995 and 4 months 1999.

Chief Clerk will work 10 months 1995.

Unit is 1990 price and 3% of increase estimated every year.

Table 10.4-8 Utility Cost

(Million Baht) in 1990 price

| Items | Fiscal Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005-14 |
| Electricity | 10.37 | 10.37 | 10.37 | 10.37 | 18.66 | 18.66 | 18.66 | 18.66 | 18.66 | 18.66 |
| Water | 0.26 | 0.26 | 0..28 | 0.36 | 0.96 | 1.02 | 1.15 | 1.22 | 1.28 | 1.34 |
| Fuel | 2.30 | 2.30 | 2.05 | 1.54 | 3.07 | 2.30 | 1.54 | 1.02 | 0.51 | 0.26 |
| $Ca(OH)_2$ | 1.92 | 1.92 | 1.92 | 2.40 | 7.20 | 7.20 | 7.68 | 7.68 | 7.92 | 7.92 |
| Coagulant | 0.02 | 0.02 | 0.02 | 0.02 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Coagulant aid | 0.02 | 0.02 | 0.02 | 0.02 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Polymer | 0.07 | 0.07 | 0.07 | 0.07 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 |
| Lubrication | 0.01 | 0.01 | 0.01 | 0.01 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Grease | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Others | 0.06 | 0.06 | 0.06 | 0.06 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| Total | 15.04 | 15.04 | 14.81 | 14.80 | 30.45 | 29.75 | 29.59 | 29.14 | 28.93 | 28.74 |

Table 10.4-9 Utility Factor

| | Unit | Unit of Cost | Fiscal Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005-14 |
| Electricity | kW | 2.7 B/kWh | 500 | 500 | 500 | 500 | 900 | 900 | 900 | 900 | 900 | 900 |
| Water | m3/d | 4 B/$m^3$ | 200 | 200 | 220 | 240 | 750 | 800 | 900 | 950 | 1,000 | 1,050 |
| Fuel | l/d | 8 B/l | 900 | 900 | 800 | 600 | 1,200 | 900 | 600 | 400 | 200 | 100 |
| $Ca(OH)_2$ | t/d | 7,500 B/t | 0.8 | 0.8 | 0.8 | 1.0 | 3.0 | 3.0 | 3.2 | 3.2 | 3.3 | 3.3 |
| Coagulant | kg/d | 7 B/kg | 7 | 7 | 7 | 7 | 20 | 20 | 20 | 20 | 20 | 20 |
| $Al_2Cl_3$ | kg/d | 8 B/kg | 7 | 7 | 7 | 7 | 20 | 20 | 20 | 20 | 20 | 20 |
| Polymer | kg/d | 225 B/kg | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 3 | 3 | 3 |
| Lubrication | kg/y | 50 B/kg | 250 | 250 | 250 | 250 | 750 | 750 | 750 | 750 | 750 | 750 |
| Grease | kg/y | 175 B/kg | 50 | 50 | 50 | 50 | 75 | 75 | 75 | 75 | 75 | 75 |
| Others | /d | 200 B/d | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 3 | 3 | 3 |

Table 10.4-10 Table of Maintenance Cost

(Million Baht) in 1990 price

| | #1 Furnace | | #2, #3 Furnace | | Total | | Grand Total |
|---|---|---|---|---|---|---|---|
| | Parts | Repair | Parts | Repair | Parts | Repair | |
| 1996 | 0.36 | 3.64 | 0.00 | 0.00 | 0.36 | 3.64 | 4.00 |
| 1997 | 0.44 | 3.64 | 0.00 | 0.00 | 0.44 | 3.64 | 4.08 |
| 1998 | 1.82 | 9.09 | 0.00 | 0.00 | 1.82 | 9.09 | 10.91 |
| 1999 | 2.00 | 40.00 | 0.00 | 0.00 | 2.00 | 40.00 | 42.00 |
| 2000 | 2.12 | 9.42 | 0.68 | 7.28 | 2.80 | 16.70 | 19.50 |
| 2001 | 3.05 | 10.10 | 0.84 | 7.28 | 3.89 | 17.38 | 21.27 |
| 2002 | 3.55 | 11.40 | 3.46 | 18.18 | 7.01 | 29.58 | 36.59 |
| 2003 | 3.61 | 65.00 | 3.80 | 80.00 | 7.41 | 145.00 | 152.41 |
| 2114 | 3.71 | 10.10 | 4.03 | 18.84 | 7.74 | 28.94 | 36.68 |
| 2005 | 3.83 | 11.40 | 5.80 | 20.20 | 9.62 | 31.60 | 41.22 |
| 2006 | 3.90 | 13.70 | 6.75 | 22.80 | 10.65 | 36.50 | 47.15 |
| 2007 | 3.95 | 77.00 | 6.86 | 130.00 | 10.81 | 207.00 | 217.81 |
| 2008 | 3.99 | 11.00 | 7.05 | 20.20 | 11.04 | 31.20 | 42.24 |
| 2009 | 4.05 | 13.00 | 7.28 | 22.80 | 11.33 | 35.80 | 47.13 |
| 2010 | 4.16 | 14.00 | 7.41 | 27.40 | 11.57 | 41.40 | 52.97 |
| 2011 | 4.65 | 84.00 | 7.51 | 154.00 | 12.16 | 238.00 | 250.16 |
| 2012 | 4.94 | 11.00 | 7.58 | 22.00 | 12.52 | 33.00 | 45.52 |
| 2013 | 5.27 | 14.00 | 7.70 | 26.00 | 12.97 | 40.00 | 52.97 |
| 2014 | 5.40 | 16.00 | 7.90 | 28.00 | 13.30 | 44.00 | 57.30 |
| Total | 64.80 | 427.49 | 84.63 | 604.98 | 149.44 | 1,032.47 | 1,181.91 |
| Average | 3.41 | 22.50 | 4.45 | 31.84 | 7.87 | 54.34 | 62.17 |

## 10.5 Subsurface Investigation

SUBSURFACE INVESTIGATION
FOR
THE STUDY ON BANGKOK SOLID
WASTE MANAGEMENT
AT
RAM INTRA AND ON NUT
BANGKOK

## CONTENTS

STS Job No. 2870

October 22, 1990

## 1. INTRODUCTION

The subsurface investigation for THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT located at Lam Intra Final Disposal Site and On Nut Incinerator Facility Area has been completed. Total of six borings were performed at above sites. Four borings, namely BH-1L, 2L, 3L, and 4L, were conducted at Lam Intra Site whereas the remained boreholes, BH-1N and BH-2N for On Nut Site. The depth of boring is 20 m except BH-4L, BH-1N & 2N, down to 40 m. The location of boreholes is shown in Figure 1& 2.

At Lam Intra Site, the borings were carried out on the corner of the pit which was excavated about 25 m deep but for On Nut site, they were drilled on the garbage.

The purpose of this report is to summarize the field and laboratory testing data.

## 2. SUBSURFACE INVESTIGATION PROCEDURE

The boreholes were executed by skid mounted drilling rig. The drilling was commenced by means of augering within 2 m and afterwards continued by means of wash boring method till the end of boring. The upper part of borehole was stabilized by steel casing, while the lower part was stabilized by bentonite slurry.

The disturbed samples were collected at 1.5 m intervals by using standard split spoon sampler during the performance of the standard penetration tests carried out according to ASTM D-1586-84.

The six undisturbed samples were also taken in soft to medium clay layer by using pushed thin wall tube having diameter of 3 in. with 1 m length at the depth of 1 m and 4 m for BH-1L and BH-3L but at 4 m and 9 m for BH-2L.

In a standard penetration test, a 2 in. O.D. split barrel sampler was driven into the soil stratum with a 140 lbs safety type hammer falling through a distance of 30 inches successively until a total of 18 in. has been achieved. The number of blows in the last 12 in. penetration will be taken as the standard penetration resistance SPT N VALUE.

Field permeability tests were done at the depth of 20 m in sand layer in borehole no. BH-1L & 3L. The type of test is variable head method.

In addition, pocket penetrometer was also used to find undrained shear strength on all cohesive soil samples.

The elevation of boreholes referred to B.M. Ele + 50.00 m for Lam Intra Site and + 10.00 m for On Nut Site is shown as follow.

| BOREHOLE NO. | Elevation, m |
|---|---|
| BH-1L | + 45.2 |
| BH-2L | + 45.8 |
| BH-3L | + 44.1 |
| BH-4L | + 43.9 |
| BH-1N | + 10.2 |
| BH-2N | + 10.5 |

## 3. LABORATORY TESTING PROGRAMME

The laboratory programme for undisturbed samples includes the following.

1) Soil Description (Visual description and Unifined Soil Classification)

2) Specific Gravity
3) Grain Size analysis including sieve and hydrometer test.
4) Natural moisture content
5) Unit Weight
6) Atterberg limit
7) Unconfined compression test
8) Unconsolidated undrained triaxial compression test
9) One-dimensional consolidation test

The testing procedures were done in accordance with ASTM specification. The test results were presented in the Appendix of this report.

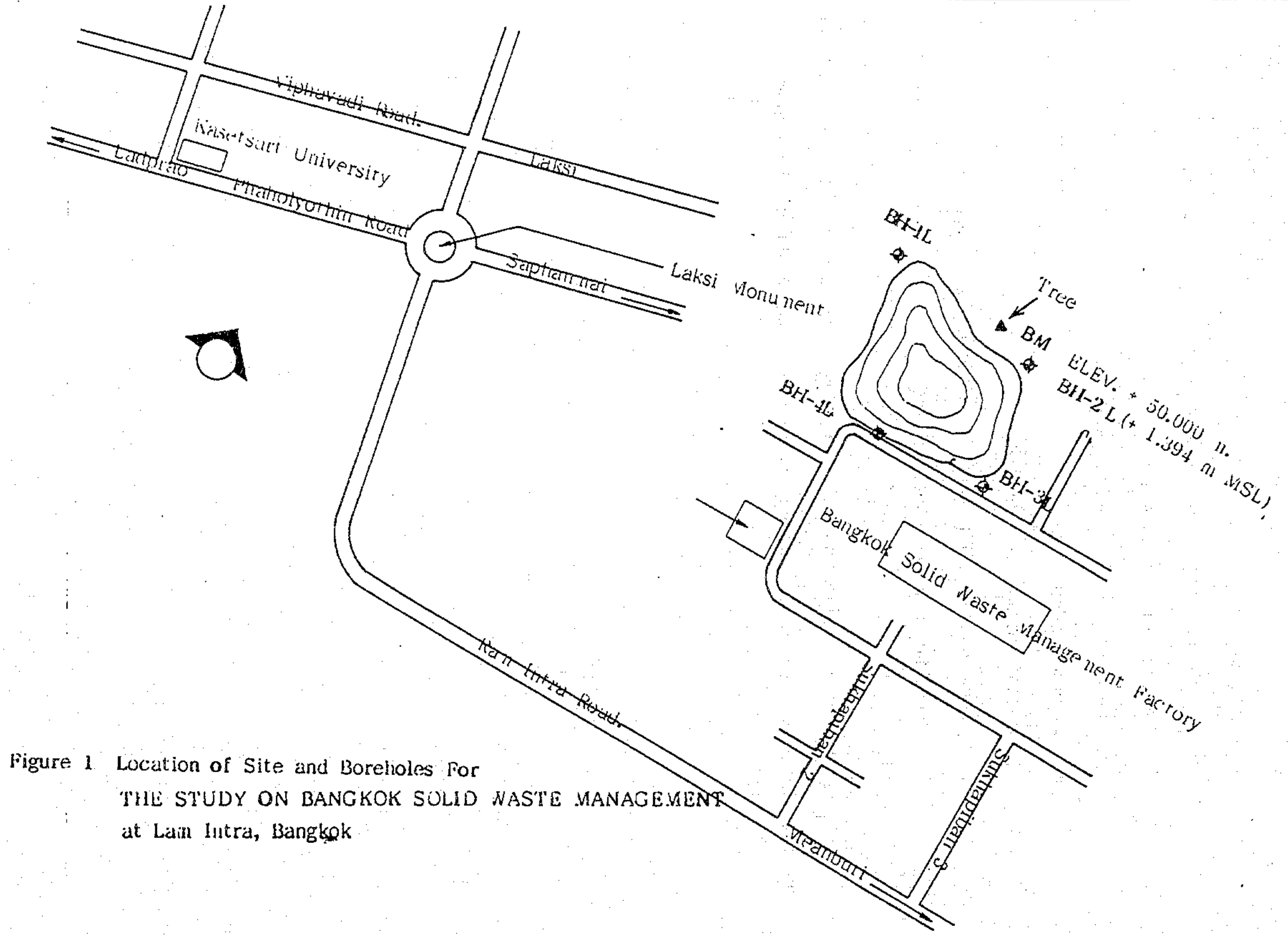


Figure 1 Location of Site and Boreholes For
THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT
at Lam Intra, Bangkok

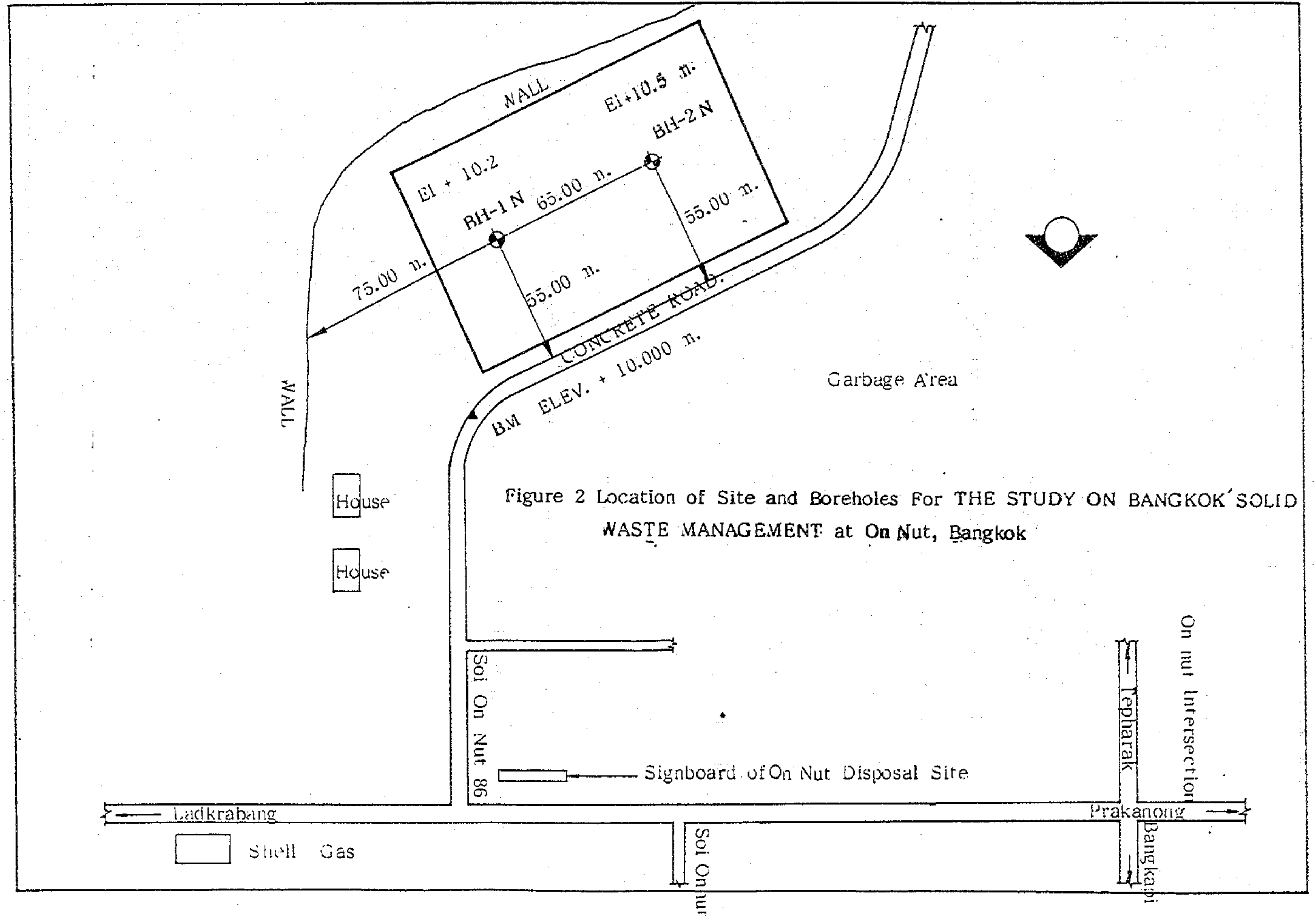


Figure 2 Location of Site and Boreholes For THE STUDY ON BANGKOK'SOLID WASTE MANAGEMENT at On Nut, Bangkok

# APPENDIX

# LIST OF TERMS USED

## DRILLING & SAMPLING SYMBOLS

SS : Split-Spoon – 1 3/8" I. D., 2" O. D., except where noted
ST : Shelby Tube – 2" O. D., except where noted
PA : Power Auger Sample
DB : Diamond Bit - NX: BX: AX:
CB : Carbology Bit - NX: BX: AX:
OS : Osterberg Sampler – 3" Shelby Tube
HS : Housel Sampler
WS : Wash Sample
FT : Fish Tail
RB : Rock Bit
WO : Wash Out

Standard "N" Penetration: Blows per foot of a 140 pound hammer falling 30 inches on a 2 inch OD split spoon, except where noted.

## WATER LEVEL MEASUREMENT SYMBOLS

WL : Water Level
WCI : Wet Cave In
DCI : Dry Cave In
WS : While Sampling

WD : While Drilling
BCR : Before Casing Removal
ACR : After Casing Removal
AB : After Boring

Water levels indicated on the boring logs are the levels measured in the boring at the times indicated. In pervious soils, the indicated elevations are considered reliable ground water levels. In impervious soils, the accurate determination of ground water elevations is not possible in even several days observation, and additional evidence on ground water elevations must be sought

## CLASSIFICATION

### COHESIONLESS SOILS

"Trace" : 1 % to 10 %
"Trace to some" : 10 % to 20 %
"Some" : 20 % to 35 %
" And " : 35 % to 50 %
Very Loose : N = 0 – 4 blows
Loose : N = 4 – 10 blows
Medium : N = 10 – 30 blows
Dense : N = 30 - 50 blows
Very Dense : N = over 50 blows

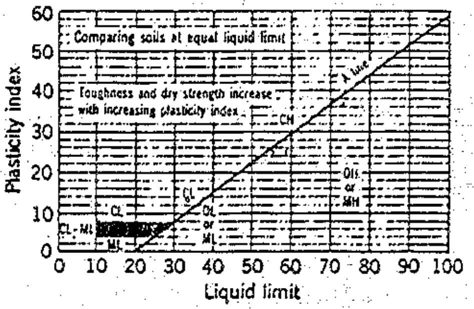
### COHESIVE SOILS

If clay content is sufficient so that clay dominates soil properties, then clay becomes the principle noun with the other major soil constituent as modifier; i.e., silty clay. Other minor soil constituents may be added according to classification breakdown for cohesionless soils, i.e., silty clay, trace to some sand, trace gravel.

Very Soft : 0.00 – 0.25 Tsf. or 0 – 2 blows
Soft : 0.25 – 0.50 Tsf. or 2 – 4 blows
Medium : 0.50 – 1.00 Tsf. or 4 – 8 blows
Stiff : 1.00 – 2.00 Tsf. or 8 – 16 blows
Very Stiff : 2.00 – 4.00 Tsf. or 16 – 32 blows
Hard : over 4.00 Tsf. or over 32 blows

LIST OF TERMS USED

# Unified Soil Classification

| Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights) | | | | | | Group Symbols[a] | Typical Names | Information Required for Describing Soils | | Laboratory Classification Criteria | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coarse-grained soils More than half of material is *larger* than No. 200 sieve size[b]<br>(The No. 200 sieve size is about the smallest particle visible to naked eye) | Gravels More than half of coarse fraction is larger than No. 4 sieve size<br>(For visual classification, the ¼ in. size may be used as equivalent to the No. 4 sieve size) | Clean gravels (little or no fines) | Wide range in grain size and substantial amounts of all intermediate particle sizes | | | *GW* | Well graded gravels, gravel-sand mixtures, little or no fines | Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbols in parentheses<br>For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics<br>Example:<br>*Silty sand*, gravelly; about 20% hard, angular gravel particles ½-in. maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*) | Use grain size curve in identifying the fractions as given under field identification | Determine percentages of gravel and sand from grain size curve<br>Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse grained soils are classified as follows:<br>Less than 5%: *GW, GP, SW, SP*<br>More than 12%: *GM, GC, SM, SC*<br>5% to 12%: *Borderline* cases requiring use of dual symbols | $C_U = \frac{D_{60}}{D_{10}}$ Greater than 4<br>$C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 | |
| | | | Predominantly one size or a range of sizes with some intermediate sizes missing | | | *GP* | Poorly graded gravels, gravel-sand mixtures, little or no fines | | | | Not meeting all gradation requirements for *GW* | |
| | | Gravels with fines (appreciable amount of fines) | Nonplastic fines (for identification procedures see *ML* below) | | | *GM* | Silty gravels, poorly graded gravel-sand-silt mixtures | | | | Atterberg limits below "A" line, or *PI* less than 4 | Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols |
| | | | Plastic fines (for identification procedures, see *CL* below) | | | *GC* | Clayey gravels, poorly graded gravel-sand-clay mixtures | | | | Atterberg limits above "A" line, with *PI* greater than 7 | |
| | Sands More than half of coarse fraction is smaller than No. 4 sieve size | Clean sands (little or no fines) | Wide range in grain sizes and substantial amounts of all intermediate particle sizes | | | *SW* | Well graded sands, gravelly sands, little or no fines | | | | $C_U = \frac{D_{60}}{D_{10}}$ Greater than 6<br>$C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 | |
| | | | Predominantly one size or a range of sizes with some intermediate sizes missing | | | *SP* | Poorly graded sands, gravelly sands, little or no fines | | | | Not meeting all gradation requirements for *SW* | |
| | | Sands with fines (appreciable amount of fines) | Nonplastic fines (for identification procedures, see *ML* below) | | | *SM* | Silty sands, poorly graded sand-silt mixtures | | | | Atterberg limits below "A" line or *PI* less than 5 | Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols |
| | | | Plastic fines (for identification procedures, see *CL* below) | | | *SC* | Clayey sands, poorly graded sand-clay mixtures | | | | Atterberg limits below "A" line with *PI* greater than 7 | |
| Fine-grained soils More than half of material is *smaller* than No. 200 sieve size | Identification Procedures on Fraction Smaller than No. 40 Sieve Size | | | | | | | | | | | |
| | | | Dry Strength (crushing characteristics) | Dilatancy (reaction to shaking) | Toughness (consistency near plastic limit) | | | | | | | |
| | Silts and clays liquid limit less than 50 | | None to slight | Quick to slow | None | *ML* | Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity | Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses<br>For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions<br>Example:<br>*Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*) | | | <br>Plasticity chart<br>for laboratory classification of fine grained soils | |
| | | | Medium to high | None to very slow | Medium | *CL* | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | | | | | |
| | | | Slight to medium | Slow | Slight | *OL* | Organic silts and organic silt-clays of low plasticity | | | | | |
| | Silts and clays liquid limit greater than 50 | | Slight to medium | Slow to none | Slight to medium | *MH* | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts | | | | | |
| | | | High to very high | None | High | *CH* | Inorganic clays of high plasticity, fat clays | | | | | |
| | | | Medium to high | None to very slow | Slight to medium | *OH* | Organic clays of medium to high plasticity | | | | | |
| Highly Organic Soils | | | Readily identified by colour, odour, spongy feel and frequently by fibrous texture | | | *Pt* | Peat and other highly organic soils | | | | | |

From Wagner, 1957.

[a] *Boundary classifications.* Soils possessing characteristics of two groups are designated by combinations of group symbols. For example *GW-GC*, well graded gravel-sand mixture with clay binder.

[b] All sieve sizes on this chart are U.S. standard.

