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METROPOLITAN WATERWORKS AND SEWERAGE SYSTEM

THE FEASIBILITY STUDY ON THE BALARA WATER TREATMENT PLANT REHABILITATION PROJECT

VOLUME III

SUPPORTING REPORT

MARCH 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

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COMPILATION OF THE REPORT

The study report for the Feasibility Study on the Balara Water Treatment Plant Rehabilitation Project is composed of the following four volumes.

Volume I	SUMMARY
Volume II	MAIN REPORT
Volume III	SUPPORTING REPORT
Volume IV	DRAWINGS

This report (Volume III) summarizes study data which support description of Volume II, Main Report setting forth the proceeding and results of the study.

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LIST OF ABBREVIATIONS

The following abbreviations have been adopted in this report.

Philippine Government Organizations:

DBP	Development Bank of the Philippines
DTI	Department of Trade and Industry
DPWH	Department of Public Works and Highways
EMB	Environmental Management Bureau
HLURB	Housing and Land Use Regulatory Board
MGB	Mines and Geoscience Bureau
MMA	Metropolitan Manila Authority
MWSS	Metropolitan Waterworks and Sewerage System
NAMRIA	National Mapping and Resource Information Authority
NEDA	National Economic and Development Authority
NEPC	National Environmental Protection Council
NHRC	National Hydraulic Research Center
NPC	National Power Corporation
NSO	National Statistics Office
NSCB	National Statistical Coordination Board
NWRB	National Water Resource Board
PIA	Philippine Information Agency
PHO	Public Health Office

Other Organizations:

ADB	Asian Development Bank
AWSOP	Angat Water Supply Optimization Project
FAWSP	Fringe Areas Water Supply Project
GWD-MWSP II	Groundwater Development-Manila Water Supply Project II
IBRD	International Bank for Reconstruction and Development

ICC	Investment Coordination Committee
JICA	Japan International Cooperation Agency
MMWDP	Metro Manila Water Distribution Project
MWSP II	Manila Water Supply Project II
MWSP III	Manila Water Supply Project III
MWSRP I	Manila Water Supply Rehabilitation Project I
MWSRP II	Manila Water Supply Rehabilitation Project II
OECF	Overseas Economic Cooperation Fund

Technical Term:

AC - Asphaltic Concrete
BCR - Benefit/Cost Ratio
BOD, BOD5 - Biochemical Oxygen Demand (5 days)
CDS - Central Distribution System
CI - Cast iron, grey
CIF - Cost, Insurance and Freight
Cl - Chloride Ion
COD - Chemical Oxygen Demand
DF/R - Draft Final Report
DO - Dissolved Oxygen
ECC - Environmental Compliance Certificate
EIRR - Economic Internal Rate of Return
EIS - Environmental Impact Statement
FIRR - Financial Internal Rate of Return
F/R - Final Report
F/S - Feasibility Study
FY - Fiscal Year
GNP - Gross National Product
GRDP - Gross Regional Domestic Product
GPP - Gross Provincial Product
IA - Implementing Arrangement
IC/R - Inception Report
IT/R - Interim Report
IRR - Internal Rate of Return
M/P - Master Plan
MPN - Most Probable Number

MSA	-	MWSS Service Area
MSL	-	Mean Sea Level
NCR	-	National Capital Region
NPV	-	Net Present Value
O & M	-	Operation and Maintenance
p.a.	-	Per Annum
pH	-	pH Value
PVC	-	Polyvinyl Chloride
SDR	-	Social Discount Rate
TOR	-	Terms of Reference
WACC	-	Weight Average Capital Cost

<u>Units of Measurements:</u>

°C	-	degree Celsius	-	Temperature Unit
cm	-	centimeter	-	Length Unit
d	-	day	-	Time Unit
g	-	gram	-	Weight or Mass Unit
ha	-	hectare	-	Area Unit
h	-	hour	-	Time Unit
HP	-	horsepower	-	Power Unit
Hz	-	hertz (cycle per second)	-	Frequency Unit
kg	-	kilogram	-	Weight Unit
km	-	kilometer	-	Length Unit
km^2	-	square kilometer	-	Unit Measurement of Area
kV	-	kilovolt	-	Electrical Potential Unit
kW	-	kilowatt	-	Power Unit
kWh	-	kilowatt-hour	-	Energy Unit
l	-	liter	-	Volume Unit
m	-	meter	-	Length Unit
mm	-	millimeter	-	Length Unit
m/sec	-	meter per second	-	Velocity Unit
m^2	-	square meter	-	Area Unit
m^3	-	cubic meter	-	Volume Unit
m^3/s	-	cubic meter per second	-	Flow Rate

m^3/d	-	cubic meter per day	-	Flow Rate
MGD	-	million gallon per day	-	Flow Rate
Ml/d	-	million liter per day	-	Flow Rate
m^3/min	-	cubic meter per minute	-	Flow Rate
m3/m2/d	-	cubic meter per square meter per day	-	Surface Loading
$m^3/m/d$	-	cubic meter per meter per day	-	Overflow Rate
mg	-	milligram	-	Weight or Mass Unit
mg/l	-	milligram per liter	-	Density Unit
rpm	-	revolution per minute	-	Angular Velocity
s	-	second	-	Time Unit
yr	-	year	-	Time Unit

Currency Conversion:

1 Peso	=	5.14 Yen
1 U.S. Dollar	=	139 Yen
1 U.S. Dollar	=	27.00 Peso
1 Yen	=	0.195 Peso

APPENDIX A CAPACITY CALCULATION

The Study Team conducted an inspection of the existing Balara Plant operating conditions and compared these with the design conditions based on modifications undertaken in 1981.

1. Design Conditions

In the verification of the Balara Plant operating conditions, the following were considered :

The existing Balara Plant is mainly composed of two Plants, Plant No. 1 with a design capacity of 470,000 m^3/d and Plant No. 2 with a design capacity of 1,130,000 m^3/d as listed in Table A.1 . The combined total design capacity is 1,600,000 m^3/d.

Plant No. 1 consists of three lines of pre-treatment processes such as coagulation/flocculation/ sedimentation process, which is composed of sedimentation basin No. 1 & No. 2 with a design capacity of 140,000 m^3/d each and accelators with a design capacity of 190,000 m^3/d. A combined total of 470,000 m^3/d treated water is introduced to 10 beds of filter through the gate chamber where treated water flows.

Plant No. 2 consists mainly of four lines of sedimentation process. Each sedimentation tank is composed of three separate tanks combined with three-step tapered flocculation process. Treated water is then combined and flow into 20 filter beds through effluent channels located at both sides of sedimentation basins.

2. Operation Conditions

Design criteria for major treatment facilities as applied in the modification of the project in 1981 are shown in Tables A.2 and A.3 for Plant No. 1 and Plant No. 2, respectively. A comparison of present operating conditions with their reference values, which are ordinarily applied in design conditions for conventional water treatment systems, are also presented in the tables.

The tables indicate several items that deviate from reference values, which could be attributed to the low efficiencies of the facilities and should be improved in the rehabilitation scheme.

TABLE A.1 DESIGN CAPACITY AND RAW WATER SUPPLY

PLANT	SUB-SYSTEM FOR PRE-TREATMENT	DESIGN CAPACITY(m^3/d)	POTENTIAL RAW WATER AMOUNT (m^3/d)
No. 1	Sedimentation basin No.1	140,000	Aqueduct # 1
	Sedimentation basin No.2	140,000	Aqueduct # 1
	Accelators (2 tanks)	190,000	Aqueduct # 2
	Sub-Total	470,000	565,000
No. 2	Sedimentation basin (4 lines)	1,130,000	Aqueduct # 3 1,140,000
Combined	Total	1,600,000	1,705,000

TABLE A.2 OPERATION CONDITIONS IN PLANT NO. 1

ITEM NO.	DESCRIPTION	UNIT	DESIGN VALUE	ACTUAL OPERATION	REFERENCE VALUE
1	Rapid mixing				
	Velocity gradient	sec^{-1}	1000	867	>100
2	Flocculation				
	No. of basins	basin	2	2	-
	Detention time	min	20	20.2	20-40
	Velocity gradient	sec^{-1}	Max. 100	12.7-33.6	10-80
3	Sedimentation				
	No. of basins	basins	2	2	-
	Detention time	hr	2.28	2.68,2.81	2-5
	Surface loading	mm/min	27.8	23.96,22.95	15-30
	Mean passing velocity	m/min	1.38	* 1.18	0.4
4	Accelators				
	No. of tanks	tank	2	2	-
	Clarification time	min	48	* 64	90-120
	Upflow rate	mm/min	100	* 92	40-60
5	Filtration				
	No. of beds	bed	10	10	-
	Filtration area	m2	162	162	-
	Filtration rate **	m/d	288	288	-
	Filter media depth **				
	Anthracite	mm	500	480	-
	Sand	mm	250	280	-
	Media effective size **				
	Anthracite	mm	0.9-1.1	* 0.57	0.7-1.5
	Sand	mm	0.45-0.55	0.69	0.45-0.70
	Backwash				
	Type		Perforated pipings		
	Rate	m3/m2/min	0.6	0.6-0.65	0.6-0.9
	Surface wash				
	Type		Perforated pipings		
	Rate	m3/m2/min	0.2	0.15-0.2	0.15-0.2

(Notes) * Shows deviation from reference value.
** Filtration particulars were designed based on the result of a pilot scale plant.

TABLE A.3 OPERATION CONDITIONS IN PLANT NO. 2

ITEM NO.	DESCRIPTION	UNIT	DESIGN VALUE	ACTUAL OPERATION	REFERENCE VALUE
1	Rapid mixing				
	Velocity gradient	sec -1	800	866	>100
2	Flocculation				
	No. of basins	basin	12	12	-
	Detention time	min	21	20.2	20-40
	Velocity gradient	sec -1	30-47	26-31	10-80
3	Sedimentation				
	No. of basins	basins	12	12	-
	Detention time	hr	1.7	* 1.61	2-5
	Surface loading	mm/min	48.3	* 52	15-30
	Mean passing velocity	m/min	0.498	* 0.71	0.4
4	Filtration				
	No. of beds	bed	20	20	-
	Filtration area	m2	162	162	-
	Filtration rate **	m/d	348	348	-
	Filter media depth **				
	Anthracite	mm	400	370	-
	Sand	mm	250	292	-
	Media effective size **				
	Anthracite	mm	0.9-1.1	* 0.53	0.7-1.5
	Sand	mm	0.45-0.55	0.64	0.45-0.70
	Backwash				
	Type			Perforated pipings	
	Rate	m3/m2/min	0.6	0.6-0.65	0.6-0.9
	Surface wash				
	Type			Perforated pipings	
	Rate	m3/m2/min	0.6	0.15-0.2	0.15-0.2

(Note) * Shows deviation from reference value.
** Filtration particulars were designed based on the result of a pilot scale plant.

3. Capacity Calculation in Plant No. 1

3.1 Rapid Mixing

1) Detention time

$V = 2 \times 2 \times 2 = 8\ m^3$

$Q = 140{,}000\ m^3/d = 97.22\ m^3/min = 1.62\ m^3/sec$

$T = V/Q = 8/1.62 = 5\ sec$

3.2 Flocculation

1) Detention time

$V = (15.25 + 3.0) \times 2 \times 4.5 \times 1/2 \times 24 = 1971\ m^3$

$Q = 97.22\ m^3/min$

$T = V/Q = 1971/97.22 = 20.2\ min$

3.3 Sedimentation Basin No. 1

1) Detention time

$V = (15.25 + 3.0) \times 2 \times 4.5 \times 1/2 \times 190.92 = 15{,}680\ m^3$

$Q = 5{,}833.3\ m^3/h$

$T = V/Q = 15{,}680/5{,}833.3 = 2.68\ h$

2) Surface loading

$A = (15.25 + 3.0 \times 2) \times 190.92 = 4{,}057.05\ m^2$

$Q = 97.22\ m^3/min$

$S = Q/A = (97.22 \times 10^{9})/(4{,}057.05 \times 10^{6}) = 23.96\ mm/min$

3) Mean passing velocity

$a = (15.25 + 3.0) \times 2 \times 4.5 \times 1/2 = 82.125\ m^2$

$Q = 97.22\ m^3/min$

$V = Q/a = 97.22/82.125 = 1.18\ m/min$

4) Weir loading rate

$140{,}000/(15.25 + 8) = 6{,}021\ m^3/m/d$

3.4 Sedimentation Basin No. 2

1) Detention time

$V = (15.25 + 3.0) \times 2 \times 4.5 \times 1/2 X 199.39 = 16,375^{3}$

$Q = 5,883.3 m^3/h$

$T = V/Q = 16,375/5,833.3 = 2.8/hr$

2) Surface loading

$A = (15.25 + 3.0 \times 2) \times 199.39 = 4,237 m^2$

$Q = 97.22 m^3/min$

$S = Q/A = (97.22 \times 10^9)/(4,237 \times 10^6) = 22.95 mm/min$

3) Mean passing velocity

V = 1.18 m/min (same as sedimentation basin no. 1)

4) Weir loading rate

$140,000/(15.25 + 8) = 6,021 m^3/m/d$

3.5 Accelator

1) Mixing and reacting time

$V_1 = 1/3 [18.9^2 \times (3.6 + 6.949) - 12.45^2 \times 6.949]$

$= 897 m^3$ (Mixing volume)

$V_2 = 12.45^2 \times 2.6$

$= 403 m^3$ (Reaction volume)

