"COMPUTER AIDED SYSTEMS IN CIVIL ENGINEERING USING DRAINAGE AS THE PRIME DATA BASE"

VOLUME .2.

DAVID MATTHEW BRAMWELL

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DEPARTMENT OF CIVIL ENGINEERING
THE UNIVERSITY OF ASTON IN BIRMINGHAM

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EXCAVATION

GANG SIZE

1 Machine & Driver

1 Banksman

Study Ref.	Description of Machine	$N = D/_W$	Excavation Time (E_t) in basic minutes for different Obstruction Factors (øf)				
			7	6	5-4	2	1
	JCB 6C	4.5	0.29	0.29	0.35	0.55	1.61
	Mustang	1.5	0.19	0.20	0.23	0.36	1.06
	JCB 3C	0.5	0.05	0.06	0.06	0.09	0.28
	JCB 6C	8.0	0.38	0.37	0.46	0.72	2.11
	JCB 6D	7.5	0.35	0.34	0.42	0.66	1.94
	JCB 3C	0.5	0.13	0.14	0.16	0.25	0.72
	JCB 3D	1.5	0.15	0.16	0.18	0.28	0.83
	JCB 5C	4.5	0.28	0.28	0.34	0.53	1.56
	JCB 7C	6.0	0.33	0.33	0.40	0.62	1.83
	JCB 3C	8.0	0.36	0.39	0.44	0.72	2.00
	JCB 3D	1.5	0.20	0.19	0.21	0.37	1.10
	RH 6	0.5	0.04	0.05	0.09	0.09	0.21
	JCB 7C	7.5	0.36	0.36	0.43	0.68	2.00

TABLE I

Study Ref.	Working Radius (M)	Travelling time (U_t) for Tracked Excavators (basic Minutes)			
	0.0	0.0	0.01	0.01	0.02
	2.0	0.10			
	3.0	0.20	0.21	0.19	
	4.0	0.20	0.19	0.20	
	5.0	0.21	0.21	0.21	
	5.6	0.20	0.21	0.21	
	6.25	0.36	0.35	0.33	
	7.5	0.40	0.39		
	8.75	0.40	0.41	0.41	0.41
	10.0	0.41	0.43	0.42	0.40

	Working Radius (M)	Travelling time (U_t) for Centre Post Excavators (basic Minutes)			
	0.0	0.0	0.0	0.01	0.01
	2.0				
	3.3	0.25	0.24		
	4.0	0.30	0.33	0.31	
	5.0	0.40			
	6.5	0.41	0.42		

TABLE 2

EXCAVATION

Ref.	Strata Grading	Proportion of Bucket Volume occupied in a single stroke (bc)		
	3	0.06	0.0	0.06
	4	0.140	0.13	0.16
	5	0.23	0.23	0.20
	6		0.31	
	7	0.39	0.39	0.40
	8	0.44	0.46	
	9	0.51	0.52	
	10	0.54		

TABLE 3

Machine Characteristics

Machine Type	Minimum Bucket width (mm)	Theoretical Bucket Capacity (M^3)	Maximum Bucket width (mm)	Theoretical Bucket Capacity (M^3)
JCB 3	225	0.08	675	0.25
JCB 3C	225	0.13	675	0.29
JCB 3D	225	0.13	675	0.29
JCB 5C	450	0.32	1200	0.56
JCB 6C	450	0.32	1300	0.49
JCB 6D	450	0.32	1300	0.49
JCB 7B	450	0.32	1200	0.67
JCB 7C	600	0.50	1300	1.06
Hy-Mac580	400	0.29	1350	0.57
RH 6	600	0.50	1300	1.06

TABLE 4

Machine Type	Digging Depth (mm)			Horizontal Reach (mm)			Loading Height (mm)		
	Normal	Short Arm	Long Arm	Normal	Short Arm	Long Arm	Normal	Short Arm	Long Arm
JCB 3	3700			5410			3450		
JCB 3C	4190			5570			3380		
JCB 3D	4190			5570			3290		
JCB 5C		5760			9020			6270	
JCB 6C		5610	6350		8740	9200		5330	6050
JCB 6D		5610	6350		8740	9200		5330	6050
JCB 7B		6100			9300			5540	
JCB 7C		5660	6730		8690	9730		5640	6100
Hy-Mac 580		2819	6425		7469	9093		5358	3073
RH 6		4500	6700		8400	10500		3000	3000

TABLE 5

TRENCH SUPPORT

(1) Trench Depth less than or equal to 3.0 m.

1 Banksman/Ganger.

3 Labourers.

(2) Trench Depth greater than 3.0 m.

1 Banksman/Ganger.

3 Labourers.

1 Machine to assist.

Ref.	Operation	Trench sheet basic minute data Length (m)			
		2	3	4	5
	Unload from	0.4	0.3	0.7	0.7
	trailer and	0.4	0.3	0.9	1.0
	stock pile at	0.5	0.2	0.5	0.5
	trench side	0.3	0.4	0.7	0.6
	Lift from	0.2	0.2	0.6	0.6
	stock pile	0.5	0.5	0.6	0.6
	and place in	0.5	0.5	0.8	0.8
	trench 2m deep	0.4	0.4	0.8	0.8
	Locate in	0.4	0.4	0.4	0.4
	trench	0.3	0.3	0.3	0.3
		0.5	0.5	0.5	0.5
	Lift from	0.3	0.4	0.6	0.8
	trench and	0.3	0.3	0.5	0.6
	place on	0.5	0.8	0.8	0.8
	trailer	0.5	0.9	0.9	1.0
	Lift from	1.0	1.0	1.0	1.0
	trench and	1.0	1.1	1.0	1.0
	manually	1.0	1.1	1.1	1.1
	transport 10m	1.0	1.0	1.0	1.0
	Lift from	0.5	0.5	0.5	0.5
	trench & place	0.6	0.8	0.8	0.8
	in stockpile at	0.6	0.6	0.6	0.6
	side of trench	0.7	0.9	0.9	0.9

TABLE 6

Ref	Operation	Timber Strut Basic Minute data								
		100 x 100 mm			150 x 150 mm			300 x 300mm		
		1m	2m	3m	1m	2m	3m	1m	2m	3m
	Unload timber from trailer and place on stockpile	0.2 0.2 0.2 0.2	0.2 0.2 0.2 0.2	0.2 0.2 0.2 0.2	0.2 0.2 0.2 0.2	0.2 0.2 0.2 0.2	0.3 0.3 0.3 0.3	0.3 0.3 0.4 0.2	0.6 0.5 0.4 0.5	0.6 0.6 0.5 0.7
	Measure and cut to length by hand	2.1 1.8 1.2 1.9	2.0 1.8 1.4 1.9	2.0 1.8 1.4 1.9	2.3 2.0 2.0 2.9	2.4 2.0 3.0 3.0	2.4 2.0 3.0 3.0	7.5 6.3 7.5 7.1	7.7 6.7 7.7 8.3	8.0 7.9 8.2 8.3
	Measure & cut to length by mechanical saw	1.0 0.6 1.0 0.6	1.0 0.6 1.0 0.6	1.0 0.6 1.0 0.6	1.0 1.1 0.8 1.5	1.0 1.1 0.8 1.5	1.1 1.2 0.8 1.7	3.0 3.5 3.1 3.2	4.2 3.6 3.5 3.5	4.2 3.6 4.0 4.0
	Lift & lower into trench (2 m deep)	0.2 0.2 0.2 0.2	0.2 0.2 0.2 0.2	0.2 0.2 0.2 0.2	0.4 0.2 0.5 0.5	1.0 0.6 0.6 0.6	1.0 0.6 0.6 0.6	0.5 0.5 0.5 0.5	0.7 0.7 0.7 0.7	1.0 1.0 1.0 1.0
	Locate and wedge into position	1.5 1.5 1.5 1.5	1.7 2.8 1.9 2.8	1.7 2.9 2.5 2.9	1.0 1.0 1.0 1.0	1.0 1.1 1.1 1.2	1.5 1.6 1.7 1.6	2.6 2.1 2.4 2.1	2.8 3.1 3.0 2.8	3.5 4.1 3.9 3.3
	Strip and remove from trench (2 m deep)	0.7 0.8 0.9 0.8	1.0 1.0 1.2 1.2	1.2 1.6 1.4 1.4	0.5 0.5 1.3 1.3	0.7 0.7 1.3 1.3	1.3 1.3 1.3 1.3	2.0 1.8 2.2 1.6	2.5 1.8 2.3 1.8	3.3 1.9 3.3 2.0
	Transport 10m manually	0.3 0.3 0.4 0.3	0.4 0.4 0.4 0.4	0.6 0.6 0.7 0.7	0.4 0.4 0.4 0.4	0.5 0.5 0.5 0.5	0.6 0.6 0.6 0.6	1.2 1.5 1.3 0.8	1.2 1.6 1.3 1.5	1.5 1.6 1.4 1.5
	Lift from 2m deep trench and place on trailer	0.3 0.5 0.5 0.3	0.4 0.8 0.5 0.7	0.6 0.8 1.0 0.8	0.5 0.5 0.5 0.5	0.6 0.6 0.6 0.6	0.8 0.8 0.8 0.8	1.0 0.9 0.6 0.7	1.5 0.9 1.1 0.9	1.7 1.6 1.6 1.1
	Lift from 2m deep trench and place on stockpile	0.3 0.3 0.3 0.3	0.3 0.5 0.3 0.5	0.5 0.5 0.5 0.5	0.4 0.5 0.4 0.3	0.5 0.5 0.4 0.6	0.7 0.5 0.6 0.6	0.7 0.7 0.8 0.7	1.0 1.0 1.0 1.0	1.3 1.4 1.2 1.3

TABLE 7

<table>
<tr><th rowspan="3">Ref</th><th rowspan="3">Operation</th><th colspan="8">Steel Water Basic Minute Data</th></tr>
<tr><th colspan="4">150 x 75 I</th><th colspan="4">200 x 113 I</th></tr>
<tr><th>2m</th><th>3m</th><th>4m</th><th>5m</th><th>2m</th><th>3m</th><th>4m</th><th>5m</th></tr>
<tr><td></td><td>Unload from trailer and place on stockpile</td><td>0.2
0.4
0.3
0.3</td><td>0.2
0.6
0.6
0.4</td><td>0.4
0.8
0.9
1.1</td><td>0.4
1.0
1.2
1.4</td><td>0.1
0.2
0.3
0.4</td><td>0.2
0.2
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0.5
0.5
0.5</td><td>0.6
0.6
0.5
0.7</td></tr>
<tr><td></td><td>Lift and position in 2 m deep trench</td><td>0.1
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0.4</td><td>0.4
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0.4</td><td>0.7
0.7
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0.7
0.7</td><td>0.4
0.4
0.4
0.4</td><td>0.8
0.5
0.8
0.7</td><td>0.9
0.7
0.9
1.1</td><td>1.0
0.9
0.9
1.2</td></tr>
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0.6
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0.9
1.0
0.9</td><td>0.8
0.9
1.0
0.9</td><td>1.2
1.2
1.0
1.3</td><td>1.2
1.3
1.1
1.3</td><td>1.4
1.4
1.4
1.4</td><td>1.5
1.5
1.6
1.5</td></tr>
<tr><td></td><td>Strip and remove from 2 m deep trench</td><td>0.7
0.8
0.9
0.8</td><td>0.9
0.9
1.2
1.0</td><td>1.1
1.1
1.4
1.2</td><td>1.1
1.1
1.4
1.2</td><td>1.4
1.2
1.2
1.4</td><td>1.5
1.2
1.2
1.4</td><td>1.5
1.5
1.4
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1.6
1.6
1.8</td></tr>
<tr><td></td><td>Transport 10 m manually</td><td>0.4
0.3
0.5
0.4</td><td>0.4
0.3
0.5
0.4</td><td>0.4
0.3
0.5
0.4</td><td>0.4
0.3
0.5
0.4</td><td>0.5
0.5
0.5
0.5</td><td>0.6
0.6
0.5
0.6</td><td>0.9
0.9
0.8
0.8</td><td>1.1
1.1
1.0
1.1</td></tr>
<tr><td></td><td>Lift from 2m deep trench & place on trailer</td><td>0.4
0.3
0.5
0.4</td><td>0.7
0.9
0.6
0.6</td><td>0.8
0.9
0.8
0.7</td><td>0.8
0.9
0.8
0.7</td><td>0.6
0.6
0.7
0.9</td><td>0.7
0.7
0.6
0.9</td><td>1.1
0.8
0.7
1.0</td><td>1.1
0.9
0.9
1.1</td></tr>
<tr><td></td><td>Lift from 2m deep trench & place on stockpile</td><td>0.3
0.3
0.3
0.3</td><td>0.6
0.6
0.6
0.6</td><td>0.6
0.6
0.6
0.6</td><td>0.6
0.6
0.6
0.6</td><td>0.7
0.6
0.6
0.6</td><td>0.6
0.7
0.6
0.5</td><td>0.9
0.7
0.6
0.7</td><td>0.9
0.7
0.8
0.7</td></tr>
</table>