### *Field Identification Procedure for Fine Grained Soils or Fractions*

These procedures are to be performed on the minus No. 40 sieve size particles, approximately $\frac{1}{64}$ in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

*Dilatancy* (Reaction to shaking):

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

*Dry Strength* (Crushing characteristics):

After removing particles larger than No. 40 sieve size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the *CH* group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

*Toughness* (Consistency near plastic limit):

After removing particles larger than the No. 40 sieve size, a specimen of soil about one-half inch cube in size, is moulded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eight inch in diameter. The thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic [illegible]

CHARACTERISTICS PERTINENT TO EMBANKMENTS AND FOUNDATIONS

| Major Divisions (1) | (2) | Letter (3) | Symbol | | Name (6) | Value for Embankments (7) | Permeability Cm Per Sec (8) | Compaction Characteristics (9) | Std AASHO Max Unit Dry Weight Lb Per Cu Ft (10) | Value for Foundations (11) | Requirements for Seepage Control (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Hatching (4) | Color (5) | | | | | | | |
| COARSE GRAINED SOILS | GRAVEL AND GRAVELLY SOILS | GW | ░ | Red | Well-graded gravels or gravel-sand mixtures, little or no fines | Very stable, pervious shells of dikes and dams | $k > 10^{-2}$ | Good, tractor, rubber-tired, steel-wheeled roller | 125-135 | Good bearing value | Positive cutoff |
| | | GP | ░ | | Poorly-graded gravels or gravel-sand mixtures, little or no fines | Reasonably stable, pervious shells of dikes and dams | $k > 10^{-2}$ | Good, tractor, rubber-tired, steel-wheeled roller | 115-125 | Good bearing value | Positive cutoff |
| | | GM | ▦ | Yellow | Silty gravels, gravel-sand-silt mixtures | Reasonably stable, not particularly suited to shells, but may be used for impervious cores or blankets | $k = 10^{-3}$ to $10^{-6}$ | Good, with close control, rubber-tired, sheepsfoot roller | 120-135 | Good bearing value | Toe trench to none |
| | | GC | ▨ | | Clayey gravels, gravel-sand-clay mixtures | Fairly stable, may be used for impervious core | $k = 10^{-6}$ to $10^{-8}$ | Fair, rubber-tired, sheepsfoot roller | 115-130 | Good bearing value | None |
| | SAND AND SANDY SOILS | SW | ░ | Red | Well-graded sands or gravelly sands, little or no fines | Very stable, pervious sections, slope protection required | $k > 10^{-3}$ | Good, tractor | 110-130 | Good bearing value | Upstream blanket and toe drainage or wells |
| | | SP | ░ | | Poorly-graded sands or gravelly sands, little or no fines | Reasonably stable, may be used in dike section with flat slopes | $k > 10^{-3}$ | Good, tractor | 100-120 | Good to poor bearing value depending on density | Upstream blanket and toe drainage or wells |
| | | SM | ▦ | Yellow | Silty sands, sand-silt mixtures | Fairly stable, not particularly suited to shells, but may be used for impervious cores or dikes | $k = 10^{-3}$ to $10^{-6}$ | Good, with close control, rubber-tired, sheepsfoot roller | 110-125 | Good to poor bearing value depending on density | Upstream blanket and toe drainage or wells |
| | | SC | ▨ | | Clayey sands, sand-silt mixtures | Fairly stable, use for impervious core for flood control structures | $k = 10^{-6}$ to $10^{-8}$ | Fair, sheepsfoot roller, rubber tired | 105-125 | Good to poor bearing value | None |
| FINE GRAINED SOILS | SILTS AND CLAYS LL < 50 | ML | ▥ | Green | Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts bith slight plasticity | Poor stability, may be used for embankments with proper control | $k = 10^{-3}$ to $10^{-6}$ | Good to poor, close control essential, rubber-tired roller, sheepsfoot roller | 95-120 | Very poor, susceptible to liquefaction | Toe trench to none |
| | | CL | ▨ | | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | Stable, impervious cores and blankets | $k = 10^{-6}$ to $10^{-8}$ | Fair to good, sheepsfoot roller, rubber tired | 95-120 | Good to poor bearing | None |
| | | OL | ▦ | | Organic silts and organic silt-clays of low plasticity | Not suitable for embankments | $k = 10^{-4}$ to $10^{-6}$ | Fair to poor, sheepsfoot roller | 80-100 | Fair to poor bearing, may have excessive settlements | None |
| | SILTS AND CLAYS LL > 50 | MH | ▥ | Blue | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts | Poor stability, core of hydraulic fill dam, not desirable in rolled fill construction | $k = 10^{-4}$ to $10^{-6}$ | Poor to very poor, sheepsfoot roller | 70-95 | Poor bearing | None |
| | | CH | ▨ | | Inorganic clays of high plasticity, fat clays | Fair stability with flat slopes, thin cores, blankets and dike sections | $k = 10^{-6}$ to $10^{-8}$ | Fair to poor, sheepsfoot roller | 75-105 | Fair to poor bearing | None |
| | | OH | ▨ | | Organic clays of medium to high plasticity, organic silts | Not suitable for embankments | $k = 10^{-6}$ to $10^{-8}$ | Poor to very poor, sheepsfoot roller | 65-100 | Very poor bearing | None |
| HIGHLY ORGANIC SOILS | | Pt | ▤ | Orange | Peat and other highly organic soils | Not used for construction | | Compaction not practical | | Remove from foundations | |

Notes:
1. Values in columns 7 and 11 are for guidance only. Design should be based on test results.
2. In column 9, the equipment listed will usually produce the desired densities with a reasonable number of passes when moisture conditions and thickness of lift are properly controlled.
3. Column 10, unit dry weights are for compacted soil at optimum moisture content for Standard AASHO (Standard Proctor) compactive effort.

# Standard Practice for
# THIN-WALLED TUBE SAMPLING OF SOILS[1]

This standard is issued under the fixed designation D 1587; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

*This practice has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards*

## 1. Scope

1.1 This practice covers a procedure for using a thin-walled metal tube to recover relatively undisturbed soil samples suitable for laboratory tests of structural properties. Thin-walled tubes used in piston, plug, or rotary-type samplers, such as the Denison or Pitcher, must comply with the portions of this practice which describe the thin-walled tubes (5.3).

NOTE 1—This practice does not apply to liners used within the above samplers.

## 2. Applicable Documents

2.1 *ASTM Standards:*

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]
D 3550 Practice for Ring-Lined Barrel Sampling of Soils[2]
D 4220 Practices for Preserving and Transporting Soil Samples[2]

## 3. Summary of Practice

3.1 A relatively undisturbed sample is obtained by pressing a thin-walled metal tube into the in-situ soil, removing the soil-filled tube, and sealing the ends to prevent the soil from being disturbed or losing moisture.

## 4. Significance and Use

4.1 This practice, or Practice D 3550, is used when it is necessary to obtain a relatively undisturbed specimen suitable for laboratory tests of structural properties or other tests that might be influenced by soil disturbance.

## 5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment may be used that provides a reasonably clean hole; that does not disturb the soil to be sampled; and that does not hinder the penetration of the thin-walled sampler. Open borehole diameter and the inside diameter of driven casing or hollow stem auger shall not exceed 3.5 times the outside diameter of the thin-walled tube.

5.2 *Sampler Insertion Equipment*, shall be adequate to provide a relatively rapid continuous penetration force. For hard formations it may be necessary, although not recommended, to drive the thin-walled tube sampler.

5.3 *Thin-Walled Tubes*, should be manufactured as shown in Fig. 1. They should have an outside diameter of 2 to 5 in. and be made of metal having adequate strength for use in the soil and formation intended. Tubes shall be clean and free of all surface irregularities including projecting weld seams.

5.3.1 *Length of Tubes*—See Table 1 and 6.4.

5.3.2 *Tolerances*, shall be within the limits shown in Table 2.

5.3.3 *Inside Clearance Ratio*, should be 1 % or as specified by the engineer or geologist for the soil and formation to be sampled. Generally, the inside clearance ratio used should increase with the increase in plasticity of the soil being sampled. See Fig. 1 for definition of inside clearance ratio.

5.3.4 *Corrosion Protection*—Corrosion, whether from galvanic or chemical reaction, can damage or destroy both the thin-walled tube and the sample. Severity of damage is a function of

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[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved Aug. 17, 1983. Published October 1983. Originally published as D 1587 - 58 T. Last previous edition D 1587 - 74.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

time as well as interaction between the sample and the tube. Thin-walled tubes should have some form of protective coating. Tubes which will contain samples for more than 72 h shall be coated. The type of coating to be used may vary depending upon the material to be sampled. Coatings may include a light coat of lubricating oil, lacquer, epoxy, Teflon, and others. Type of coating must be specified by the engineer or geologist if storage will exceed 72 h. Plating of the tubes or alternate base metals may be specified by the engineer or geologist.

5.4 *Sampler Head*, serves to couple the thin-walled tube to the insertion equipment and, together with the thin-walled tube, comprises the thin-walled tube sampler. The sampler head shall contain a suitable check valve and a venting area to the outside equal to or greater than the area through the check valve. Attachment of the head to the tube shall be concentric and coaxial to assure uniform application of force to the tube by the sampler insertion equipment.

## 6. Procedure

6.1 Clean out the borehole to sampling elevation using whatever method is preferred that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above ground water level during the sampling operation.

6.2 Bottom discharge bits are not permitted. Side discharge bits may be used with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted. Remove loose material from the center of a casing or hollow stem auger as carefully as possible to avoid disturbance of the material to be sampled.

NOTE 2—Roller bits are available in downward-jetting and diffused-jet configurations. Downward-jetting configuration rock bits are not acceptable. Diffuse-jet configurations are generally acceptable.

6.3 Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler without rotation by a continuous relatively rapid motion.

6.4 Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays.

NOTE 3—Weight of sample, laboratory handling capabilities, transportation problems, and commercial availability of tubes will generally limit maximum practical lengths to those shown in Table 1.

6.5 When the formation is too hard for push-type insertion, the tube may be driven or Practice D 3550 may be used. Other methods, as directed by the engineer or geologist, may be used. If driving methods are used, the data regarding weight and fall of the hammer and penetration achieved must be shown in the report. Additionally, that tube must be prominently labeled a "driven sample."

6.6 In no case shall a length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 in. for sludge-end cuttings.

NOTE 4—The tube may be rotated to shear bottom of the sample after pressing is complete.

6.7 Withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample.

## 7. Preparation for Shipment

7.1 Upon removal of the tube, measure the length of sample in the tube. Remove the disturbed material in the upper end of the tube and measure the length again. Seal the upper end of the tube. Remove at least 1 in. of material from the lower end of the tube. Use this material for soil description in accordance with Practice D 2488. Measure the overall sample length. Seal the lower end of the tube. Alternatively, after measurement, the tube may be sealed without removal of soil from the ends of the tube if so directed by the engineer or geologist.

NOTE 5—Field extrusion and packaging of extruded samples under the specific direction of a geotechnical engineer or geologist is permitted.

NOTE 6—Tubes sealed over the ends as opposed to those sealed with expanding packers should contain end padding in end voids in order to prevent drainage or movement of the sample within the tube.

7.2 Prepare and immediately affix labels or apply markings as necessary to identify the sample. Assure that the markings or labels are adequate to survive transportation and storage.

## 8. Report

8.1 The appropriate information is required as follows:

8.1.1 Name and location of the project.

8.1.2 Boring number and precise location on project.

8.1.3 Surface elevation or reference to a datum.

8.1.4 Date and time of boring—start and finish.

8.1.5 Depth to top of sample and number of sample.

8.1.6 Description of sampler: size, type of metal, type of coating.

8.1.7 Method of sampler insertion: push or drive.

8.1.8 Method of drilling, size of hole, casing, and drilling fluid used.

8.1.9 Depth to groundwater level: date and time measured.

8.1.10 Any possible current or tidal effect on water level.

8.1.11 Soil description in accordance with Practice D 2488.

8.1.12 Length of sampler advance, and

8.1.13 Recovery; length of sample obtained.

## 9. Precision and Bias

9.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

TABLE 1 Suitable Thin-Walled Steel Sample Tubes[A]

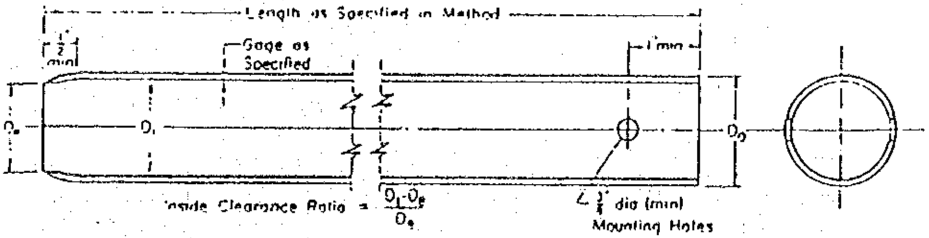
| | | | |
|---|---|---|---|
| Outside diameter: | | | |
| in. | 2 | 3 | 5 |
| mm | 50.8 | 76.2 | 127 |
| Wall thickness: | | | |
| Bwg | 18 | 16 | 11 |
| in. | 0.049 | 0.065 | 0.120 |
| mm | 1.24 | 1.65 | 3.05 |
| Tube length: | | | |
| in. | 36 | 36 | 54 |
| m | 0.91 | 0.91 | 1.45 |
| Clearance ratio, % | 1 | 1 | 1 |

[A] The three diameters recommended in Table 1 are indicated for purposes of standardization, and are not intended to indicate that sampling tubes of intermediate or larger diameters are not acceptable. Lengths of tubes shown are illustrative. Proper lengths to be determined as suited to field conditions.

TABLE 2 Dimensional Tolerances for Thin-Walled Tubes

| Nominal Tube Diameters from Table 1[A] Tolerances, in. | | | |
|---|---|---|---|
| Size Outside Diameter | 2 | 3 | 5 |
| Outside diameter | +0.007 | +0.010 | +0.015 |
| | −0.000 | −0.000 | −0.000 |
| Inside diameter | +0.000 | +0.000 | +0.000 |
| | −0.007 | −0.010 | −0.015 |
| Wall thickness | ±0.007 | ±0.010 | ±0.015 |
| Ovality | 0.015 | 0.020 | 0.030 |
| Straightness | 0.030/ft | 0.030/ft | 0.030/ft |

[A] Intermediate or larger diameters should be proportional. Tolerances shown are essentially standard commercial manufacturing tolerances for seamless steel mechanical tubing. Specify only two of the first three tolerances; that is, O.D. and I.D., or O.D. and Wall, or I.D. and Wall.



NOTE 1—Minimum of two mounting holes on opposite sides for 2 to 3½ in. sampler.

NOTE 2—Minimum of four mounting holes spaced at 90° for samplers 4 in. and larger.

NOTE 3—Tube held with hardened screws.

NOTE 4—Two-inch outside diameter tubes are specified with an 18-gage wall thickness to comply with area ratio criteria accepted for "undisturbed samples." Users are advised that such tubing is difficult to locate and can be extremely expensive in small quantities. Sixteen-gage tubes are generally readily available.

Metric Equivalents

| in. | mm |
|---|---|
| ¼ | 6.77 |
| ½ | 12.7 |
| 1 | 25.4 |
| 2 | 50.8 |
| 3½ | 88.9 |
| 4 | 101.6 |

FIG. 1 Thin-Walled Tube for Sampling

*The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103.*

Designation: D 1586 – 84

## Standard Method for
## PENETRATION TEST AND SPLIT-BARREL SAMPLING OF SOILS[1]

This standard is issued under the fixed designation D 1586; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

*This method has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.*

### 1. Scope

1.1 This method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample and a measure of the resistance of the soil to penetration of the sampler.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific precautionary statement, see 5.4.1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

### 2. Applicable Documents

2.1 *ASTM Standards:*

D 2487 Test Method for Classification of Soils for Engineering Purposes[2]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

### 3. Descriptions of Terms Specific to This Standard

3.1 *anvil*—that portion of the drive-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.4 *drive-weight assembly*—a device consisting of the hammer, hammer fall guide, the anvil, and any hammer drop system.

3.5 *hammer*—that portion of the drive-weight assembly consisting of the 140 ± 2 lb (63.5 ± 1 kg) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.6 *hammer drop system*—that portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.8 *N-value*—the blowcount representation of the penetration resistance of the soil. The *N*-value, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.9 *ΔN*—the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.10 *number of rope turns*—the total contact angle between the rope and the cathead at the

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[1] This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved Sept. 11, 1984. Published November 1984. Originally published as D 1586 – 58 T. Last previous edition D 1586 – 67 (1974).

[2] *Annual Book of ASTM Standards*, Vol 04.08.

beginning of the operator's rope slackening to drop the hammer, divided by 360° (see Fig. 1).

3.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.12 *SPT*—abbreviation for Standard Penetration Test, a term by which engineers commonly refer to this method.

## 4. Significance and Use

4.1 This method provides a soil sample for identification purposes and for laboratory tests appropriate for soil obtained from a sampler that may produce large shear strain disturbance in the sample.

4.2 This method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and widely published correlations which relate SPT blowcount, or *N*-value, and the engineering behavior of earthworks and foundations are available.

## 5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment that provides at the time of sampling a suitably clean open hole before insertion of the sampler and ensures that the penetration test is performed on undisturbed soil shall be acceptable. The following pieces of equipment have proven to be suitable for advancing a borehole in some subsurface conditions.

5.1.1 *Drag, Chopping, and Fishtail Bits,* less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjuction with open-hole rotary drilling or casing-advancement drilling methods. To avoid disturbance of the underlying soil, bottom discharge bits are not permitted; only side discharge bits are permitted.

5.1.2 *Roller-Cone Bits,* less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods if the drilling fluid discharge is deflected.

5.1.3 *Hollow-Stem Continuous Flight Augers,* with or without a center bit assembly, may be used to drill the boring. The inside diameter of the hollow-stem augers shall be less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm).

5.1.4 *Solid, Continuous Flight, Bucket and Hand Augers,* less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used if the soil on the side of the boring does not cave onto the sampler or sampling rods during sampling.

5.2 *Sampling Rods*—Flush-joint steel drill rods shall be used to connect the split-barrel sampler to the drive-weight assembly. The sampling rod shall have a stiffness (moment of inertia) equal to or greater than that of parallel wall "A" rod (a steel rod which has an outside diameter of 1⅝ in. (41.2 mm) and an inside diameter of 1⅛ in. (28.5 mm).

NOTE 1—Recent research and comparative testing indicates the type rod used, with stiffness ranging from "A" size rod to "N" size rod, will usually have a negligible effect on the *N*-values to depths of at least 100 ft (30 m).

5.3 *Split-Barrel Sampler*—The sampler shall be constructed with the dimensions indicated in Fig. 2. The driving shoe shall be of hardened steel and shall be replaced or repaired when it becomes dented or distorted. The use of liners to produce a constant inside diameter of 1⅜ in. (35 mm) is permitted, but shall be noted on the penetration record if used. The use of a sample retainer basket is permitted, and should also be noted on the penetration record if used.

NOTE 2—Both theory and available test data suggest that *N*-values may increase between 10 to 30 % when liners are used.

5.4 *Drive-Weight Assembly:*

5.4.1 *Hammer and Anvil*—The hammer shall weigh 140 ± 2 lb (63.5 ± 1 kg) and shall be a solid rigid metallic mass. The hammer shall strike the anvil and make steel on steel contact when it is dropped. A hammer fall guide permitting a free fall shall be used. Hammers used with the cathead and rope method shall have an unimpeded overlift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged.

NOTE 3—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic, or automatic hammer drop systems may be used, providing the lifting apparatus will not cause penetration of the sampler while re-engaging and lifting the hammer.

5.5 *Accessory Equipment*—Accessories such as labels, sample containers, data sheets, and groundwater level measuring devices shall be provided in accordance with the requirements of the project and other ASTM standards.

## 6. Drilling Procedure

6.1 The boring shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 mm) or less in homogeneous strata with test and sampling locations at every change of strata.

6.2 Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

6.2.1 Open-hole rotary drilling method.

6.2.2 Continuous flight hollow-stem auger method.

6.2.3 Wash boring method.

6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable borings. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the boring below a water table or below the upper confining bed of a confined non-cohesive stratum that is under artesian pressure. Casing may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

6.4 The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

## 7. Sampling and Testing Procedure

7.1 After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

7.1.1 Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling rods and sampler are lowered into the borehole.

7.1.3 Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the boring, remove the sampler and sampling rods from the boring and remove the cuttings.

7.1.4 Mark the drill rods in three successive 6-in. (0.15-m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-in. (0.15-m) increment.

7.2 Drive the sampler with blows from the 140-lb (63.5-kg) hammer and count the number of blows applied in each 6-in. (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 6-in. (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

7.2.4 The sampler is advanced the complete 18 in. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.3 Record the number of blows required to effect each 6 in. (0.15 m) of penetration or fraction thereof. The first 6 in. is considered to be a seating drive. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance", or the "*N*-value". If the sampler is driven less than 18 in. (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 6-in. (0.15-m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 1 in. (25 mm), in addition to the number of blows. If the sampler advances below the bottom of the boring under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lb

(63.5-kg) hammer shall be accomplished using either of the following two methods:

7.4.1 By using a trip, automatic, or semi-automatic hammer drop system which lifts the 140-lb (63.5-kg) hammer and allows it to drop 30 ± 1.0 in. (0.76 m ± 25 mm) unimpeded.

7.4.2 By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM, or the approximate speed of rotation shall be reported on the boring log.

7.4.2.3 No more than 2¼ rope turns on the cathead may be used during the performance of the penetration test, as shown in Fig. 1.

NOTE 4—The operator should generally use either 1¾ or 2¼ rope turns, depending upon whether or not the rope comes off the top (1¾ turns) or the bottom (2¼ turns) of the cathead. It is generally known and accepted that 2¾ or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be maintained in a relatively dry, clean, and unfrayed condition.

7.4.2.4 For each hammer blow, a 30-in. (0.76-m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

7.5 Bring the sampler to the surface and open. Record the percent recovery or the length of sample recovered. Describe the soil samples recovered as to composition, color, stratification, and condition, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing job designation, boring number, sample depth, and the blow count per 6-in. (0.15-m) increment. Protect the samples against extreme temperature changes. If there is a soil change within the sampler, make a jar for each stratum and note its location in the sampler barrel.

## 8. Report

8.1 Drilling information shall be recorded in the field and shall include the following:

8.1.1 Name and location of job,

8.1.2 Names of crew,

8.1.3 Type and make of drilling machine,

8.1.4 Weather conditions,

8.1.5 Date and time of start and finish of boring,

8.1.6 Boring number and location (station and coordinates, if available and applicable),

8.1.7 Surface elevation, if available,

8.1.8 Method of advancing and cleaning the boring,

8.1.9 Method of keeping boring open,

8.1.10 Depth of water surface and drilling depth at the time of a noted loss of drilling fluid, and time and date when reading or notation was made,

8.1.11 Location of strata changes,

8.1.12 Size of casing, depth of cased portion of boring,

8.1.13 Equipment and method of driving sampler,

8.1.14 Type sampler and length and inside diameter of barrel (note use of liners),

8.1.15 Size, type, and section length of the sampling rods, and

8.1.16 Remarks.

8.2 Data obtained for each sample shall be recorded in the field and shall include the following:

8.2.1 Sample depth and, if utilized, the sample number,

8.2.2 Description of soil,

8.2.3 Strata changes within sample,

8.2.4 Sampler penetration and recovery lengths, and

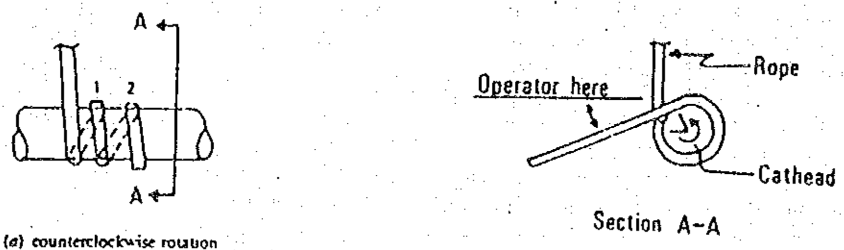
8.2.5 Number of blows per 6-in. (0.15-m) or partial increment.

## 9. Precision and Bias

9.1 Variations in *N*-values of 100 % or more have been observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, *N*-values in the same soil can be reproduced with a coefficient of variation of about 10 %.

9.2 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in *N*-values obtained between operator-drill rig systems.