$[(V_1 + V_2)] = 897 + 403$

$= 1,300 m^3$

Mixing and reacting time

$$T = \frac{V_1 + V_2}{Q} = \frac{1,300 \times 2 \times 24 \times 60}{190,000} = 19.7 \text{ min}$$

2) Clarification time

$29.56^2 \times (61.3-54.89)-5.33^2 \times 1/2 \times (29.56-5.33) \times 4$

$= 4,224 m^3$

Clarification time

$T = 24 \times 60 \times 4,224/(190,000/2) = 64.0$ min

3) Upflow rate

$A = 29.56^2 - 12.45^2 = 718.8\ m^2$

$\mu = 190{,}000\ /\ (718.8 \times 2 \times 24 \times 60)$

$= 92$ mm/min

4. Capacity Calculation in Plant No.2

4.1 Flocculation

1) Detention time

$V = (994 + 1{,}408 + 1{,}561) \times 4 = 15{,}852\ m^3$

$Q = 1{,}130{,}000\ m^3/d = 47{,}084\ ^3/hr = 784.7\ m^3/min$

$T = V/Q = 15{,}852/784.7 = 20.2$ min

4.2 Sedimentation

1) Detention time

$V = 18{,}916 \times 4 = 75{,}664\ m^3$

$Q = 47{,}084\ m^3/hr$

$T = V/Q = 75{,}664/47{,}084 = 1.61$ hr

2) Surface loading

$A = 18.3 \times 3 \times 68.5 \times 4 = 15{,}043\ m^2$

$Q = 47{,}084\ m^3/hr$

$S = Q/A = 47{,}084/15{,}043 = 3.13$ m/hr (≈ 52 mm/min)

3) Mean passing velocity

$A = 5.03 \times 18.3 \times 3 \times 4 = 1{,}105\ m^2$

$Q = 784.7\ m^3/min$

$V = Q/A = 784.7/1{,}105 = 0.71$ m/min

4) Weir loading rate

$1{,}130{,}000\ /\ [\ (16.52 + 16.62 \times 2) \times 4\ ] = 5{,}677\ m^3/m/d$

5. Preliminary Design for Launder in Sedimentation Basin

According to the inquiry for the existing weirs installed at the end of the sedimentation basins, 6,021 $m^3/m/d$ of weir loading rate is extremely deviated from the 300 to 500 $m^3/m/d$ standard. That could result in flocs carryover to filter beds and filter run may be shortened.

To improve such conditions, launders are proposed to be constructed at the end of the existing sedimentation basins and designed as follows:

5.1 Plant No.1

5.1.1 Design Conditions

(1) Collecting capacity : Q=140,000 m^3/d (=1.62 m^3/sec)
(2) Weir loading rate : 400 $m^3/m/d$
(3) Diameter Orifice : 0.03 m @ 0.1 m (both sides)

5.1.2 Required Total Length of Launder (L)

$$L = 140{,}000 \times (1/2) \times (1/400) = 175\ (m)$$

5.1.3 Launder Length (l)

Assuming that numbers of launder is 10 pcs.

$$l = 175 \times (1/10) = 17.5\ (m)$$

5.1.4 Total Opening Area of Orifice (A)

$$A = (\pi/4) \times 0.03^2 \times (17.5/0.1) \times 2 \times 10 = 2.474\ m^2$$

5.1.5 Loss of Head (h)

$h = (1/2g) \times (Q/CA)^2$

where,

g : Acceleration of gravity = 9.81 m/sec^2

C : Coefficient of orifice = 0.62

$= (1/2 \times 9.81) \times \{(140,000/86,400)/(0.62 \times 2.474)\}^2$

$= 0.057$ (m)

5.1.6 Required Collecting Capacity per Launder (q)

$q = 1.62/10$

$= 0.162\ m^3/sec$

5.1.7 Critical Depth at End of Launder (H_c)

$H_c = \{q^2/(gB^2)\}^{1/3}$

where,

B : Width of launder = 0.6 m

$= \{0.162^2/(9.81 \times 0.6^2)\}^{1/3}$

$= 0.195$ m

5.1.8 Initial Depth at Upstream of Launder (D_i)

$D_i = \sqrt{3} \times H_c$

$= \sqrt{3} \times 0.195$

$= 0.338$ m

<DESIGN RESULTS FOR PLANT NO. 1>

10 launders with dimensions of 600 mm width, 485 mm depth, and 17.5 m length are necessary to install at the both end of the sedimentation basins No. 1 and No. 2 of Plant No. 1.

5.2. Plant No.2

As same manner as Plant No. 1, the weir loading rate of the existing sedimentation basins is 5,677 $m^3/m/d$ which is extremely deviated from the standard.

To improve such conditions, launders are proposed to be constructed at the end of the existing sedimentation basins and designed as follows:

5.2.1 Design Conditions

(1) Total Collecting capacity : 1,130,000 m^3/d (=162 m^3/sec)

(2) Collecting Capacity Per Basin : 1,130,000/(4X3)=94,167 $m^3/d/basin$
(Q=1.09 m^3/sec)

(3) Weir loading : 400 $m^3/m/d$

(4) Diameter Orifice : 0.03 m @ 0.1 m (both sides)

5.2.2 Required Total Length of Launder (L)

L= 94,167 x (1/2) x (1/400)
= 118 (m)

5.2.3 Launder Length (l)

Assuming that numbers of launder is 9 pcs.

l= 118 x (1/9)
= 13.1 say 13.5 (m)

5.2.4 Total Opening Area of Orifice (A)

$A= (\pi/4) \times 0.03^2 \times (13.5/0.1) \times 2 \times 9$
$= 1.718\ m^2$

5.2.5 Loss of Head (h)

$h= (1/2g) \times (Q/CA)^2$

where,

g : Acceleration of gravity = 9.81 m/sec^2

C : Coefficient of orifice = 0.62

$= (1/2x9.81) \times \{1.09/(0.62x1.718)\}^2$

= 0.053 (m)

5.2.6 Required Collecting Capacity per Launder (q)

$q = 1.09/9$

$= 0.121\ m^3/sec$

5.2.7 Critical Depth at End of Launder (H_c)

$H_c = \{q^2/(gB^2)\}^{1/3}$

where,

B : Width of launder = 0.6 m

$= \{0.162^2/(9.81 x 0.6^2)\}^{1/3}$

$= 0.161$ m

5.2.8 Initial Depth at Upstream of Launder (D_i)

$D_i = \sqrt{3} \times H_c$

$= \sqrt{3} \times 0.161$

$= 0.279$ m

<DESIGN RESULTS FOR PLANT NO. 2>

108 launders (9 launders x 12 basins = 108) with dimensions of 600 mm width, 420 mm depth, and 13.5 m length are necessary to install at the end of the sedimentation basins of Plant No. 2.

APPENDIX B G-VALUE CALCULATION

The design of rapid mixing and flocculation is commonly based on two criteria: detention time and mixing energy level. The detention time is described in APPENDIX A, and the mixing level is discussed hereunder. The mixing level defined as G-value was verified based on the actual operating conditions. Data are shown as follows:

1. Operation Conditions

Plant No. 1	
Rapid Mixer Rotation	105 rpm
Flocculation Rotation	
Basin No.1	12 to 23 rpm
Basin No.2	13 to 22 rpm
Plant No. 2	
Hydraulic Jump	
Available Loss of Head	0.56 to 0.7 m
Flocculator	
1st	2.83 rpm
2nd	2.12 rpm
3rd	2.12 rpm

2. Findings

The velocity gradient of rapid mixing in Plant No. 1 and No. 2, both computed more than 800 sec^{-1}, are within the standard level of more than 300 sec^{-1} to ensure sufficient mixing effects.

However, velocity gradient of flocculation in Plant No. 1 and No. 2, computed 12.7 to 33.6 sec^{-1} and 26 to 31 sec^{-1} ,respectively, are not satisfied the required level of 10 to 80 sec^{-1}.

Therefore, there is a need to adjust the rotating speed of flocculators.

3. Calculation

3.1 Plant No. 1 Rapid Mixer

$G = \{[\rho \cdot C \cdot \Sigma i(ai \cdot Vi^3)]/2\mu \cdot V\}^{\frac{1}{2}}$

where,

ρ : Specific gravity in water (25°C, 997.1 kg/m^3)

C : Coefficient of paddle (1.5)

ai: Area of paddles ($0.175 \times 0.22 = 38.5 \times 10^{-3}$)

Vi: Mean velocity of paddles ($\pi \times (0.831-0.175) \times 105/60 = 3.606$ m/sec)

μ : Coefficient of viscosity in water (25 °C, 0.898×10^{-3} kg/m.sec)

V : Volume of rapid mixing tank ($2 \times 2 \times 2 = 8\ m^3$)

$$= \{997.1 \times 1.5 \times 4 \times 38.5 \times 10^{-3} \times 3.606^3)/(2 \times 0.898 \times 10^{-3} \times 8)\}^{\frac{1}{2}}$$

$$= 867\ sec^{-1}$$

3.2 Plant No. 1 Flocculation

Using same formula as shown in rapid mixer:

(1) Basin No. 1

$$G = \{\frac{997.1 \times 1.5 \times 4 \times 110.88 \times 10^{-3} \times (0.756^3 \sim 0.395^3)}{2 \times 0.898 \times (1/1000) \times (5.6 \times 5.6 \times 4.5)}\}^{\frac{1}{2}}$$

$$= 33.6 \sim 12.7\ sec^{-1}$$

(2) Basin No. 2

$$G = \{\frac{997.1 \times 1.5 \times 4 \times 110.88 \times 10^{-3} \times (0.723^3 \sim 0.427^3)}{2 \times 0.898 \times (1/1000) \times (5.6 \times 5.6 \times 4.5)}\}^{\frac{1}{2}}$$

$$= 31.5 \sim 14.3\ sec^{-1}$$

3.3 Plant No. 2 Parshall Flume (Hydraulic Jump)

$G = \{(\rho \cdot g \cdot h)/(T \cdot \mu)\}^{\frac{1}{2}}$

Where,

ρ : Specific gravity in water (25°C, 997.1 kg/m^3)

g : Accelaration of gravity (9.81 m/sec^2)

h : Loss of head (0.56 m ~ 0.70 m)

T : Detention time (8.14 sec)

μ : Coefficient of viscosity in water (25 °C, 0.898 x 10^{-3} kg/m.sec)

$= \{997.1 \times 9.81 \times (0.56 \sim 0.70)/(8.14 \times 0.898 \times 10^{-3})\}^{\frac{1}{2}}$

$= 866 \sim 968\ sec^{-1}$

3.4 Plant No. 2 Flocculator

Using same formula as shown in Plant No. 1 Rapid Mixer:

$G_1 = \{[\rho \cdot C \cdot \Sigma i(ai \cdot Vi^3)]/(2\mu \cdot V_1)\}^{\frac{1}{2}}$

$\Sigma i(ai \cdot Vi^3) = \Sigma 8\pi^3 \cdot a \cdot r^3 \cdot N^3$

$= 8\pi^3 \times (0.09 \times 3.01 \times 4) \times (1.315^3 + 0.965^3 + 0.615^3) \times (2.83/60)^3) \times 4$

$= 0.384$

$V_1 = (4.83 + 3.16) \times 5 \times \frac{1}{2} \times 16.52$

$= 330$

$= \{997.7 \times 1.5 \times 0.384/(2 \times 0.898 \times 10^{-3} \times 330)\}^{\frac{1}{2}}$

$= 31\ sec^{-1}$

$G_2 = \{[\rho \cdot C \cdot \Sigma i(ai \cdot Vi^3)]/(2\mu \cdot V_2)\}^{\frac{1}{2}}$

$\Sigma i(ai \cdot Vi)^3 = \Sigma 8\pi^3 \cdot a \cdot r^3 \cdot N^3$

$= 8\pi^3 \times (0.1 \times 3.07 \times 4) \times (1.72^3 + 1.33^3) \times (2.12/60)^3 \times 4$

$= 0.400$

$V_2 = (4.93 + 4.83) \times 5.8 \times \frac{1}{2} \times 16.52$

$= 467.6$

$= \{997.1 \times 1.5 \times 0.4/(2 \times 0.898 \times 10^{-3} \times 467.6)\}^{\frac{1}{2}}$

$= 27\ sec^{-1}$

$$G_3 = \{[\rho \cdot C \cdot \Sigma i(ai \cdot Vi^3)]/(2\mu \cdot V_3)\}^{\frac{1}{2}}$$

$$\Sigma i(ai \cdot Vi)^3 = \Sigma 8\pi^3 \cdot a \cdot r^3 \cdot N^3$$

$$= 8\pi^3 \times (0.15 \times 3.15 \times 4) \times 1.725^3 \times (2.12/60)^3 \times 4$$

$$= 0.425$$

$$V_3 = (5.03 + 4.93) \times 6.3 \times \tfrac{1}{2} \times 16.52$$

$$= 518.3$$

$$= \{997.7 \times 1.5 \times 0.425/(2 \times 0.898 \times 10^{-3} \times 518.3)\}^{\frac{1}{2}}$$

$$= 26\ sec^{-1}$$

APPENDIX C GRAIN SIZE ANALYSIS

The Study Team conducted an investigation of the filters including depth of filter bed and grain size analysis such as maximum and minimum size, effective size, uniformity coefficient, specific gravity, solubility of hydrochloric acid, porosity, and dry weight reduction based on the Standard of Japan Water Works Association (JWWA A 103-1988).

1. Findings

As shown in summary of filter media analysis (see Table C.1), the existing anthracite is not satisfactory particularly in size. Tested effective size of 0.53 to 0.57 mm shows remarkable deviation from that of the designed value of 0.9 to 1.1 mm. However, the existing sand is generally acceptable.