TABLE 8

PIPE LAYING

Gang Size

See figure 1 (page 12)

Pipelaying

Operation	Pipe laying Basic minute data pipe length = 2.44 m							
	100	300	600	900	1200	1500	1800	2100
Prepare Base	0.4	1.15	2.30	3.30	3.90	4.25	4.45	4.50
Lower Blocks (2m)	0.22	0.95	1.20	1.21	1.20	1.15	1.20	1.20
Place and Level blocks	2.0	5.60	6.80	6.95	6.95	6.95	6.95	6.95
Place Sling on Pipe	0.44	0.94	1.36	1.60	1.76	1.92	2.08	2.23
Lower and Position pipe (2 m cover)	0.40	1.15	2.28	3.42	4.55	5.70	6.82	7.95
Lower and Position pipe (4 m cover)	0.50	2.10	4.50	7.00	9.10	11.60	14.15	15.80
Place Gasket	0.12	0.33	0.66	0.99	1.34	1.67	2.00	2.33
Lubricate Socket	0.25	0.80	1.57	2.37	3.17	3.95	4.75	5.60
Set Jack	0.40	1.16	2.35	3.50	4.69	5.85	7.03	8.20
Jack	0.43	1.25	2.43	3.64	4.85	6.05	7.25	8.45
Release Jack	0.14	0.36	0.72	1.06	1.42	1.78	2.13	2.50
Lower Traveller	0.14	0.38	0.75	1.12	1.50	1.86	2.21	2.61
Bone	1.16	1.16	1.16	1.16	1.20	1.16	1.17	1.16
Lift Traveller	0.11	0.31	0.59	0.86	1.16	1.95	1.74	2.02
Adjust Pipe	0.10	0.40	1.00	1.90	3.10	4.30	5.35	5.40
Remove Sling	0.50	0.90	1.24	1.44	1.60	1.76	1.92	2.08
Check Level (spirit)	0.14	0.38	0.75	1.12	1.49	1.86	2.23	2.61

TABLE 9

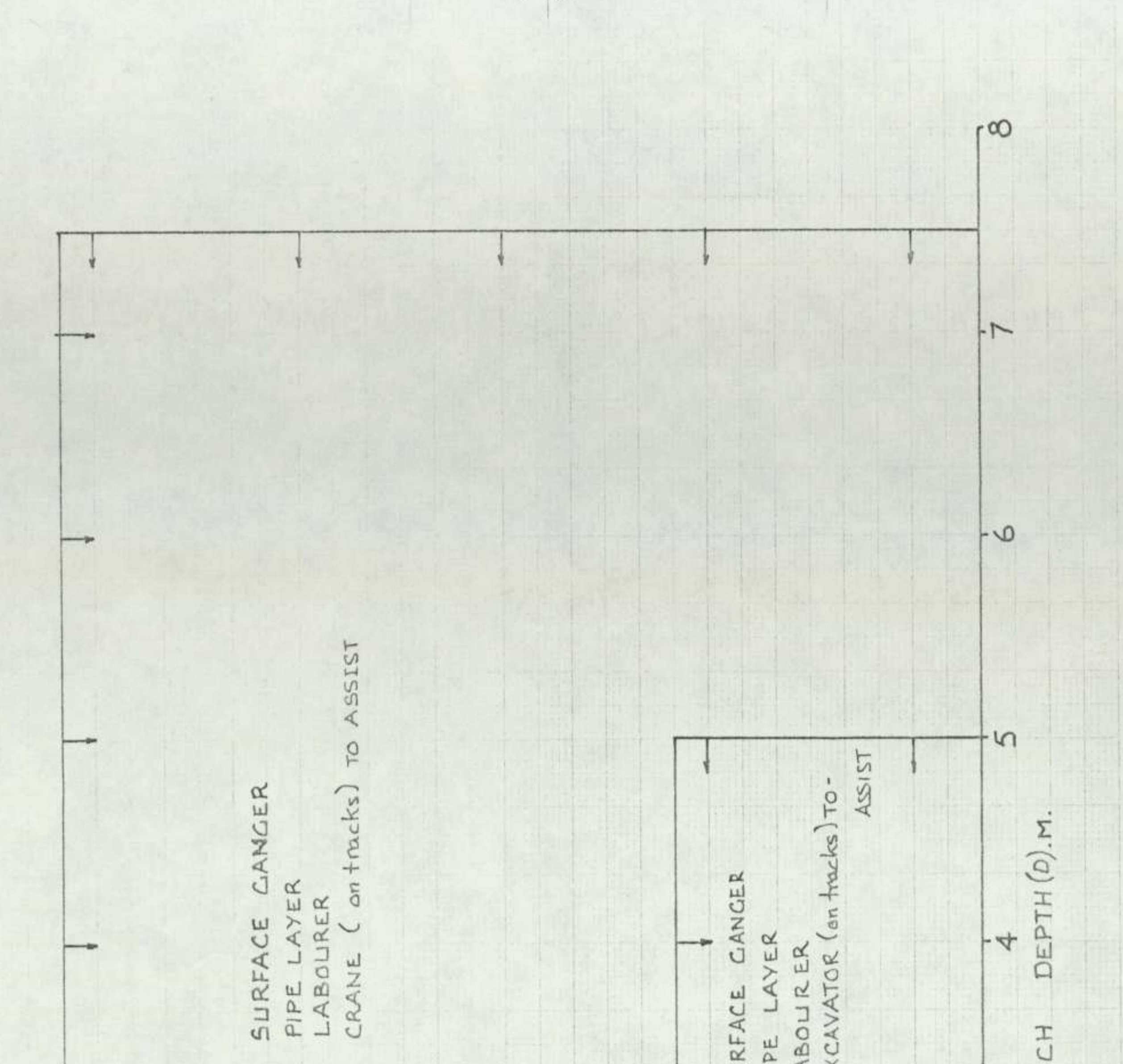
PIPE DIAMETER .MM.
TRENCH DEPTH (D).M.
2200
2000
1800
1600
1400
1200
1000
800
600
500
400
300
200
100
0
0
1
2
3
4
5
6
7
8
1 SURFACE GANGER
1 PIPE LAYER
1 LABOURER
1 CRANE (on tracks) TO ASSIST
1 SURFACE GANGER
1 PIPE LAYER
1 LABOURER
1 EXCAVATOR (on tracks) TO-ASSIST
1 SURFACE GANGER.
1 PIPE LAYER.
1 LABOURER.

Figure.1.

PIPE BEDDING

Gang Size

1 Ganger/Banksman.

2 Labourers.

Concrete Pipe Bedding

Operation	Pipe Bedding Basic Minute Data/m^3							
	100	300	600	900	1200	1500	1800	2100
Concrete								
Unrestricted discharge from wagon or large skip. Time includes shaping and tamping.	16.8	16.5	17.0	16.1	6.3	16.8	16.3	16.0
Concrete placed by hand from a heap at the trench side.This includes shaping and tamping.	28.0	28.0	27.3	27.9	25.8	28.5	28.0	28.7
Restricted discharge through trench supports and services etc. from wagon 2 m cover.	20.3	20.6	17.8	16.8	15.1	14.6	14.7	13.4
Restricted discharge through trench supports and services etc. from wagon 4 m cover.	39.3	38.6	35.7	32.6	28.0	26.3	26.1	25.6

TABLE 10

Granular Pipe Bedding

Operation	Pipe Bedding Basic Minute Data/m^3							
	100	300	600	900	1200	1500	1800	2100
Granular (10-20mmø)								
Unrestricted discharge from a wagon or skip. Time includes shaping.	11.7	12.0	12.1	11.5	11.3	8.8	9.2	8.9
Discharged from wagon and placed by hand. Time includes shaping.	19.8	21.8	19.3	19.7	17.8	18.3	17.5	16.4
Restricted discharge through trench supports and services from a wagon. (2 m cover)	15.3	15.6	13.8	12.5	12.0	9.7	9.5	8.6
Restricted discharge through trench supports and services from a wagon. (4 m cover)	27.8	25.2	23.5	22.0	22.6	21.6	22.3	16.5

TABLE 11

BACKFILL

Gang Size

Included in the data.

BACKFILL

	Backfill Basic Minute Data			
Layer Thickness	150 mm	300 mm	450 mm	
Description				
Backfill by hand		19.8		
from heap at trench		19.8	25.8	
side. Compacting	50.0	25.2	18.7	
time included.	62.5	16.3	20.0	
MEAN	56.25	20.25	21.5	2 men + Roller
Backfill using Dumper. Compacting time included.				
	7.10	6.50	5.0	2 men + Dumper + Roller
Backfill using	6.10	4.01		
Excavator. Compac-	4.05	3.70	4.80	
ting time included.	5.60	4.00	4.02	
MEAN	5.25	3.90	4.41	2 men + Exca-vator + Roller
Backfill using	4.00	3.05	2.50	
tracked loader.	4.50	4.06	2.70	
MEAN	4.25	3.55	2.60	2 men + Drott + Roller

TABLE 12

PRE-CAST CONCRETE RING MANHOLES

Gang Size

Included in the data

			Assuming a mean ring height of 0.5 m			
Internal Diameter (mm)	Volume of Mortar per Joint M^3	Volume of Mortar per Metre M^3	Standard Duration per ring hrs	Standard Duration per metre hrs	Standard Man-hours per ring hrs	Standard Man-hours per metre hrs
914	0.004	0.008	0.28	0.56	1.12	2.24
1067	0.004	0.008	0.31	0.62	1.24	2.48
1219	0.005	0.010	0.34	0.68	1.36	2.72
1372	0.006	0.012	0.43	0.86	1.72	3.44
1524	0.007	0.014	0.48	0.96	1.96	3.84
1892	0.014	0.028	0.53	1.06	2.12	4.24

Gang Size:-

1 Machine with Driver

1 Labourer

1 Pipelayer

1 Banksman/Ganger

CHAMBER RINGS

TABLE 13

Height (mm)	Internal Diameters (mm)	Volume of Mortar per Joint M^3	Volume of Mortar per Metre M^3	Standard Duration per ring hrs	Standard Duration per metre hrs	Standard Man-hours per ring hrs	Standard Man-hours per metre hrs
610	686 - 914	0.003		0.34		1.36	
610	686 - 1067	0.004		0.35		1.40	
610	686 - 1219	0.005		0.39		1.56	
914	686 - 1372	0.006		0.48		1.92	
914	686 - 1524	0.007		0.59		2.36	
914	686 - 1829	0.014		0.69		2.76	
914	726 - 1067	0.004		0.39		1.56	

Gang Size:-

1 Machine and Driver
1 Labourer
1 Pipelayer
1 Banksman/Ganger

STRAIGHT BACKED TAPERS

TABLE 14

Internal Diameter (mm)	Volume of Mortar per Joint (M^3)	Volume of Mortar per Metre (M^3)	Standard Duration per ring hrs	Standard Duration per metre hrs	Standard Man-hours per ring hrs	Standard Man-hours per metre hrs
686	0.003	0.006	0.24	0.48	0.96	1.92
762	0.003	0.006	0.26	0.52	1.04	2.08

Gang Size:-

1 Machine and Driver

1 Labourer

1 Pipe Layer

1 Banksman/ Ganger

SHAFT RINGS

TABLE 15

Shaft Diameter (mm)	Volume of Mortar per Joint (M^3)	Standard Duration per Slab hrs	Standard Man-hours per Slab hrs
686	0.003	0.23	0.92
762	0.003	0.25	1.00
914	0.004	0.28	1.12
1067	0.004	0.33	1.32
1219	0.005	0.38	1.52
1372	0.006	0.42	1.68
1524	0.007	0.47	1.88
1829	0.014	0.54	2.16