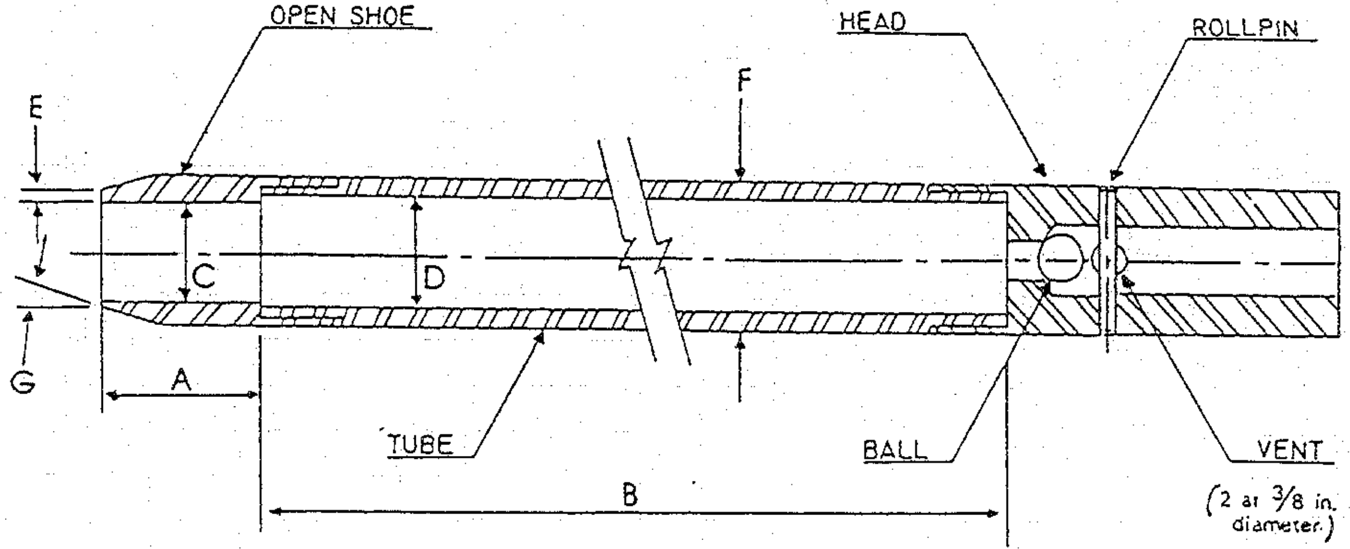
9.3 The variability in N-values produced by different drill rigs and operators may be reduced by measuring that part of the hammer energy delivered into the drill rods from the sampler and adjusting N on the basis of comparative energies. A method for energy measurement and N-value adjustment is currently under development.



(a) counterclockwise rotation approximately 1¾ turns

(b) clockwise rotation approximately 2¼ turns

FIG. 1 Definitions of the Number of Rope Turns and the Angle for (a) Counterclockwise Rotation and (b) Clockwise Rotation of the Cathead



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 − 0.00 in. (38.1 ± 1.3 − 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 − 0.00 in. (50.8 ± 1.3 − 0.0 mm)
G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

FIG. 2 Split-Barrel Sampler

# SUMMARY OF TEST RESULTS

PROJECT THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT | LOCATION ON NUT INCINERATOR FACILITY AREA

DATE 22/10/90 | BORING No. BH-1N | JOB No. 2870 | BY CK | OBSERVED W.L. -1.5 m.

| SAMPLE No. | DEPTH M | | WATER CONTENT % | ATTERBERG LIMIT % | | | WET UNIT WEIGHT t/m³ | SIEVE ANALYSIS % FINER | | | | | CLASSIFICATION | UNDRAINED SHEAR STRENGTH t/m² | | | | | STANDARD PENETRATION (N) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | UNCONFINED SHEAR | | FIELD VANE SHEAR | | POCKET PENETRATION | | | |
| | FROM | TO | | LL | PL | PI | | No. 3/8" | No. 4 | No. 10 | No. 40 | No. 200 | | Qu/2 | Qu'/2 | Qv | Qv' | ½Qp | | | |
| SS-1 | 1.50 | 1.95 | | (No Recovery) | | | | | | | | | (CH) | | | | | | 3 | | |
| SS-2 | 3.00 | 3.45 | | (No Recovery) | | | | | | | | | (CH) | | | | | | 1 | | |
| SS-3 | 4.50 | 4.95 | | | | | | | | | | | CH | | | | | 0.5 | 1 | | |
| SS-4 | 6.00 | 6.45 | | | | | | | | | | | CH | | | | | 0.7 | 1 | | |
| SS-5 | 7.50 | 7.95 | | | | | | | | | | | CH | | | | | 1.3 | 1 | | |
| SS-6 | 9.00 | 9.45 | | | | | | | | | | | CH | | | | | 1.3 | 1 | | |
| SS-7 | 10.50 | 10.95 | | | | | | | | | | | CH | | | | | 0.7 | 1 | | |
| SS-8 | 12.00 | 12.45 | | | | | | | | | | | CH | | | | | 1.9 | 1 | | |
| SS-9 | 13.50 | 13.95 | | | | | | | | | | | CH | | | | | 10.7 | 3 | | |
| SS-10 | 15.00 | 15.45 | | | | | | | | | | | CH | | | | | 11.3 | 14 | | |
| SS-11 | 16.50 | 16.95 | | | | | | | | | | | CH | | | | | 20.0 | 23 | | |
| SS-12 | 18.00 | 18.45 | | | | | | | | | | | CH | | | | | 20.0 | 28 | | |
| SS-13 | 19.50 | 19.95 | | | | | | | | | | | CH | | | | | 11.3 | 13 | | |
| SS-14 | 21.00 | 21.45 | | | | | | | | | | | CH | | | | | 22.5⁺ | 23 | | |
| SS-15 | 22.50 | 22.95 | | | | | | | | | | | CH | | | | | | 28 | | |
| SS-16 | 24.00 | 24.45 | | | | | | | | | | | SM | | | | | | 58 | | |
| SS-17 | 25.50 | 25.95 | | | | | | | | | | | SM | | | | | | 47 | | |
| SS-18 | 27.00 | 27.45 | | | | | | | | | | | SM | | | | | | 44 | | |
| SS-19 | 28.50 | 28.95 | | | | | | | | | | | SM-SP | | | | | | 70 | | |
| SS-20 | 30.00 | 30.45 | | | | | | | | | | | CH | | | | | 16.9 | 26 | | |
| SS-21 | 31.50 | 31.95 | | | | | | | | | | | CL | | | | | | 47 | | |

# SUMMARY OF TEST RESULTS

| | | | |
|---|---|---|---|
| PROJECT THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT | | LOCATION ON NUT INCINERATOR FACILITY AREA | |
| DATE 22/10/90 | BORING No. BH-1N | JOB No. 2870 | BY CK | 
| | | | OBSERVED W.L. -1.5 m. |

| SAMPLE No. | DEPTH M | | WATER CONTENT % | ATTERBERG LIMIT % | | | WET UNIT WEIGHT t/m$^3$ | SIEVE ANALYSIS % FINER | | | | | CLASSIFICATION | UNDRAINED SHEAR STRENGTH t/m.$^2$ | | | | | STANDARD PENETRATION (N) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | UNCONFINED SHEAR | | FIELD VANE SHEAR | | POCKET PENETRATION | | | |
| | FROM | TO | | LL | PL | PI | | No 3/8" | No. 4 | No. 10 | No 40 | No. 200 | | Qu/2 | Qu'/2 | Qv | Qv' | $\frac{1}{2}$Qp | | | |
| SS-22 | 33.00 | 33.45 | | | | | | | | | | | CL | | | | | 18.8 | 32 | | |
| SS-23 | 34.50 | 34.95 | | | | | | | | | | | CL | | | | | | 19 | | |
| SS-24 | 36.00 | 36.45 | | | | | | | | | | | CL | | | | | | 40 | | |
| SS-25 | 37.50 | 37.95 | | | | | | | | | | | SC | | | | | | 26 | | |
| SS-26 | 39.00 | 39.45 | | | | | | | | | | | SC | | | | | | 19 | | |

# SUMMARY OF TEST RESULTS

PROJECT THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT LOCATION ON NUT INCINERATOR FACILITY AREA

DATE 22/10/90 BORING No. BH-2 N JOB No. 2870 BY CK OBSERVED W.L. -2.0 m.

| SAMPLE No. | DEPTH M |  | WATER CONTENT % | ATTERBERG LIMIT % |  |  | WET UNIT WEIGHT $t/m^3$ | SIEVE ANALYSIS % FINER |  |  |  |  | CLASSIFICATION | UNDRAINED SHEAR STRENGTH $t/m.^2$ |  |  |  |  | STANDARD PENETRATION (N) |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  |  |  |  |  | UNCONFINED SHEAR |  | FIELD VANE SHEAR |  | POCKET PENETRATION |  |  |  |
|  | FROM | TO |  | LL | PL | PI |  | No 3/8" | No 4 | No. 10 | No 40 | No. 200 |  | Qu/2 | Qu'/2 | Qv | Qv' | $\frac{1}{2}Q_p$ |  |  |  |
| SS-1 | 1.50 | 1.95 |  | (No Recovery) |  |  |  |  |  |  |  |  | GARBAGE |  |  |  |  |  |  |  |  |
| SS-2 | 3.00 | 3.45 |  | (No Recovery) |  |  |  |  |  |  |  |  | GARBAGE |  |  |  |  |  |  |  |  |
| SS-3 | 4.50 | 4.95 |  | (No Recovery) |  |  |  |  |  |  |  |  | GARBAGE |  |  |  |  |  |  |  |  |
| SS-4 | 6.00 | 6.45 |  |  |  |  |  |  |  |  |  |  | CH |  |  |  |  | 1.2 | 1 |  |  |
| SS-5 | 7.50 | 7.95 |  |  |  |  |  |  |  |  |  |  | CH |  |  |  |  |  | 1 |  |  |
| SS-6 | 9.00 | 9.45 |  |  |  |  |  |  |  |  |  |  | CH |  |  |  |  | 1.3 | 1 |  |  |
| SS-7 | 10.50 | 10.95 |  |  |  |  |  |  |  |  |  |  | CH |  |  |  |  |  | 1 |  |  |
| SS-8 | 12.00 | 12.45 |  |  |  |  |  |  |  |  |  |  | CH |  |  |  |  | 2.5 | 1 |  |  |
| SS-9 | 13.50 | 13.95 |  |  |  |  |  |  |  |  |  |  | CH |  |  |  |  | 1.3 | 2 |  |  |
| SS-10 | 15.00 | 15.45 |  |  |  |  |  |  |  |  |  |  | CH |  |  |  |  | 11.3 | 10 |  |  |
| SS-11 | 16.50 | 16.95 |  |  |  |  |  |  |  |  |  |  | CH |  |  |  |  | 15.0 | 20 |  |  |
| SS-12 | 18.00 | 18.45 |  |  |  |  |  |  |  |  |  |  | CH |  |  |  |  | $22.5^+$ | 27 |  |  |
| SS-13 | 19.50 | 19.95 |  |  |  |  |  |  |  |  |  |  | CH |  |  |  |  | 15.0 | 25 |  |  |
| SS-14 | 21.00 | 21.45 |  |  |  |  |  |  |  |  |  |  | CH |  |  |  |  | 14.4 | 20 |  |  |
| SS-15 | 22.50 | 22.95 |  |  |  |  |  |  |  |  |  |  | CH |  |  |  |  | $22.5^+$ | 25 |  |  |
| SS-16 | 24.00 | 24.45 |  |  |  |  |  |  |  |  |  |  | CH |  |  |  |  | $22.5^+$ | 45 |  |  |
| SS-17 | 25.50 | 25.95 |  |  |  |  |  |  |  |  |  |  | SC |  |  |  |  |  | 52 |  |  |
| SS-18 | 27.00 | 27.45 |  |  |  |  |  |  |  |  |  |  | SM |  |  |  |  |  | 35 |  |  |
| SS-19 | 28.50 | 28.95 |  | (No Recovery) |  |  |  |  |  |  |  |  | SM) |  |  |  |  |  | 77 |  |  |
| SS-20 | 30.00 | 30.45 |  |  |  |  |  |  |  |  |  |  | SM |  |  |  |  |  | 58 |  |  |
| SS-21 | 31.50 | 31.95 |  |  |  |  |  |  |  |  |  |  | CL |  |  |  |  | 13.2 | 46 |  |  |

# SUMMARY OF TEST RESULTS

PROJECT THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT
LOCATION ON NUT INCINERATOR FACILITY AREA
DATE 22/10/90
BORING No. BH-2N
JOB No. 2870
BY CK
OBSERVED W.L. -2.0 m.

| SAMPLE No. | DEPTH M | | WATER CONTENT % | ATTERBERG LIMIT % | | | WET UNIT WEIGHT t/m³ | SIEVE ANALYSIS % FINER | | | | | CLASSIFICATION | UNDRAINED SHEAR STRENGTH t/m.² | | | | | STANDARD PENETRATION (N) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | UNCONFINED SHEAR | | FIELD VANE SHEAR | | POCKET PENETRATION | | | |
| | FROM | TO | | LL. | PL. | PI. | | No 3/8" | No. 4 | No. 10 | No 40 | No. 200 | | Qu/2 | Qu'/2 | Qv | Qv' | $\frac{1}{2}Q_p$ | | | |
| SS-22 | 33.00 | 33.45 | | | | | | | | | | | CL | | | | | 18.8 | 38 | | |
| SS-23 | 34.50 | 34.95 | | | | | | | | | | | CL | | | | | 12.5 | 45 | | |
| SS-24 | 36.00 | 36.45 | | | | | | | | | | | CL/SM | | | | | 18.8 | 53 | | |
| SS-25 | 37.50 | 37.95 | | (No Recovery) | | | | | | | | | (SM) | | | | | | 48 | | |
| SS-26 | 39.00 | 39.45 | | | | | | | | | | | SM | | | | | | 41 | | |

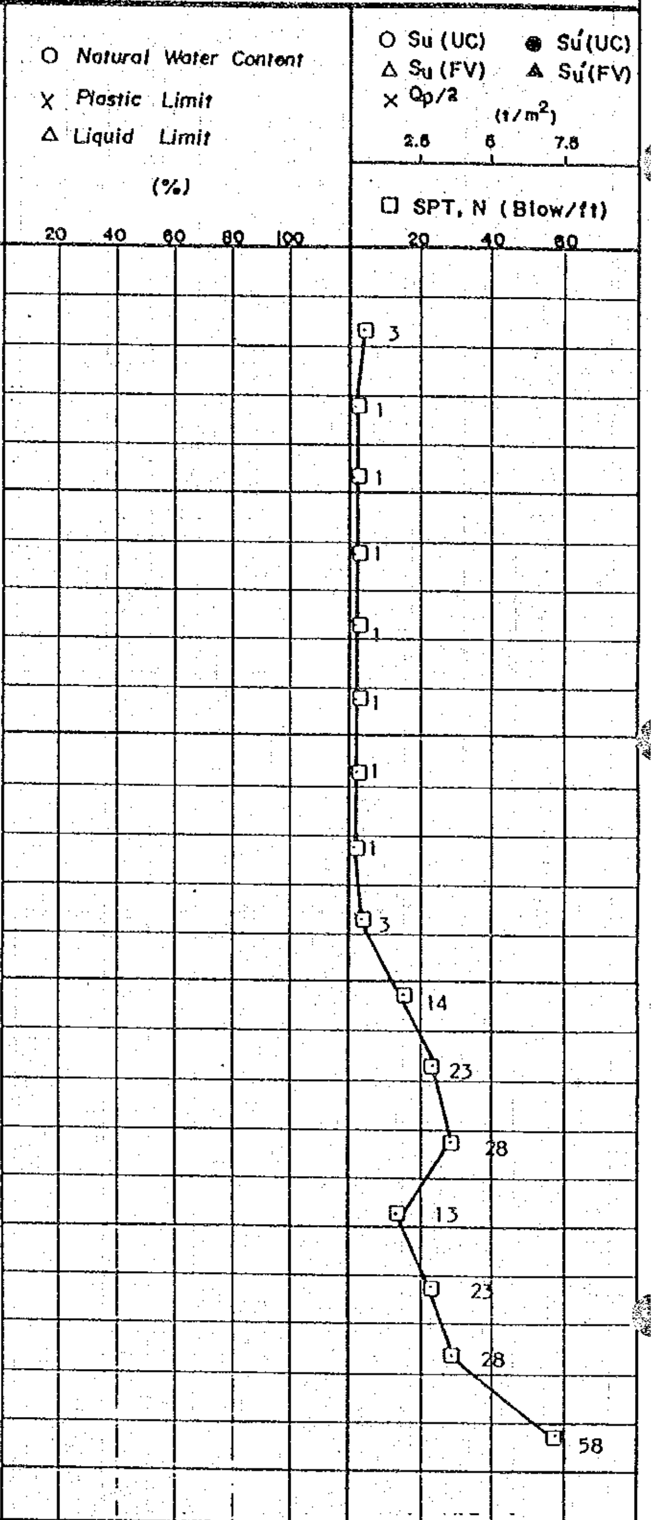
# LOG OF BORING No. BH-IN

**PROJECT NAME.** THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

**LOCATION.** ON NUT INCINERATOR FACILITY AREA

**OWNER**

| DEPTH, m. | SAMPLE No. | TYPE OF SAMPLE | DESCRIPTION OF MATERIAL |
|---|---|---|---|
| 0 | | | CLAY with garbage, dark grey.<br>1.5 m |
| | 1 | SS | CLAY trace shell fragment, greenish grey, soft.<br>(CH) |
| | 2 | SS | |
| 5 | 3 | SS | |
| | 4 | SS | |
| | 5 | SS | |
| | 6 | SS | |
| 10 | 7 | SS | |
| | 8 | SS | |
| | 9 | SS | 15.0 m |
| 15 | 10 | SS | Silty CLAY trace fine sand, greyish brown but greenish grey @ SS-12, stiff to very stiff.<br>(CH) |
| | 11 | SS | |
| | 12 | SS | |
| 20 | 13 | SS | |
| | 14 | SS | |
| | 15 | SS | 23.6 m |
| | 16 | SS | Silty fine SAND but medium to coarse grain @ SS-19, greyish brown, dense to very dense. (SM) |
| 25 | | | |



| | | |
|---|---|---|
| BORING STARTED. 10/10/90 | RIG. PORTABLE | WL.-1.50 M. 24 HRS AFTER BORING. |
| BORING FINSHED. 11/10/90 | FOREMAN. SR | JOB No. 2870 |

# LOG OF BORING No. BH-1N

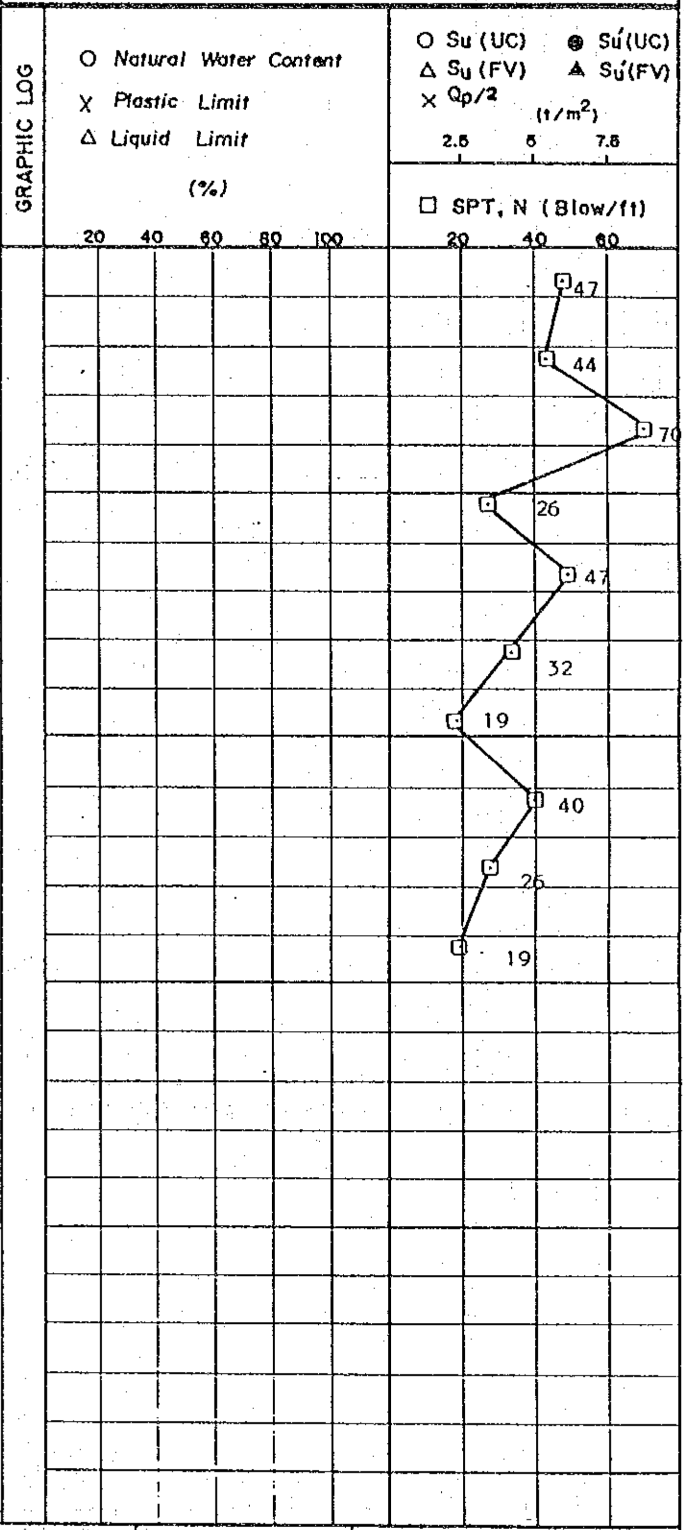
**PROJECT NAME.** THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

**LOCATION.** ON NUT INCINERATOR FACILITY AREA

**OWNER**

| DEPTH, m. | SAMPLE No. | TYPE OF SAMPLE | SAMPLE DIST | RECOVERY | DESCRIPTION OF MATERIAL |
|---|---|---|---|---|---|
| 25 | | | | | |
| | 17 | SS | ▨ | | Silty fine SAND but medium to coarse grain @ SS-19, greyish brown, dense to very dense. (SM) |
| | 18 | SS | ▨ | | |
| | 19 | SS | ▨ | | 29.8 m |
| 30 | 20 | SS | ▨ | | Silty CLAY trace fine sand, li-brownish grey, very stiff. (CH) 31.5 m |
| | 21 | SS | ▨ | | Fine sandy CLAY, greyish brown, hard. (CL) 33.0 m |
| | 22 | SS | ▨ | | |
| 35 | 23 | SS | ▨ | | Silty CLAY some fine to medium sand pocket, greyish brown, very sitff to hard. (CL) |
| | 24 | SS | ▨ | | 37.3 m |
| | 25 | SS | ▨ | | Clayey fine SAND, grey, medium dense. (SC) |
| 40 | 26 | SS | ▨ | | 39.45 m |