Anthracite layer has lost 2 to 3 cm , and sand layer is 3 to 4 cm thicker compared to the design values . Expansion rate was 17 %.

Therefore replacement of the anthracite layer is recommended to ensure effective filtration and backwash..

Comparison of turbidity between before and after backwash indicated that the existing backwash system works effectively.

2. Investigation

Filter investigation procedure consisted of 8 steps as shown in Fig.C.1. During the process, necessary sampling was conducted and analyzed.

Procedures for sieve analysis and specific gravity analysis are shown in Figs. C.2 and C.3.

3. Verification of Filter Expansion Rate

The grain size analysis shows that the existing anthracite are of insufficient grading. The effective size of 0.53 mm to 0.57 mm deviates from design value of 0.9 mm to 1.1 mm. The specific gravity of 1.7 is also within the designed value of 1.45 to 1.60. Therefore, replacement of the anthracite is recommended as stated in Level 2 of the rehabilitation works.

Expansion rate, one important factor in backwashing is usually between 20% to 30 %, to allow effective backwashing.

Following are verification of the backwash effects after rehabilitation works of Level 2 as recommended by the Study Team. Conditions such as size, specific gravity, and porosity of filter media used in the design were collected by the Study Team through the laboratory experiments.

According to the calculation results, allowable expansion rate of 20% and 22% in Plant No. 1 and in Plant No. 2, respectively are given after replacement of the existing anthracite.

3.1 Plant No. 1

$$E = (\epsilon - \epsilon_0)/(1 - \epsilon)$$

$$\epsilon = (U_B/U_t)^{0.222}$$

where, E : Expansion ratio

E_a (for anthracite)

E_s (for sand)

ϵ : Porosity in buckwash

ϵ_a (for anthracite)

ϵ_s (for sand)

ϵ_0: Porocity before backwash

ϵ_{0a} (for anthracite = 0.55)

ϵ_{0s} (for sand = 0.54)

U_B: Backwash rate

0.65 m/min = 10.8 x 10^{-3} m/sec

U_t: Terminal velocity of media

U_{ta} (for anthracite)

U_{ts} (for sand)

$$U_t = \left\{ \frac{4}{225} \times \frac{(\rho - \rho F)^2 \times g^2}{\rho F \times \mu} \right\}^{1/3} \times D$$

where,

ρ : Specific gravity of media

(for anthracite = 1550 kg/m^3)

(for sand = 2700 kg/m^3)

ρF: Specific gravity in water= 997.1 kg/m^3

μ : Coefficient of viscosity in water =0.898 x 10^{-3} kg/m.sec

g : Accelation of gravity = 9.81 m/sec^2

D : Diameter of media (m)

D_a (for anthracite =1 x 10^{-3})

D_s (for sand =0.69 x 10^{-3})

$$U_{ta} = \left\{ \frac{4}{225} \times \frac{(1550 - 997.1)^2 \times 9.81^2}{997.1 \times 0.898 \times 10^{-3}} \right\}^{1/3} \times 1.0 \times 10^{-3}$$

$= 83.6 \times 10^{-3}$ m/sec

$$U_{ts} = \left\{ \frac{4}{225} \times \frac{(2700 - 997.1)^2 \times 9.81^2}{997.1 \times 0.898 \times 10^{-3}} \right\}^{1/3} \times 0.69 \times 10^{-3}$$

$= 122 \times 10^{-3}$ m/sec

$\epsilon_a = (U_B/U_{ta})^{0.222} = (10.8 \times 10^{-3}/83.6 \times 10^{-3})^{0.222}$

$= 0.635$

$\epsilon_s = (U_B/U_{ts})^{0.222} = (10.8 \times 10^{-3}/122 \times 10^{-3})^{0.222}$

$= 0.584$

$E_a = (\epsilon_a - \epsilon_{0a})/(1 - \epsilon_a) = (0.635 - 0.55)/(1-0.635)$

$= 0.233$

$E_s = (\epsilon_s - \epsilon_{0s})/(1 - \epsilon_s) = (0.584-0.54)/(1-0.584)$

$= 0.106$

Then, Anthracite depth (L_a) and sand depth (L_s) in backwash is obtained as follows;

L_a = (Anthracite depth before backwash) x (1 + E_a)
= 0.50 x (1 + 0.233)
= 0.617 m

L_s = (Sand depth before backwash) x (1+ E_s)
= 0.25 x (1 + 0.106)
= 0.277 m

Total Expansion Ratio
= (0.617 + 0.277)/(0.50 + 0.25)
= 1.20 (20%)

Therefore, Expansion Rate shall be of desirable value of 20 % after rehabilitation in Plant No. 1.

3.2 Plant No. 2

$E = (\epsilon - \epsilon_0)/(1 - \epsilon)$

$\epsilon = (U_B / U_t)^{0.222}$

where, E : Expansion ratio
E_a (for anthracite)
E_s (for sand)
ϵ : Porocity in backwash
ϵ_a (for anthracite)
ϵ_s (for sand)
ϵ_0: Porocity before backwash
ϵ_{0a} (for anthracite = 0.55)
ϵ_{0s} (for sand = 0.54)
U_B: Backwash rate
0.65 m/min = 10.8 x 10^{-3} m/sec
U_t: Terminal velocity of media
U_{ta} (for anthracite)
U_{ts} (for sand)

$$U_t = \left\{ \frac{4}{225} \times \frac{(\rho - \rho_F)^2 \times g^2}{\rho_F \times \mu} \right\}^{1/3} \times D$$

where,

ρ : Specific gravity of media

(for anthracite = 1550 kg/m^3)

(for sand = 2790 kg/m^3)

ρ_F: Specific gravity in water= 997.1 kg/m^3

μ : Coefficient of viscosity in water =0.898 x 10^{-3} kg/m.sec

g : Accelation of gravity = 9.81 m/sec^2

D : Diameter of media (m)

D_a (for anthracite =1 x 10^{-3})

D_s (for sand =0.64 x 10^{-3})

$$U_{ta} = \left\{ \frac{4}{225} \times \frac{(1550 - 997.1)^2 \times 9.81^2}{997.1 \times 0.898 \times 10^{-3}} \right\}^{1/3} \times 1.0 \times 10^{-3}$$

$$= 83.6 \times 10^{-3} \text{ m/sec}$$

$$U_{ts} = \left\{ \frac{4}{225} \times \frac{(2790 - 997.1)^2 \times 9.81^2}{997.1 \times 0.898 \times 10^{-3}} \right\}^{1/3} \times 0.64 \times 10^{-3}$$

$$= 117 \times 10^{-3} \text{ m/sec}$$

$$\epsilon_a = (U_B/U_{ta})^{0.222} = (10.8 \times 10^{-3}/83.6 \times 10^{-3})^{0.222}$$

$$= 0.635$$

$$\epsilon_s = (U_B/U_{ts})^{0.222} = (10.8 \times 10^{-3}/117 \times 10^{-3})^{0.222}$$

$$= 0.589$$

$$E_a = (\epsilon_a - \epsilon_{0a})/(1 - \epsilon_a) = (0.635 - 0.55)/(1-0.635)$$

$$= 0.233$$

$$E_s = (\epsilon_s - \epsilon_{0s})/(1 - \epsilon_s) = (0.589-0.54)/(1-0.589)$$

$$= 0.119$$

Then, Anthracite depth (L_a) and sand depth (L_s) in backwash is obtained as follows;

L_a = (Anthracite depth before backwash) x (1 + E_a)
= 0.40 x (1 + 0.233)
= 0.493 m

L_s = (Sand depth before backwash) x (1+ E_s)
= 0.25 x (1 + 0.119)
= 0.298 m

Total Expansion Ratio
= (0.493 + 0.298)/(0.40 + 0.25)
= 1.22 (22%)

Therefore, Expansion Rate shall be of desirable value of 22 % after rehabilitation in PLant No. 2.

TABLE C.1 SUMMARY OF FILTER MEDIA ANALYSIS

1. GRAIN SIZE ANALYSIS

ANTHRACITE	PLANT NO. 1	PLANT NO. 2	JWWA	DESIGN
MAX. SIZE (mm)	2.51	2.36	<2.8	N/A
EFFECTIVE SIZE (mm)	*0.57	*0.53	0.7-1.5	0.9-1.1
MIN. SIZE (mm)	*0.355	*0.378	>0.5	N/A
UNIFORMITY COEFFICIENT	*2.79	*2.5	<1.5	1.5
SAND				
MAX. SIZE (mm)	2.00	2.00	<2.00	N/A
EFFECTIVE SIZE (mm)	0.69	0.64	0.45-0.70	0.45-0.55
MIN. SIZE (mm)	0.355	0.402	>0.3	N/A
UNIFORMITY COEFFICIENT	1.42	1.36	<1.7	1.5

(Notes) * shows deviation from standard.

2. SPECIFIC GRAVITY ANALYSIS

	PLANT NO. 1	PLANT NO. 2	JWWA	DESIGN
ANTHRACITE	*1.72	*1.71	1.40-1.60	1.45-1.60
SAND	*2.70	*2.79	2.57-2.67	N/A

(Notes) * shows deviation from standard.