Gang Size:-

1 Machine and Driver

1 Labourer

1 Pipe Layer

1 Ganger/Banksman

COVER SLABS (75mm thick)

TABLE 16

Shaft Diameter (mm)	Volume of Mortar per Joint (M^3)	Standard Duration per Slab hrs	Standard Man-hours per Slab hrs
686	0.003	0.23	0.92
762	0.003	0.27	1.08
914	0.004	0.30	1.20
1067	0.004	0.34	1.36
1219	0.005	0.40	1.60
1372	0.006	0.45	1.80
1524	0.007	0.55	2.20
1829	0.014	0.64	2.56

Gang Size:-

1 Machine and Driver

1 Labourer

1 Pipelayer

1 Ganger/Banksman

COVER SLABS (150 mm Thick)

TABLE 17

Internal Diameter (mm)	Volume of Mortar per Joint (M^3)	Standard Duration per base (hrs)	Standard Man-hours per base (hrs)
686	0.005	0.24	0.96
762	0.009	0.31	1.24
914	0.014	0.32	1.28
1067	0.019	0.38	1.52
1219	0.024	0.46	1.84
1372	0.028	0.48	1.92
1524	0.033	0.58	2.32
1829	0.042	0.68	2.72

Gang Size:-

1 Machine and Driver

1 Labourer

1 Pipe Layer

1 Ganger/Banksman

BASE UNITS (Complete with benching, 600 mm high)

TABLE 18

BRICK MANHOLES

Gang Size

Included in the data

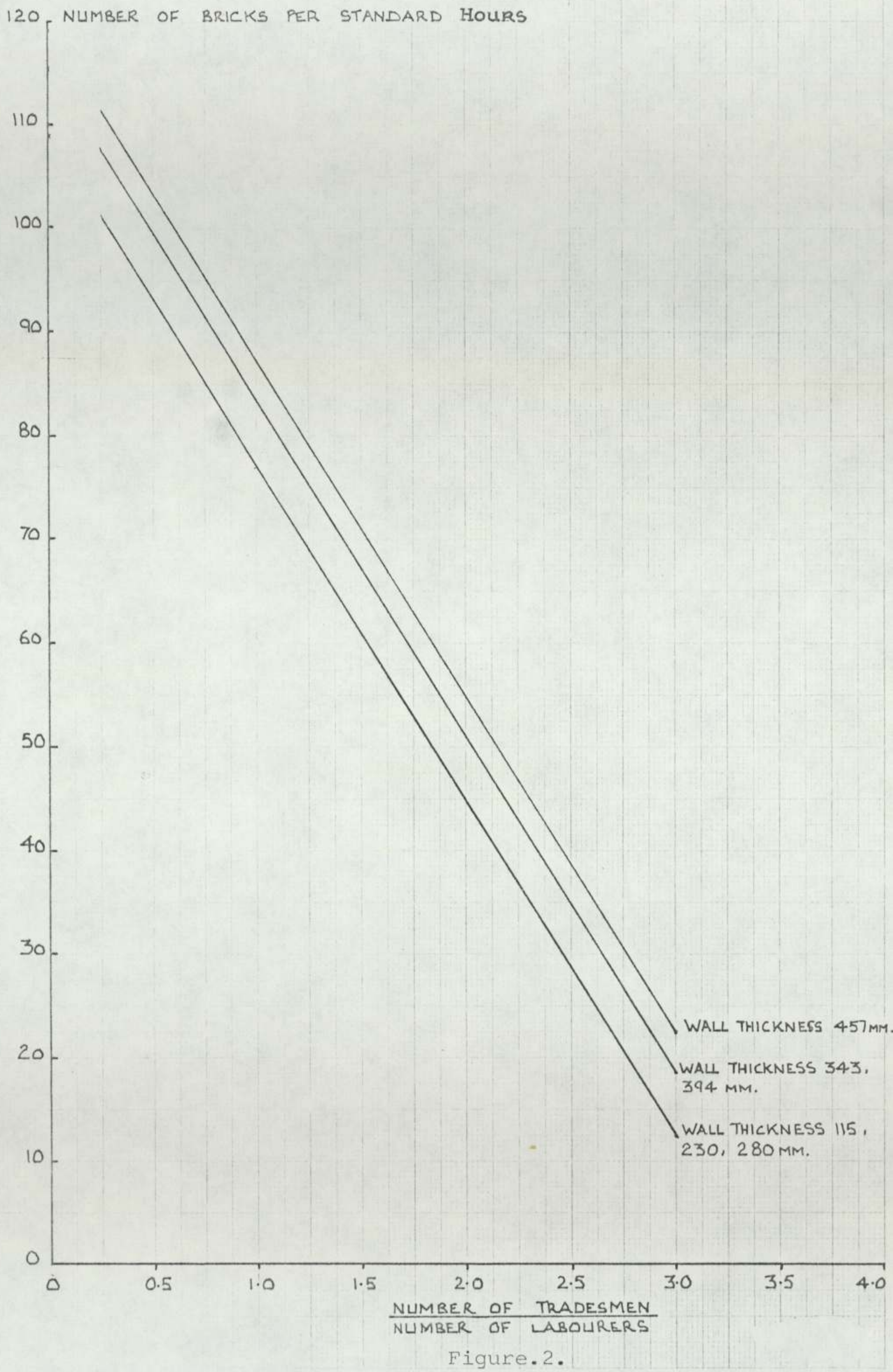
NUMBER OF BRICKS PER STANDARD HOURS
120
110
100
90
80
70
60
50
40
30
20
10
0
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
WALL THICKNESS 457MM.
WALL THICKNESS 343, 394 MM.
WALL THICKNESS 115, 230, 280 MM.
NUMBER OF TRADESMEN
NUMBER OF LABOURERS

Figure.2.

MANHOLE FITTINGS

Gang Size

Included in the data

STEP IRONS

No.	Item	Gang	Unit	Standard Man-hours/ Unit
1	Wedge and point step irons into pre-drilled concrete manhole rings.	1	No	0.075
2	Drill holes, wedge and point step irons into pre-cast concrete manhole rings	1	No	0.55
3	Set and point step irons into brick work.	1	No	0.05
4	Drill holes, wedge and point step irons into brick manhole	1	No	0.4

COVER

No.	Item	Gang	Unit	Standard Man-hours/ Unit
1	Place and level manhole cover on mortar bed.	2	No	1.0

FORMWORK

No.	Item	Gang	Unit	Standard Man-hours/ Unit
1	Fix and strike light-weight formwork to circular concrete manholes.		No	1.50
2	Make form work for manhole slabs and sides.		M^2	1.055
3	Fix form work for manhole slabs and sides.		M^2	1.130
4	Strike form work for manhole slabs and sides.		M^2	0.538

STEEL REINFORCEMENT

No.	Item	Gang	Unit	Standard Man Hours/Unit
1	Cutting	See Section (8) Miscellaneous 'Steel'		
2	Bending by Hand			
3	Power Bending			
4	Fixing			

CONCRETE

No.	Item		Gang	Unit	Standard Man Hours/Unit
1	150mm Concrete surround to manholes		2	M^3	1.027
2	In situ concrete base to form channels and branch connections.				
	No. of Channels	No. of Branches			
	1	0	2	M^2	2.691
	1	1	2	M^2	2.906
	1	2	2	M^2	3.122
	1	3	2	M^2	3.337
	1	4	2	M^2	3.552

TRANSPORTATION

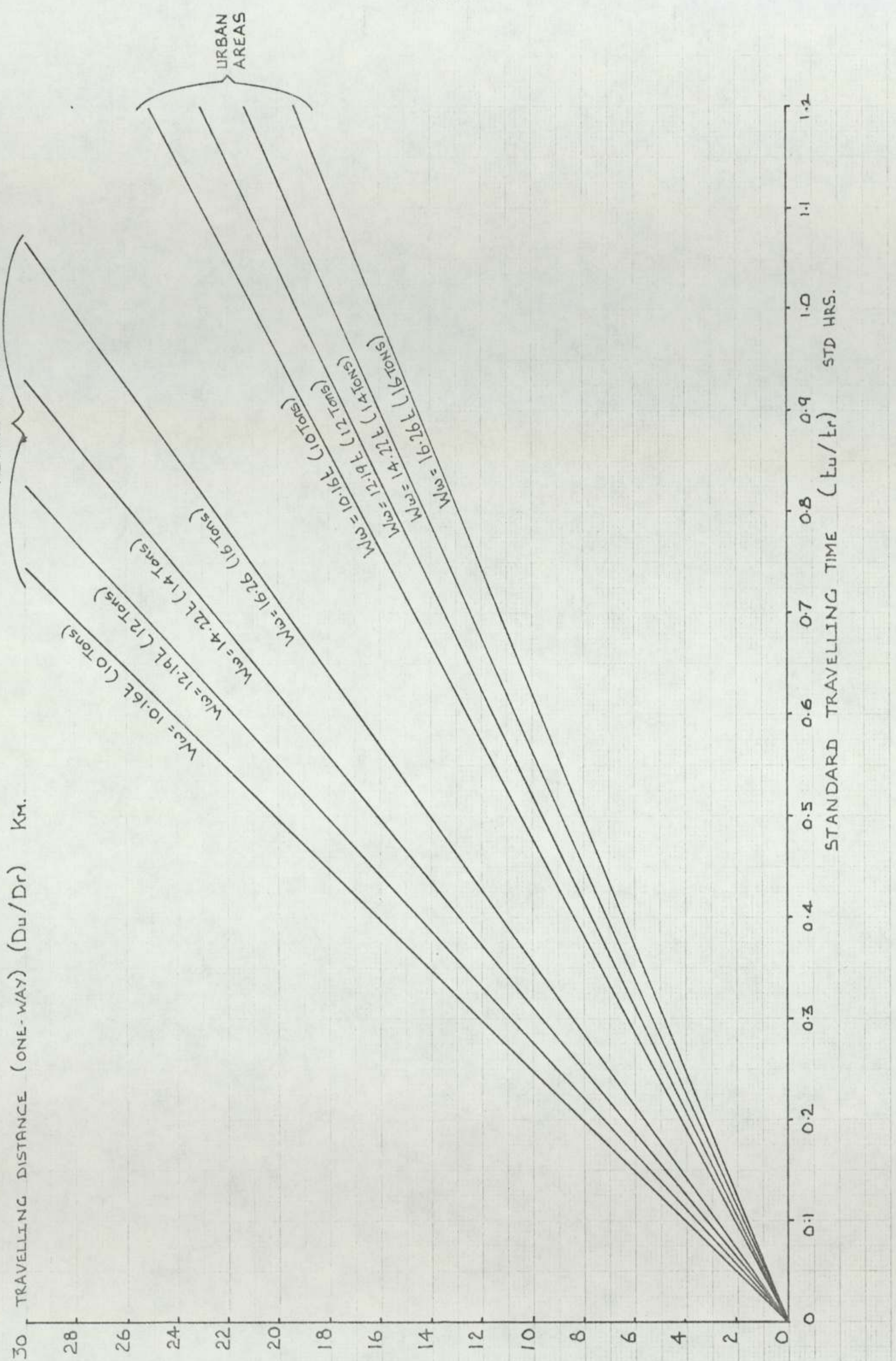
TRAVELLING DISTANCE (ONE-WAY) (Du/Dr) KM.
STANDARD TRAVELLING TIME (tu/tr) STD HRS.
RURAL AREAS
URBAN AREAS
Ww = 10.16t (10 Tons)
Ww = 12.19t (12 Tons)
Ww = 14.22t (14 Tons)
Ww = 16.26 (16 Tons)
Ww = 10.16t (10 Tons)
Ww = 12.19t (12 Tons)
Ww = 14.22t (14 Tons)
Ww = 16.26t (16 Tons)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2

Figure.3.