END OF BORING

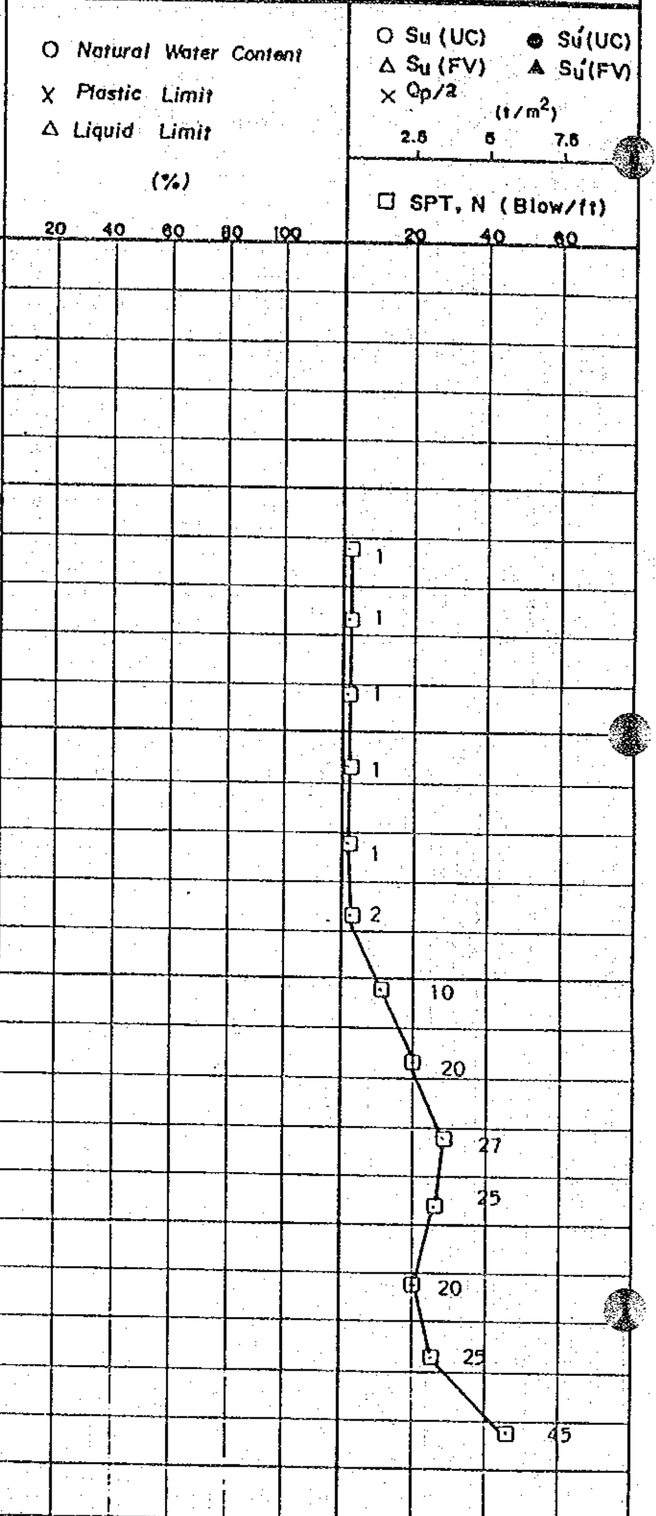


| | | |
|---|---|---|
| BORING STARTED. 10/10/90 | RIG. PORTABLE | WL. -1.50 M. 24 HRS AFTER BORING. |
| BORING FINSHED. 11/10/90 | FOREMAN. SR | JOB No.. 2870 |

# LOG OF BORING No. BH-2N

| | |
|---|---|
| **PROJECT NAME.** THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT | **LOCATION.** ON NUT INCINERATOR FACILITY AREA |
| **OWNER** | |

| DEPTH, m. | SAMPLE No. | TYPE OF SAMPLE | SAMPLE DIST / RECOVERY | DESCRIPTION OF MATERIAL | GRAPHIC LOG |
|---|---|---|---|---|---|
| 0 | | | | | |
| | 1 | SS | ▨ | GARBAGE. | |
| | 2 | SS | ▨ | | |
| 5 | 3 | SS | ▨ | 5.0 m | |
| | 4 | SS | ▨▨ | | |
| | 5 | SS | ▨▨ | CLAY trace shell fragment, greenish grey, soft, (CH) | |
| 10 | 6 | SS | ▨▨ | | |
| | 7 | SS | ▨▨ | | |
| | 8 | SS | ▨▨ | | |
| | 9 | SS | ▨▨ | | |
| 15 | | | | 15.0 m | |
| | 10 | SS | ▨▨ | | |
| | 11 | SS | ▨ | Silty CLAY trace fine sand, greyish brown but greenish grey @ SS-12 & 14, stiff to hard. (CH) | |
| | 12 | SS | ▨▨ | | |
| 20 | 13 | SS | ▨▨ | | |
| | 14 | SS | ▨▨ | | |
| | 15 | SS | ▨ | | |
| | 16 | SS | ▨▨ | | |
| 25 | | | | 25.5 m<br>(SC) | |

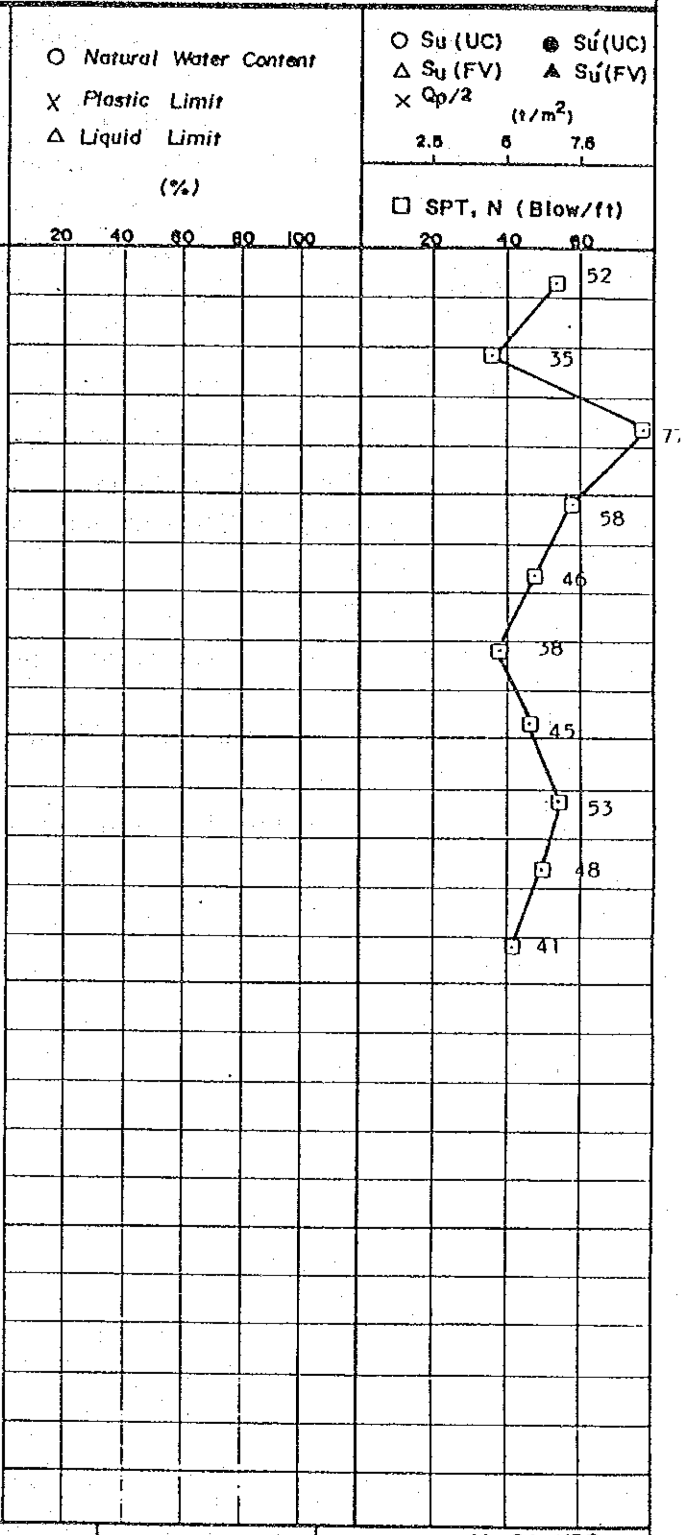


| | | |
|---|---|---|
| BORING STARTED. 12/10/90 | RIG. PORTABLE | WL. -2.00 M. 24 HRS. AFTER BORING. |
| BORING FINSHED. 13/10/90 | FOREMAN. SR | JOB No. 2870 |

# LOG OF BORING No. BH-2N

| | |
|---|---|
| PROJECT NAME. THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT | LOCATION. ON NUT INCINERATOR FACILITY AREA |
| OWNER | |

| DEPTH, m. | SAMPLE No. | TYPE OF SAMPLE | SAMPLE DIST | RECOVERY | DESCRIPTION OF MATERIAL |
|---|---|---|---|---|---|
| 25 | | | | | (CH) 25.5 m |
| | 17 | SS | ▨ | ▨ | Clayey fine SAND trace medium sand, grey, very dense. (SC) 27.0 m |
| | 18 | SS | ▨ | ▨ | |
| | 19 | SS | ▨ | | Silty fine SAND trace medium sand, brownish grey, dense to very dense. (SM) |
| 30 | 20 | SS | ▨ | ▨ | 31.5 m |
| | 21 | SS | ▨ | ▨ | |
| | 22 | SS | ▨ | ▨ | Silty CLAY trace fine sand, greyish li-brown, hard. (CH) |
| 35 | 23 | SS | ▨ | ▨ | 36.2 m |
| | 24 | SS | ▨ | ▨ | |
| | 25 | SS | ▨ | | Silty fine SAND trace medium sand, brown, dense. (SM) |
| | 26 | SS | ▨ | ▨ | 39.45 m |
| 40 | | | | | END OF BORING |



| | | |
|---|---|---|
| BORING STARTED. 12/10/90 | RIG. PORTABLE | WL.-2.00 M. 24 HRS. AFTER BORING. |
| BORING FINSHED. 13/10/90 | FOREMAN. SR | JOB No. 2870 |

# Chapter 11. Disposal

## 11.1 Design of Leachate Treatment Plant

### 11.1.1 Study on Suitable Leachate Treatment System in Bangkok

At present, the BMA applies open-dumping methods for all landfill site Leachate from open-dumping. This creates a negative impact to surrounding environment, because of the highly concentrated leachate with considerable potential for problems caused from the leachate. Therefore a suitable leachate treatment system must be considered. In order to select the suitable leachate treatment system, the following items must be examined.

1. Present conditions leachate at existing disposal sites,
2. Design characteristics of influence leachate,
3. Design characteristics of the effluent from the leachate treatment plant, and
4. Proposal of the leachate treatment system design which is based on of effluent quality.

1) Present Conditions of Leachate at Existing Disposal Sites

Characteristics of the leachate at On Nut and, Nong Khaem are shown in Tables 11.1-1 and 11.1-2. The concentration of COD is higher than that of BOD; the range of SS is large (as thirty times at On Nut disposal site); the annual change of quality is not clearly observed.

Table 11.1-1 Characteristics of the Leachate at On Nut Disposal Site

| Items | Unit | Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1988 | | 1990 | | | | | |
| | | Oct. | Dec. | Feb. | Apr. | Jun. | Aug. | Oct. | Dec. |
| Temperature | ℃ | 29.5 | 25.8 | 30.5 | 33.0 | 31.0 | 29.0 | 29.0 | 24.5 |
| pH | - | 8.2 | 8.3 | 8.2 | 8.5 | 8.2 | 8.2 | 7.0 | 8.0 |
| Alkalinity | mg/l | 8,500 | 6,000 | 6,000 | 5,650 | 3,000 | 2,040 | 3,060 | 3,400 |
| BOD | " | 682 | 106 | 167 | 449 | 48 | 95 | 205 | 300 |
| COD | " | 3,840 | 2,400 | 2,530 | 3,094 | 2,491 | 2,744 | 1,744 | 1,700 |
| T-KN | " | 1,625 | 504.4 | 504 | 953 | 280 | 224 | 897 | 560 |
| SS | " | 1,177 | 886 | 117 | 135 | 63 | 76 | 460 | 37 |
| TS | " | 9,678 | 9,232 | 9,857 | 11,013 | 9,430 | 6,800 | 5,884 | 6,478 |
| VS | " | 2,753 | 4,964 | 2,440 | 2,693 | 2,170 | 1,708 | 1,568 | 1,606 |
| Sludge | " | 6,927 | 9,224 | 7,417 | 8,320 | 7,256 | 5,092 | 4,316 | 4,872 |

| Items | Unit | Data | | Ave. | Range | SD | CV | Siginificant Level (95%) |
|---|---|---|---|---|---|---|---|---|
| | | 1990 | | | | | | |
| | | Mar. | Jun. | | | | | |
| Temperature | ℃ | 29.0 | 29.0 | 29.0 | 24.5 - 33.0 | 2.4 | ±8.3% | 27.3 - 30.7 |
| pH | - | 7.9 | 8.3 | 8.1 | 7.0 - 8.5 | 0.4 | ±4.9% | 7.8 - 8.4 |
| Alkalinity | mg/l | 2,460 | 3,980 | 4,409 | 2,040 - 8,500 | 2,048 | ±46.5% | 2,944 - 5,874 |
| BOD | " | 90 | 300 | 244 | 48 - 449 | 198 | ±81.1% | 126 - 362 |
| COD | " | 1,444 | 3,530 | 2,552 | 1,444 - 3,840 | 787 | ±30.8% | 1,988 - 3,115 |
| T-KN | " | 168 | 616 | 633 | 168 - 1,625 | 435 | ±68.7% | 322 - 944 |
| SS | " | 116 | 600 | 287 | 37 - 1,177 | 365 | ±27.2% | 26 - 548 |
| TS | " | 6,576 | 14,092 | 8,904 | 5,884 - 14,092 | 2,541 | ±28.5% | 7,086 - 10,722 |
| VS | " | 1,412 | 3,396 | 2,471 | 1,412 - 4,964 | 1,083 | ±43.8% | 1,696 - 3,246 |
| Sludge | " | 5,164 | 10,696 | 6,928 | 4,316 - 10,696 | 2,089 | ±30.2% | 5,434 - 8,422 |

Table 11.1-2 Characteristics of the Leachate at Nong Khaem Disposal Site

| Items | Unit | Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1988 | | 1990 | | | | | |
| | | Oct. | Dec. | Feb. | Apr. | Jun. | Aug. | Oct. | Dec. |
| Temperature | ℃ | 29.9 | 24.5 | 30.4 | 29.0 | 28.0 | 29.5 | 29.5 | 24.5 |
| pH | - | 8.2 | 8.1 | 8.1 | 8.4 | 8.6 | 9.0 | 7.0 | 7.8 |
| Alkalinity | mg/l | 10,000 | 11,000 | 8,900 | 6,650 | 8,500 | 2,200 | 2,960 | 7,300 |
| BOD | " | 268 | 202 | 262 | 254 | 108 | 238 | 360 | 410 |
| COD | " | 3,940 | 2,040 | 4,346 | 9,724 | 10,041 | 7,115 | 1,958 | 5,440 |
| T-KN | " | 827 | 1,177 | 897 | 224 | 673 | 616 | 392 | 1,233 |
| SS | " | 113 | 238 | 138 | 69 | 102 | 68 | 1,070 | 83 |
| TS | " | 1,432 | 14,188 | 18,203 | 20,613 | 21,782 | 15,233 | 8,568 | 13,988 |
| VS | " | 2,768 | 2,428 | 6,183 | 6,580 | 6,348 | 5,087 | 2,064 | 3,810 |
| Sludge | " | 6,663 | 6,804 | 12,020 | 4,033 | 15,434 | 10,147 | 6,504 | 10,178 |

| Items | Unit | Data | | Ave. | Range | SD | CV | Significant Level (95%) |
|---|---|---|---|---|---|---|---|---|
| | | 1990 | | | | | | |
| | | Mar. | Jun. | | | | | |
| Temperature | ℃ | 31.0 | 28.0 | 28.4 | 24.5 - 31.0 | 2.3 | ±8.1% | 26.8 - 30.0 |
| pH | - | 8.1 | 8.3 | 8.2 | 7.0 - 9.0 | 0.5 | ±6.1% | 7.8 - 8.6 |
| Alkalinity | mg/l | 2,800 | 5,400 | 6,571 | 2,200 - 11,000 | 3,141 | ±47.8% | 4,324 - 8,818 |
| BOD | " | 114 | 360 | 258 | 107 - 410 | 100 | ±38.8% | 186 - 330 |
| COD | " | 3,376 | 5,940 | 5,392 | 1,958 - 10,041 | 2,866 | ±53.2% | 3,342 - 7,442 |
| T-KN | " | 168 | 953 | 716 | 168 - 1,233 | 371 | ±51.8% | 451 - 981 |
| SS | " | 47 | 820.0 | 275 | 47 - 1,070 | 362 | ±31.6% | 16 - 534 |
| TS | " | 9,846 | 16,396 | 14,025 | 1,432 - 21,782 | 6,092 | ±43.4% | 9,668 - 18,382 |
| VS | " | 2,878 | 5,212 | 4,336 | 2,064 - 6,580 | 1,748 | ±40.3% | 3,086 - 5,586 |
| Sludge | " | 6,968 | 11,184 | 8,993 | 4,033 - 15,434 | 3,388 | ±37.7% | 6,570 - 11,416 |

### 2) Design Characteristics of Influent Leachate

The characteristics of leachate at existing disposal site are shown in Table 11.1-3. Data in Table 11.1-3 is the upper limit of 95% reliable section (as shown in Tables 11.1-1 and 11.1-2) COD and colour is higher than that of Japanese disposal sites. Based on the existing characteristics of leachate, the design leachate is shown in Table 11.1-4.

Table 11.1-3 Characteristics of Leachate at Existing Disposal Sites

| Items | Unit | On Nut*1 | Nong Khaem | Assumed *3 Characteristics |
|---|---|---|---|---|
| Temperature | ℃ | 30.7 | 30.0 | 30.4 |
| pH | - | 8.4 | 8.6 | 8.5 |
| Alkalinity | mg/l | 5,847 | 8,818 | 7,400 |
| BOD | " | 362 | 330 | 350 |
| COD | " | 3,115 | 7,442 | 5,300 |
| T-KN | " | 944 | 981 | 970 |
| SS | " | 548 | 534 | 550 |
| TS | " | 10,722 | 18,382 | 15,000 |
| VS | " | 3,246 | 5,586 | 4,500 |
| Sludge | " | 8,422 | 11,416 | 10,000 |
| Colour*2 | | 17,000 ~ 30,000 | | |

*1: The data at On Nut and Nong Khaem apply at the upper limit of 95% reliability.

*2: Colour characteristics indicated in the study of the faculty of Engineering Chulalongkorn University, because there is no analytical data at both disposal sites between Oct. 1988 to June 1990.

*3: Assumed characteristics is an average of both disposal sites.

Table 11.1-4 Design Characteristics of Influent Leachate

| BOD (mg/l) | COD (mg/l) | SS (mg/l) | pH (-) | Colour (Pt-Co unit) |
|---|---|---|---|---|
| 350 | 5,300 | 550 | 8.5 | 30,000 |

3) Design Characteristics of the Effluence from Leachate Treatment Plant

For the design characteristics of the effluence from leachate treatment plant, three cases are set which accord with a degree of leachate treatment. The three cases are:

Case 1: leachate treatment method that satisfies the industrial effluent standards in Bangkok

Case 2: leachate treatment method that satisfies the industrial efflient standards except BODt

Case 3: leachate treatment method without using Fenton method

According to the above cased, the design characteristics of the effluence from leachate treatment plant are shown in Table 11.1-5.

Table 11.1-5 Design Characteristics of the Effluence from Leachate Treatment Plant

|  | BOD*1 (mg/l) | COD*2 (mg/l) | SS*1 (mg/l) | pH*1 (-) | Colour*3 (Pt-Co unit) |
|---|---|---|---|---|---|
| Case 1 | 60 | 180 | 30 | 5 ~ 9 | 250 |
| Case 2 | 350 | 180 | 30 | 5 ~ 9 | 250 |
| Case 3 | 60 | Not Specified | 30 | 5 ~ 9 | Not Specified |

*1: BOD, SS and pH are based on the industrial effluent standards in Laws and Standards on Pollution Control in Thailand

*2: COD based on the study of Bangkok Metropolitan Nong Khaem Nightsoil Treatment Plant

*3: Colour needs the "preventing environmental pollution standards" of Ministry of Industry in Thailand

### 4) Proposed Leachate Treatment System

The leachate treatment system that is based on the degrees of effluent quality is shown in Figure 11.1-1, 11.1-2 and 11.1-3.

Since these leachate treatment systems, however, have some of merit and demerit, Case-1 is recommended as a suitable leachate treatment systems which can keep appropriate conditions on public aquifers.

Further, the another leachate treatment system are more economic when used with aerated lagoons. The design calculation of the aerated lagoon method is shown as follows:

#### (1) Design Tank Volume of Aerated Lagoon

Table 11.1-6 Design of Aerated Lagoon Method (1)

| | | |
|---|---|---|
| Aerated Lagoon | BOD volumetric loading | < = 0.1 kg/($m^3$·d) |
| | BOD-SS loading | < = 0.05 kg/(kg-SS·d) |
| | MLSS | About 1,000 mg/l |
| | Return sludge rate | About 15% |
| Sedimentation Tank | Surface loading | < = 20 $m^3/(m^2$·d) |
| | Weir loading | < = 70 $m^3/(m^2$·d) |
| | Retention time | > = 4 hrs |

Table 11.1-7 Design of Aerated Lagoon Method (2)

| Items | Oswald (1963) | | | Metcalf & Eddy (1972) | | | | |
|---|---|---|---|---|---|---|---|---|
| | Aerobic Pond | Facultative Anaerobic | Anaerobic Pond | Aerobic Pond | Facultative Anaerobic | w/Surface Stirrer | Anaerobic Pond | Aerated Lagoon |
| Depth (feet) | 0.6~1.0 | 1~4 | 8~10 | 3~4 | 3~6 | 3~8 | 8~15 | 6~20 |
| Retention period (days) | 2~6 | 7~40 | 30~50 | 10~40 | 7~30 | 7~20 | 20~50 | 3~10 |
| Organic loading (lb/acre-day) | 100~200 | 20~50 | 300~500* | 60~120 | 15~50 | 30~100 | 200~500 | - |
| BOD removal rate (%) | 80~95 | 70~85 | 50~70 | 80~95 | 80~95 | 80~95 | 50~80 | 80~95 |

1 ft = 0.3048 (m), 1 lb BOD/acre-day = 1.12 kg BOD/ha-day

*: Assuming BOD influent 1,200 (mg/l)

$$V = \frac{Q_S \cdot C_S}{C_A \cdot L_S}$$

where, $V$ = Volume ($m^3$)

$Q_S$ = Quantity of influent ($m^3/d$)

[$= 300 + 0.15 \times 300 = 345\ m^3/d$]

$C_S$ = BOD concentration of influent (mg/l)

[$= \frac{300 \times 1200 + 0.15 \times 300 \times 60}{345} \div 1050$ mg/l]

$C_A$ = Mixed Liquor Suspended Solid [1000 mg/l]

$L_S$ = BOD-SS loading [0.05 kg/SS kg/d]

$$V = \frac{345 \times 1050}{1000 \times 0.05}$$
$$= 7245 \div 7300\ m^3$$

where, depth (H) = 5.0 m

$$A = \frac{V}{H} = \frac{7300}{5.0} = 1460\ m^2\ [{}^{L}30m \times {}^{B}16m \times 3\ \text{sets}]$$

and Retention time (t) is

$$t = \frac{V}{Q_S} = \frac{30 \times 16 \times 5}{345 \times 1/3} \div 21\ \text{(day)}$$

tank BOD volumetric loading

$$Lv = \frac{Q_S \cdot C_S}{V} \times 10^{-3}$$
$$= \frac{345 \times 1/3 \times 1050}{30 \times 16 \times 5} \times 10^{-3}$$
$$\div 0.05\ kg/m^3 \cdot d \leq 0.1\ kg/m^3 \cdot d$$

Design of aerated lagoon volume is shown in the following:

$^{L}30m \times {}^{B}16m \times {}^{H}5m \times 3$ sets

It is possible to remove BOD load by 80 -95 %.

## (2) Design of Sedimentation Tank

(a) Retention time : 4 hr.

(b) Surface loading : 20 $m^3/m^2 \cdot d$

(c) Sedimentation tank volume V = 345 $m^3/d$ x 4 hr

= 57.5 $m^3$

(d) Surface area A = 345 $m^3/d/20\ m^3/m^2 \cdot d$

= 17.25 $m^2$

(e) Available depth H = 57.5 $m^3/17.25\ m^2$

= 3.3 m

Design of sedimentation tank is shown in the following:

$^{L}6.0m \times {}^{B}3.0m \times {}^{H}3.3m$

It is possible to remove SS load by 90 %.