3. SOLUBILITY OF HYDROCHLORIC ACID (%)

	TOTAL	JWWA	DESIGN
ANTHRACITE	3.33	<6	N/A
SAND	1.46	<3.5	N/A

4. POROSITY (%)

	TOTAL	JWWA
ANTHRACITE	50.3	>50
SAND	54.6	N/A

5. DRY WEIGHT REDUCTION (%)

	TOTAL	JWWA	DESIGN
SAND	0.73	<0.75	N/A

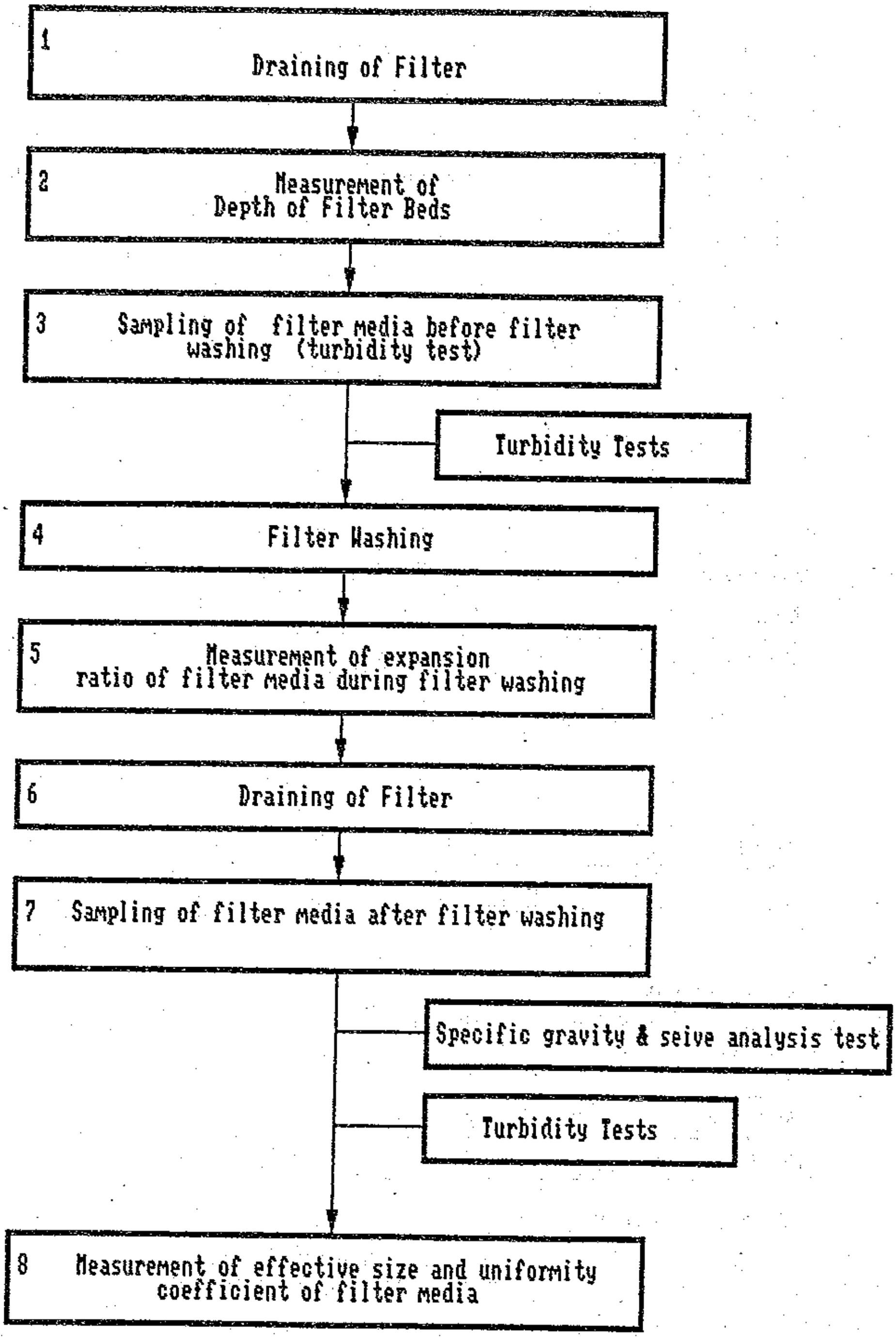


FIG. C.1 FILTER INVESTIGATION PROCEDURES

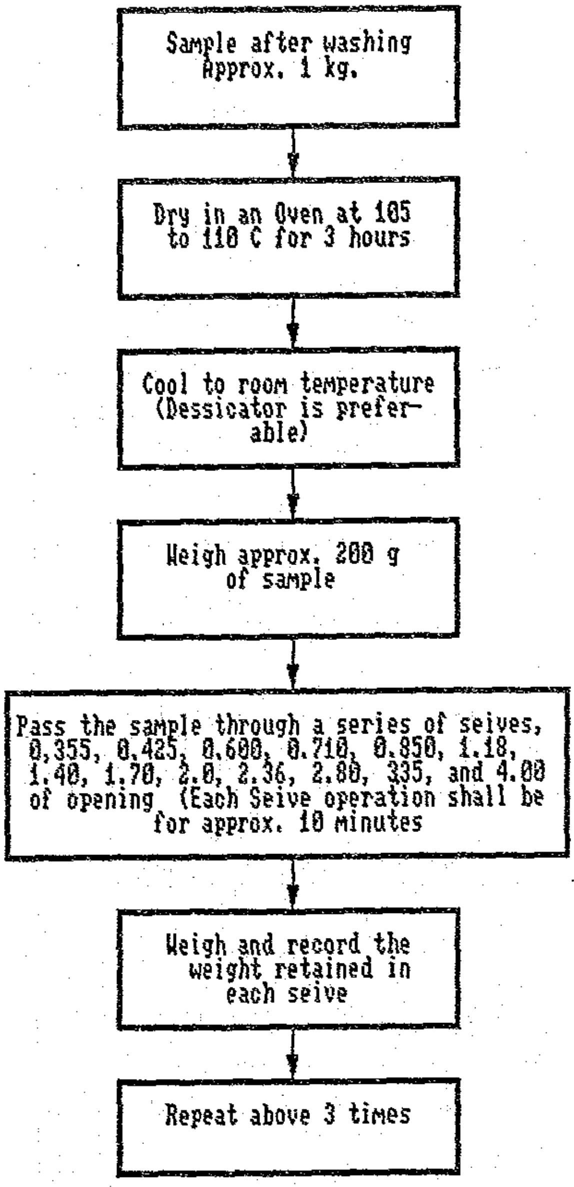


FIG. C.2 SEIVE ANALYSIS

1. Sample after washing Approximate 50 g
2. Dry in an oven at 105 to 110 C for 3 hours
3. Cool to room temperature
4. Preparation of 3 calibrated Pycnometer
5. Weigh pycnometer with full water and record the weight as Wa
6. Take approx. 20 g of dried sample and record the weight as Ws
7. Transfer carefully the sample to the calibrated pycnometer, and add distilled water until about 1/2 full.
   Note: Avoid loss of sample during the transfer
8. Remove entrapped air by rolling occassionally the pycnometer to assist in the removal of air.
9. Weigh the pycnometer with water and sample and record the weight as Wb
10. Calculation of Gs

$$Gs = \frac{Gt \times Ws}{Ws + Wa - Wb}$$

Where:

- Gs: specific gravity of sample
- Gt: specific gravity of distilled water at the temperature when Wb was obtained.
- Ws: weight of oven-dry sample
- Wa: weight of pycnometer with full distilled water
- Wb: weight of pycnometer with water and sample

FIG. C.3 SPECIFIC GRAVITY ANLYSIS

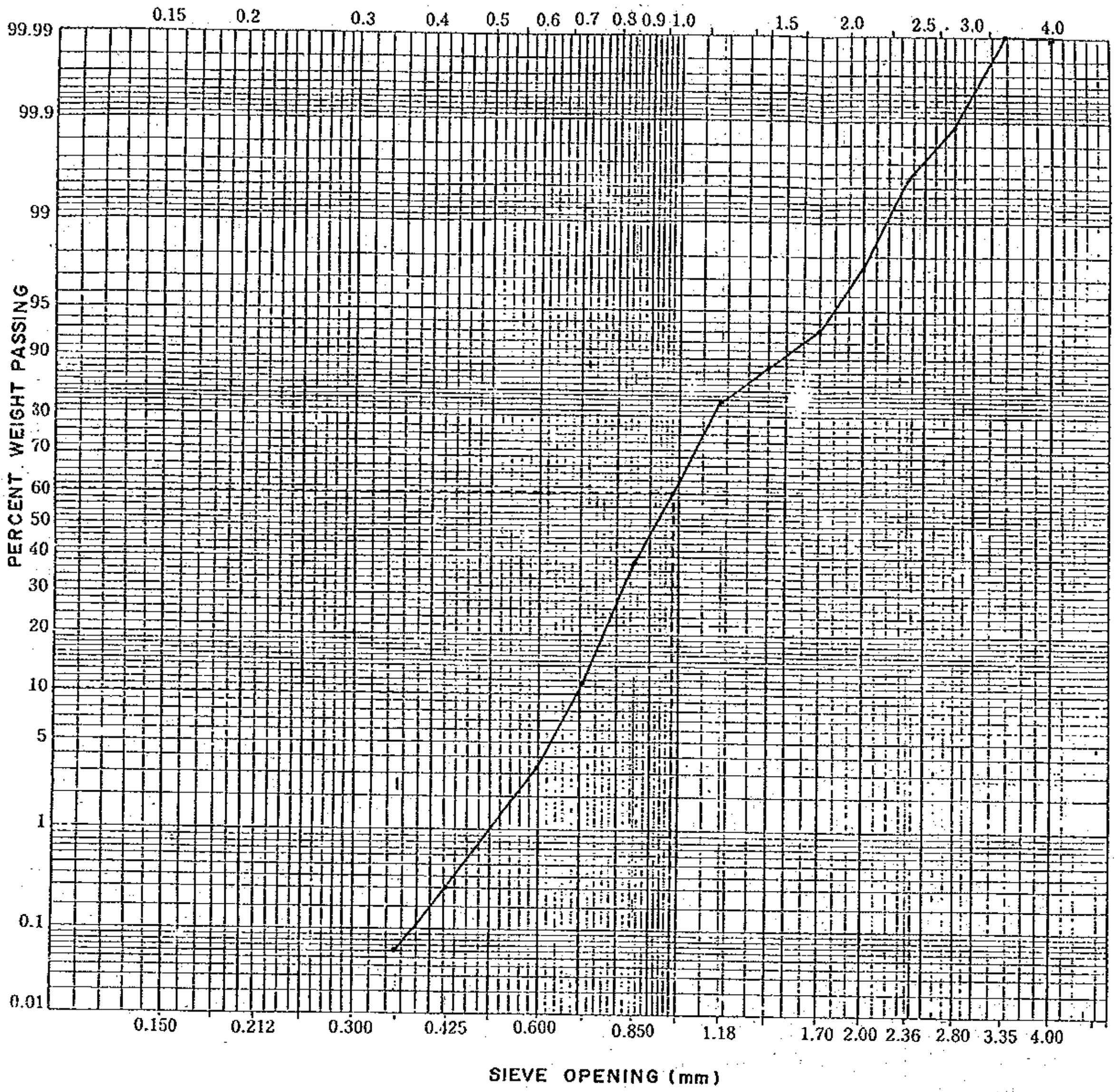
SEIVE ANALYSIS DATA

TRIAL NO. 1 SAND

DATE: 10/3/91 SOURCE: FILTER NO. 1

SEIVE OPENING	WT. RET.	WT. CORR.	CUMULATIVE WT. PASSING	CUMULATIVE % PASSING
4.00	0.00	0.00	150.00	100.00
3.35	0.00	0.00	150.00	100.00
2.80	0.20	0.20	149.80	99.87
2.36	0.40	0.41	149.39	99.59
2.00	3.00	3.05	146.34	97.56
1.70	6.50	6.61	139.73	93.15
1.40	8.20	8.33	131.40	87.60
1.18	6.90	7.01	124.39	82.93
0.85	65.90	66.98	57.41	38.27
0.71	39.40	40.04	17.37	11.58
0.61	12.30	12.50	4.87	3.25
0.425	4.60	4.67	0.20	0.13
0.355	0.10	0.10	0.10	0.07
PAN	0.10	0.10	0.00	0.00
TOTAL	147.60	150.00		

PLOT OF GRAIN SIZE ANALYSIS



Sample : SAND
Source : FILTER NO. 1
Trial No. 1
U.C. = 1.40
E.S. = 0.7 mm

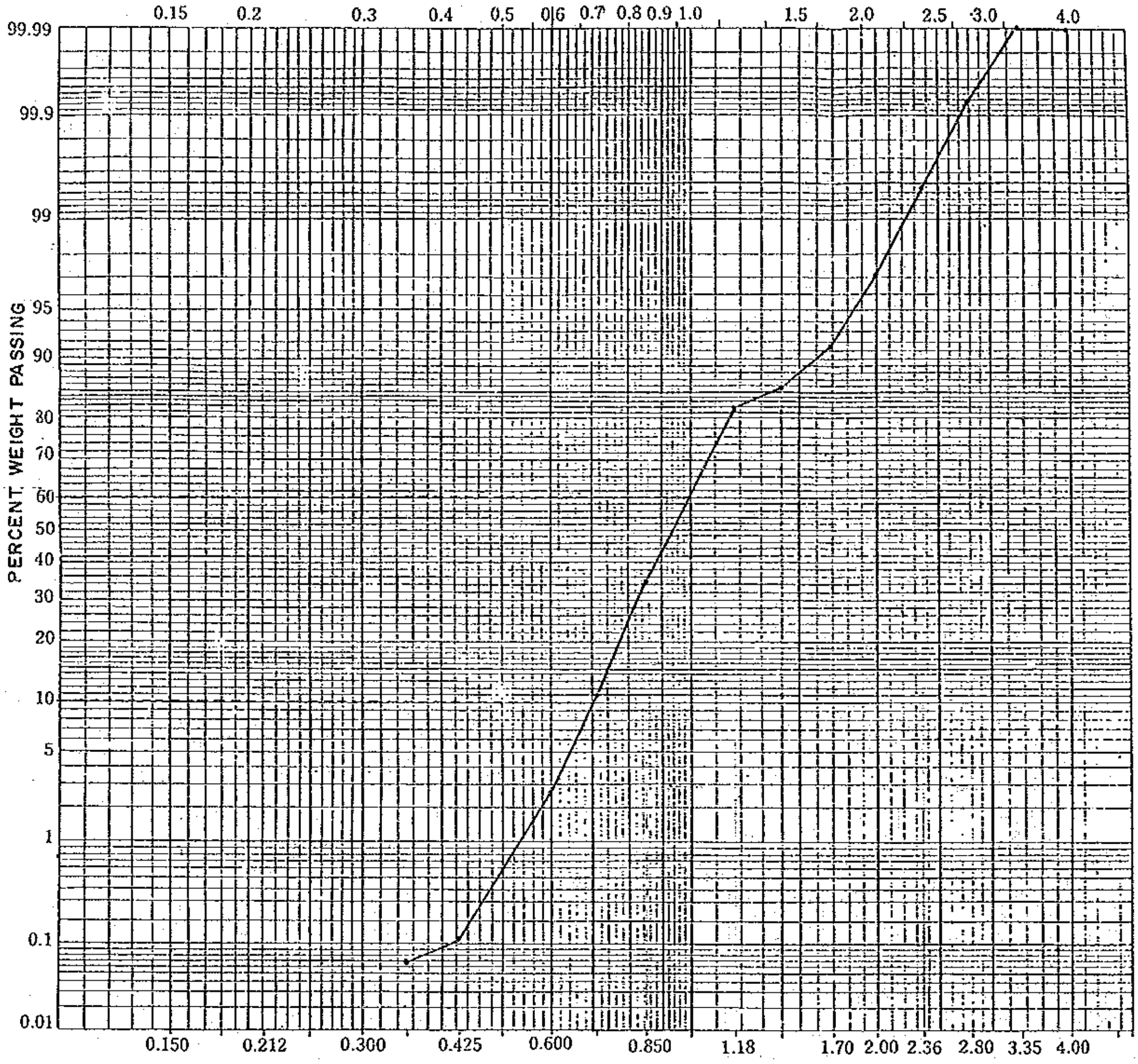
SEIVE ANALYSIS DATA

DATE: 10/3/91

TRIAL NO. 2 SAND
SOURCE: FILTER NO. 1

SEIVE OPENING	WT. RET.	WT. CORR.	CUMULATIVE WT. PASSING	CUMULATIVE % PASSING
4.00	0.00	0.00	150.00	100.00
3.35	0.00	0.00	150.00	100.00
2.80	0.10	0.10	149.90	99.93
2.36	0.70	0.70	149.20	99.47
2.00	3.50	3.50	145.70	97.13
1.70	8.30	8.31	137.39	91.59
1.40	8.80	8.81	128.58	85.72
1.18	5.30	5.30	123.28	82.19
0.85	70.00	70.05	53.23	35.49
0.71	36.60	36.62	16.61	11.07
0.61	12.50	12.51	4.10	2.73
0.425	3.90	3.90	0.20	0.13
0.355	0.10	0.10	0.10	0.07
PAN	0.10	0.10	0.00	0.00
TOTAL	149.90	150.00		