7.3 Small Dumpers

Make and Model	Capacity: Water Level YD³	Capacity: Water Level M³	Capacity: Struck YD³	Capacity: Struck M³	Capacity: Heaped YD³	Capacity: Heaped M³	Max Speed MPH	Max Speed KPH	Fuel Type	Fuel Tank Cap. (gals)	Fuel Consumption Pints/hr
Barford 15cwt. two-wheel drive, Gravity tip.	0.44	0.34	0.56	0.43	0.66	0.50	32	20	D	1.5	2.0
Barford 30cwt. two-wheel drive, Gravity tip	0.88	0.67	1.00	0.76	1.33	1.02	30.6	19	D	1.5	4.0
Barford 35cwt. two-wheel drive, Gravity tip.	1.22	0.93	1.30	0.99	1.67	1.28	30.6	19	D	1.5	5.0
Barford 150, two-wheel drive, Gravity tip.	0.85	0.65	1.22	0.93	1.63	1.25	30.6	19	D	1.5	2.0
Winget 4/35, four-wheel drive, hydraulic tip.	0.81	0.62	1.26	0.96	1.48	1.13	30.6	19	D	1.5	6.0
Barford 35cwt. four-wheel drive, Gravity tip.	1.22	0.93	1.30	0.99	1.67	1.28	30.6	19	D	1.5	6.0
Barford 200, four-wheel drive, hydraulic tip.	1.11	0.85	1.48	1.13	1.85	1.41	30.6	19	D	1.5	4.0

TABLE 19

SMALL DUMPERS

7.4 Trailers

TABLE 20

TRAILERS

Make & Model	Deck	No. of Wheels	Location of Wheels	Working Capacity
Wheatley 'Princess' low loading Trailer	Flat or with sides	2	Wheels set below deck level	2.5 ton
Wheatley 'Deeping'	Flat or with sides	4	Wheels set below deck level	5 or 6 ton
Wheatley Crawler Carrier	Flat	2	Wheels set at deck centre line	4 ton

Manufacturer: F. W. Wheatley (Trailers) Ltd.,
Padholme Road,
Peterborough,
England. Tel: 67077 (4 lines)

Agents: Bristol Street Equipment,
Alcester Road,
Portway. Tel: Wythall 2041/3

Other Manufacturers:

(a) Weeks and Co. (Engineers) Ltd.,
Hessle,
Yorkshire,
England. Tel: Hull (0428) 642171/4

(b) Power Trailer System: Land Drive Ltd.,
Canonbie,
Dumfrieshire.
Tel: Canonbie 355.

(c) Power Trailer System: Pinfold Plant Ltd.,
Victoria Road,
Fenton,
Stoke-on-Trent.
Tel: 22943

(d) Power and Dead Trailer Systems:

Harold Poole Ltd.,
Aspenden House,
Aspenden,
Buntingford,
Hertfordshire.
Te;L Royston Herts. 71332.

7.5 Tractors

Make and Model	BHP	Maximum Speed (MPH)										Mean Speed	Max Torque
		1	2	3	4	5	6	7	8	9	10	MPH	lb ft
Ford 2000	37	1.2	1.1	2.7	3.6	4.3	5.4	9.6	13.1			5.1	105
Ford 3000	47	1.2	1.1	2.7	3.6	4.3	5.4	9.6	13.1			5.1	134
Ford 4000	62	1.1	1.4	2.5	3.4	4.1	5.1	8.9	12.2			4.8	163
Ford 5000	75	1.6	2.0	3.5	4.7	5.6	7.0	12.4	16.8			6.7	211
Shire 500	75	1.6	2.0	3.5	4.7	5.6	7.0	12.4	16.8			6.7	211
County Super	75	1.5	1.9	3.3	4.6	5.5	6.8	11.9	16.2			6.5	211
County Super 6	98.5	1.6	2.0	3.5	4.8	5.7	7.1	12.5	17.0			6.8	250
Industrial 634	66	L1 1.7	L2 2.3	L3 2.9	H1 3.3	H2 4.5	H3 5.5	14 8.1	H4 15.7			5.5	225
Muir-Hill 161	163	2.3	2.9	3.8	4.8	6.0	7.8	10.1	13.9	16.6	20.6	8.9	390

TABLE 20

TRACTORS

MANUFACTURERS AND AGENTS

1 Muir-Hill Ltd.,
Bristol Road,
Gloucester GL1 5RX.
Tel: (0452) 21481.

2 County Commercial Cars Ltd.,
Fleet,
Hants.
Tel: 02-51422111.

3 International Harvester Company
of Great Britain Ltd.,
259 City Road,
London EC1.

4 Shire Tractors:

Perry's,
Potters Bar,
Herts.
Tel: Potters Bar 53211.

5 Ford Motor Company Ltd.,
Tractor Operations,
Basildon,
England.

MISCELLANEOUS DRAINAGE ITEMS

Gang Size

Given within

BRICKWORK

Item No	Item Description	Gang	Unit	Standard Man Hrs/Unit
1	Construct two course of 225 mm brick work to take a manhole cover. The item includes for building to line and level and pointing the inner face.	1	Metre Lin	0.30
2	Break out small quantities of manhole brickwork by hand.		M^3	2.25
3	Break out small quantities of manhole brickwork using pneumatic tools.		M^3	1.50

BENDS

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Fix 150mm diameter spigot and socket bend. The item includes setting to line and level and jointing with yarn and mortar.	1	No	0.35
2	Fix 225mm diameter spigot and socket bend. The item includes setting to line and level and jointing with yard and mortar.	1	No	0.56
3	Fix 300mm diameter spigot and socket bend. The item includes setting to line and level and jointing with yarn and mortar.	1	No	0.80

CHANNELS

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Lay 150mm diameter channels on a lean concrete bed. The item includes for positioning to line and level and cutting where necessary.	1	No	0.38
2	Lay 225mm diameter channels on a lean concrete bed. The item includes for positioning to line and level and cutting where necessary.	1	No	0.56
3	Lay 300mm diameter channels on a lean concrete bed. The item includes for positioning to line and level and cutting where necessary	1	No	0.75

CONCRETE

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Break out small quantities of cured mass concrete by hand.		M^3	7.0
2	Break out cured mass concrete using pneumatic equipment.		M^3	4.98
3	Break out cured reinforced concrete using pneumatic equipment.		M^3	4.98
4	Break out cured mass concrete carriageway using an IPH or other heavy mechanised pneumatic equipment.		M^3	1.54

COVERS (IRON)

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Bed and lay iron manhole covers to line and level.			
	Weight			
	0 - 50 kg	2	No	0.60
	50 - 100 kg	2	No	0.94
	100 - 150 kg	2	No	1.31
	above - 150 kg	2	No	1.62
2	Unload and stack iron manhole covers.			
	Weight			
	0 - 50 kg	1 + M/C & driver	No	0.08
	50 - 100 kg	1 + M/C & driver	No	0.15
	100 - 150 kg	1 + M/C & driver	No	0.20
	above - 150 kg	1 + M/C & driver	No	0.25

GULLIES

Item No.	Item Description		Gang	Unit	Standard Man Hours/Unig
1	Yard Gullies, the item includes excavate, position and surround with concrete.			No	0.56
2	Reversible Gullies, the item includes excavate, position and surround with concrete.				
	No. of inlets:-				
	1 only			No	0.75
	2 only			No	0.88
3	Road Gullies, the item includes excavation, positioning and concrete surround.				
	Diameter (mm)	Depth (mm)			
	225	600		No	1.13
	225	750		No	1.31
	300	600		No	1.26
	300	750		No	1.50
	300	900		No	1.75
	375	600		No	1.62
	375	750		No	1.88
	375	900		No	2.18
	450	750		No	2.06
	450	900		No	2.42

GULLY CONNECTIONS

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Fix first 2m of 150mm diameter clay pipe for gulley connection.		Gully	0.465
2	Fix straight 150mm x 1220mm long clay pipes.		Metre Lin	0.13

GULLY FRAMES AND GRATINGS

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Assemble to line and level and set on mortar bed Gully Frame and grating. The item includes the brick construction between the base of the frame and the top of the gully.			
	Weight			
	0 - 100 kg		No	1.88
	above 100 kg		No	2.25
2	Unload gully frames and grade from wagon and stock pile.			
	Weight			
	0 - 50 kg	2+M/C	No	0.08
	50 - 100 kg	2+M/C	No	0.15
	100 - 150 kg	2+M/C	No	0.20
	above 150 kg	2+M/C	No	0.25

GULLIES

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Unload Gullies from wagon and stock pile	2+M/C	No	0.15

HARDCORE

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Spread and level hardcore in 100mm layers and blind with ash.	2+M/C	M^3	2.0
2	Spread and level hardcore in 150mm layers and blind with ash.	2+M/C	M^3	1.88
3	Spreak and level hardcore in 225mm layers and blind with ash.	2+M/C	M^3	1.78

TRAPS

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Excavate, position, joint and surround with concrete 'P' traps.		No	0.375
2	Excavate, position, joint and surround with concrete intercepter traps.		No	1.13

PIPES

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Lay and joint clay ware spigot and socket pipe. The item includes jointing with yarn and mortar, and cutting, where necessary.			
	Diameter (mm)			
	100		Metre lin	0.098
	150		Metre lin	0.113
	225		Metre lin	0.143
	300		Metre lin	0.187
2	Unload and stock pile clay ware pipes individually.			
	Diameter (mm)			
	100	3	10 pipes	0.1
	150	3	10 pipes	0.2
	225	3	10 pipes	0.2
	300	3	10 pipes	0.2

RODDING EYES AND COVERS

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Fix 150 mm diameter spigot and socket Rodding Eye. The item includes setting to line and level and jointing with yarn and mortar.	1	No	0.32

REVERSIBLE GULLIES

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Excavate, position, joint and surround with concrete. Reversible Gullies containing one inlet only.		No	0.75
2	Excavate, position, joint and surround with concrete. Reversible Gullies containing two inlets only.		No	0.88

ROADS (Breakout)

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Break out metalled road surface, using an IPH or other heavy mechanised pneumatic equipment.		M^3	1.15
2	Break out cured mass concrete carriageway using an IPH or other heavy mechanised pneumatic equipment.		M^3	1.54

SLABS

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Unload precast manhole slabs and bases from wagon and stock pile.			
	Diameter			
	0 - 686 mm		No	0.5
	686 - 914 mm		No	0.53
	914 - 1067 mm		No	0.56
	1067 - 1219 mm		No	0.67

SADDLES

Item No.	Item Description	Gang	Unit	Standard Man Hours/ Unit
1	Cut and trim a 225 mm diameter clayware pipe and bed a 225 x 300 mm saddle to concrete line and level.		No	0.58

STEEL

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Cut, bend and fix 10 mm diameter steel. The cutting and bending should be performed by powered machines.			
	Power Cut		t	2.25
	Power Bend		t	8.70
	Fix		t	21.80
2	Cut, bend and fix 12 mm diameter stee. The cutting and bending should be performed by powered machines.			
	Power Cut		t	1.77
	Power Bend		t	7.18
	Fix		t	17.75
3	Cut, bend and fix 16 mm diameter stee. The cutting and bending should be performed by powered machines.			
	Power Cut		t	1.28
	Power Bend		t	5.13
	Fix		t	12.80

APPENDIX 2

PIPELINE ANALYSIS PROGRAMME

PIPELINE

CONTENTS

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NOTATION

		UNIT
Rs	Standard Mean Rate of Excavation	M^3/hr
R_{si}	Standard Rate of Excavation at depth increment 'i'	M^3/hr
Qe	Actual quantity of material excavated in one digging stroke	M^3
CT_i	Standard cycle time at depth increment 'i'	mins
UT	Above ground cycle time component	mins
E_{Ti}	Below ground cycle time component	mins
n	Integer	
Bc	Theoretical bucket capacity	M^3
s	Strata Grading	
b	Machine bucket width	MM
bc	Proportion of the theoretical bucket capacity utilised	
D	Depth of Excavation	M
w	Width of Excavation	M
N	Depth to width ratio	
R	Required machine working reach	M
Ap	Apparent Earth Pressure	KN/M^2
C	Constant	
K_A	Coefficient of Active Earth Pressure	
γ	Density	kg/M^3
c	Cohesion	kg/M^2
ϕ	Angle of Internal Friction	degs
f	Permissible Bending Stress	N/MM^2
M	Bending Moment	KNM

		UNIT
I	Second moment of Area	CM^4
Z	Section Modulus	CM^3
L	Maximum permissible waler spacing	M
L_D	Required Waler spacing	M
Ca	Applied compressive stress	N/MM^2
Cp	Allowable compressive stress	N/MM^2
B	Depth/width of timber struts	MM
r	Radius of Gyration	M
l	Effect length of the member	M
Zr	Required Section Modulus	KG/M^3
r	Working Radius	M
H	Unloading Height	M

1. <u>Introduction</u>

This programme is designed for use by contractors and design engineers. It analyses the pipeline operation which is assumed to consist of:-

(a) Road Breakout

(b) Excavation (including machine selection)

(c) Trench Support

(d) Pipe Laying

(e) Pipe Bedding

(f) Backfill

The results produced contain design information where necessary (Trench Support), together with recommended gang sizes, material quantities and construction durations at standard performance.