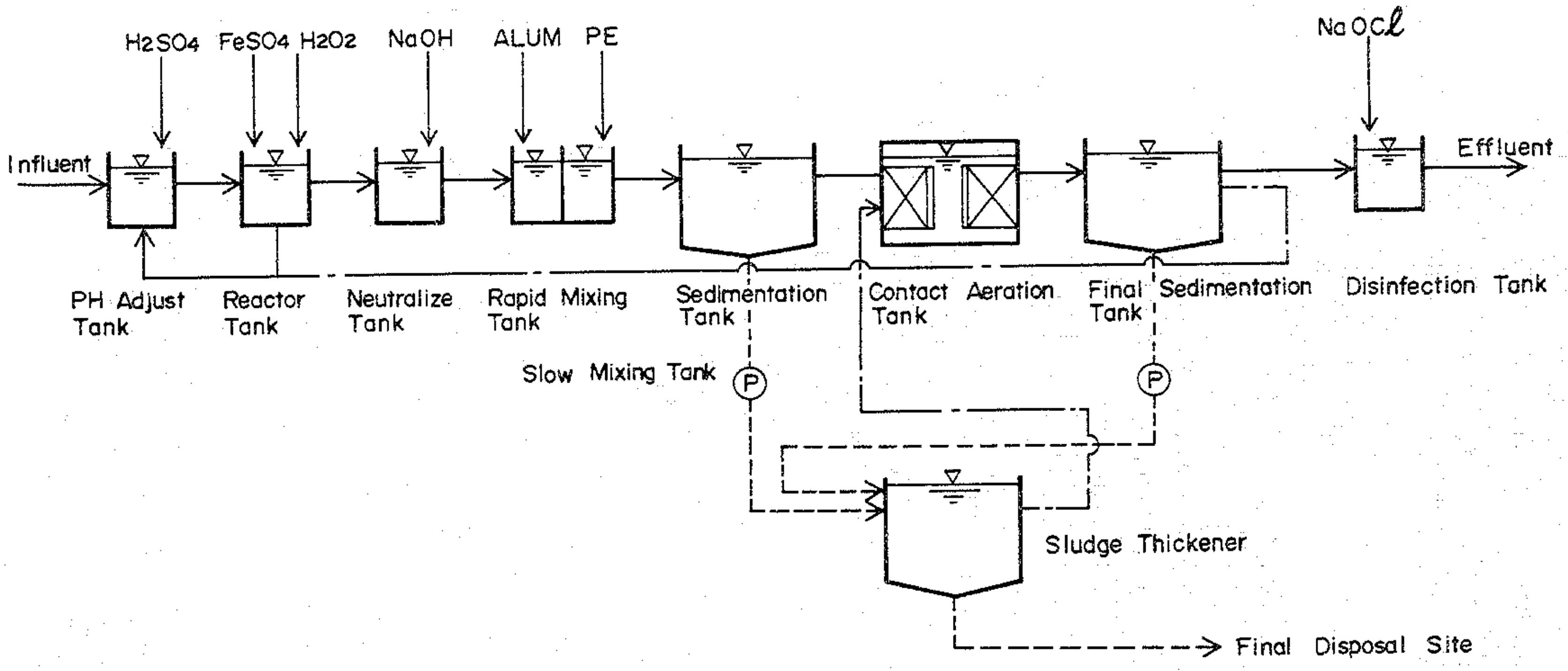


Fig. 11.1-1 Leachate Treatment Facilty — Case I —

( Fenton + Chemical + Biological Treatment )

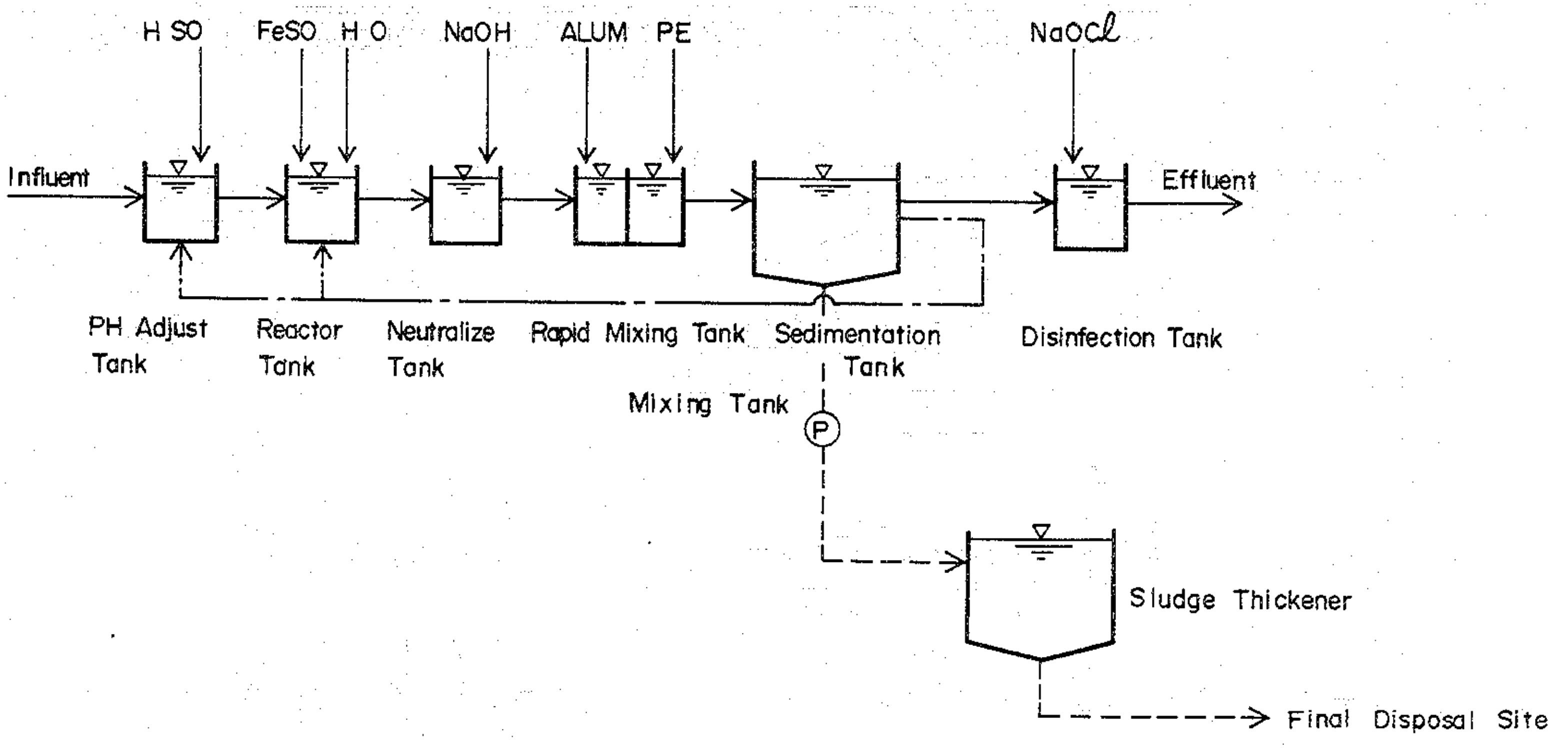


Fig. 11.1-2 Leachate Treatment Facility —Case 2—
(Fenton + Chemical Treatment)

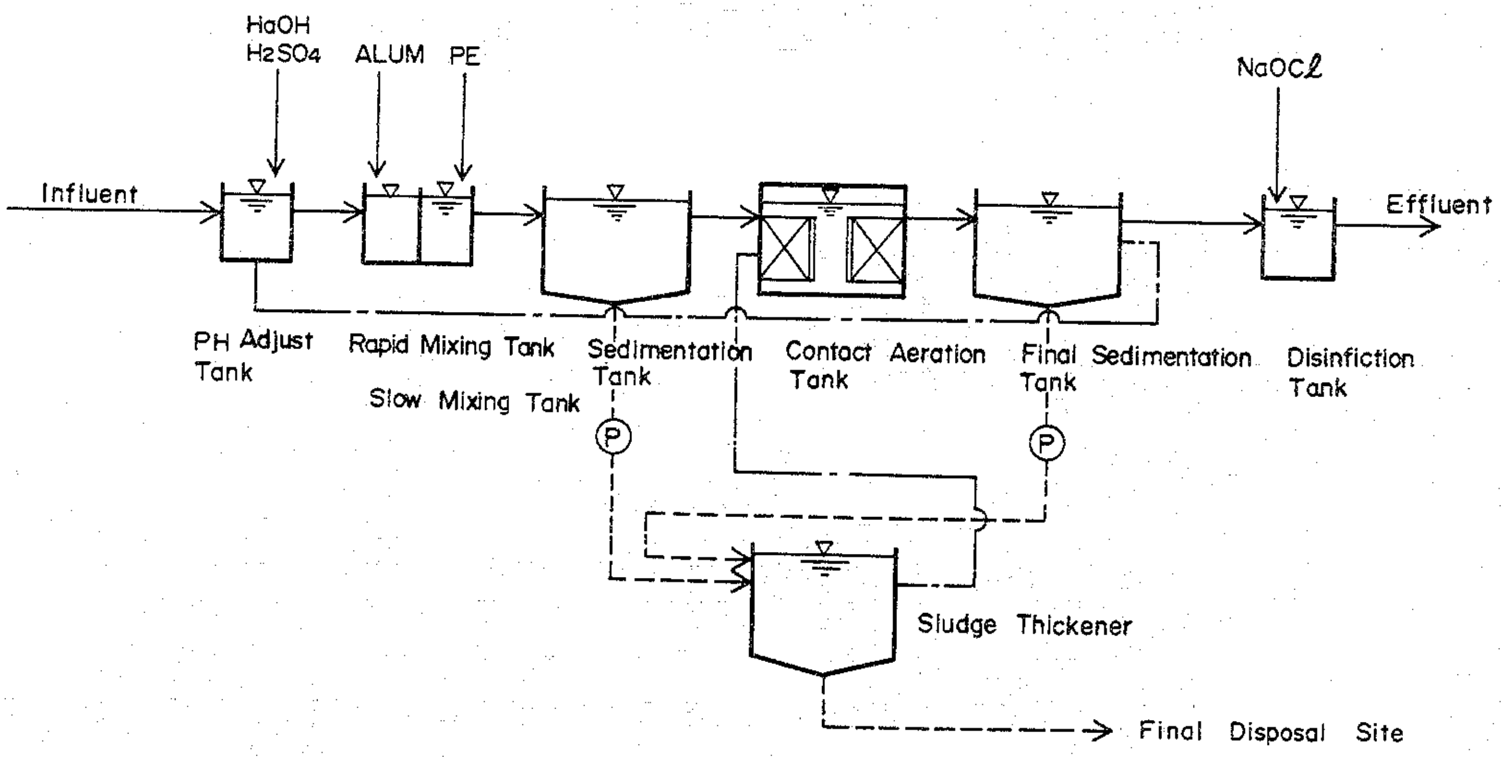


Fig. 11.1-3 **Leachate Treatment Facility — Case 3 —**

**( Chemical + Biological Treatment)**

### 11.1.2 Capacity Calculation of Leachate Treatment Facility

#### 1) Climate Condition in Bangkok

General climatological data of latest 10 years in Bangkok are attached on Appendix 1. These data show that average temperature is 28.6°C and average rainfall is 1,351.1 mm/year. Average temperature and average rainfall are presented on Table 11.1-8 and Table 11.1-9.

#### 2) Water Balance

##### (1) Rainfall

Table 11.1-8 shows maximum rainfall for ten years up to 1988, and value is 1,673.7 mm/year. Average rainfall and maximum rainfall are presented on Table 11.1-10.

##### (2) Evaporation

Evaporation is calculated on "Thornthwaste Formula". The formulae is shown below and the evaporation calculation results are summarised in Table 11.1-11.

<Thornthwaste formulae>

$$Ep = 0.533Dj\,(10tj/J)^{a}$$

$$a = 0.000000675J^{3} - 0.000071J^{2} + 0.01792J + 0.49239$$

$$J = \sum_{J=1}^{12}(tj/5)^{1.514}$$

where, Ep = Average monthly evaporation (mm/d)

*Dj = Monthly coefficient (12 hrs/d=1.0)

tj = Average monthly temperature (°C)

* Monthly coefficient table is attached on Appendix 2.

Observed evaporation value data by Pan from 1961 to 1985 are attached as Appendix 3. These data show that calculated value is higher than observed evaporation value,moreover observed value is higher than actual possible evaporation value, so that the calculated value should be empirically modified.

It is emprically proved that the calculated value is higher than the observed value. The relationship between them are indicated as;

Observed value $\doteqdot$ 0.8 x Calculation value

The modified evaporation values are shown in Table 11.1-12. And these values are further modified by a monthly coefficient. The results are shown as Table 11.1-13. These relations are presented in Fig. 11.1-4. And actual possible evaporation value is almost 80% of observed value by Pan, so that the actual possible evaporation values can be estimated from 0.8 times of the modified evaporation values are shown in Table 11.1-13. The actual evapotation values are shown in Table 11.1-14

### (3) Water Balance

Relationship between the evaporation and the rainfall is shown in Table 11.1-15, which shows that rainfall is evaporated except during the rainy season.

### 3) Capacity of Leachate Treatment Facility

To minimize capacity of the leachate treatment facility standing water in the rainy season should be treated on a one year cycle, as shown in Fig. 11.1-5. In the case of average rainfall year, leachate is treated by 1.16 mm/d.

Table 11.1-8 Monthly Rainfall

| month year | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANNVAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1980 | — | — | 7.5 | 17.3 | 12.8 | 205.8 | 22.9 | 78.3 | 178.1 | — | — | — | (522.7) |
| 1981 | 0 | 9.2 | 50.2 | 29.7 | 216.2 | 96.9 | 67.3 | 88.5 | 167.0 | 82.7 | — | — | (801.7) |
| 1982 | 0 | 25.9 | 28.1 | 58.5 | 133.7 | 90.6 | 127.8 | 128.4 | 168.4 | 235.5 | 96.0 | 14.6 | 1,107.5 |
| 1983 | 0 | 0 | 24.7 | 0 | 2.4 | 109.4 | 132.0 | 558.8 | 272.8 | 272.7 | 285.9 | 11.0 | 1,669.7 |
| 1984 | 0 | 0 | 47.3 | 39.5 | 143.1 | 39.2 | 150.4 | 115.8 | 149.9 | 65.2 | 50.6 | 0 | 801.0 |
| 1985 | 0 | 0 | 0 | 0 | — | — | 152.1 | 156.1 | 309.9 | 272.7 | 68.2 | 0 | (959.0) |
| 1986 | 0 | 2.4 | 0 | 10.4 | 375.7 | 54.3 | 143.0 | 135.1 | — | 252.7 | — | — | (973.6) |
| 1987 | 0 | 0 | 32.5 | 41.8 | 35.0 | 185.4 | 25.9 | 136.2 | 380.7 | 379.0 | 305.0 | 0 | 1,521.5 |
| 1988 | 0 | 63.2 | 15.7 | 91.5 | 283.9 | 146.1 | 126.9 | 312.8 | 373.1 | 260.2 | 0 | — | (1,673.4) |
| 1989 | 29.2 | 0.9 | 82.0 | 2.4 | 128.2 | 86.5 | 176.8 | 181.1 | 410.1 | 315.5 | 33.7 | — | (1,496.4) |
| TOTAL | 29.2 | 101.6 | 288.0 | 291.1 | 1,331.0 | 1,014.2 | 1,125.1 | 1,891.1 | 2,410.0 | 2,136.2 | 839.4 | 25.6 | — |
| Av. | 3.2 | 11.3 | 28.8 | 29.1 | 147.9 | 112.7 | 112.5 | 189.1 | 267.8 | 237.4 | 139.9 | 5.1 | 1,357.1 |

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Table 11.1-9 Monthly Temperature

| month<br>year | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANNVAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1980 | 27.5 | 28.8 | 30.5 | 31.5 | 31.7 | 29.4 | 29.4 | 29.3 | 28.8 | 28.6 | 28.0 | 27.2 | 29.2 |
| 1981 | 26.3 | 28.3 | 29.7 | 30.3 | 29.5 | 29.3 | 29.0 | 28.7 | 29.0 | 28.5 | 27.3 | 24.9 | 28.4 |
| 1982 | 26.2 | 28.6 | 29.7 | 29.9 | 30.4 | 29.2 | 28.9 | 28.5 | 28.3 | 28.5 | 29.0 | 24.7 | 28.5 |
| 1983 | 26.3 | 28.5 | 29.6 | 31.6 | 31.6 | 30.0 | 29.7 | 28.9 | 28.6 | 28.1 | 26.3 | 26.2 | 28.8 |
| 1984 | 26.0 | 28.7 | 29.5 | 31.0 | 30.3 | 29.1 | 28.8 | 29.3 | 28.6 | 27.9 | 27.9 | 26.8 | 28.7 |
| 1985 | 27.6 | 29.3 | 30.2 | 30.6 | 29.6 | 29.3 | 28.4 | 28.9 | 28.3 | 27.8 | 28.0 | 26.0 | 28.7 |
| 1986 | 25.4 | 27.6 | 28.7 | 30.6 | 29.4 | 29.7 | 28.7 | 29.2 | 28.7 | 28.3 | 27.4 | 26.1 | 28.3 |
| 1987 | 26.9 | 28.1 | 29.5 | 30.8 | 30.2 | 29.8 | 30.1 | 29.9 | 28.7 | 28.6 | 28.5 | 24.5 | 28.8 |
| 1988 | 27.4 | 28.6 | 30.4 | 30.5 | 29.4 | 29.5 | 29.1 | 28.4 | 28.9 | 27.9 | 26.3 | 25.5 | 28.5 |
| 1989 | 28.0 | 28.1 | 28.8 | 31.5 | 30.1 | 29.1 | 29.2 | 29.1 | 28.7 | 28.2 | — | — | — |
| Av. | 26.8 | 28.5 | 29.7 | 30.8 | 30.2 | 29.4 | 29.1 | 29.0 | 28.7 | 28.2 | 27.6 | 25.8 | 28.6 |

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Table 11.1-10 Rainfall Data (Maximum, and Average latest 10 years)

| month<br>year | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANNVAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988 | 0 | 63.2 | 15.7 | 91.5 | 283.9 | 146.1 | 126.9 | 312.8 | 373.1 | 260.2 | 0 | — | 1,673.4 |
| Av. | 3.2 | 11.3 | 28.8 | 29.1 | 147.9 | 112.7 | 112.5 | 189.1 | 267.8 | 237.4 | 139.9 | 5.1 | 1,357.1 |

Table 11.1-11 Evaporation Calculation Result by Thornthwaste Formulae

| month<br>year | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANNVAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988 | 147.3 | 151.2 | 249.4 | 247.4 | 231.3 | 221.1 | 222.8 | 192.6 | 190.4 | 166.2 | 116.0 | 106.5 | 2,242.5 |
| Av. | 122.1 | 144.8 | 210.8 | 265.5 | 266.0 | 217.2 | 218.6 | 206.8 | 178.8 | 166.8 | 135.3 | 99.8 | 2,232.5 |

Table 11.1-12 First Modified Calculation Values

| month<br>year | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANNVAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988 | 117.8 | 121.0 | 199.5 | 198.1 | 185.0 | 176.9 | 178.4 | 154.1 | 152.3 | 133.0 | 92.8 | 85.2 | 1,794.1 |
| Av. | 97.7 | 115.8 | 168.6 | 212.4 | 212.8 | 173.8 | 174.9 | 165.4 | 143.0 | 133.4 | 108.2 | 79.8 | 1,786.0 |

Table 11.1-13 Second Modified Calculation Values (Table 5 x Monthly Coefficient)

| month ITEM | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANNVAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coeficient | 1.40 | 1.20 | 1.10 | 0.90 | 0.80 | 0.85 | 0.85 | 0.90 | 0.90 | 0.95 | 1.15 | 1.65 | |
| 1988 | 164.9 | 145.2 | 219.5 | 178.3 | 148.0 | 150.4 | 151.6 | 138.7 | 137.1 | 126.4 | 106.7 | 140.6 | |
| Av. | 136.8 | 139.0 | 185.5 | 191.2 | 170.2 | 147.7 | 148.7 | 148.9 | 128.7 | 126.7 | 124.4 | 131.7 | |

Table 11.1-14 Actual Evaporation Values (Table 6 x 0.8)

| month year | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANNVAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988 | 131.9 | 116.2 | 175.6 | 142.6 | 118.4 | 120.3 | 121.3 | 111.0 | 109.7 | 101.1 | 85.4 | 112.5 | |
| Av. | 109.4 | 111.2 | 148.4 | 152.9 | 136.2 | 118.2 | 118.9 | 119.1 | 103.0 | 101.4 | 99.5 | 105.3 | |

Table 11.1-15 Volume of Standing Water

| month<br>year | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANNVAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| '88 | R | 0 | 63.2 | 15.7 | 91.5 | 283.9 | 146.1 | 126.9 | 312.8 | 373.1 | 260.1 | 0 | 0 | 1,673.4 |
| | E | 131.9 | 116.2 | 175.6 | 142.6 | 118.4 | 120.3 | 121.3 | 111.0 | 109.7 | 101.1 | 85.4 | 112.5 | 1,446.0 |
| | △ | – | – | – | – | 165.5 | 25.8 | 5.6 | 201.8 | 263.4 | 159.0 | – | – | 821.1 |
| AV. | R | 3.2 | 11.3 | 28.8 | 29.1 | 147.9 | 112.7 | 112.5 | 189.1 | 267.8 | 237.4 | 139.9 | 5.1 | 1,357.1 |
| | E | 109.4 | 111.2 | 148.4 | 152.9 | 136.2 | 118.2 | 118.9 | 119.1 | 103.0 | 101.4 | 99.5 | 105.3 | 1,423.5 |
| | △ | – | – | – | – | 11.7 | – | – | 70.0 | 164.8 | 136.0 | 40.4 | – | 422.9 |