PLOT OF GRAIN SIZE ANALYSIS



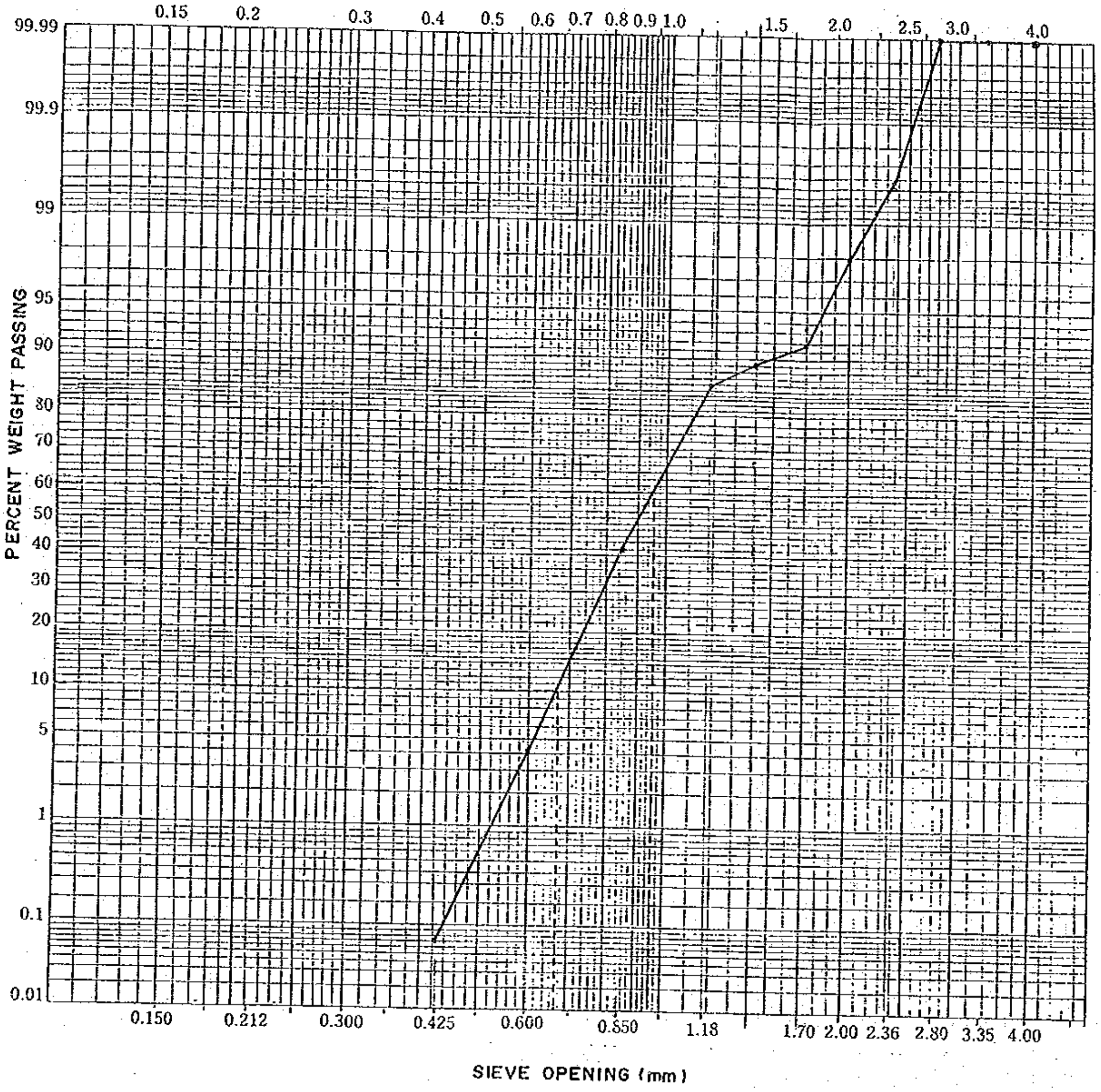
Sample : SAND
Source : FILTER NO. 1
Trial No. 2
U.C. = 1.43
E.S. = 0.7 mm

SEIVE ANALYSIS DATA

DATE: 10/4/91 TRIAL NO. 3 SOURCE: SAND FILTER NO. 1

SEIVE OPENING	WT. RET.	WT. CORR.	CUMULATIVE WT. PASSING	CUMULATIVE % PASSING
4.00	0.00	0.00	150.00	100.00
3.35	0.00	0.00	150.00	100.00
2.80	0.00	0.00	150.00	100.00
2.36	0.60	0.61	149.39	99.59
2.00	2.40	2.45	146.94	97.96
1.70	6.30	6.43	140.51	93.67
1.40	6.90	7.05	133.46	88.97
1.18	4.50	4.59	128.87	85.91
0.85	64.60	65.97	62.90	41.93
0.71	38.10	38.90	24.00	16.00
0.61	17.40	17.77	6.23	4.15
0.425	6.00	6.13	0.10	0.07
0.355	0.10	0.10	0.00	0.00
PAN	0.00	0.00	0.00	0.00
TOTAL	146.90	150.00		

PLOT OF GRAIN SIZE ANALYSIS



Sample : SAND
Source : FILTER NO. 1
Trial No. 3
U.C. = 1.43
E.S. = 0.67 mm

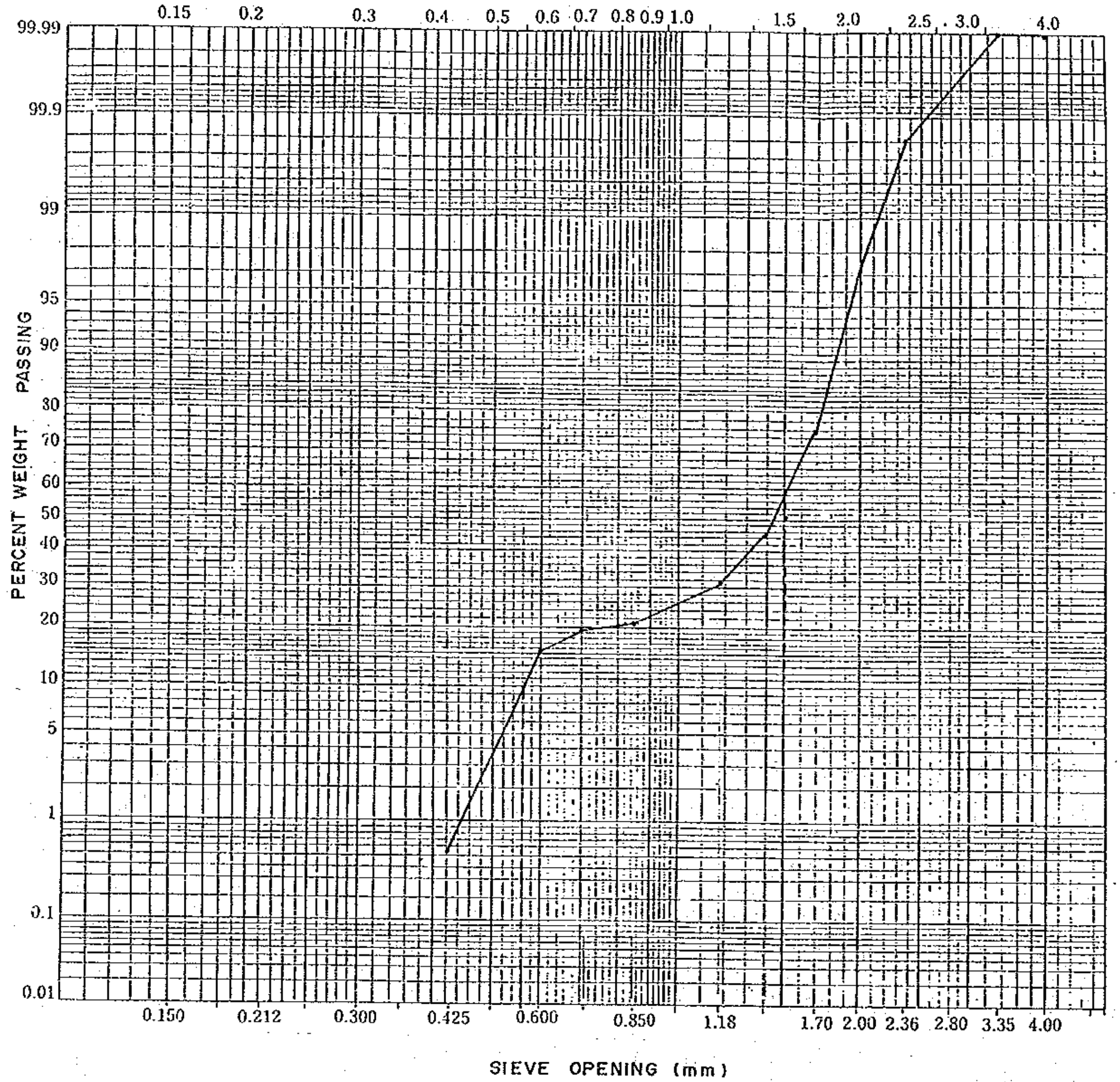
SEIVE ANALYSIS DATA

DATE: 10/4/91

TRIAL NO. 1 ANTHRACITE
SOURCE: FILTER NO. 1

SEIVE OPENING	WT. RET.	WT. CORR.	CUMULATIVE WT. PASSING	CUMULATIVE % PASSING
4.00	0.00	0.00	150.00	100.00
3.35	0.00	0.00	150.00	100.00
2.80	0.10	0.10	149.90	99.93
2.36	0.20	0.20	149.70	99.80
2.00	3.80	3.89	145.81	97.21
1.70	31.20	31.90	113.91	75.94
1.40	44.80	45.82	68.09	45.39
1.18	20.60	21.06	47.03	31.35
0.85	14.00	14.31	32.72	21.81
0.71	3.30	3.37	29.35	19.57
0.61	5.70	5.83	23.52	15.68
0.425	22.20	22.70	0.82	0.54
0.355	0.80	0.82	0.00	0.00
PAN	0.00	0.00	0.00	0.00
TOTAL	146.70	150.00		

PLOT OF GRAIN SIZE ANALYSIS



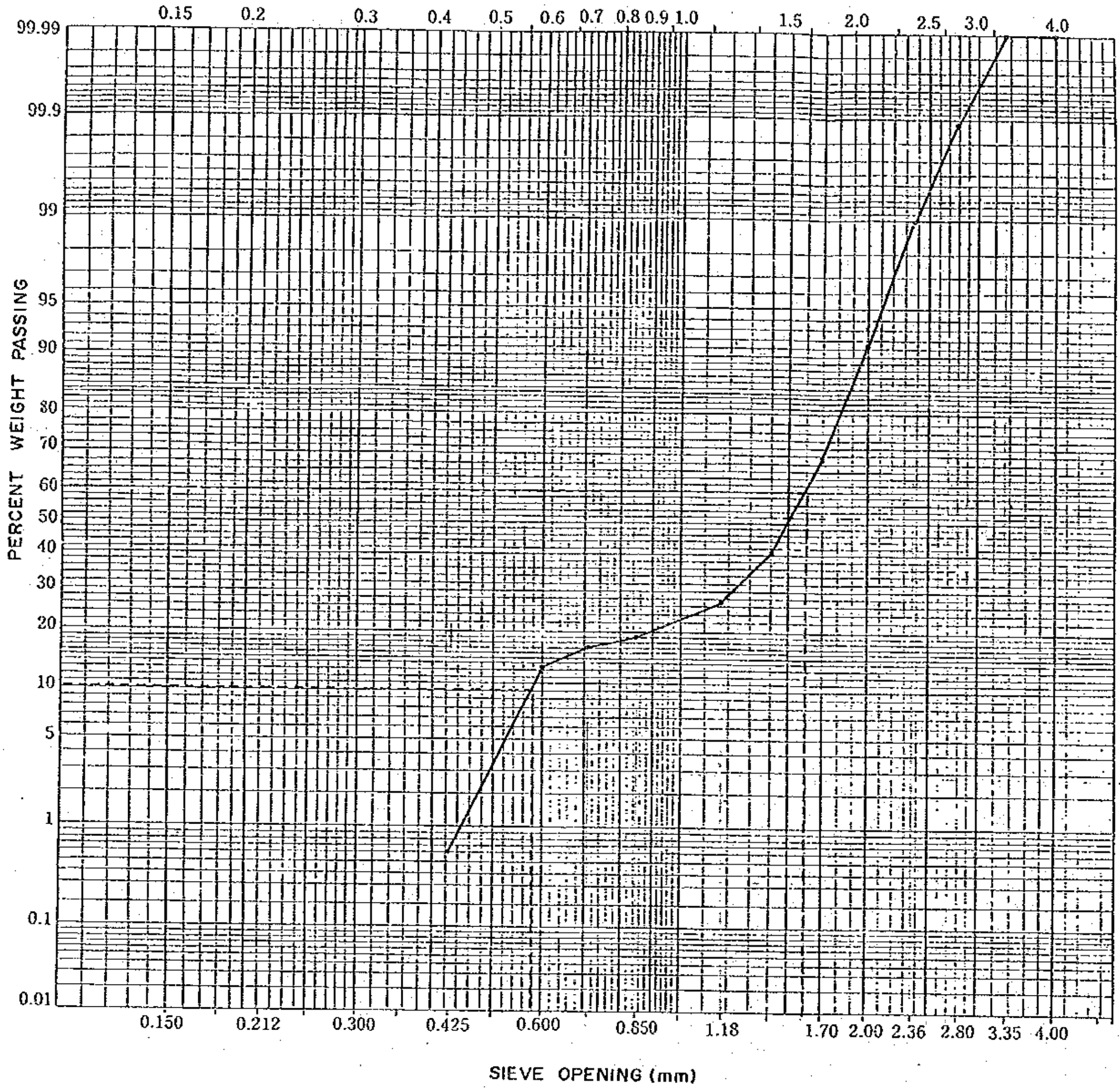
Sample : ANTHRACITE
Source : FILTER NO. 1
Trial No. 1
U.C. = 2.68
E.S. = 0.56mm