2. <u>Software Language</u>

FORTRAN

3. <u>Hardware Configuration</u>

1905E Central Processing Unit with hardware floating point
96K words of 1.8 μsec store (K = 1024, word = 24 bits)
Operators' console
Input: 2101 card reader, 2000 cards/minute
1916 paper tape reader, 1000 characters/second
Output: 1933 lineprinter, 1350 lines/minute, 120 characters line
1925 paper tape punch, 110 characters/second

1934 graph plotter, 30" wide, 300 steps/second, step size 0.005"

Magnetic Tapes:

4 magnetic tape decks using 0.5" magnetic tapes. Information is stored across 7 tracks at a density of 556 characters/inch. The maximum transfer rate is 20,800 characters/second.

2 magnetic tape decks using 0.5" magnetic tape. Information is stored across 9 tracks at a density of 1600 characters/inch. The maximum transfer rate is 160,000 characters/second.

Magnetic Discs:

4 exchangeable disc drives, each drive holding 8,192,000 characters stored on 200 tracks. The transfer rate is 208,000 characters/second.

3 exchangeable disc drives, each drive holding 60,000,000 characters.

Magnetic Drum:

1 drum with a storage capacity of 512K (K = 1024) words. The maximum transfer rate is 100,000 characters/second.

7007 Multiplexor

7008 Telegraph Data terminals

7010 Telephone Data terminal

In the main building, room 416, the following equipment is installed:-

7022 Card reader, 300 cards/minute
7021 Lineprinter, 300 lines/minute
Operators' console
418A teletype terminals

4. Programme Configuration and Theory

The programme processes the pipeline operation in technological sequence. To maintain flexibility, all elements of the operation are processed in 'sub-programmes' each of which contain several 'element subroutines' which store the work measurement information, calculate material quantities and determine the gang sizes. The 'element subroutine' are supported by 'ancillary subroutines' which prepare the input and output information. The sub-programmes deal with:-

(1) Road Breakout

(2) Excavation

(3) Excavation Support

(4) Pipe Laying

(5) Pipe Bedding

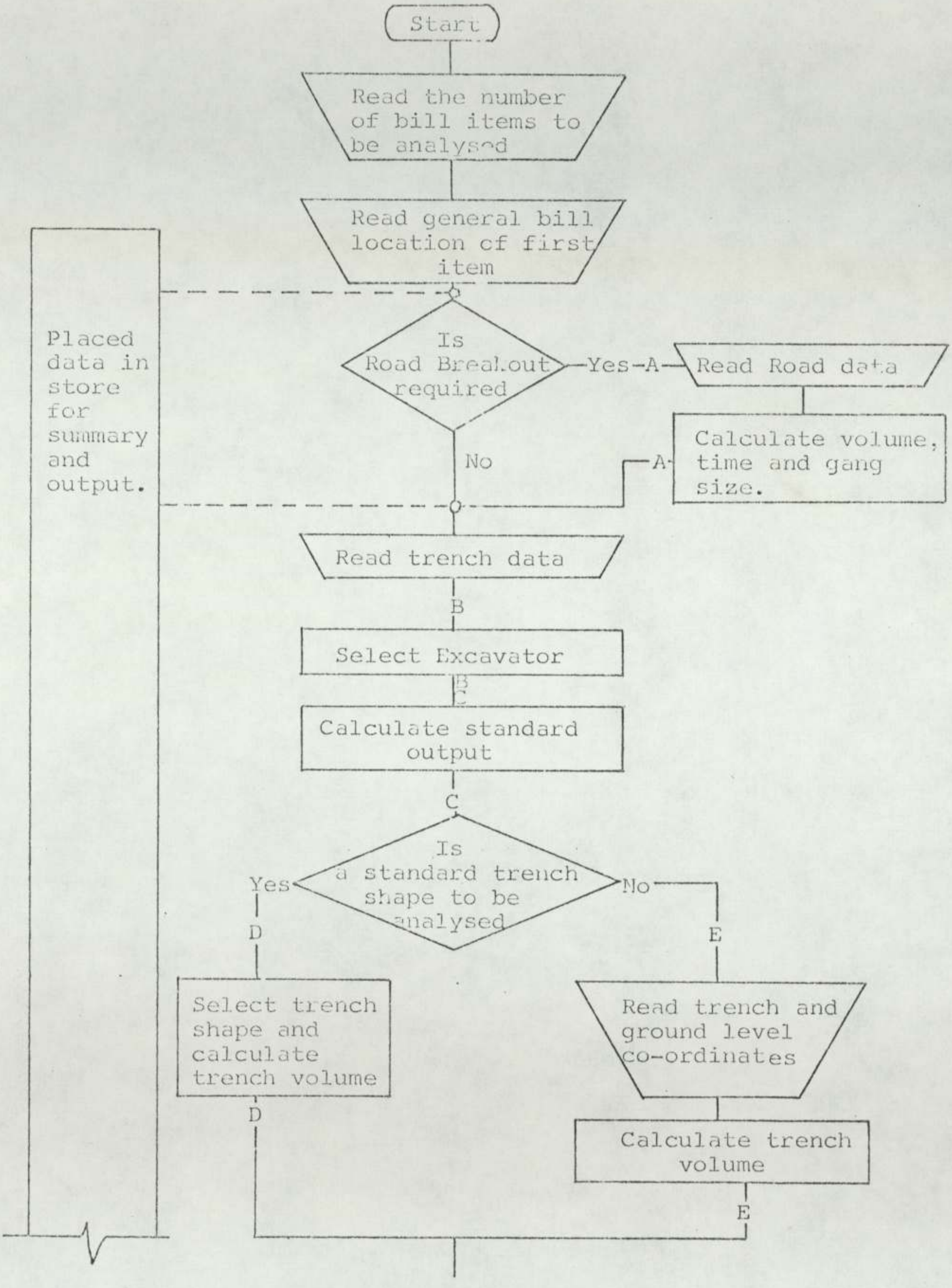
(6) Backfill

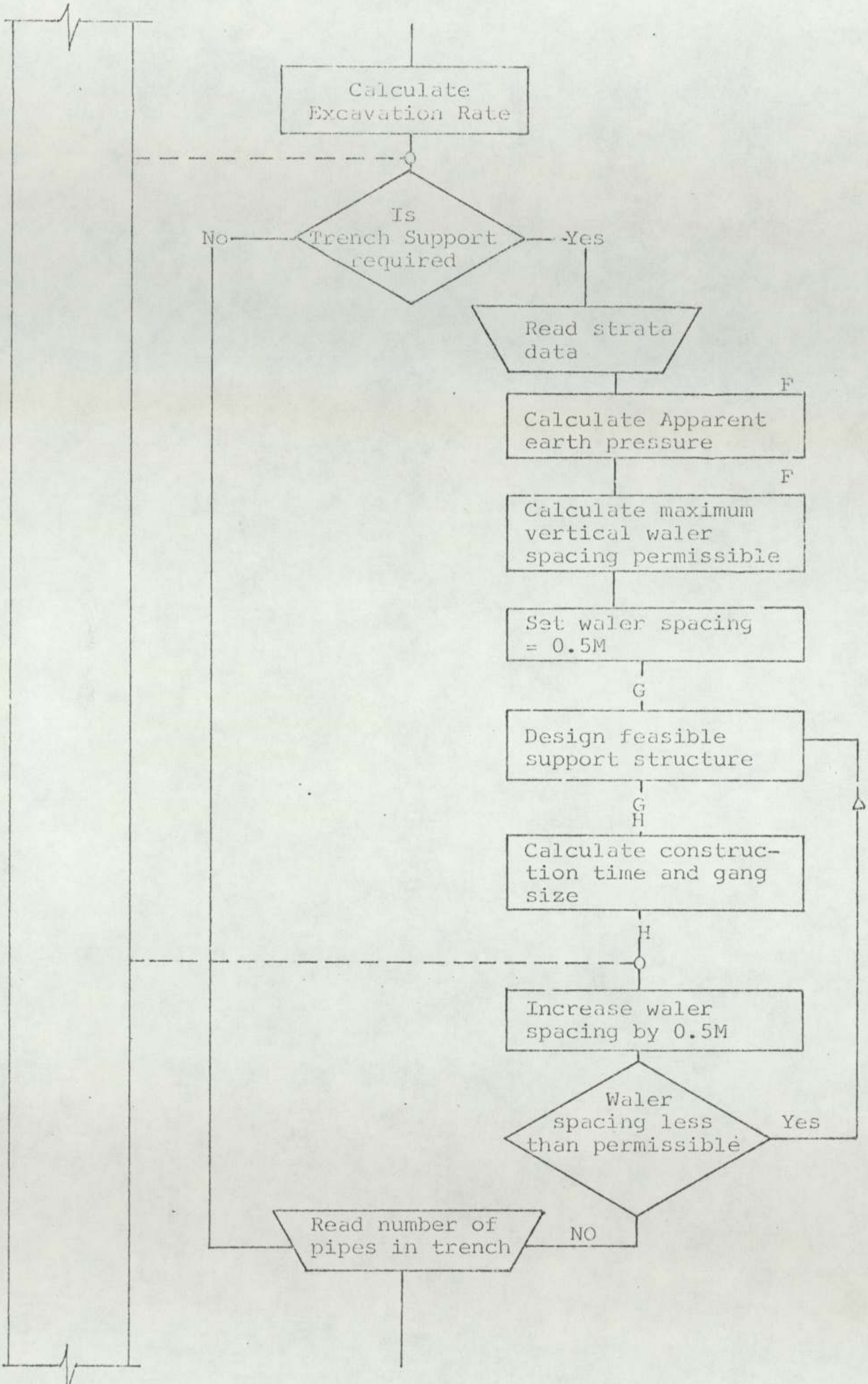
All 'element subroutines' and most of their associated 'ancillary subroutines', are controlled from the master programme segment (Figure.1.). After processing each element of the pipeline operations, the ancillary subroutines produce a comprehensive output and, on completion of the analysis, a general summary is given.