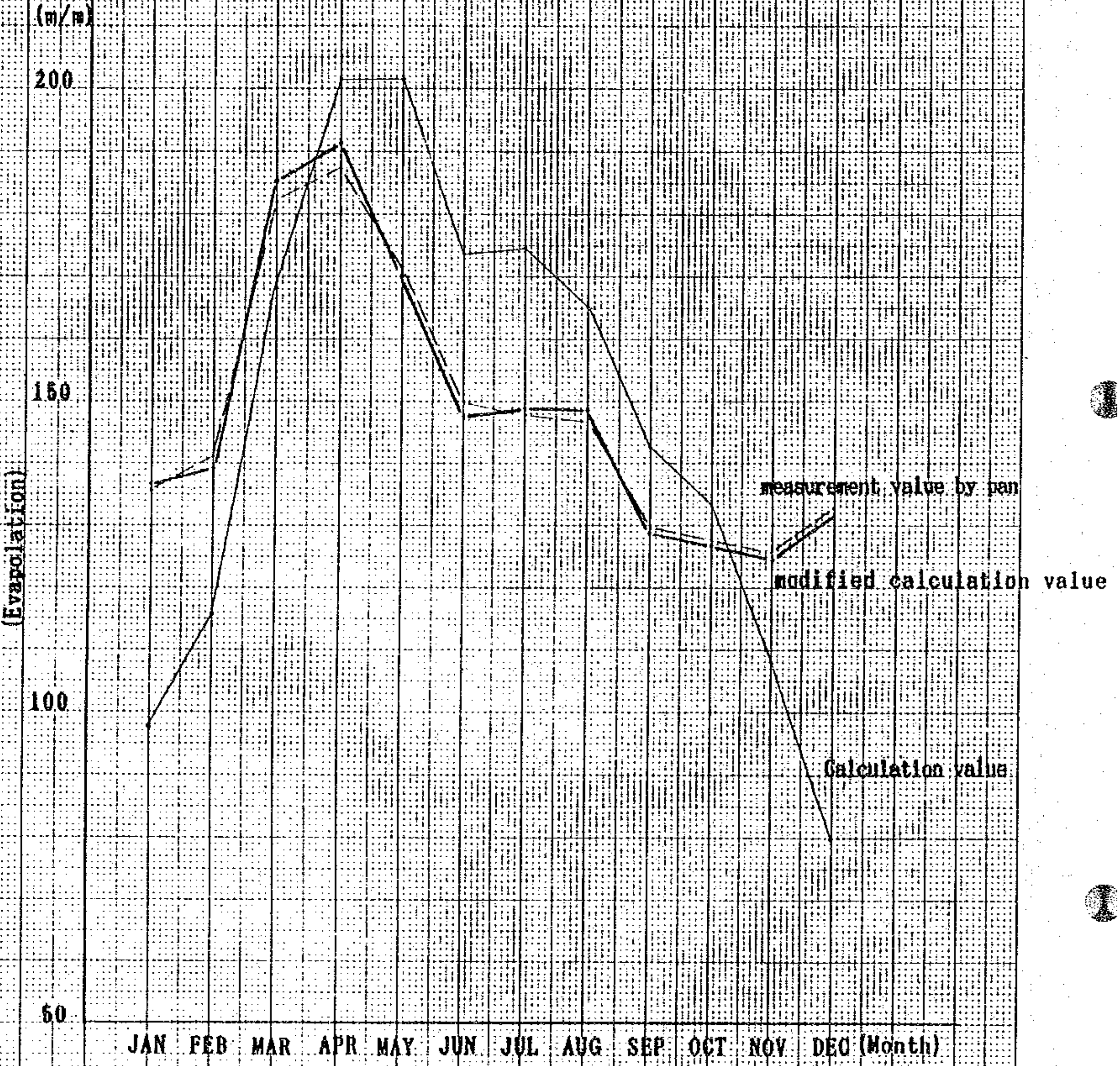

Fig. 11.1-4 Relation between Calculation Value and Measurement Value by Average

Table 11.1-16 Monthly Temperature in Celsius

STATION : 455201 BANGKOK METROPOLIS

| YEAR | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANNUAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1980 | MEAN | 27.5 | 28.8 | 30.5 | 31.5 | 31.7 | 29.4 | 29.4 | 29.3 | 28.8 | 28.6 | 28.0 | 27.2 | 29.2 |
| | MAXIMUM | 34.9 | 36.1 | 37.1 | 38.4 | 39.0 | 37.0 | 36.4 | 35.5 | 35.0 | 34.8 | 34.0 | 34.3 | 39.0 |
| | DAY | 26 | 18 | 29 | 25 | 5 | 1 | 2 | 6, 8 | 17 | 13 | 12,27 | 18 | 5/05 |
| | MINIMUM | 19.6 | 17.9 | 23.3 | 23.0 | 25.2 | 23.8 | 24.2 | 23.7 | 23.2 | 22.0 | 22.2 | 17.2 | 17.2 |
| | DAY | 30 | 16 | 17 | 2 | 10 | 4 | 27 | 17 | 11 | 29 | 23 | 24 | 24/12 |
| 1981 | MEAN | 26.3 | 28.3 | 29.7 | 30.3 | 29.5 | 29.3 | 29.0 | 28.7 | 29.0 | 28.5 | 27.3 | 24.9 | 28.4 |
| | MAXIMUM | 35.5 | 34.7 | 35.5 | 37.8 | 36.3 | 33.8 | 34.5 | 35.0 | 34.8 | 34.9 | 34.6 | 33.2 | 37.8 |
| | DAY | 31 | 14 | 30 | 2 | 29 | 1, 2 | 14,17 | 23 | 9 | 23 | 1 | 12,13 | 2/04 |
| | MINIMUM | 13.9 | 18.5 | 22.5 | 21.9 | 23.6 | 24.4 | 23.6 | 23.0 | 23.9 | 23.3 | 19.7 | 15.8 | 13.9 |
| | DAY | 14 | 19 | 11 | 13 | 6 | 26 | 12 | 13 | 18 | 10 | 10 | 21 | 14/01 |
| 1982 | MEAN | 26.2 | 28.6 | 29.7 | 29.9 | 30.4 | 29.2 | 28.9 | 28.5 | 28.3 | 28.5 | 29.0 | 24.7 | 28.5 |
| | MAXIMUM | 33.5 | 34.0 | 36.5 | 36.9 | 36.5 | 34.4 | 34.3 | 34.3 | 35.0 | 34.5 | 34.7 | 33.7 | 36.9 |
| | DAY | 1,25 | 14 | 24 | 27 | ( 3) | 5 | 20 | 3 | 20 | 5 | 22,29 | 10 | 27/04 |
| | MINIMUM | 16.3 | 22.1 | 23.2 | 22.5 | 23.0 | 24.3 | 22.9 | 22.6 | 22.3 | 22.5 | 22.7 | 12.0 | 12.0 |
| | DAY | 10 | 1 | 26 | 9 | 12 | 18 | 13 | 29 | 10 | 9 | 11 | 29 | 29/12 |
| 1983 | MEAN | 26.3 | 28.5 | 29.6 | 31.6 | 31.6 | 30.0 | 29.7 | 28.9 | 28.6 | 28.1 | 26.3 | 26.2 | 28.8 |
| | MAXIMUM | 34.7 | 35.2 | 36.8 | 37.2 | 39.5 | 36.3 | 36.7 | 35.5 | 34.3 | 34.3 | 33.5 | 33.7 | 39.5 |
| | DAY | 18 | 16 | 22 | 30 | 22 | 16 | 5 | 1 | 23 | 7,25 | 4 | 16 | 22/05 |
| | MINIMUM | 14.0 | 22.3 | 20.7 | 26.7 | 24.1 | 24.0 | 23.1 | 23.6 | 23.5 | 22.4 | 15.8 | 15.8 | 14.0 |
| | DAY | 24 | 3 | 6 | 1 | 9 | 3 | 16 | 5,19 | 1, 7 | 31 | 29 | 1 | 24/01 |
| 1984 | MEAN | 26.0 | 28.7 | 29.5 | 31.0 | 30.3 | 29.1 | 28.8 | 29.3 | 28.6 | 27.9 | 27.9 | 26.8 | 28.7 |
| | MAXIMUM | 34.1 | 34.6 | 35.8 | 37.0 | 38.0 | 34.5 | 34.6 | 34.5 | 34.8 | 33.8 | 34.6 | 34.0 | 38.0 |
| | DAY | 31 | 6 | 29 | 20 | 5 | 4 | 19 | 18 | 12 | 12 | 7 | 19 | 5/05 |
| | MINIMUM | 14.0 | 19.5 | 21.5 | 23.8 | 23.8 | 23.4 | 22.2 | 23.4 | 22.7 | 21.0 | 19.4 | 18.6 | 14.0 |
| | DAY | 10 | 8 | 3 | 27 | 7 | 6 | 14 | 8 | 10 | 28 | 26 | 3,31 | 10/01 |
| 1985 | MEAN | 27.6 | 29.3 | 30.2 | 30.6 | 29.6 | 29.3 | 28.4 | 28.9 | 28.3 | 27.8 | 28.0 | 26.0 | 28.7 |
| | MAXIMUM | 34.1 | 35.7 | 36.0 | 39.7 | 38.0 | 34.3 | 34.2 | 34.5 | 33.7 | 33.3 | 33.5 | 33.5 | 39.7 |
| | DAY | 23 | 8 | 3,30 | 13 | 5 | 8 | 22 | 18 | 2 | 30 | 21 | 8 | 13/04 |
| | MINIMUM | 20.4 | 21.8 | 21.4 | 23.6 | 23.8 | 23.5 | 22.6 | 22.6 | 23.3 | 23.2 | 20.4 | 16.0 | 16.0 |
| | DAY | 1 | 1 | 3 | 17 | 7,13 | 24 | 11 | 6 | 15 | 30 | 24 | 17 | 17/12 |
| 1986 | MEAN | 25.4 | 27.6 | 28.7 | 30.6 | 29.4 | 29.7 | 28.7 | 29.2 | 28.7 | 28.3 | 27.4 | 26.1 | 28.3 |
| | MAXIMUM | 33.8 | 35.7 | 36.6 | 35.7 | 35.5 | 35.7 | 35.8 | 35.0 | 34.8 | 34.0 | 34.3 | 32.8 | 36.6 |
| | DAY | 19 | 19 | 30 | 1,27 | 31 | 10 | 1 | 24 | 18 | 22 | 7 | 18 | 30/03 |
| | MINIMUM | 14.9 | 20.2 | 15.7 | 23.4 | 23.6 | 23.6 | 23.0 | 24.0 | 23.0 | 22.5 | 19.2 | 18.7 | 14.9 |
| | DAY | 8 | 20 | 4 | 7 | 9 | 19,27 | 24 | 10 | 3,24 | 31 | 30 | 24 | 8/01 |
| 1987 | MEAN | 26.9 | 28.1 | 29.5 | 30.8 | 30.2 | 29.8 | 30.1 | 29.9 | 28.7 | 28.6 | 28.5 | 24.5 | 28.8 |
| | MAXIMUM | 34.0 | 33.9 | 37.0 | 37.7 | 36.3 | 35.3 | 36.0 | 37.0 | 35.4 | 34.5 | 34.1 | 33.3 | 37.7 |
| | DAY | 21 | 27 | 21 | 11 | 25 | 25 | 22 | 14 | 4 | 31 | 25 | 30 | 11/04 |
| | MINIMUM | 18.9 | 19.1 | 22.2 | 22.4 | 22.8 | 23.5 | 24.2 | 23.0 | 22.8 | 21.6 | 23.0 | 15.2 | 15.2 |
| | DAY | 15 | 6 | 27 | 16 | 26 | 8 | 31 | 2 | 6 | 27 | 1 | 8 | 8/12 |
| 1988 | MEAN | 27.4 | 28.6 | 30.4 | 30.5 | 29.4 | 29.5 | 29.1 | 28.4 | 28.9 | 27.9 | 26.3 | 25.5 | 28.5 |
| | MAXIMUM | 34.4 | 35.8 | 36.5 | 36.3 | 36.4 | 35.5 | 35.5 | 34.5 | 36.0 | 34.1 | 32.8 | 33.4 | 36.5 |
| | DAY | 30 | 7 | 30 | 22 | 25 | 11,28 | 8, 9 | 5 | 3 | 3 | 2 | 20 | 30/03 |
| | MINIMUM | 18.0 | 21.2 | 22.4 | 23.0 | 23.6 | 23.9 | 23.2 | 22.2 | 22.7 | 20.2 | 19.2 | 17.4 | 17.4 |
| | DAY | 20 | 22 | 10 | 13 | 15 | 18 | 22 | 28 | 10 | 31 | 12 | 13 | 13/12 |
| 1989 | MEAN | 28.0 | 28.1 | 28.8 | 31.5 | 30.1 | 29.1 | 29.2 | 29.1 | 28.7 | 28.2 | - | - | - |
| | MAXIMUM | 34.5 | 33.7 | 34.6 | 37.5 | 37.7 | 35.5 | 35.4 | 35.2 | 34.6 | 35.2 | - | - | - |
| | DAY | 21 | 27 | 31 | 8 | 3 | 30 | 3 | 9 | 13 | 28 | - | - | - |
| | MINIMUM | 20.4 | 21.7 | 19.5 | 25.6 | 23.1 | 22.5 | 22.7 | 22.5 | 22.2 | 20.4 | - | - | - |
| | DAY | 17 | 13 | 9 | 5 | 15 | 17 | 12 | 12 | 13 | 22 | - | - | - |
| MEAN | MEAN | 26.8 | 28.5 | 29.7 | 30.8 | 30.2 | 29.4 | 29.1 | 29.0 | 28.7 | 28.2 | 27.6 | 25.8 | 28.6 |
| EXT. | MAXIMUM | 35.5 | 36.1 | 37.1 | 39.7 | 39.5 | 37.0 | 36.7 | 37.0 | 36.0 | 35.2 | 34.7 | 34.3 | 39.7 |
| EXT. | MINIMUM | 13.9 | 17.9 | 15.7 | 21.9 | 22.8 | 22.5 | 22.2 | 22.2 | 22.2 | 20.2 | 15.8 | 12.0 | 12.0 |

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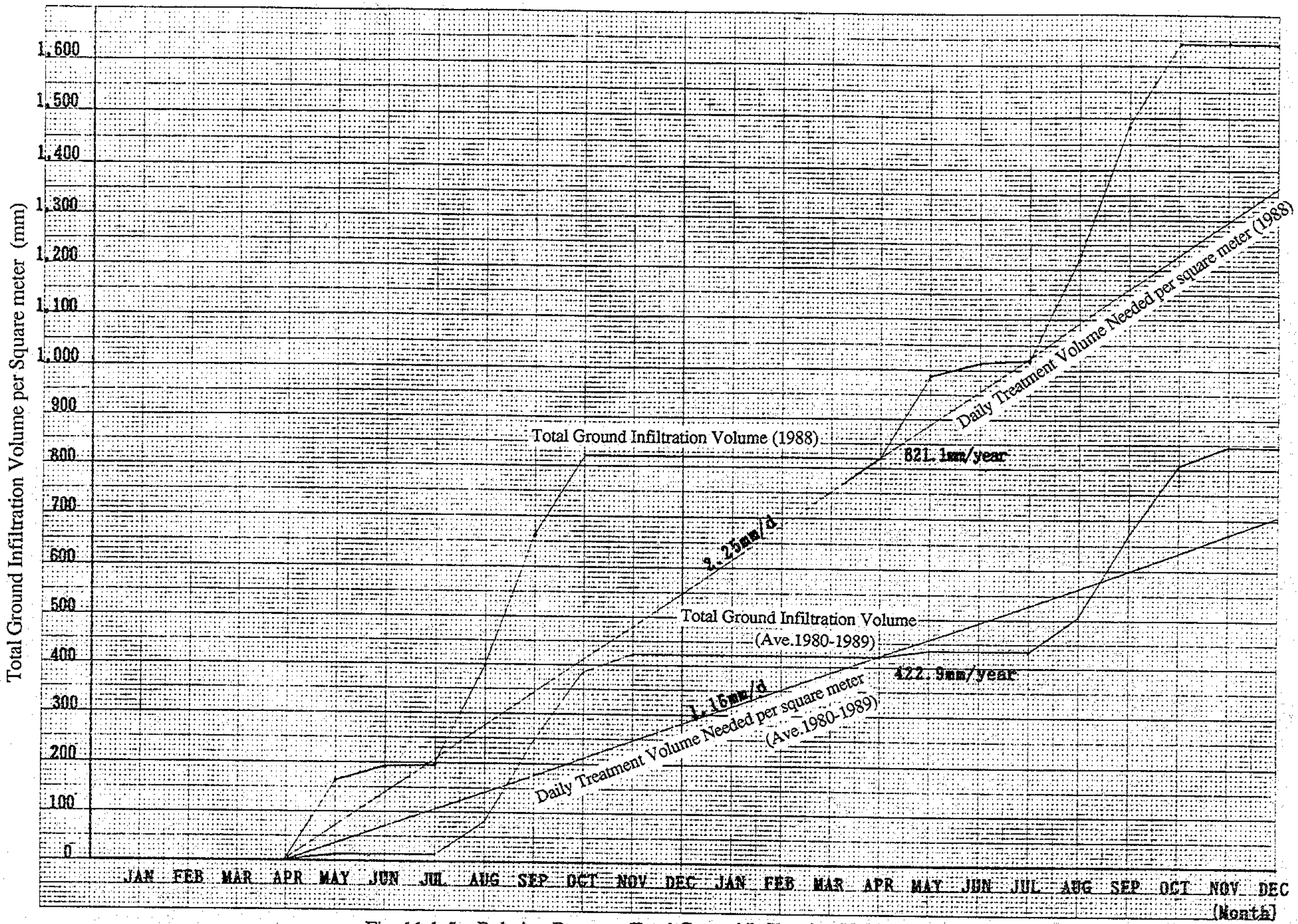

Fig. 11.1-5 Relation Between Total Ground Infiltration Volume and Daily Treatment Volume Needed

## Table 11.1-17 Monthly Relative Humidity (%)

STATION : 455201 BANGKOK METROPOLIS

| YEAR | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANNUAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1980 | MEAN | 70.6 | 70.8 | 74.7 | 73.9 | 72.4 | 79.6 | 77.4 | 76.9 | 79.7 | 82.1 | 75.6 | 69.4 | 75.3 |
| | MEAN MAX. | 91.9 | 88.1 | 90.8 | 88.4 | 85.6 | 92.3 | 89.2 | 90.4 | 92.8 | 94.3 | 90.5 | 87.8 | 90.2 |
| | MEAN MIN. | 42.8 | 48.4 | 52.3 | 53.6 | 54.6 | 62.0 | 61.0 | 60.0 | 62.1 | 64.4 | 57.7 | 49.0 | 55.7 |
| | MINIMUM | 30.0 | 30.0 | 27.0 | 37.0 | 40.0 | 49.0 | 51.0 | 48.0 | 53.0 | 50.0 | 47.0 | 41.0 | 27.0 |
| 1981 | MEAN | 67.9 | 74.2 | 75.3 | 75.3 | 80.3 | 78.1 | 77.9 | 77.9 | 80.3 | 79.6 | 80.0 | 67.7 | 76.2 |
| | MEAN MAX. | 87.8 | 91.8 | 90.6 | 90.0 | 93.5 | 89.8 | 91.0 | 90.1 | 92.8 | 92.2 | 91.6 | 84.0 | 90.4 |
| | MEAN MIN. | 43.3 | 50.6 | 55.8 | 54.9 | 63.0 | 63.5 | 62.6 | 63.6 | 62.6 | 62.7 | 65.0 | 49.8 | 58.1 |
| | MINIMUN | 35.0 | 30.0 | 48.0 | 45.0 | 53.0 | 51.0 | 55.0 | 53.0 | 50.0 | 54.0 | 52.0 | 39.0 | 30.0 |
| 1982 | MEAN | 68.2 | 76.6 | 76.5 | 75.0 | 76.3 | 78.4 | 78.1 | 79.4 | 81.4 | 82.0 | 75.9 | 70.4 | 76.5 |
| | MEAN MAX. | 88.1 | 91.1 | 89.5 | 90.0 | 89.9 | 89.7 | 91.6 | 91.7 | 92.5 | 94.1 | 91.2 | 87.1 | 90.5 |
| | MEAN MIN. | 44.3 | 56.7 | 58.5 | 55.9 | 58.8 | 64.1 | 62.5 | 63.2 | 65.1 | 65.4 | 57.7 | 50.9 | 58.6 |
| | MINIMUM | 32.0 | 42.0 | 42.0 | 39.0 | 44.0 | 52.0 | 52.0 | 53.0 | 50.0 | 55.0 | 46.0 | 38.0 | 32.0 |
| 1983 | MEAN | 69.4 | 76.6 | 74.8 | 73.6 | 72.3 | 76.1 | 77.1 | 81.9 | 83.3 | 84.6 | 77.0 | 69.1 | 76.3 |
| | MEAN MAX. | 86.6 | 92.6 | 90.3 | 87.2 | 85.6 | 89.4 | 90.5 | 94.6 | 94.7 | 84.6 | 91.6 | 84.0 | 89.3 |
| | MEAN MIN. | 48.1 | 53.5 | 54.5 | 53.9 | 54.7 | 60.5 | 60.3 | 65.6 | 67.0 | 68.8 | 59.5 | 52.0 | 58.2 |
| | MINIMUM | 38.0 | 30.0 | 31.0 | 48.0 | 40.0 | 50.0 | 51.0 | 49.0 | 55.0 | 58.0 | 46.0 | 44.0 | 30.0 |
| 1984 | MEAN | 71.7 | 73.5 | 73.0 | 74.1 | 74.3 | 76.5 | 76.7 | 73.7 | 80.4 | 78.7 | 72.5 | 68.6 | 74.5 |
| | MEAN MAX. | 88.7 | 88.7 | 88.8 | 89.2 | 88.5 | 88.3 | 89.7 | 86.3 | 93.7 | 92.7 | 88.0 | 85.3 | 89.0 |
| | MEAN MIN. | 51.0 | 54.0 | 52.2 | 54.9 | 57.0 | 62.6 | 60.2 | 59.8 | 62.2 | 60.4 | 54.3 | 49.4 | 56.5 |
| | MINIMUM | 41.0 | 41.0 | 40.0 | 43.0 | 40.0 | 57.0 | 48.0 | 50.0 | 53.0 | 36.0 | 44.0 | 42.0 | 36.0 |
| 1985 | MEAN | 72.1 | 73.7 | 70.4 | 72.5 | 77.4 | 74.1 | 75.6 | 74.8 | 79.6 | 81.2 | 75.5 | 64.2 | 74.3 |
| | MEAN MAX. | 89.9 | 89.6 | 86.7 | 88.1 | 90.7 | 85.5 | 88.7 | 88.0 | 92.4 | 93.3 | 90.5 | 83.5 | 88.9 |
| | MEAN MIN. | 49.0 | 51.5 | 49.4 | 52.2 | 58.0 | 61.1 | 59.1 | 58.8 | 51.0 | 63.7 | 56.7 | 42.7 | 54.5 |
| | MINIMUM | 36.0 | 31.0 | 23.0 | 31.0 | 43.0 | 46.0 | 44.0 | 50.0 | 63.6 | 37.0 | 38.0 | 36.0 | 23.0 |
| 1986 | MEAN | 63.6 | 72.6 | 67.2 | 71.4 | 73.4 | 72.6 | 75.7 | 73.6 | 78.8 | 81.7 | 71.1 | 70.0 | 72.6 |
| | MEAN MAX. | 84.2 | 89.9 | 84.8 | 86.4 | 86.3 | 86.7 | 89.2 | 88.3 | 93.0 | 94.3 | 86.7 | 87.3 | 88.1 |
| | MEAN MIN. | 39.1 | 50.1 | 45.6 | 50.2 | 57.8 | 56.9 | 60.4 | 56.9 | 59.9 | 63.4 | 52.6 | 50.7 | 53.7 |
| | MINIMUM | 29.0 | 24.0 | 25.0 | 39.0 | 39.0 | 43.0 | 45.0 | 47.0 | 45.0 | 53.0 | 45.0 | 38.0 | 24.0 |
| 1987 | MEAN | 63.6 | 69.8 | 68.8 | 69.7 | 73.6 | 75.4 | 68.6 | 71.5 | 79.4 | 79.6 | 79.1 | 62.0 | 71.8 |
| | MEAN MAX. | 82.2 | 86.4 | 86.9 | 85.3 | 87.9 | 88.3 | 83.3 | 85.9 | 92.5 | 93.4 | 92.3 | 80.1 | 87.0 |
| | MEAN MIN. | 41.8 | 47.8 | 44.7 | 48.0 | 56.0 | 61.2 | 52.0 | 54.6 | 62.2 | 61.2 | 61.4 | 41.1 | 52.7 |
| | MINIMUM | 28.0 | 29.0 | 17.0 | 31.0 | 46.0 | 49.0 | 41.0 | 44.0 | 45.0 | 43.0 | 44.0 | 29.0 | 17.0 |
| 1988 | MEAN | 66.0 | 74.8 | 71.2 | 74.9 | 79.5 | 73.3 | 75.2 | 79.8 | 80.7 | 79.7 | 66.3 | 64.9 | 73.9 |
| | MEAN MAX. | 85.0 | 89.6 | 85.2 | 88.0 | 91.8 | 87.3 | 89.2 | 92.3 | 92.8 | 92.3 | 81.2 | 83.4 | 88.2 |
| | MEAN MIN. | 45.2 | 55.1 | 52.7 | 57.7 | 63.1 | 57.3 | 59.0 | 64.7 | 62.9 | 62.5 | 50.2 | 46.2 | 56.4 |
| | MINIMUM | 31.0 | 32.0 | 40.0 | 46.0 | 47.0 | 44.0 | 47.0 | 50.0 | 45.0 | 46.0 | 35.0 | 38.0 | 31.0 |
| 1989 | MEAN | 75.4 | 75.8 | 74.4 | 68.0 | 71.9 | 71.1 | 73.2 | 72.7 | 78.2 | 80.2 | - | - | - |
| | MEAN MAX. | 91.1 | 91.0 | 89.0 | 83.6 | 87.5 | 86.5 | 86.2 | 86.2 | 92.1 | 93.7 | - | - | - |
| | MEAN MIN. | 55.6 | 55.3 | 55.6 | 46.5 | 53.8 | 55.7 | 57.2 | 57.2 | 59.6 | 61.6 | - | - | - |
| | MINIMUM | 4.6 | 4.3 | 4.1 | 2.6 | 3.5 | 4.3 | 4.0 | 4.6 | 4.8 | 4.7 | - | - | - |
| MEAN | MEAN | 68.9 | 73.8 | 72.6 | 72.8 | 75.1 | 75.5 | 75.6 | 76.2 | 80.2 | 80.9 | 74.8 | 67.4 | 74.5 |
| MEAN | MEAN MAX. | 87.6 | 89.9 | 88.3 | 87.6 | 88.7 | 88.4 | 88.9 | 89.4 | 92.9 | 92.5 | 89.3 | 84.7 | 89.0 |
| MEAN | MEAN MIN. | 46.0 | 52.3 | 52.1 | 52.8 | 57.7 | 60.5 | 59.4 | 60.4 | 61.5 | 63.4 | 57.2 | 48.0 | 55.9 |
| EXT. | MINIMUM | 4.6 | 4.3 | 4.1 | 2.6 | 3.5 | 4.3 | 4.0 | 4.6 | 4.8 | 4.7 | 35.0 | 29.0 | 2.6 |