SEIVE ANALYSIS DATA

DATE: 10/7/91 TRIAL NO. 2 ANTHRACITE
SOURCE: FILTER NO. 1

SEIVE OPENING	WT. RET.	WT. CORR.	CUMULATIVE WT. PASSING	CUMULATIVE % PASSING
4.00	0.00	0.00	150.00	100.00
3.35	0.00	0.00	150.00	100.00
2.80	0.20	0.20	149.80	99.87
2.36	1.30	1.31	148.49	98.99
2.00	8.60	8.68	139.81	93.21
1.70	35.40	35.71	104.10	69.40
1.40	41.80	42.16	61.94	41.27
1.18	20.30	20.48	41.46	27.64
0.85	12.70	12.81	28.65	19.10
0.71	3.20	3.23	25.42	16.95
0.61	4.90	4.94	20.48	13.65
0.425	19.40	19.57	0.91	0.60
0.355	0.90	0.91	0.00	0.00
PAN	0.00	0.00	0.00	0.00
TOTAL	148.70	150.00		

PLOT OF GRAIN SIZE ANALYSIS



Sample : ANTHRACITE
Source : FILTER NO. 1
Trial No. 2
U.C. = 2.76
E.S = 0.58 mm

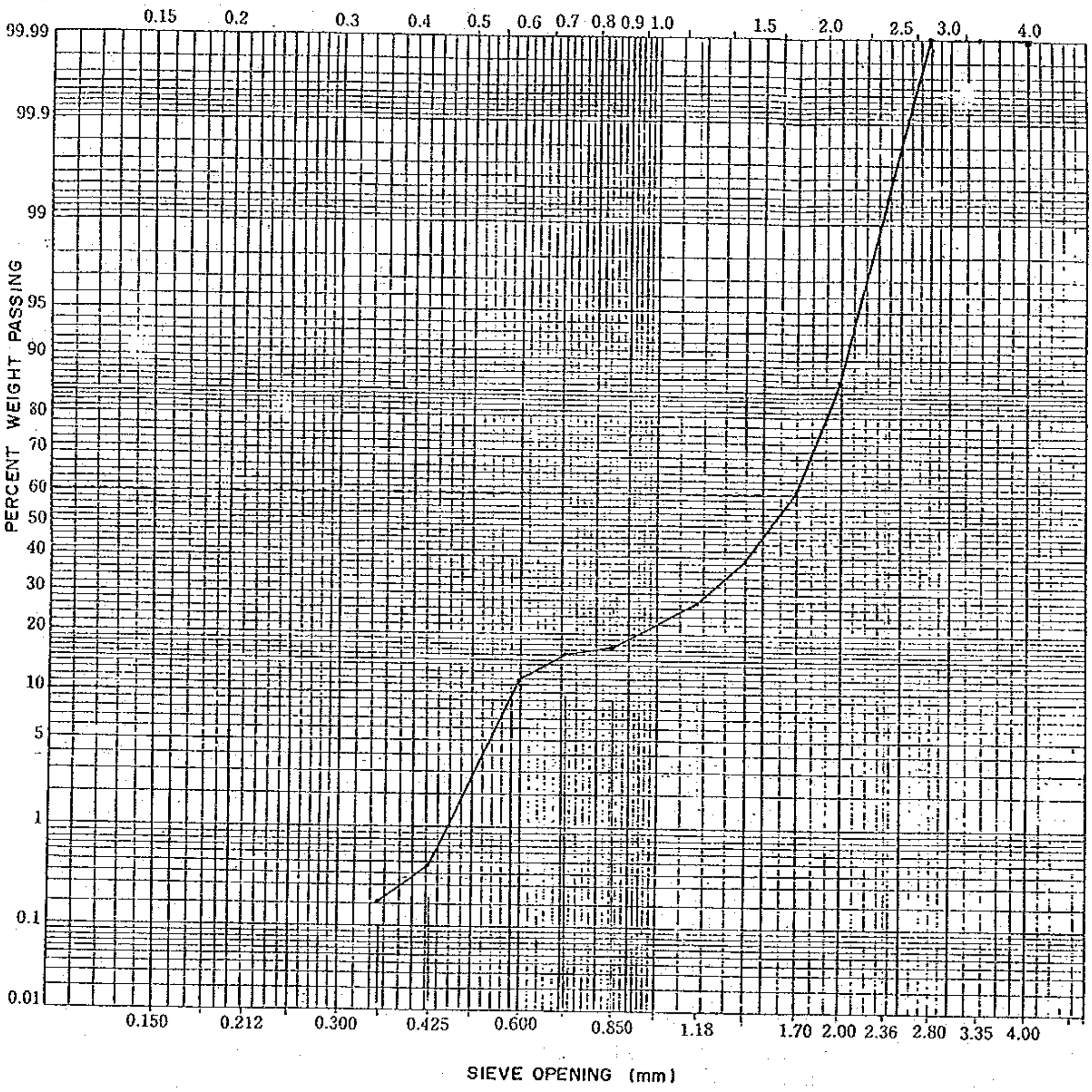
SEIVE ANALYSIS DATA

DATE: 10/7/91

TRIAL NO. 3 ANTHRACITE
SOURCE: FILTER NO. 1

SEIVE OPENING	WT. RET.	WT. CORR.	CUMULATIVE WT. PASSING	CUMULATIVE % PASSING
4.00	0.00	0.00	150.00	100.00
3.35	0.00	0.00	150.00	100.00
2.80	0.00	0.00	150.00	100.00
2.36	0.90	0.91	149.09	99.39
2.00	19.20	19.43	129.66	86.44
1.70	38.90	39.37	90.29	60.19
1.40	31.10	31.48	58.81	39.21
1.18	18.60	18.83	39.98	26.65
0.85	12.90	13.06	26.92	17.95
0.71	2.90	2.94	23.98	15.99
0.61	6.10	6.17	17.81	11.87
0.425	16.90	17.11	0.70	0.47
0.355	0.40	0.40	0.30	0.20
PAN	0.30	0.30	0.00	0.00
TOTAL	148.20	150.00		

PLOT OF GRAIN SIZE ANALYSIS



Sample : ANTHRACITE
Source : FILTER NO.1
Trial No. 3
U.C. = 2.93
E.S. = 0.58 mm

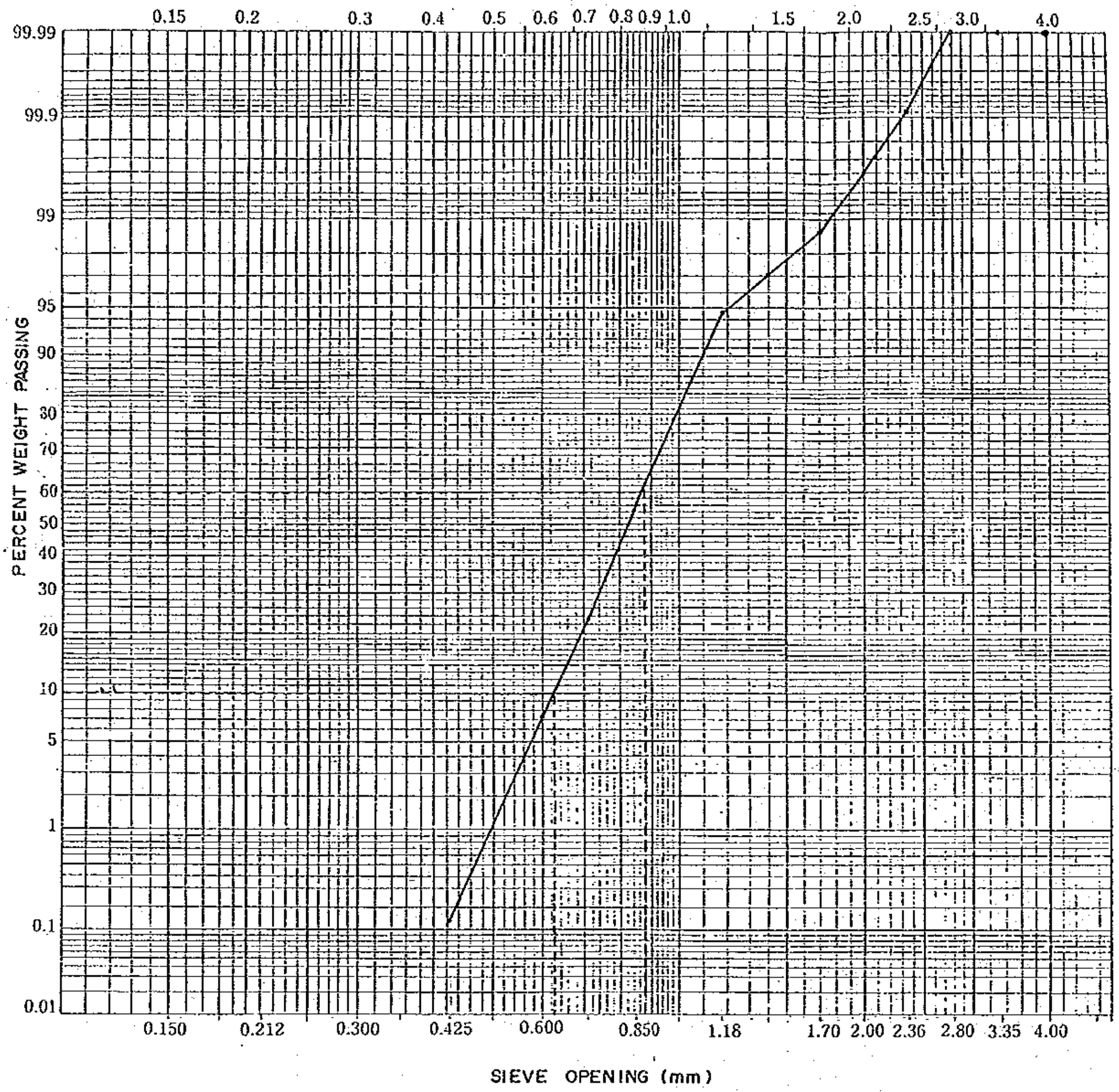
SEIVE ANALYSIS DATA

DATE: 10/7/91

TRIAL NO. 1 SAND
SOURCE: FILTER NO. 2

SEIVE OPENING	WT. RET.	WT. CORR.	CUMULATIVE WT. PASSING	CUMULATIVE % PASSING
4.00	0.00	0.00	130.00	100.00
3.35	0.00	0.00	130.00	100.00
2.80	0.20	0.00	130.00	100.00
2.36	0.10	0.10	129.90	99.92
2.00	0.40	0.40	129.50	99.62
1.70	1.20	1.20	128.30	98.69
1.40	2.20	2.20	126.10	97.00
1.18	2.70	2.70	123.40	94.92
0.85	51.00	51.04	72.36	55.66
0.71	42.20	42.23	30.13	23.18
0.61	21.00	21.02	9.11	7.00
0.425	8.90	8.91	0.20	0.15
0.355	0.20	0.20	0.00	0.00
PAN	0.00	0.00	0.00	0.00
TOTAL	129.90	130.00		