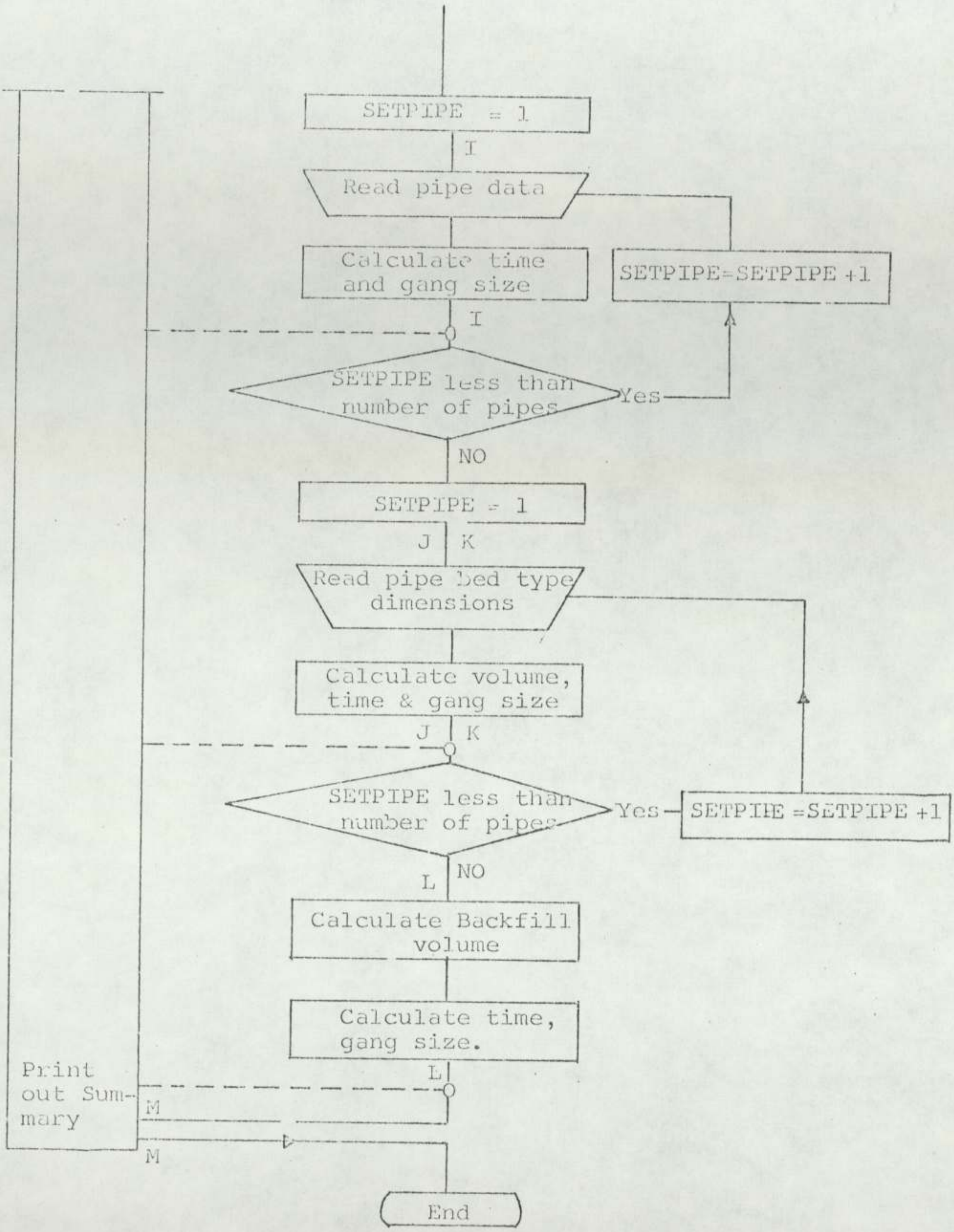
The programme produces several alternative methods for the Road Breakout, Excavation Support, and Backfill operation elements, thus permitting the user to specify the method used. On completing the pipeline analysis, the programme gives overall construction time and the labour and plant required.

FIGURE. 1 .

STRUCTURE OF MASTER SEGMENT




Calculate Excavation Rate
Is Trench Support required
No
Yes
Read strata data
F
Calculate Apparent earth pressure
F
Calculate maximum vertical waler spacing permissible
Set waler spacing = 0.5M
G
Design feasible support structure
G
H
Calculate construction time and gang size
H
Increase waler spacing by 0.5M
Waler spacing less than permissible
Yes
NO
Read number of pipes in trench


SETPIPE = 1
I
Read pipe data
Calculate time and gang size
SETPIPE=SETPIPE +1
I
SETPIPE less than number of pipes
Yes
NO
SETPIPE = 1
J K
Read pipe bed type dimensions
Calculate volume, time & gang size
J K
SETPIPE less than number of pipes
Yes
SETPIPE =SETPIPE +1
NO
L
Calculate Backfill volume
Calculate time, gang size.
L
Print out Summary
M
M
End

The following sections of this Appendix present the theory and a detailed breakdown of each sub-programme, the associated flow diagram being referenced to the master segment flow diagram (Figure.1.).

4.1 <u>Road Breakout Sub-Programme</u>

This (Figure.2.) contains two 'element subroutines' each storing the work measurement information given in Appendix 1. The first calculates the standard breakout time for a gang using medium breakers (essentially a manual process). The second calculates the standard breakout time for a gang assisted by a machine. Both results are output and the user selects the one applicable.

The sub-programme determines the breakout time and gang size for either flexible or rigid road construction and the quantities of breakout do not allow for over dig.

4.2 <u>Excavation Sub-Programme</u>

This sub-programme contains four 'element subroutines':-

(a) Machine Selection

(b) Excavation Rate

(c) Standard Trench Shape Volume

(d) Unique Trench Shape Volume

4.2.1 <u>Machine Selection Element Sub-routine</u>

The excavation machine required is selected from 10 hydraulic excavators frequently used by the company. Their physical characteristics (Appendix 1) are stored within the 'element subroutine'(Figure.3.). The machines considered are:-

Structure of Road Breakout Subroutines

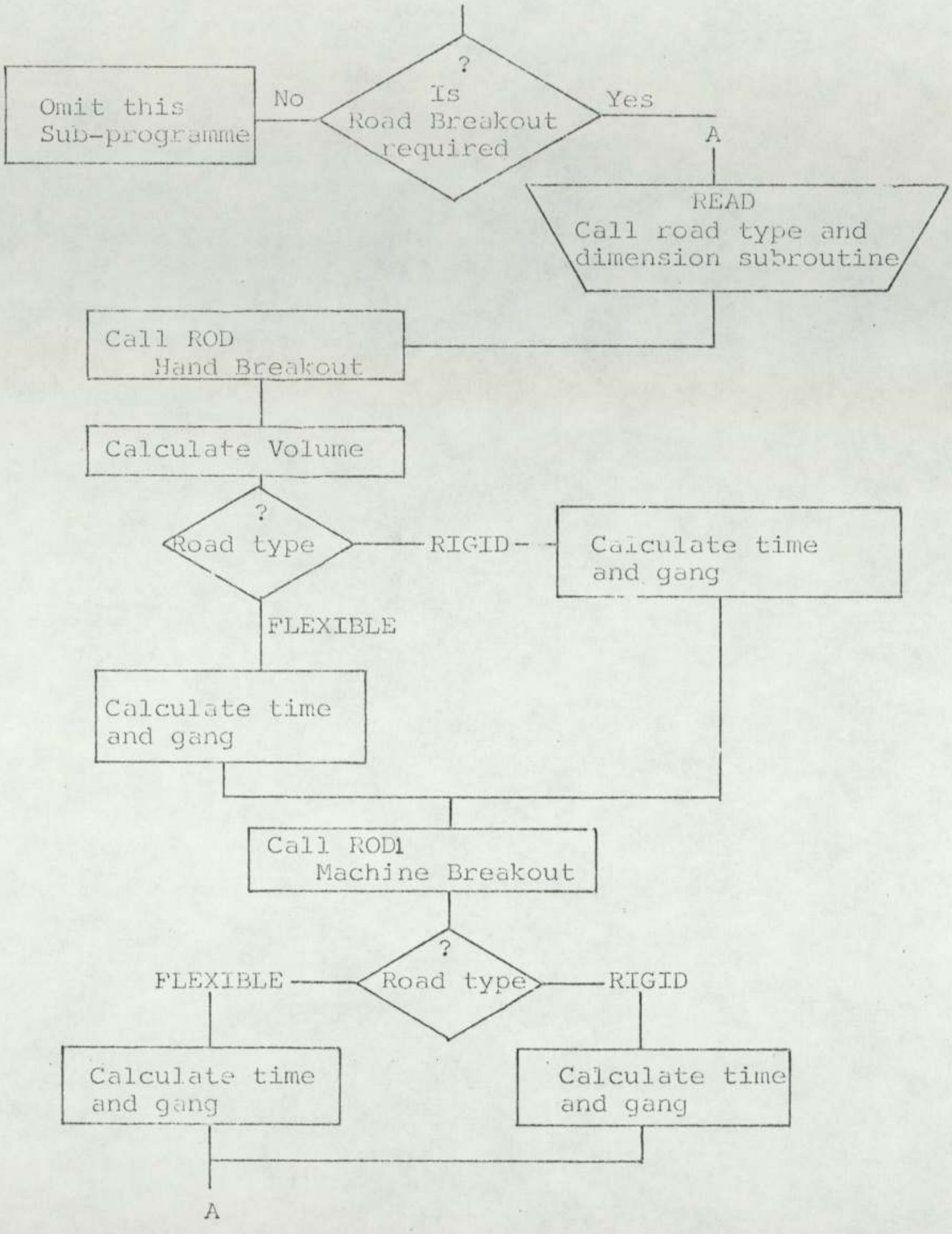
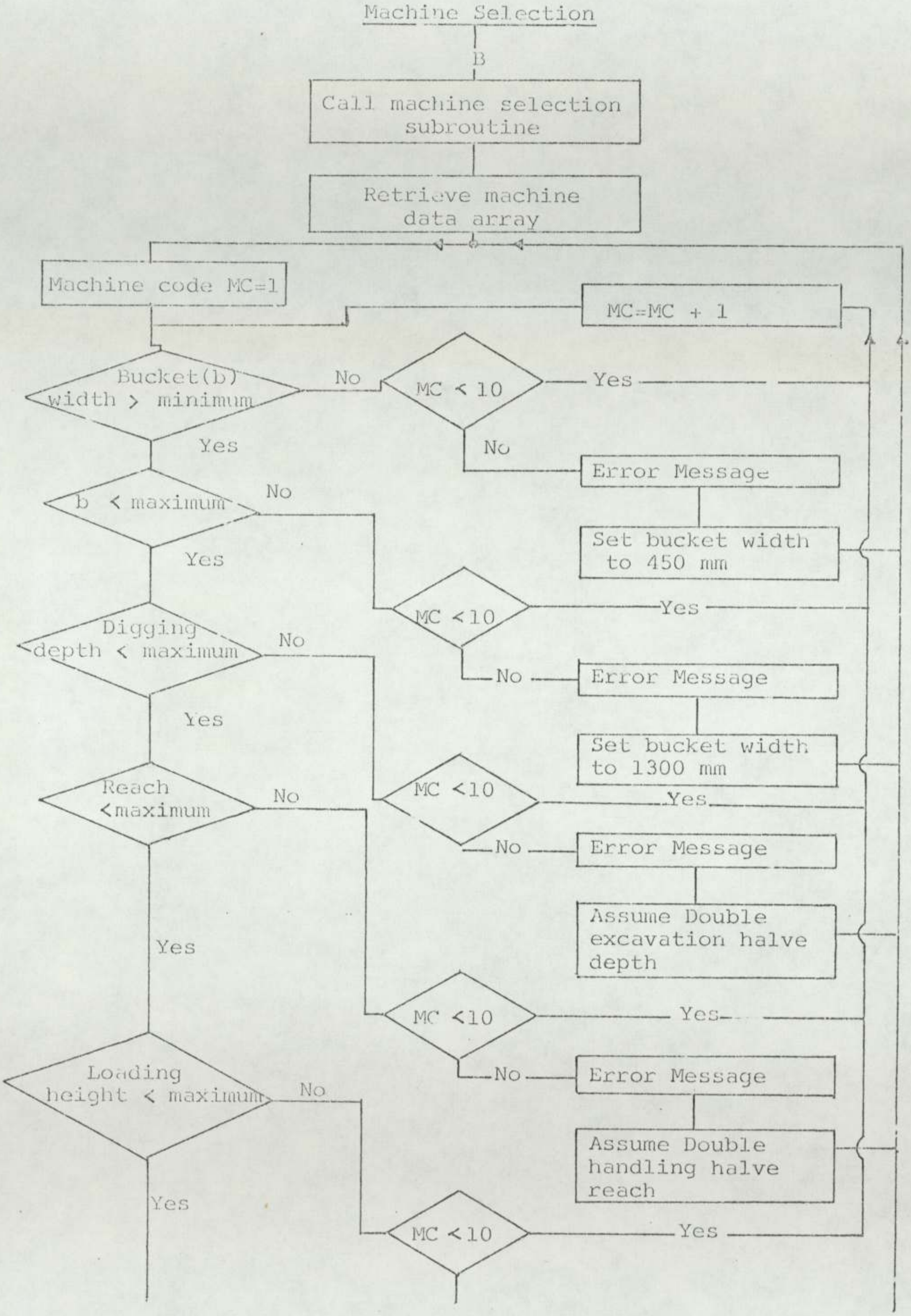


FIGURE. 2 .