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Table 11.1-18 Modified Coefficient of the Time from Sunrise to Sunset

| NL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1.04 | .94 | 1.04 | 1.01 | 1.04 | 1.01 | 1.04 | 1.04 | 1.01 | 1.04 | 1.01 | 1.04 |
| 5 | 1.02 | .93 | 1.03 | 1.02 | 1.06 | 1.03 | 1.06 | 1.05 | 1.01 | 1.03 | .99 | 1.02 |
| 10 | 1.00 | .91 | 1.03 | 1.03 | 1.08 | 1.06 | 1.08 | 1.07 | 1.02 | 1.02 | .98 | .99 |
| 15 | .97 | .91 | 1.03 | 1.04 | 1.11 | 1.08 | 1.12 | 1.08 | 1.02 | 1.01 | .95 | .97 |
| 20 | .95 | .90 | 1.03 | 1.05 | 1.13 | 1.11 | 1.14 | 1.11 | 1.02 | 1.00 | .93 | .94 |
| 25 | .93 | .89 | 1.03 | 1.06 | 1.15 | 1.14 | 1.17 | 1.12 | 1.02 | .99 | .91 | .91 |
| 26 | .92 | .88 | 1.03 | 1.06 | 1.15 | 1.15 | 1.17 | 1.12 | 1.02 | .99 | .91 | .91 |
| 27 | .92 | .88 | 1.03 | 1.07 | 1.16 | 1.15 | 1.18 | 1.13 | 1.02 | .99 | .90 | .90 |
| 28 | .91 | .88 | 1.03 | 1.07 | 1.16 | 1.16 | 1.18 | 1.13 | 1.02 | .98 | .90 | .90 |
| 29 | .91 | .87 | 1.03 | 1.07 | 1.17 | 1.16 | 1.19 | 1.13 | 1.03 | .98 | .90 | .89 |
| 30 | .90 | .87 | 1.03 | 1.08 | 1.18 | 1.17 | 1.20 | 1.14 | 1.03 | .98 | .89 | .88 |
| 31 | .90 | .87 | 1.03 | 1.08 | 1.18 | 1.18 | 1.20 | 1.14 | 1.03 | .98 | .89 | .88 |
| 32 | .89 | .86 | 1.03 | 1.08 | 1.19 | 1.19 | 1.21 | 1.15 | 1.03 | .98 | .88 | .87 |
| 33 | .88 | .86 | 1.03 | 1.09 | 1.19 | 1.20 | 1.22 | 1.15 | 1.03 | .97 | .88 | .86 |
| 34 | .88 | .85 | 1.03 | 1.09 | 1.20 | 1.20 | 1.22 | 1.16 | 1.03 | .97 | .87 | .86 |
| 35 | .87 | .85 | 1.03 | 1.09 | 1.21 | 1.21 | 1.23 | 1.16 | 1.03 | .97 | .86 | .85 |
| 36 | .87 | .85 | 1.03 | 1.10 | 1.21 | 1.22 | 1.24 | 1.16 | 1.03 | .97 | .86 | .84 |
| 37 | .86 | .84 | 1.03 | 1.10 | 1.22 | 1.23 | 1.25 | 1.17 | 1.03 | .97 | .85 | .83 |
| 38 | .85 | .84 | 1.03 | 1.10 | 1.23 | 1.24 | 1.25 | 1.17 | 1.04 | .96 | .84 | .83 |
| 39 | .85 | .84 | 1.03 | 1.11 | 1.23 | 1.24 | 1.26 | 1.18 | 1.04 | .96 | .84 | .82 |
| 40 | .84 | .83 | 1.03 | 1.11 | 1.24 | 1.25 | 1.27 | 1.18 | 1.04 | .96 | .83 | .81 |
| 41 | .83 | .83 | 1.03 | 1.11 | 1.25 | 1.26 | 1.27 | 1.19 | 1.04 | .96 | .82 | .80 |
| 42 | .82 | .83 | 1.03 | 1.12 | 1.26 | 1.27 | 1.28 | 1.19 | 1.04 | .95 | .82 | .79 |
| 43 | .81 | .82 | 1.02 | 1.12 | 1.26 | 1.28 | 1.29 | 1.20 | 1.04 | .95 | .81 | .77 |
| 44 | .81 | .82 | 1.02 | 1.13 | 1.27 | 1.29 | 1.30 | 1.20 | 1.04 | .95 | .80 | .76 |
| 45 | .80 | .81 | 1.02 | 1.13 | 1.28 | 1.29 | 1.31 | 1.21 | 1.04 | .94 | .79 | .75 |
| 46 | .79 | .81 | 1.02 | 1.13 | 1.29 | 1.31 | 1.32 | 1.22 | 1.04 | .94 | .79 | .74 |
| 47 | .77 | .80 | 1.02 | 1.14 | 1.30 | 1.32 | 1.33 | 1.22 | 1.04 | .93 | .78 | .73 |
| 48 | .76 | .80 | 1.02 | 1.14 | 1.31 | 1.33 | 1.34 | 1.23 | 1.05 | .93 | .77 | .72 |
| 49 | .75 | .79 | 1.02 | 1.14 | 1.32 | 1.34 | 1.35 | 1.24 | 1.05 | .93 | .76 | .71 |
| 50 | .74 | .78 | 1.02 | 1.15 | 1.33 | 1.36 | 1.37 | 1.25 | 1.06 | .92 | .76 | .70 |

Table 11.1-19 Monthly Rainfall (mm), Rain-Days and Daily Maximum

STATION : 455066 SINGHARAT PHIT. SC.
PROVINCE : BANGKOK METROPOLIS

| YEAR | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANNUAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1979 | AMT. | 18.5 | .0 | .0 | .0 | 147.6 | 53.4 | 14.1 | 261.0 | 162.6 | .0 | .0 | .0 | 657.2 |
| | R-DAY | 1 | 0 | 0 | 0 | 6 | 5 | 2 | 7 | 9 | 0 | 0 | 0 | 30 |
| | MAX. | 18.5 | .0 | .0 | .0 | 58.2 | 26.1 | 10.3 | 45.5 | 30.0 | .0 | .0 | .0 | 58.2 |
| 1980 | AMT. | - | - | 7.5 | 17.3 | 12.8 | 205.8 | 22.9 | 78.3 | 176.1 | - | - | - | - |
| | R-DAY | - | - | 1 | 2 | 3 | 13 | 5 | 6 | 11 | - | - | - | - |
| | MAX. | - | - | 7.5 | 9.8 | 6.5 | 45.0 | 10.5 | 20.7 | 34.0 | - | - | - | - |
| 1981 | AMT. | .0 | 9.2 | 50.2 | 29.7 | 216.2 | 96.9 | 67.3 | 82.5 | 167.0 | 82.7 | - | - | - |
| | R-DAY | 0 | 1 | 1 | 2 | 13 | 8 | 7 | 7 | 10 | 6 | - | - | - |
| | MAX. | .0 | 9.2 | 50.2 | 27.3 | 48.3 | 26.9 | 18.3 | 24.3 | 37.1 | 26.3 | - | - | - |
| 1982 | AMT. | .0 | 25.9 | 28.1 | 58.5 | 133.7 | 90.6 | 127.8 | 128.4 | 168.4 | 235.5 | 96.0 | 14.6 | 1107.5 |
| | R-DAY | 0 | 3 | 3 | 4 | 7 | 7 | 9 | 13 | 15 | 12 | 6 | 2 | 81 |
| | MAX. | .0 | 14.6 | 13.6 | 27.6 | 40.8 | 35.9 | 52.8 | 31.1 | 48.7 | 49.5 | 27.7 | 7.9 | 52.8 |
| 1983 | AMT. | .0 | .0 | 24.7 | .0 | 2.4 | 109.4 | 132.0 | 558.8 | 272.8 | 272.7 | 285.9 | 11.0 | 1669.7 |
| | R-DAY | 0 | 0 | 1 | 0 | 1 | 9 | 10 | 23 | 13 | 9 | 8 | 2 | 76 |
| | MAX. | .0 | .0 | 24.7 | .0 | 2.4 | 31.9 | 36.4 | 67.2 | 50.1 | 96.5 | 95.4 | 8.6 | 96.5 |
| 1984 | AMT. | .0 | .0 | 47.3 | 39.5 | 143.1 | 39.2 | 150.4 | 115.8 | 149.9 | 65.2 | 50.6 | .0 | 801.0 |
| | R-DAY | 0 | 0 | 3 | 6 | 14 | 3 | 12 | 8 | 9 | 8 | 5 | 0 | 68 |
| | MAX. | .0 | .0 | 36.7 | 13.1 | 21.9 | 21.2 | 36.4 | 22.6 | 42.6 | 15.3 | 16.1 | .0 | 42.6 |
| 1985 | AMT. | .0 | .0 | .0 | .0 | - | - | 152.1 | 156.1 | 309.9 | 272.7 | 68.2 | .0 | - |
| | R-DAY | 0 | 0 | 0 | 0 | - | - | 11 | 11 | 10 | 11 | 4 | 0 | - |
| | MAX. | .0 | .0 | .0 | .0 | - | - | 57.4 | 32.2 | 77.9 | 92.7 | 33.5 | .0 | - |
| 1986 | AMT. | .0 | 2.4 | .0 | 10.4 | 375.7 | 54.3 | 143.0 | 135.1 | - | 252.7 | - | - | - |
| | R-DAY | 0 | 1 | 0 | 2 | 6 | 5 | 9 | 8 | - | 15 | - | - | - |
| | MAX. | .0 | 2.4 | .0 | 7.5 | 136.2 | 20.4 | 58.6 | 38.7 | - | 61.9 | - | - | - |
| 1987 | AMT. | .0 | .0 | 32.5 | 41.8 | 35.0 | 185.4 | 25.9 | 136.2 | 380.7 | 379.0 | 305.0 | .0 | 1521.5 |
| | R-DAY | 0 | 0 | 2 | 2 | 3 | 10 | 6 | 5 | 19 | 19 | 15 | 0 | 81 |
| | MAX. | .0 | .0 | 30.2 | 34.7 | 19.8 | 49.7 | 10.0 | 62.3 | 69.4 | 66.8 | 49.7 | .0 | 69.4 |
| 1988 | AMT. | .0 | 63.2 | 15.7 | 91.5 | 283.9 | 146.1 | 126.1 | 312.8 | 373.1 | 260.2 | .0 | - | - |
| | R-DAY | 0 | 3 | 2 | 5 | 18 | 11 | 13 | 18 | 15 | 8 | 0 | - | - |
| | MAX. | .0 | 34.2 | 8.9 | 52.9 | 58.7 | 36.7 | 41.5 | 71.5 | 72.6 | 110.8 | .0 | - | - |
| MEAN | AMT. | 2.1 | 11.2 | 20.6 | 28.9 | 150.0 | 109.0 | 96.2 | 196.5 | 240.3 | 202.3 | 115.1 | 4.3 | 1176.5 |
| MEAN | R-DAY | .1 | .9 | 1.3 | 2.3 | 7.9 | 7.9 | 8.4 | 10.6 | 12.3 | 9.8 | 5.4 | .7 | 67.6 |
| EXT. | MAX. | 18.5 | 34.2 | 50.2 | 52.9 | 136.2 | 49.7 | 58.6 | 71.5 | 77.9 | 110.8 | 95.4 | 8.6 | 136.2 |
| 1989 | | 29.2 | 0.9 | 82.0 | 2.4 | 128.2 | 86.5 | 176.8 | 181.1 | 410.1 | 315.5 | 33.7 | — | (1496.4) |

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Table 11.1-20 Monthly Mean Wind Speed (Knots) and Prevailing Wind

STATION : 455201 BANGKOK METROPOLIS

| YEAR | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANNUAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1979 | SPD. | 4.0 | 5.5 | 7.3 | 6.0 | 5.4 | 3.5 | 5.0 | 4.8 | 2.8 | 2.5 | 3.7 | 2.9 | 4.5 |
| | PREV. | S | S | S | S | S | S | S | S | S | N | N | NE | S |
| 1980 | SPD. | 2.8 | 6.2 | 5.9 | 4.9 | 6.5 | 2.8 | 4.5 | 4.8 | 3.2 | 2.3 | 2.5 | 2.7 | 4.1 |
| | PREV. | S | S | S | S | S | SW | S | SW | SW | N | N | NE | S |
| 1981 | SPD. | 3.0 | 4.7 | 6.1 | 4.8 | 3.5 | 4.7 | 4.3 | 4.7 | 2.6 | 2.8 | 2.3 | 3.3 | 3.9 |
| | PREV. | NE | S | S | S | S | S | S | SW | SW | S | N | N | S |
| 1982 | SPD. | 2.3 | 5.1 | 6.3 | 3.2 | 4.0 | 4.4 | 4.7 | 4.3 | 3.3 | 1.7 | 2.2 | 2.0 | 3.6 |
| | PREV. | NE | S | S | S | S | S | S | SW | W | E | E | NE | S |
| 1983 | SPD. | 3.1 | 6.4 | 6.9 | 7.8 | 6.0 | 5.2 | 4.3 | 3.7 | 2.2 | 2.2 | 2.3 | 3.5 | 4.5 |
| | PREV. | E | SW | SW | SW | W | W | W | W | W | NE | E | NE | W |
| 1984 | SPD. | 2.6 | 4.2 | 5.6 | 5.3 | 3.8 | 5.3 | 4.6 | 6.0 | 2.9 | 2.2 | .6 | 3.1 | 3.9 |
| | PREV. | E | W | SW | W | W | W | W | W | W | E | E | E | W |
| 1985 | SPD. | 2.9 | 5.4 | 5.7 | 5.1 | 4.1 | 6.1 | 4.2 | 5.0 | 3.0 | 1.8 | 2.2 | 2.7 | 4.0 |
| | PREV. | SE | W | W | W | W | W | W | SW | W | N | N | N | W |
| 1986 | SPD. | 3.2 | 5.1 | 6.7 | 5.5 | 5.7 | 5.7 | 4.3 | 4.6 | 2.8 | 2.1 | 2.1 | 2.6 | 4.2 |
| | PREV. | E | S | S | S | SW | SW | SW | W | SW | NE | NE | NE | SW |
| 1987 | SPD. | 3.4 | 6.0 | 5.6 | 4.9 | 4.4 | 4.8 | 5.0 | 5.1 | 2.2 | 1.8 | 2.2 | 3.1 | 4.0 |
| | PREV. | E | S,SW | S | S | S | S | SW | SW | W | E | NE | N | S |
| 1988 | SPD. | 2.9 | 4.1 | 6.5 | 4.4 | 3.4 | 4.8 | 4.1 | 2.8 | 2.4 | 2.4 | 4.8 | 4.1 | 3.9 |
| | PREV. | SW | SW | SW | SW | SW | SW | SW | SW | SW | W | NE | NE, E | SW |
| MEAN SPD. | | 3.0 | 5.3 | 6.3 | 5.2 | 4.7 | 4.7 | 4.5 | 4.6 | 2.7 | 2.2 | 2.5 | 3.0 | 4.1 |
| PREV. WIND | | E | S | S | S | S | S | S | SW | W | N, E | N | NE | S |

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## Table 11.1-21 Climatological Data for the Period 1956-1985

| | | | | |
|---|---|---|---|---|
| Station | BANGKOK METROPOLIS | Elevation of station above MSL | 2 | meters |
| Index Station | 48455 | Height of barometer above MSL | 20 | meters |
| Latitude | 13° 44' N. | Height of thermometer above ground | 1.25 | meters |
| Longitude | 100° 34' E. | Height of wind vane above ground | 33.10 | meters |
| | | Height of raingauge | 1.00 | meters |

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pressure (+1000 or 900 mbs.)** | | | | | | | | | | | | | |
| Mean | 12.47 | 10.99 | 09.96 | 08.40 | 06.85 | 06.34 | 06.46 | 06.51 | 07.56 | 09.75 | 11.60 | 12.65 | 09.13 |
| Ext. Max. | 26.50 | 20.96 | 20.97 | 17.74 | 14.06 | 13.00 | 13.34 | 13.50 | 14.38 | 18.02 | 20.38 | 21.32 | 26.50 |
| Ext. Min. | 04.42 | 02.27 | 02.08 | 99.66 | 99.40 | 97.76 | 98.78 | 99.36 | 98.20 | 01.22 | 04.60 | 03.87 | 97.76 |
| Mean daily range | 4.81 | 4.80 | 4.85 | 4.83 | 4.46 | 3.80 | 3.75 | 3.93 | 4.39 | 4.43 | 4.28 | 4.51 | 4.40 |
| **Temperature (°C)** | | | | | | | | | | | | | |
| Mean | 25.6 | 27.2 | 28.6 | 29.6 | 29.3 | 28.7 | 28.1 | 27.9 | 27.6 | 27.5 | 26.7 | 25.5 | 27.7 |
| Mean Max. | 31.9 | 32.8 | 33.9 | 34.9 | 34.2 | 33.1 | 32.6 | 32.4 | 32.0 | 31.8 | 31.5 | 31.4 | 32.7 |
| Mean Min. | 20.6 | 23.1 | 24.8 | 25.9 | 25.6 | 25.3 | 24.9 | 24.8 | 24.5 | 24.3 | 23.0 | 20.9 | 24.0 |
| Ext. Max. | 35.7 | 36.6 | 39.8 | 40.0 | 39.5 | 37.7 | 37.8 | 36.3 | 36.0 | 35.3 | 35.1 | 35.2 | 40.0 |
| Ext. Min. | 11.5 | 14.9 | 16.5 | 19.9 | 21.1 | 21.7 | 22.2 | 21.2 | 21.6 | 18.3 | 14.2 | 10.5 | 10.5 |
| **Relative Humidity (%)** | | | | | | | | | | | | | |
| Mean | 72.1 | 75.7 | 76.0 | 76.0 | 78.4 | 78.5 | 79.3 | 80.2 | 82.8 | 82.2 | 77.5 | 72.5 | 77.6 |
| Mean Max. | 90.6 | 92.2 | 91.6 | 90.7 | 92.2 | 91.5 | 91.8 | 93.2 | 94.8 | 94.3 | 92.5 | 90.0 | 92.1 |
| Mean Min. | 48.6 | 53.4 | 55.2 | 55.8 | 60.1 | 62.5 | 63.5 | 63.9 | 66.0 | 65.6 | 59.4 | 52.1 | 58.8 |
| Ext. Min. | 27.0 | 17.0 | 23.0 | 28.0 | 30.0 | 38.0 | 43.0 | 47.0 | 49.0 | 36.0 | 36.0 | 31.0 | 17.0 |
| **Dew Point (°C)** | | | | | | | | | | | | | |
| Mean | 19.6 | 22.1 | 23.6 | 24.5 | 24.8 | 24.2 | 23.9 | 23.9 | 24.2 | 23.9 | 22.1 | 19.7 | 23.0 |
| **Evaporation (mm.)** | | | | | | | | | | | | | |
| Mean - Pan | 135.9 | 141.1 | 182.1 | 187.5 | 171.4 | 150.1 | 147.9 | 147.1 | 130.4 | 127.9 | 125.8 | 133.3 | 1780.5 |
| **Cloudiness (0-10)** | | | | | | | | | | | | | |
| Mean | 5.9 | 6.5 | 6.8 | 7.0 | 8.2 | 8.5 | 8.6 | 8.9 | 9.0 | 8.2 | 6.8 | 5.9 | 7.5 |
| **Sunshine Duration (hr.)** | | | | | | | | | | | | | |
| Mean | 276.6 | 252.5 | 270.0 | 256.0 | 222.4 | 178.5 | 169.1 | 139.4 | 152.6 | 202.0 | 242.6 | 266.1 | 2647.8 |
| **Visibility (km.)** | | | | | | | | | | | | | |
| 0700 L.S.T. | 5.2 | 4.9 | 5.9 | 7.5 | 8.6 | 8.7 | 8.4 | 8.1 | 8.0 | 8.0 | 8.1 | 7.5 | 7.4 |
| Mean | 9.6 | 9.2 | 9.4 | 10.7 | 11.9 | 12.1 | 11.9 | 11.6 | 8.6 | 11.4 | 11.7 | 11.2 | 10.8 |
| **Wind (knots)** | | | | | | | | | | | | | |
| Prevailing wind | NE | S | S | S | S | SW | SW | SW | SW | NE | NE | NE | - |
| Mean wind speed | 2.6 | 4.1 | 5.0 | 4.6 | 3.8 | 3.8 | 3.5 | 3.6 | 2.7 | 2.3 | 2.3 | 2.4 | - |
| Max. wind speed | 31 NNE | 37 N | 48 ENE | 52 E,<br>ESE | 41 SSW | 41 W | 41 W,NW,<br>WNW,S | 43 E | 44 SSW | 40 NE | 37 SE,<br>ESE | 31 SE,<br>NNE | 52 E,ESE |
| **Rainfall (mm.)** | | | | | | | | | | | | | |
| Mean | 9.3 | 29.1 | 26.2 | 66.4 | 189.9 | 156.1 | 158.7 | 204.6 | 339.4 | 239.3 | 48.3 | 9.7 | 1477.0 |
| Mean rainy days | 1.3 | 2.9 | 3.0 | 6.4 | 15.7 | 16.7 | 18.1 | 20.6 | 21.5 | 17.0 | 5.9 | 1.3 | 130.4 |
| Greatest in 24 hr. | 39.3 | 73.0 | 88.4 | 89.7 | 124.2 | 167.3 | 108.6 | 97.8 | 153.7 | 123.2 | 81.2 | 32.0 | 167.3 |
| Day/Year | 31/61 | 11/64 | 30/82 | 29/57 | 15/66 | 13/79 | 28/76 | 26/71 | 23/68 | 5/60 | 2/69 | 8/72 | 13/79 |
| **Number of days with** | | | | | | | | | | | | | |
| Haze | 19.1 | 15.9 | 16.3 | 9.3 | 2.9 | 1.3 | 0.8 | 0.8 | 1.0 | 2.2 | 6.3 | 11.8 | 87.7 |
| Fog | 3.5 | 1.2 | 0.4 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.3 | 0.7 | 6.4 |
| Hail | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Thunderstorm | 0.5 | 0.8 | 2.4 | 8.1 | 15.8 | 9.7 | 10.3 | 11.0 | 16.3 | 14.7 | 3.7 | 0.7 | 94.0 |
| Squall | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.2 |

Remark : Evaporation 1961 - 1985

## 11.2 Process Calculation

### 11.2.1 Generality

1) Capacity of plant : 100 m3 x 2 lines

2) Working period : 24 hr

3) Characteristics of leachate :

| | Influent | Effluent |
|---|---|---|
| pH | 8.5 | 5 - 9 |
| BOD | 350 | 60 |
| SS | 550 | 40 |
| Color | 30,000 | 250 |

4) Flow sheet (See Figure 11.1-6)

5) Water & Material Balance

(1) Excess sludge amounts

a. CAT

$200\ m^3/d \times (175 - 60) \times 0.5 \times 10^{-3} = 11.5\ kg/d$

$(0.8\%\ solution = 230\ m^3/d)$

b. Coagulation

- SS Removal

  $200\ m^3/d \times (550 - 40) \times 10^{-3} = 102.0\ kg/d$

- Conversion alum

  $200\ m^3/d \times 2{,}000\ mg/l \times 0.4 \times 10^{-3} = 160.0\ kg/d$

---

Sub total = 11.5 + 102.0 + 160.0 = 273.5 kg/d

c. Sludge Amounts

$0.8\%\ Sol = 273.5\ kg/d/8\ kg/m^3 = 34.2\ m^3/d$

$1.5\%\ Sol. = 273.5\ kg/d/15\ kg/m^3 = 18.2\ m^3/d$

---

$Separated\ water\ amounts = 34.2 - 18.2 = 16.0\ m^3/d$

d. Defoaming Water amount

pH Adjustment tank = 10 l/min x 1,440 min/d x 2 = 28.8 $m^3/d$

Fenton tank = 15 l/min x 1,440 min.d x 2 = 43.2 $m^3/d$

---

Sub total = 28.8 + 43.2 = 72.0 $m^3/d$

e. Chemical Use Amount

i) $H_2SO_4$ 98% sol. s.g. 1.84

$200 \ m^3/d \times 1.5 \ l/m^3 \times 10^{-3} \times 1.84 = 0.55 \ t/d \ (300 \ l/d)$

ii) $FeSO_4$ 10% sol. s.g. 1.45

$200 \ m^3/d \times 2{,}500 \ mg/l \times 10^{-3} = 500 \ kg/d$

$500 \ kg/d \times \frac{100}{10} \times \frac{1}{1.45} = 3.5 \ m^3/d$

iii) $H_2O_2$ 35% sol. s.g. 1.13

$200 \ m^3/d \times 150 \ mg/l \times \frac{100}{35} \times \frac{34}{16} = 182 \ kg/d$

$182 \ kg/d \times \frac{1}{1.13} = 161 \ l/d$

iv) Alum 8% sol. s.g. 1.32

$200 \ m^3/d \times 1.5 \ l/m^3 \times 0.35 \ t/m^3 \times 10^{-3} = 105 \ kg/d$

$105 \ kg/d \times \frac{100}{8} \times \frac{1}{1.32} = 944 \ l/d$

v) NaOH 24% sol.