PLOT OF GRAIN SIZE ANALYSIS



Sample : SAND
Soure : FILTER NO. 2
Trial No. 1
U.C. = 1.40
E.S = 0.63 mm

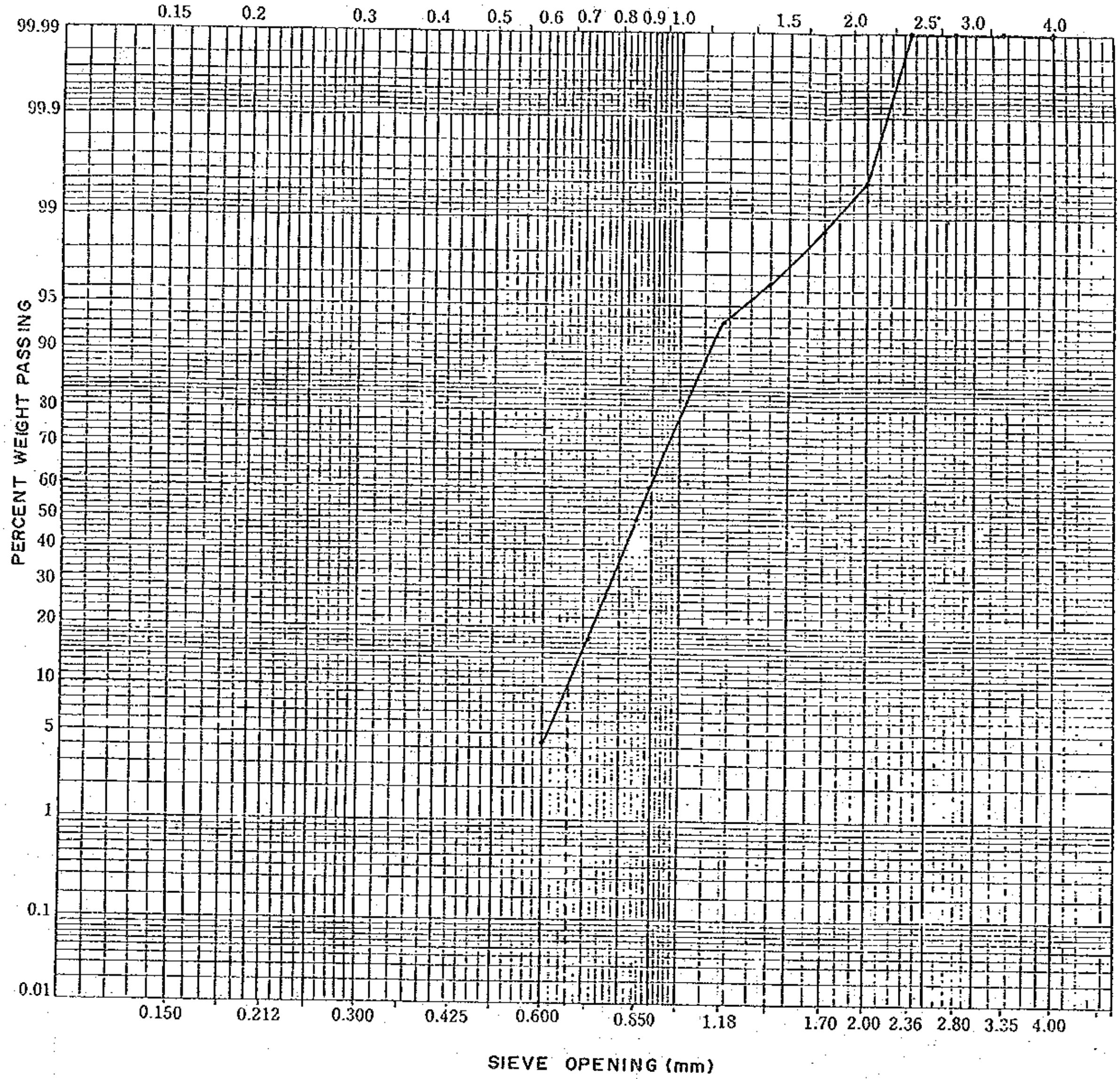
SEIVE ANALYSIS DATA

TRIAL NO. 2 SAND

DATE: 10/8/91 SOURCE: FILTER NO. 2

SEIVE OPENING	WT. RET.	WT. CORR.	CUMULATIVE WT. PASSING	CUMULATIVE % PASSING
4.00	0.00	0.00	130.00	100.00
3.35	0.00	0.00	130.00	100.00
2.80	0.00	0.00	130.00	100.00
2.36	0.00	0.00	130.00	100.00
2.00	0.60	0.61	129.39	99.53
1.70	1.50	1.52	127.87	98.36
1.40	2.20	2.23	125.64	96.65
1.18	3.60	3.65	121.99	93.84
0.85	57.00	57.81	64.18	49.37
0.71	40.50	41.07	23.11	17.78
0.61	17.50	17.74	5.37	4.13
0.425	5.30	5.37	0.00	0.00
0.355	0.00	0.00	0.00	0.00
PAN	0.00	0.00	0.00	0.00
TOTAL	128.20	130.00		

PLOT OF GRAIN SIZE ANALYSIS



Sample: SAND
Source: FILTER NO.2
Trial No. 2
U.C. = 1.36
E.S. = 0.66mm

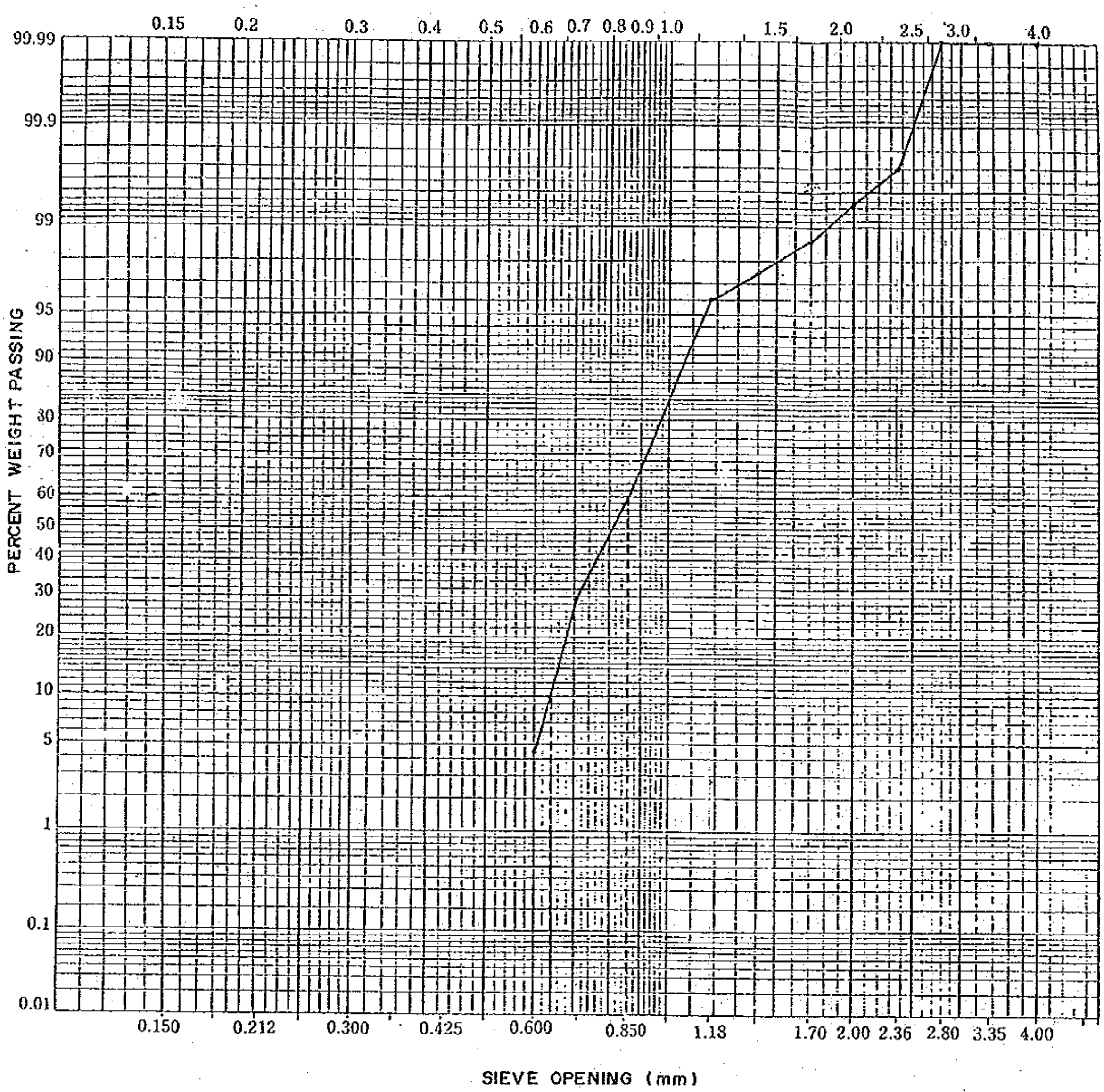
SEIVE ANALYSIS DATA

DATE: 10/8/91

TRIAL NO. 3 SAND
SOURCE: FILTER NO. 2

SEIVE OPENING	WT. RET.	WT. CORR.	CUMULATIVE WT. PASSING	CUMULATIVE % PASSING
4.00	0.00	0.00	130.00	100.00
3.35	0.00	0.00	130.00	100.00
2.80	0.00	0.00	130.00	100.00
2.36	0.40	0.40	130.00	99.69
2.00	0.40	0.40	129.60	99.38
1.70	0.90	0.91	128.20	98.68
1.40	1.50	1.51	126.78	97.52
1.18	1.90	1.91	124.87	96.05
0.85	48.40	48.79	76.08	58.52
0.71	38.70	39.00	37.08	28.52
0.61	30.90	31.14	5.94	4.57
0.425	5.90	5.94	0.00	0.00
0.355	0.00	0.00	0.00	0.00
PAN	0.00	0.00	0.00	0.00
TOTAL	129.00	130.00		

PLOT OF GRAIN SIZE ANALYSIS



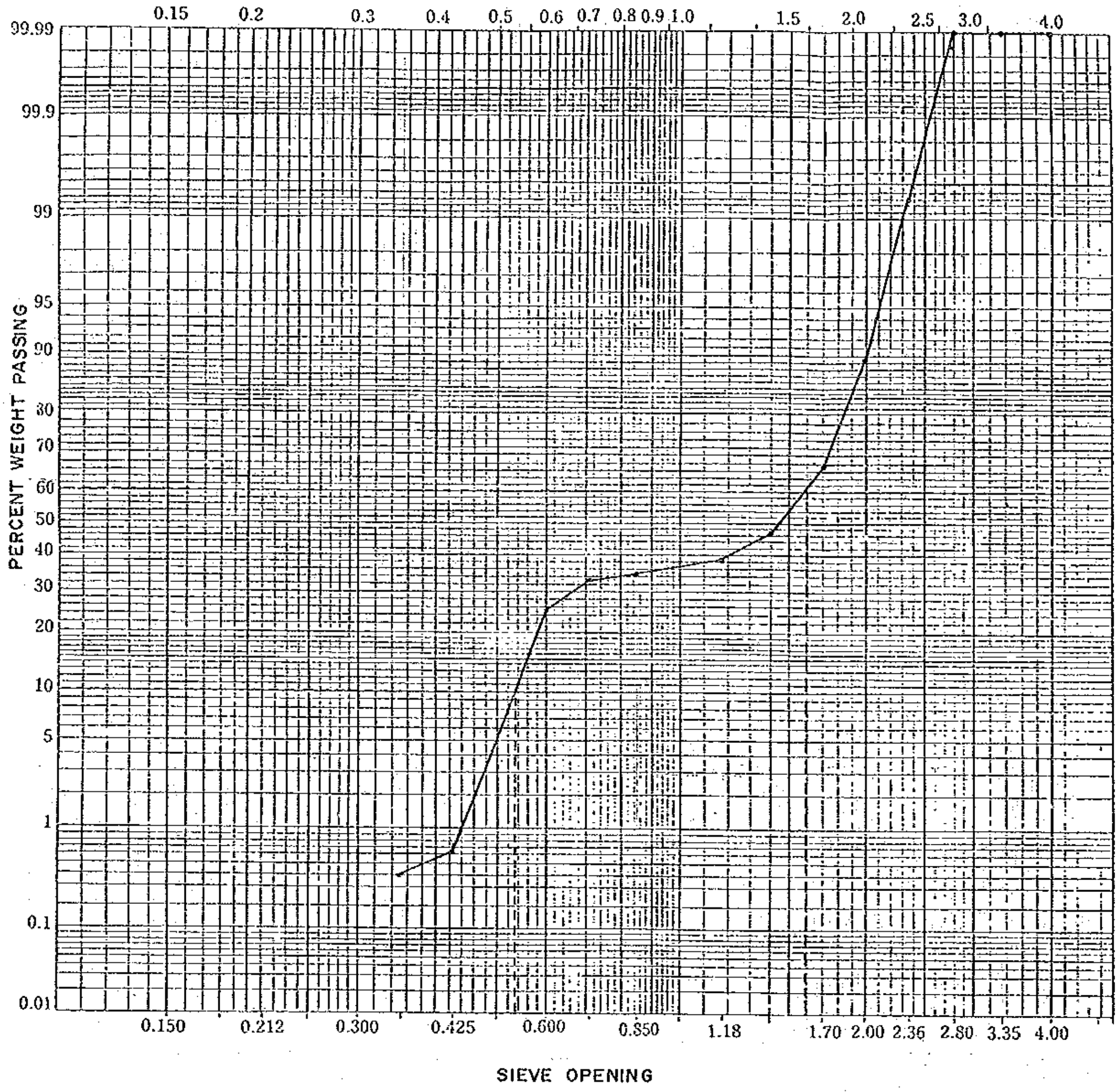
Sample : SAND
Source : FILTER NO. 2
Trial No. 3
U.C. = 1.33
E.S. = 0.64 mm

SEIVE ANALYSIS DATA

DATE: 10/7/91 TRIAL NO. 1 ANTHRACITE
SOURCE: FILTER NO. 2

SEIVE OPENING	WT. RET.	WT. CORR.	CUMULATIVE WT. PASSING	% PASSING
4.00	0.00	0.00	150.00	100.00
3.35	0.00	0.00	150.00	100.00
2.80	0.00	0.00	150.00	100.00
2.36	1.00	1.00	149.00	99.33
2.00	14.40	14.43	134.57	89.71
1.70	33.00	33.07	101.50	67.67
1.40	30.10	30.16	71.34	47.56
1.18	12.80	12.83	58.51	39.01
0.85	5.90	5.91	52.60	35.07
0.71	3.80	3.81	48.79	32.53
0.61	11.10	11.12	37.67	25.11
0.425	36.80	36.87	0.80	0.53
0.355	0.60	0.60	0.20	0.13
PAN	0.20	0.20	0.00	0.00
TOTAL	149.70	150.00		