A - A reference figure.


Machine Selection
B
Call machine selection subroutine
Retrieve machine data array
Machine code MC=1
MC=MC + 1
Bucket(b) width > minimum
No
MC < 10
Yes
No
Yes
Error Message
b < maximum
No
Set bucket width to 450 mm
Yes
MC < 10
Yes
Digging depth < maximum
No
No
Error Message
Yes
Set bucket width to 1300 mm
Reach <maximum
No
MC <10
Yes
No
Error Message
Assume Double excavation halve depth
Yes
MC <10
Yes
No
Error Message
Loading height < maximum
No
Assume Double handling halve reach
Yes
MC <10
Yes

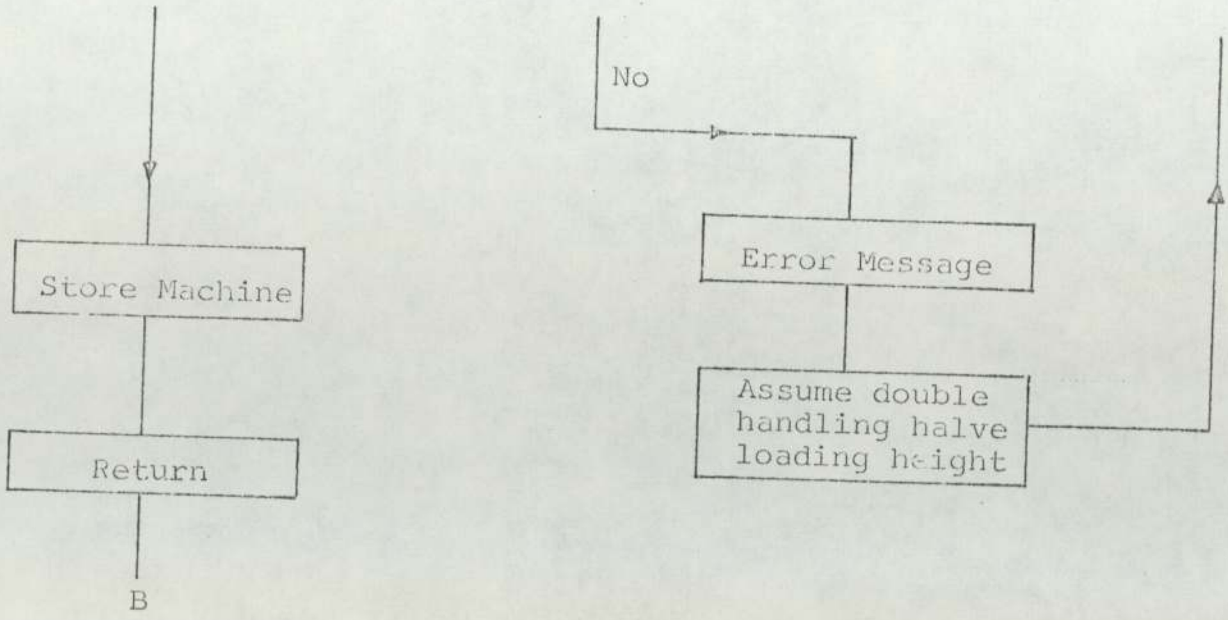

No
Store Machine
Return
B
Error Message
Assume double handling halve loading height

FIGURE. 3 .

(1) JCB 3

(2) JCB 3C

(3) JCB 3D

(4) JCB 5C

(5) JCB 7B

(6) Hy-Mac 580

(7) JCB 6C

(8) JCB 6D

(9) JCB 7C

(10) RH 6

The machine is selected using the depth, bucket width, loading height and horizontal reach information supplied by the user. Several 'ancillary subroutines' detect and inform the user if a machine, to satisfy the requirements, cannot be found. The errors are non-fatal but are necessary to indicate where excess demands have been made on the element subroutine. If the bucket width requested is too large or too small, maximum or minimum widths are assumed from the data stored. Similarly, if the digging depth, horizontal reach and/or the loading height requested is too great, they are halved, thus assuming double handling of excavated material.

4.2.2 Excavation Rate Element Subroutine

The standard mean rate of excavation (Rs) expected from the machine selected is determined analytically.

In general terms, the standard mean rate of excavation at a depth 'D_i' is given by:-

$$R_{si} = Qe/C_{Ti} \quad \text{..............(1)}$$

where $$C_{Ti} = U_T + E_{Ti} \quad \text{..............(2)}$$

Hence, the mean standard rate of excavation at a total trench depth of 'D' is given by the mean rate observed from 'n' depth increments in the form:-

$$R_s = \frac{Qe}{n} \sum_{i=1}^{i=n} \frac{1}{U_T + E_{Ti}} \quad \text{..........(3)}$$

The quantity of material excavated (Qe) is dependent upon the theoretical bucket volume (Bc) and the type of strata being excavated (s). Relationships between bucket width (b) and their theoretical capacity (Bc) produced by the machine manufacturers are given in Figure.4.).

The proportion of the theoretical bucket volume utilised (bc) was determined by site investigation (Appendix 1, Table.3.), the strata excavated being categorised according to Table.1. and the bc/s relationship used in the element subroutine is given in figure .5.

Studies indicated that the above ground cycle time component (U_T) is primarily dependent upon the slewing action of the excavation machine. Machine types 1 to 3 inclusive exhibit 'centre post' slewing actions, (the body of the machine remains stationary, only the slewing are moved), the remainder exhibit a 'Radial' slewing action (the body of the machine and the slewing are moved). Figures.6. and .7. show the relationships between (U_T) and the working radius for both slewing configurations.

The below ground excavation time component (E_T) is assumed to be independent of the type of excavation machine used, but dependent upon the trench shape (defined by the depth/width ratio (N)) and the frequency of obstruction, five categories of obstruction grading (øf) are used. (Table.2.). The relationship between E_{Ti}/N for the obstruction gradings is given in figure.8.).

The element subroutine stores all the relationships and the method used for calculating the mean standard rate of excavation is presented in flow diagram form in Figure.9 .

4.2.3 Standard and Unique Trench Shape Volume Element Subroutine

The volume of excavated material is calculated in one of two ways. Firstly, it is determined from basic data input by the user which is associated with specified standard trench shapes (Figure.10). Secondly, by using change in level co-ord nates supplied by the user. (Figure.11).

4.3 Excavation Support Sub-Programme

This sub-programme contains three 'element subroutines' which determine:-

(1) The apparent earth pressure

(2) Several feasible support structures

(3) The erection time, gang size and plant requirements.

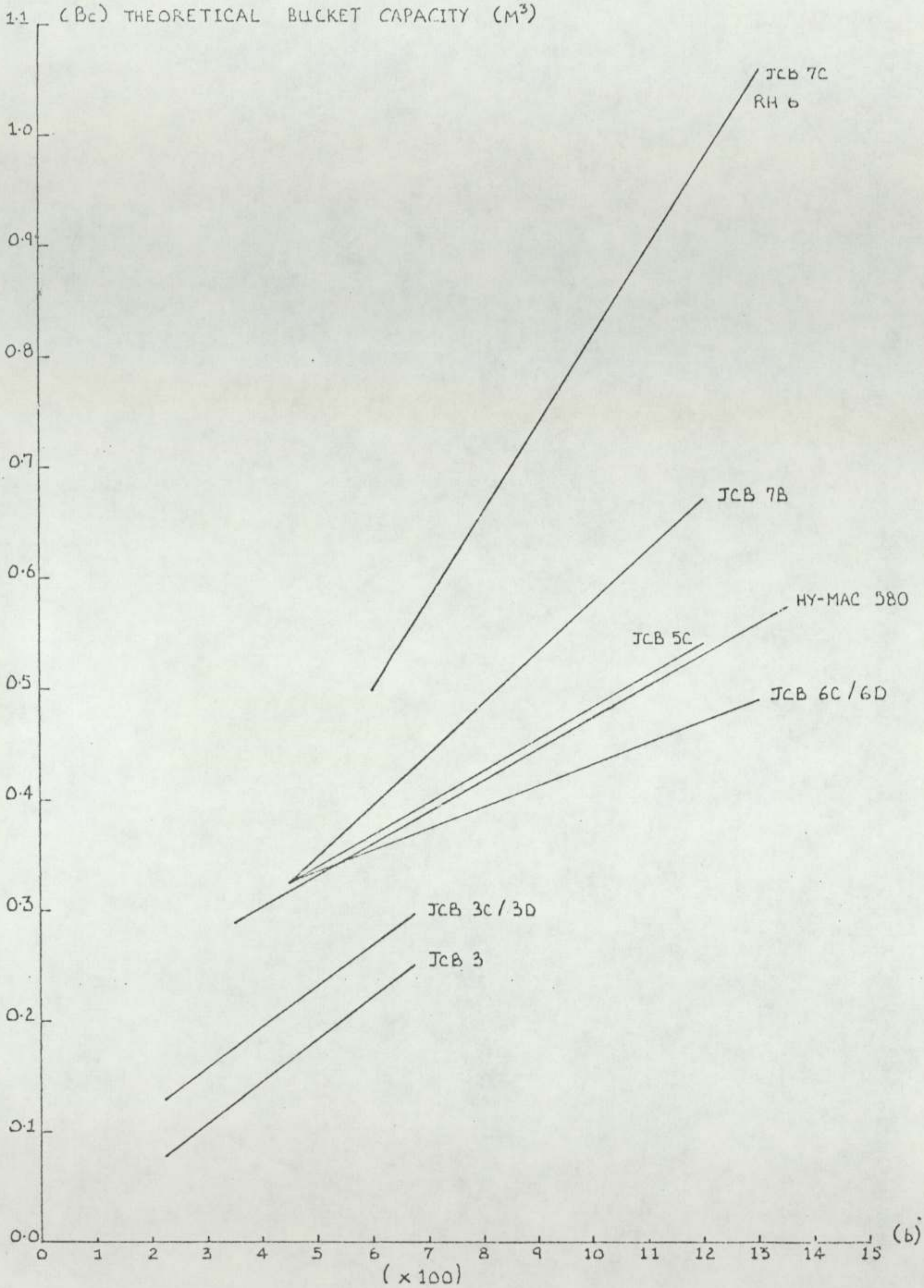
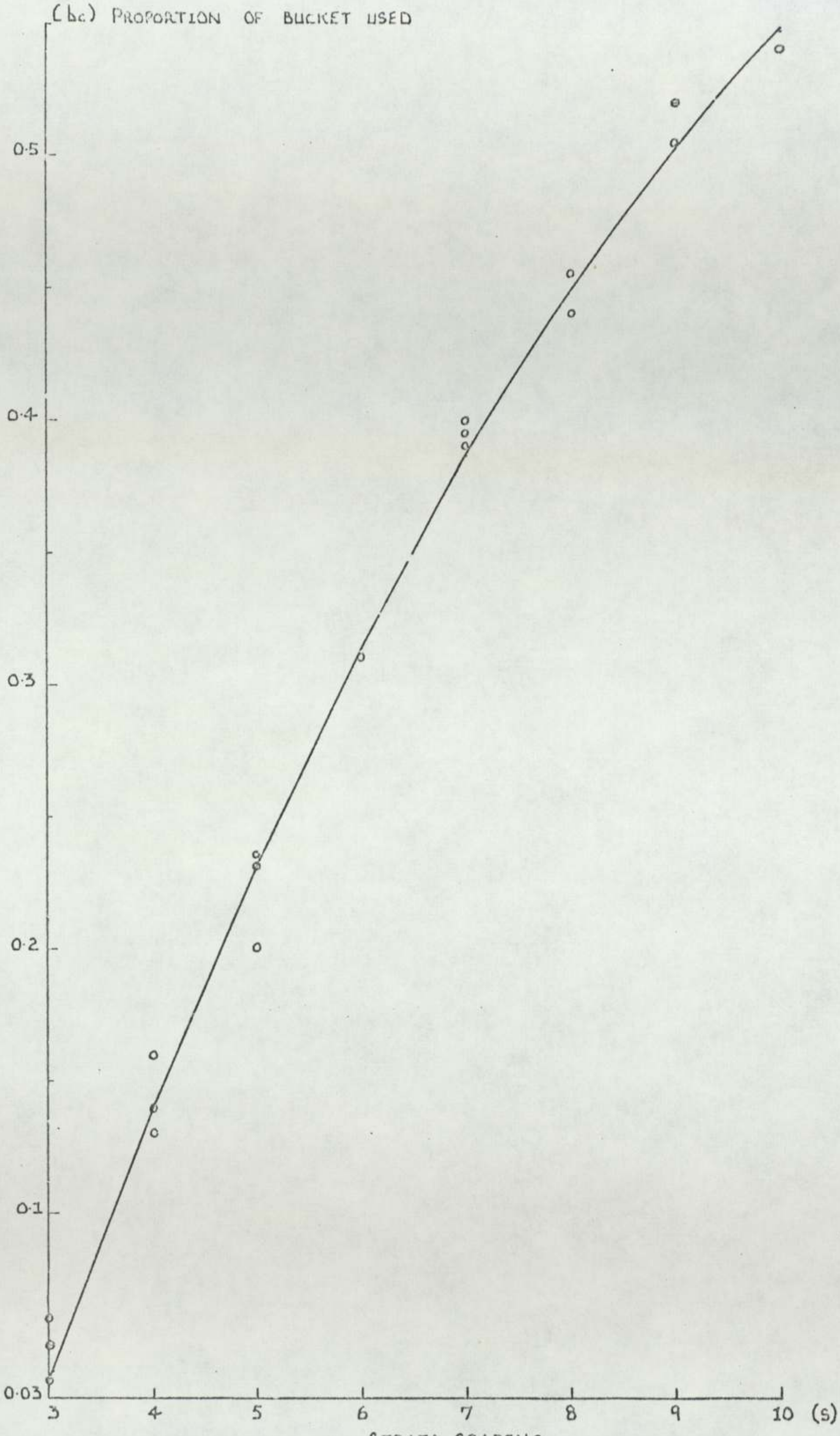