$200 \ m^3/d \times 3.0 \ l/m^3 \times 240 \ kg/m^3 \times 10^{-3} = 144 \ kg/d$

vi) Polymer

$200 \ m^3/d \times 5 \ mg/l \times 10^{-3} = 1 \ kg/d$

vii) Disinfection

$200 \ m^3/d \times 5 \ mg/l \times \frac{100}{12} \times 10^{-3} = 8.4 \ kg/d$

### 11.2.2 Calculation

1) Intake Equipment

(1) Intake Pump

a. Intake amounts : $200\ m^3/d \times \frac{1}{1{,}440\ min} = 0.14\ m^3/min$
b. Type : Submersible waste water pump
c. Spec : ø80 m/m x 0.2 $m^3$/minx 14 m x 2.2 kW
d. Number : 2 (included spares 1)

2) pH Adjustment Equipment

(1) pH Adjustment Basin (No. 1 Rough)

a. Structure : Rectangular Reinforced Concrete
Inside Rubber lining
b. Supply amount : 114.4 $m^3$/d x 2
c. Detention time : 5 min
d. Capacity plan : 114.4 $m^3$/d x 5/1,440 = 0.4 $m^3$ x 1.2
= 0.48 $m^3$ x 2 sets
e. Actual capacity and dimension : 0.6 m x 0.6 m x 1.5 m = 0.54 $m^3$
f. Rapid mixer : Marine Propeller Type
D = 200 m/m, 3 Blades x 0.2 kW
Impeller, Shaft (both SS) + Rubber lining

(2) pH Adjustment Basin

a. Structure : Same 1)-(1)
b. Supply amount : 114.4 $m^3$/d x 2
c. Detention time : 10 min
d. Capacity plan : 114.4 $m^3$/d x 10/1,440 = 0.8 $m^3$
0.8 $m^3$ x 1.2 = 0.966 $m^3$ x 2 sets
e. Actual capacity and dimension : 0.8 m x 0.8 m x 1.5 m = 0.96 $m^3$
f. Rapid mixer : Double Marine Propeller
D = 400 m/m, 3 Blades x 0.4 kW
Impeller, Shaft (both SS) + Rubber lining

### 3) Color Removal Equipment

#### (1) Reactor

a. Structure : Same 1)-(1)
b. Supply amount : 130.6 m$^3$/d x 2
c. Detention time : 30 min
d. Capacity plan : 130.6 m$^3$/d x 30/1,440 = 2.8 m$^3$
2.8 m$^3$ x 1.2 = 3.36 m$^2$x 2 sets
e. Actual capacity and dimension : 1.6 m x 1.6 m x 1.5 m = 3.84 m$^3$
f. Rapid mixer : Double Marine Propeller
D = 1,000 m/m, 4 Blades x 1.5 kW
Impeller, Shaft (both SS) + Rubber lining

### 4) Neutralize Basin

a. Structure : Same 1)-(1)
b. Supply amount : 136.0 m$^3$/d x 2
c. Detention time : 15 min
d. Capacity plan : 136.0 m$^3$/d x 15/1,440 = 1.4 m$^3$
1.4 m$^3$ x 1.2 = 1.7 m$^3$ x 2 sets
e. Actual capacity and dimension : 1.1 m x 1.1 m x 1.5 m = 1.82 m$^3$
f. Rapid Mixer : Same 2)-(2)

### 5) Coagulation

#### (1) Rapid Mixing Tank

a. Structure : Rectangular Reinforced Concrete
Inside Epoxy Coating
b. Supply amount : 136.0 m$^3$/d x 2
c. Detention time : 3 min
d. Available volume : 136.0 m$^3$/d x 3/1,440 = 0.3 m$^3$
0.3 m$^3$ x 1.2 = 0.36 m$^3$ x 2 sets
e. Dimension : 0.6 m x .6 m x 1.5 m = 0.54 m$^3$
f. Rapid mixer : Same 2)-(1)
Materials SUS 304

### (2) Slow Mixing Tank

a. Structure : Same 1)-(1)
b. Supply amount : 136.0 $m^3/d$ x 2
c. Detention time : 20 min
d. Available Volume : 136.0 $m^3/d$ x 20/1,440 = 1.9 $m^3$
1.9 $m^3$ x 1.2 = 2.28 $m^3$ x 2 sets
e. Dimension : 1.3 m x 1.3 m x 1.5 m = 2.54 $m^3$
f. Slow Mixer : Puddle type, 4 Blades, D = 800 m/m, 0.75 kW

### (3) Sedimentation Tank

a. Structure : Reinforced Concrete
Inside epoxy coating
b. Supply amount : 136.0 $m^3/d$ x 2
c. Detention time : 3 hrs
d. Available Volume : 136.0 $m^3/d$ x 3/24 = 17.0 $m^3$
17.0 $m^3$ x 1.2 = 20.4 $m^3$ x 2 sets
e. Surface area : 136.0 $m^3/d/20\ m^3/m^2 \cdot d$ = 6.8 $m^2$
f. Depth : 20.4 $m^3/6.8\ m^2$ = 3.0 m
g. Dimension : ø3.0 m (7.1 $m^2$) x 3.0 = 21.2 $m^3$
h. Scraper : ø3.0 m x 0.75 kW x 2

### (4) Sludge Pump

a. Sludge amounts : 32.8 $m^3/d$ (16.4 $m^3/d$ x 2)
16.4 $m^3/d$ = 0.02 $m^3/min$
b. Type : Submersible waste water pump
c. Spec. : ø80 x 0.2 $m^3/min$ x 10 m x 1.5 kW (with Timer)
d. Number : 4 units (included Spares 2)

## 6) Contact Aeration Tank Equipment

### (1) CAT

a. BOD amounts : 200 mg/l x 200 $m^3/d$ = 40 kg/d
b. BOD/CAT load : 0.5 $kg/m^3 \cdot d$
c. CAT volume : 40 kg/d / 0.5 $kg/m^3 \cdot d$ = 80 $m^3$
80 $m^3$ x 1.2 = 48 $m^3$ x 2 sets

(2) CAT Basin

a. CAT surface area/volume : 100 $m^2/m^3$

b. CAT surface area : 40 $m^3$ x 100 $m^2$ = 4,000 $m^2$

(3) Sedimentation Tank

a. Structure : Reinforced Concrete

b. Supply amounts : 127.6 $m^3/d$ x 2

c. Detention time : 4 hrs

d. Available volume : 127.6 $m^3/d$ x 4/24 = 21.3 $m^3$
21.3 $m^3$ x 1.2 = 25.6 $m^3$ x 2 sets

e. Surface area : 127.6 $m^3/d$ / 15 $m^3/m^2 \cdot d$ = 8.5 $m^2$

f. Depth : 25.6 $m^3$/8.5 $m^2$ = 3.0 m

g. Dimension : ø3.3 m (8.6 $m^2$) x 3.0 m = 25.7 $m^3$ x 2

h. Scraper : ø3.3 m x 0.75 kW

(4) Sludge Pump

a. Sludge amounts : 1.4 $m^3/d$ (0.7 $m^3/d$ x 2)

b. Type : Submersible waste water pump

c. Spec : Same 5)-(4)

d. Number : 4 sets (included Spares 2)

(5) Scum Skimming Pump

a. Type : Submersible waste water pump

b. Spec : Same 5)-(4) (without Timer)

c. Number : 4 sets (included Spares 2)

7) Sludge Treatment

(1) Excess Sludge Amounts

| | Volume (m3/d) | D.S. (kg/d) | Conc. (%) |
|---|---|---|---|
| Coagulation | 32.8 | 262 | 0.8 |
| CAT | 1.4 | 11.5 | 0.8 |
| Total | 34.2 m3/d | 273.5 kg/d | 0.8% |

(2) Sludge Thickener

a. Structure : Reinforced Concrete
b. Supply amounts : 34.2 $m^3/d$
c. Detention time : 12 hrs
d. Available volume : 34.2 $m^3/d$ x 12/24 = 17.1 $m^3$
17.1 $m^3$ x 1.2 = 20.5 $m^3$
e. Depth : 4 m
f. Surface area : 20.5 $m^3/4$ m = 5.13 $m^2$
g. Dimension : ø2.6 m (5.3 $m^2$) x 4 = 21.2 $m^3$
h. Scraper : ø2.6 m x 0.75 kW

(3) Sludge Draw Off Pump

a. Sludge amounts : 18.2 $m^3/d$ = 0.01 $m^3/min$
b. Type : Submersible waste water pump
c. Spec : Same 5)-(4)
d. Number : 2 sets (included Spare 1)

8) Chemical Usage

(1) pH Adjustment

a. $H_2SO_4$
  i) Composition : 98% sol. s.g. = 1.84
  ii) Use amounts : 0.30 $m^3/d$ = 0.55 t/d [max]

b. Stock Tank
  i) Structure : FRP
  ii) Capacity : 0.30 $m^3/d$ x 7 days = 2.1 $m^3$
  iii) Number : 2 sets (included Spare 1)

c. Supply pump
  i) Supply amounts : 0.30 $m^3/d$ = 0.10 l/min x 2
  ii) Type : Diaphragm pump
  iii) Spec : ø15 x 300 ml/min x 5 $kg/cm^2$ x 0.2 kW
  iv) Number : 3 sets (included Spare 1)
  v) Materials : Pump head PMMA
  Diaphragm PTFE
  Check ball or equivalent FPM

## (2) Fenton Process

a. $FeSO_4 \cdot 7H_2O$
- i) Composition : 10% sol. s.g. = 1.45
- ii) Use amounts : 2.1 m$^3$/d, 300 kg/d

b. Stock tank
- i) Structure : FRP
- ii) Capacity : 3.5 m$^3$/d x 7 days = 24.5 m$^3$
- iii) Number : 3 units (included Spare 1)

c. Supply Pump
- i) Supply amounts : 3.5 m$^3$/d = 1.22 l/min x 2
- ii) Type : Diaphragm pump
- iii) Spec : ø15 x 1.8 l/min x 5 kg/cm$^2$ x 0.2 kW
- iv) Number : 3 sets (included Spare 1)
- v) Materials : Same 8)-(1)-c

d. Rapid Mixer
- i) Type : Vertical mixer
  Double marine propeller type
- ii) Spec : ø600 m/m, 3 Blades x 5.5 kW
  Impeller, Shaft (both SS) + Rubber lining
- iii) Number : 3 sets

e. $H_2O_2$
- i) Composition : 35% sol. s.g. = 1.13
- ii) Use amount : 0.161 m$^3$/d, 0.18 t/d [max]

f. Stock Tank
- i) Structure : FRP
- ii) Capacity : 0.16 m$^3$/d x 7 days = 1.12 m$^3$
- iii) Number : 2 sets (included spare 1)

g. Supply Pump
- i) Supply amounts : 0.161 m$^3$/d = 56 ml/min x 2
- ii) Type : Diaphragm pump
- iii) Spec : ø15 x 150 ml/min x 5 kg/cm2 x 0.2 kW

iv) Number : 3 sets (included spare 1)
v) Materials : Same 8)-(1)-c

(3) pH Neutralize

a. NaOH
i) Composition : 24%, s.g. = 1.2
ii) Use amounts : 0.6 $m^3/d$ = 144 kg/d [max]

b. Stock Tank
i) Structure : FRP
ii) Capacity : 0.6 $m^3/d$ x 7 days = 4.2 $m^3$
iii) Number : 2 sets (included Spare 1)

c. Supply Pump
i) Supply amounts : 600 l/d = 210 ml/min x 2
ii) Type : Diaphragm pump
iii) Spec : ø15 x 400 $m^3/min$ x 5 $kg/cm^2$ x 0.2 kW
iv) Number : 3 sets (included Spare 1)
v) Materials : Same 8)-(1)-c

(4) Coagulation

a. Alum
i) Composition : $Al_2O_3$
ii) Use amounts : 1.0 $m^3/d$

b. Stock Tank
i) Structure : FRP
ii) Use amounts : 1.0 $m^3/d$, 0.105 t/d
iii) Number : 2 sets (included Spare 1)

c. Rapid Mixer
i) Type : Vertical mixer (SUS 316)
Double marine propeller type
ii) spec : ø550 m/m x 3 blades x 2.2 kW
iii) Number : 2 sets (included Spare 1)

d. Supply Pump
   - i) Supply amounts : 1,000 l/d = 0.35 l/min x 2
   - ii) Type : Diaphragm pump
   - iii) Spec : ø15 x 700 ml/min x 5 kg $cm^2$ x 0.2 kW
   - iv) Number : 3 sets (included Spare 1)
   - v) Materials : Same 8)-(1)-c

e. Polymer
   - i) Composition : Nonion powder
   - ii) Use amounts : 1.0 $m^3$/d, 1.0 kg/d (0.1% sol.)

f. Stock Tank
   - i) Structure : FRP
   - ii) Capacity : 1 $m^3$/d x 7 days = 7 $m^3$
   - iii) Number : 2 sets (included Spare 1)

g. Rapid Mixer
   - i) Type : Vertical mixer (SUS 316)
   - ii) Spec : Same 8)-(4)-c
   - iii) Number : 2 sets (included Spare 1)

h. Supply Pump
   - i) Supply amounts : 1,000 l/d = 350 ml/min x 2
   - ii) Type : Diaphragm pump
   - iii) Spec : ø15 x 70 ml/min x 5 kg/$cm^2$ x 0.2 kW
   - iv) Number : 3 sets (included Spare 1)

(5) Disinfection

a. NaOCl
   - i) Composition : 12% sol. s.g. = 1.21
   - ii) Use amounts : 8.4 kg/d, 7 l/d

b. Stock Tank
   - i) Structure : FRP
   - ii) Capacity : 1 $m^3$
   - iii) Number : 1 set

c. Supply Pump

i) Supply amounts : 7 l/d = 2.5 ml/min x 2

ii) Type : Diaphragm pump

iii) spec : ø10 x 5 ml/min x 10 $kg/cm^2$ x 0.1 kW

iv) Number : 2 sets (included Spare 1)

v) Materials : Pump head, Diaphragm,Checkball: PTFE or Equivalent

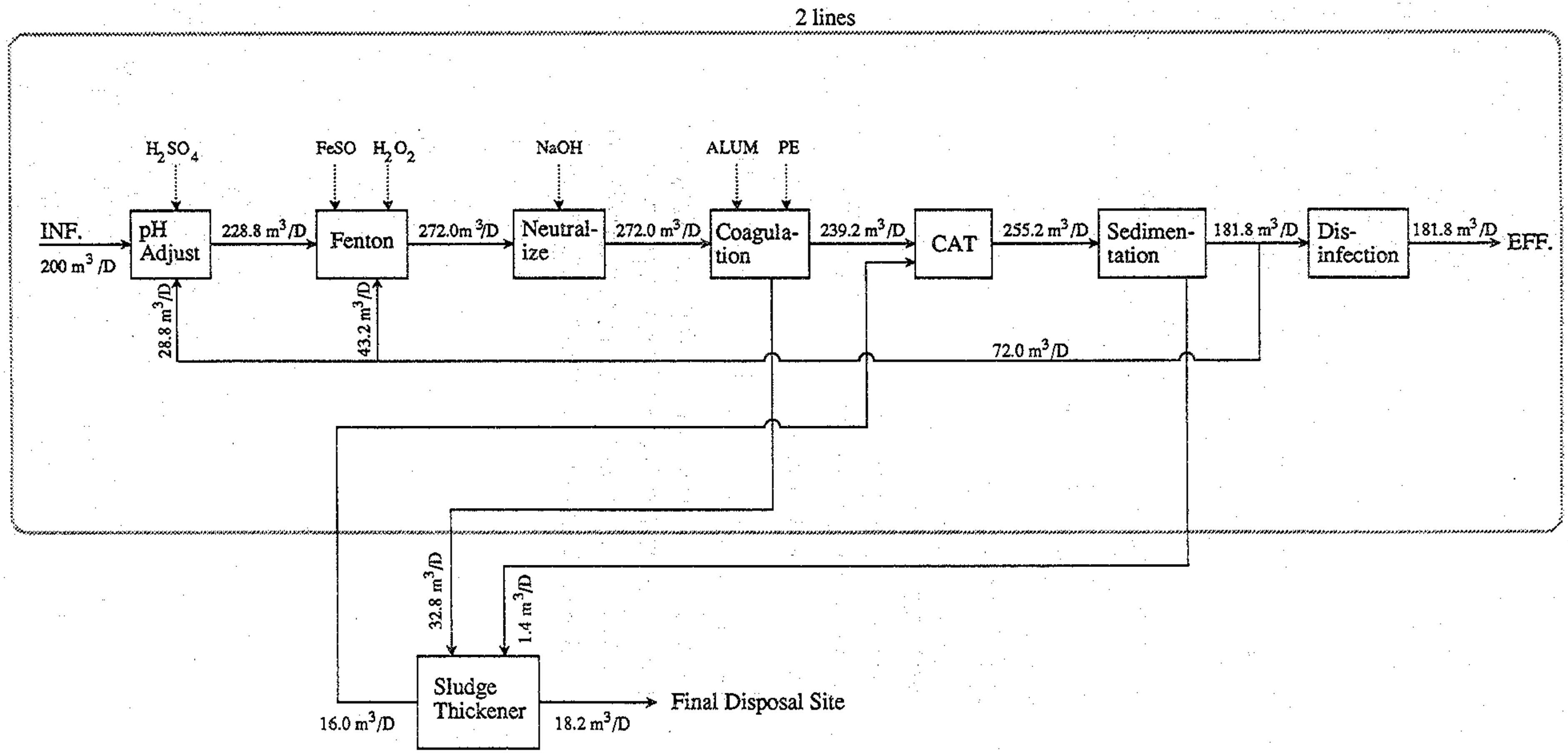
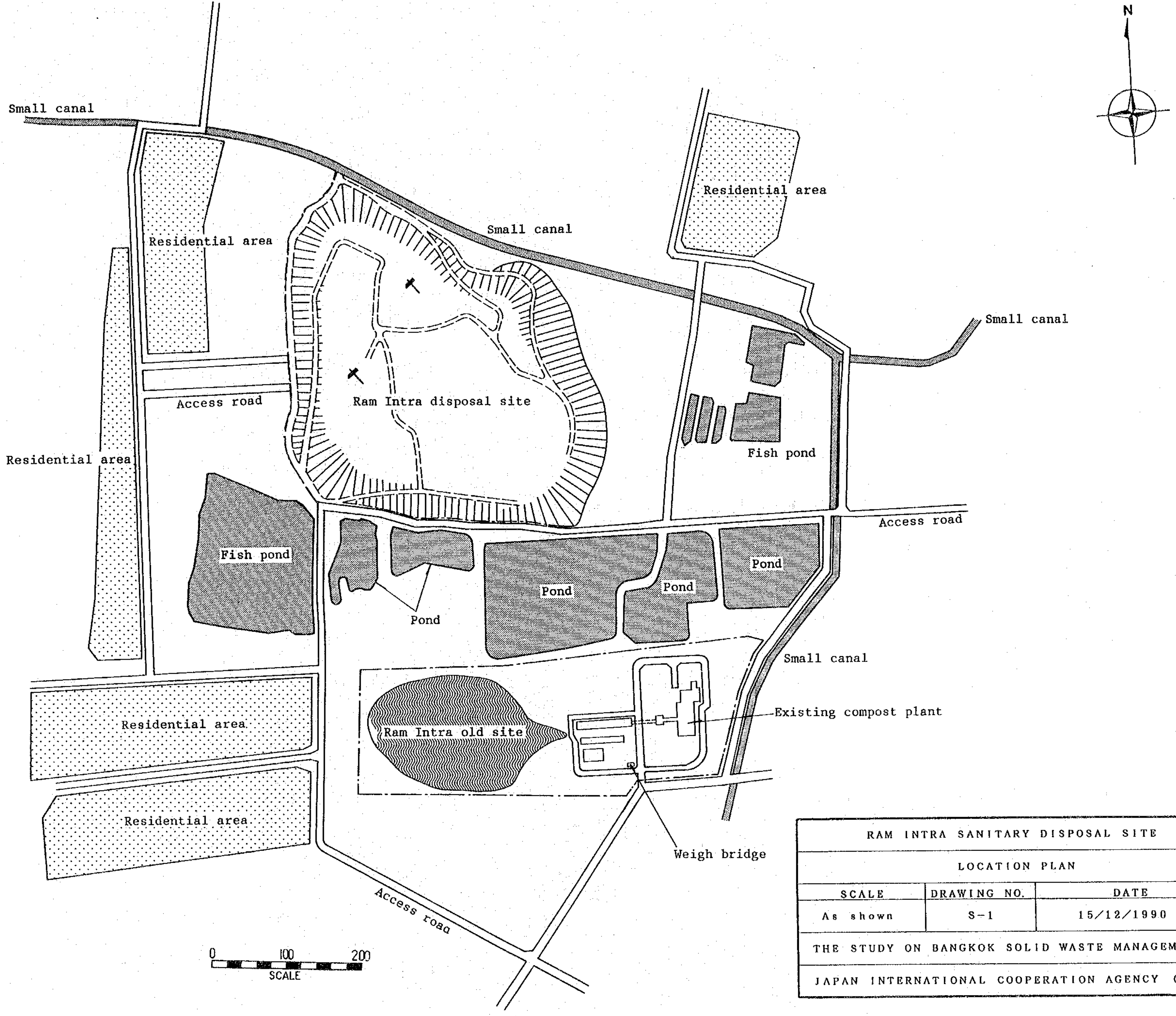


Fig. 11.1-6 Leachate Treatment Flow

## 11.3 Drawing List

| No. | Name |
|---|---|
| S-1 | LOCATION MAP |
| S-2 | TOPOGRAPHICAL MAP |
| S-3 | PLAN |
| S-4 | TYPICAL CROSS SECTION |
| S-5 | PROFILE |
| S-6 | CROSS SECTION (1) |
| S-7 | CROSS SECTION (2) |
| S-8 | CROSS SECTION (3) |
| S-9 | CROSS SECTION (4) |
| S-10 | CROSS SECTION (5) |
| S-11 | CROSS SECTION (6) |
| S-12 | CROSS SECTION (7) |
| S-13 | FACILITY STRUCTURE (1) |
| S-14 | FACILITY STRUCTURE (2) |
| S-15 | FACILITY STRUCTURE (3) |
| S-16 | FINAL PLAN |
| S-17 | PLAN (CASE 2) |
| S-18 | LEACHATE TREATMENT FACILITY FLOW CHART |
| S-19 | LEACHATE TREATMENT FACILITY STRUCTURE (1) |
| S-20 | LEACHATE TREATMENT FACILITY STRUCTURE (2) |
| S-21 | LEACHATE TREATMENT FACILITY STRUCTURE (3) |



RAM INTRA SANITARY DISPOSAL SITE

LOCATION PLAN

| SCALE | DRAWING NO. | DATE |
|---|---|---|
| As shown | S-1 | 15/12/1990 |

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)