PLOT OF GRAIN SIZE ANALYSIS



Sample : ANTHRACITE
Source : FILTER NO. 2
Trial. No. 1
U.C. = 3.02
E.S. = 0.53mm

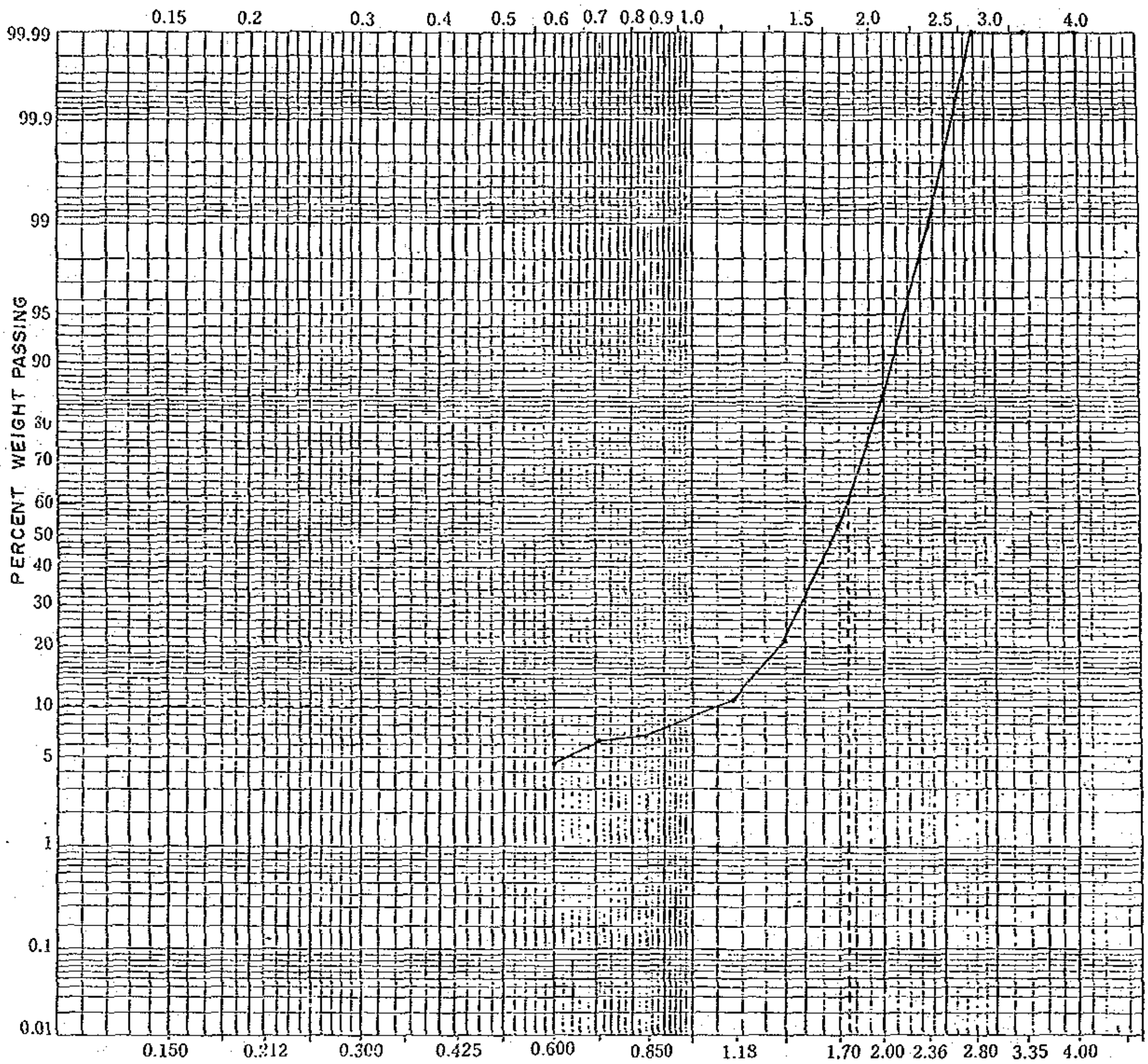
SEIVE ANALYSIS DATA

TRIAL NO. 2 ANTHRACITE

DATE: 10/7/91 SOURCE: FILTER NO. 2

SEIVE OPENING	WT. RET.	WT. CORR.	CUMULATIVE WT. PASSING	CUMULATIVE % PASSING
4.00	0.00	0.00	150.00	100.00
3.35	0.00	0.00	150.00	100.00
2.80	0.00	0.00	150.00	100.00
2.36	1.50	1.53	148.47	98.98
2.00	20.40	20.84	127.63	85.09
1.70	47.40	48.43	79.20	52.80
1.40	46.60	47.62	31.58	21.05
1.18	14.60	14.92	16.66	11.11
0.85	5.80	5.93	10.73	7.15
0.71	1.20	1.23	9.50	6.33
0.61	2.30	2.35	7.15	4.77
0.425	7.00	7.15	0.00	0.00
0.355	0.00	0.00	0.00	0.00
PAN	0.00	0.00	0.00	0.00
TOTAL	146.80	150.00		

PLOT OF GRAIN SIZE ANALYSIS



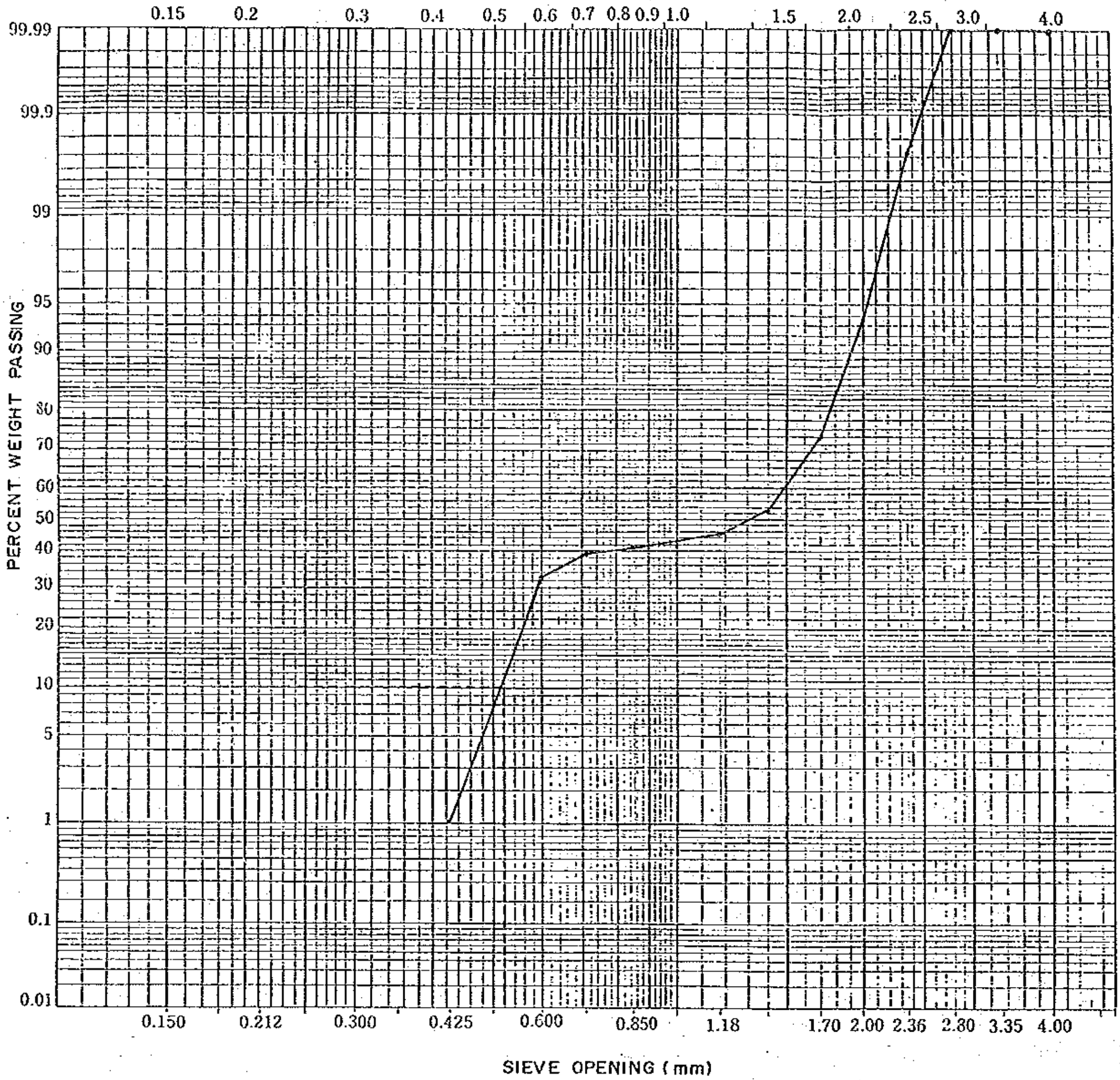
Sample : ANTHRACITE
Source : FILTER NO. 2
Trial No. 2
U.C. = 1.59
E.S. = 1.10 mm

SEIVE ANALYSIS DATA

DATE: 10/7/91 TRIAL NO. 3 ANTHRACITE
SOURCE: FILTER NO. 2

SEIVE OPENING	WT. RET.	WT. CORR.	CUMULATIVE WT. PASSING	CUMULATIVE % PASSING
4.00	0.00	0.00	150.00	100.00
3.35	0.00	0.00	150.00	100.00
2.80	0.00	0.00	150.00	100.00
2.36	0.40	0.41	149.59	99.73
2.00	8.90	9.05	140.54	93.69
1.70	28.20	28.70	111.84	74.56
1.40	30.70	31.24	80.60	53.73
1.18	11.70	11.91	68.69	45.79
0.85	6.50	6.61	62.08	41.39
0.71	2.10	2.14	59.94	39.97
0.61	11.00	11.19	48.75	32.50
0.425	46.30	47.12	1.63	1.09
0.355	1.60	1.63	0.00	0.00
PAN	0.00	0.00	0.00	0.00
TOTAL	147.40	150.00		

PLOT OF GRAIN SIZE ANALYSIS



Sample :ANTHRACITE
Source :FILTER NO. 2
Trial No. 3
U.C. = 2.88
E.S. = 0.52 mm

SPECIFIC GRAVITY

SAMPLE: SAND
FILTER # 1

10/3/91

DETERMINATION NO.	1	2	3
PYCNOMETER NO.	33	55	81
PYCNOMETER + WATER (Wa)	78.60	79.60	80.50
PYCNOMETER + WATER + SOIL (Wb)	84.70	86.10	86.70
TEMPERATURE (T)	26.20	25.70	26.30
DISH + DRY SOIL	58.60	52.40	59.60
DISH	48.80	42.40	49.60
DRY SOIL (Ws)	9.80	10.00	10.00
SP GR. OF WATER AT (T) (GT)	1.00	1.00	1.00
SP. GR. OF SOIL (Gs)	2.64	2.85	2.62

SPECIFIC GRAVITY ANALYSIS

SAMPLE: ANTHRACITE
FILTER # 1

10/4/91

DETERMINATION NO.	1	2	3
PYCNOMETER NO.	33	47	81
PYCNOMETER + WATER (Wa)	78.60	83.20	80.50
PYCNOMETER + WATER + SOIL (Wb)	82.70	87.30	84.90
TEMPERATURE (T)	25.00	25.00	25.00
DISH + DRY SOIL	58.70	57.90	59.30
DISH	48.70	47.90	49.30
DRY SOIL (Ws)	10.00	10.00	10.00
SP GR. OF WATER AT (T) (GT)	1.00	1.00	1.00
SP. GR. OF SOIL (Gs)	1.69	1.69	1.78

SPECIFIC GRAVITY

SAMPLE: SAND
FILTER # 2

10/9/91

DETERMINATION NO.	1	2	3
PYCNOMETER NO.	33	42	55
PYCNOMETER + WATER (Wa)	78.70	83.20	79.80
PYCNOMETER + WATER + SOIL (Wb)	85.20	89.50	86.30
TEMPERATURE (T)	24.00	24.00	24.00
DISH + DRY SOIL	54.90	58.70	62.40
DISH	44.90	48.70	52.40
DRY SOIL (Ws)	10.00	10.00	10.00
SP GR. OF WATER AT (T) (GT)	1.00	1.00	1.00
SP. GR. OF SAND (Gs)	2.85	2.70	2.85

SPECIFIC GRAVITY

SAMPLE: ANTHRACITE
FILTER # 2

10/8/91

DETERMINATION NO.	1	2	3
PYCNOMETER NO.	33	42	55
PYCNOMETER + WATER (Wa)	78.80	83.20	79.90
PYCNOMETER + WATER + SOIL (Wb)	83.00	87.40	84.00
TEMPERATURE (T)	26.00	26.00	26.00
DISH + DRY SOIL	58.70	56.70	62.30
DISH	48.70	46.70	52.30
DRY SOIL (Ws)	10.00	10.00	10.00
SP GR. OF WATER AT (T) (GT)	1.00	1.00	1.00
SP. GR. OF SOIL (Gs)	1.72	1.72	1.69

APPENDIX D CONCRETE COMPRESSIVE TEST USING TYPE N CONCRETE TEST HAMMER

1. Methodology

1.1 Selecting the Points to be Tested

Above all, vertical surfaces of concrete structures which were encased in a form are to be favored, form joints, honey combs and porous areas are to be avoided within the structural parts (slabs and walls less than 4 in. thick, columns less than 5 in. thick) special care must be exercised as the elasticity of such structural parts may falsify the test hammer indications.

With low-grade concrete the possibility must always be taken into account that its rebound number and likewise its strength will decrease considerably within a cast from bottom to top. Therefore, reliance should not be put exclusively on testing the bottom surface but the aim should be to make some tests on a clean vertical surface too.

1.2 Preparing Points to be Tested

Before testing, any plasterwork or architectural cladding must be removed. Slightly uneven surfaces caused by unplaced wooden forms can be smoothed by hand with the carborundum stone supplied with the hammer.

The top surface of the concrete is only suitable for hammer tests if the always present cement slurry is previously removed. To be sure of achieving this, the concrete must as a rule be ground off until its normal texture is exposed.

The ground surface must at least be as large as to permit 5 to 10 test hammer impacts to be made on the mortar w/o hitting coarse aggregate particles. As a rule, an area of 4 in. x 4 in. will suffice.