1.1
(Bc) THEORETICAL BUCKET CAPACITY (M³)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
JCB 7C
RH 6
JCB 7B
HY-MAC 580
JCB 5C
JCB 6C / 6D
JCB 3C / 3D
JCB 3
(b)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
(x 100)
BUCKET WIDTH (MM)

Figure . 4 .



(bc) PROPORTION OF BUCKET USED
0.5
0.4
0.3
0.2
0.1
0.03
3
4
5
6
7
8
9
10 (s)
STRATA GRADING

Figure. 5.

CENTRE POST EXCAVATORS

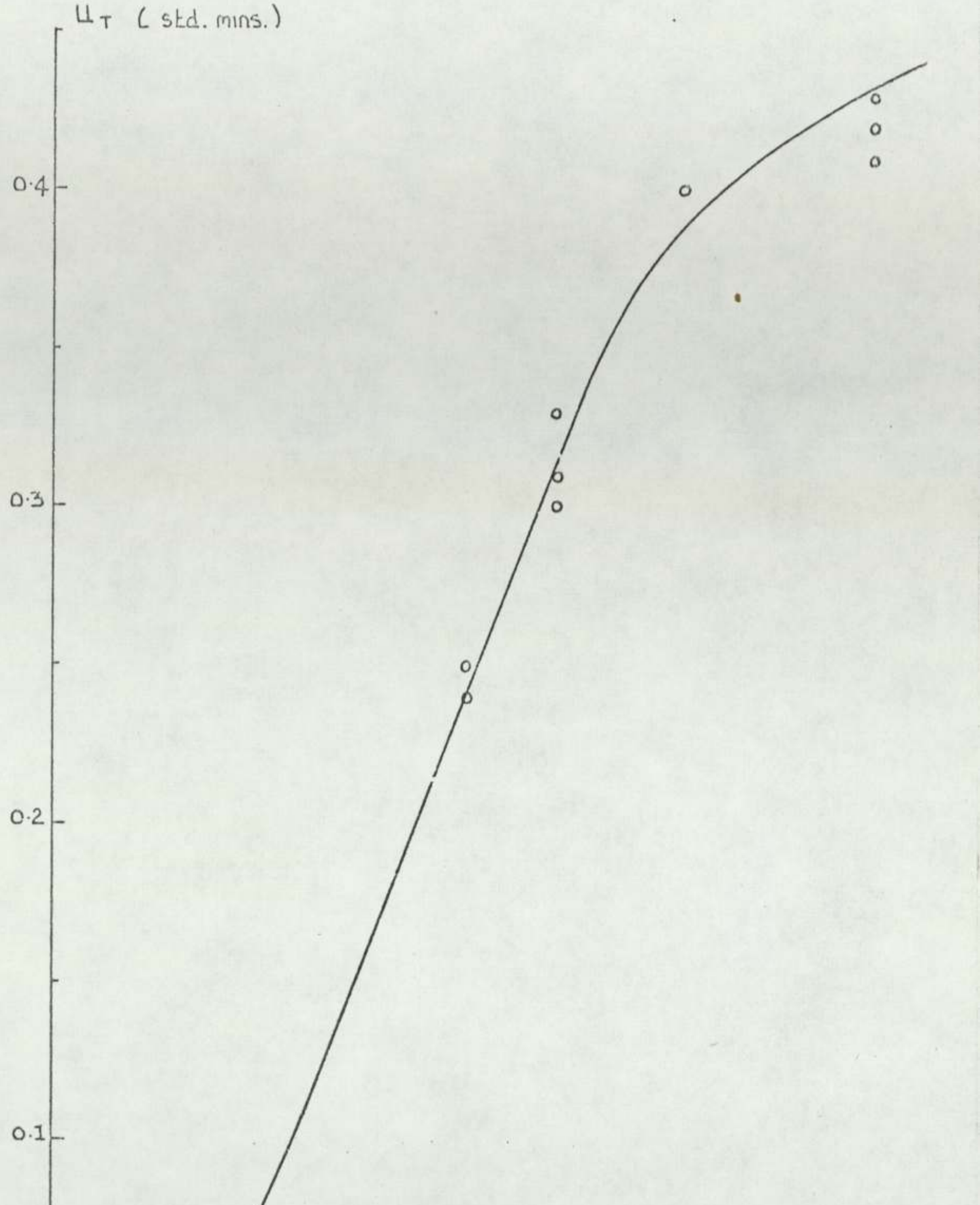


Figure . 6 .

RADIAL EXCAVATORS

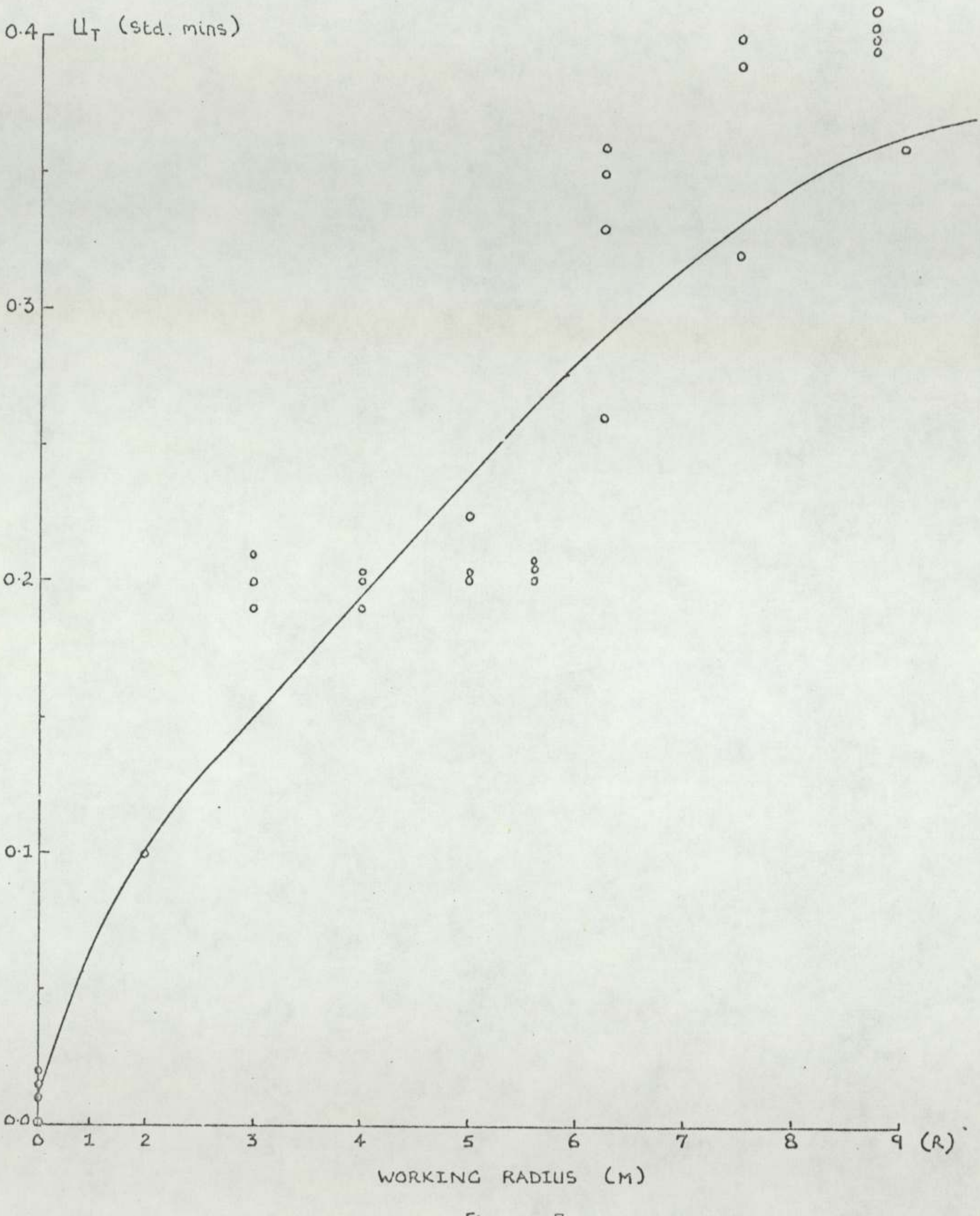


Figure .7 .

TABLE. 1 .

STRATA GRADING

DESCRIPTION	GRADING
'ROCK' shall mean those geological strata and individual boulders exceeding 6 cubic feet (0.17m) in size or other masses of hard material outside those strata which necessitate the use of blasting or approved pneumatic tools for their removal.*	1
'MEDIUM ROCK' As 'A' above but not exceedind 6 cubic feet (0.17m) but exceeding 1 cubic foot (0.028m).	2
'SOFT ROCK' As 'B' but not exceeding 1 cubic foot (0.028m) and possessing bedding plains to allow breakage.	3
'SOFT LAMINATED ROCK' As 'C' but with excess laminations or bedding plains (slate, soft sandstone, shale).	4
'COHESIVE SOIL' (stiff) includes clays and marls with up to 20 per cent of gravel having a moisture content not less than the value of the plastic limit (BS 1377) minus 4; also chalk having a saturation moisture content of 20 per cent or greater.*	5-6
'SOFT COHESIVE SOIL' (medium) As '5-6' but excluding marls and including all clays and approximately 10 per cent sand or below.	7
Well-graded granular and dry cohesive soils, include clays or marls containing more than 20 per cent gravel.*	8
Well-graded sand and gravels with uniformity coefficient exceeding 10, also clinker and spent domestic refuse.	9
Uniformity graded material includes sands and gravels with uniformity coefficient of 10 or less, all silts and pulverised fuel ashes.*	10

* "Specification for Road and Bridge Works". 1969. Clause 601, 1.(iv), 2.(i), 2.(ii), 2.(iii).

TABLE. 2 .

OBSTRUCTION GRADING

DESCRIPTION	GRADING
Excavation involving the breaking out of metalled road surfaces or other such obstructions situated on top of frequently occurring services.	1
Excavating in ground possessing frequently occurring major services and house connection.	2
(a) Excavating in ground possessing infrequent major services but frequently occurring house services.	
(b) Excavating in ground possessing infrequent major services and infrequent minor services.	
(c) Excavating in ground possessing infrequent minor services and for tree roots etc.	3
Excavating in ground possessing minor obstructions only, i.e. tree roots, small quantities of hard core, etc.	4
Excavating in ground possessing no obstructions other than those which are an integral part of the strata.	5

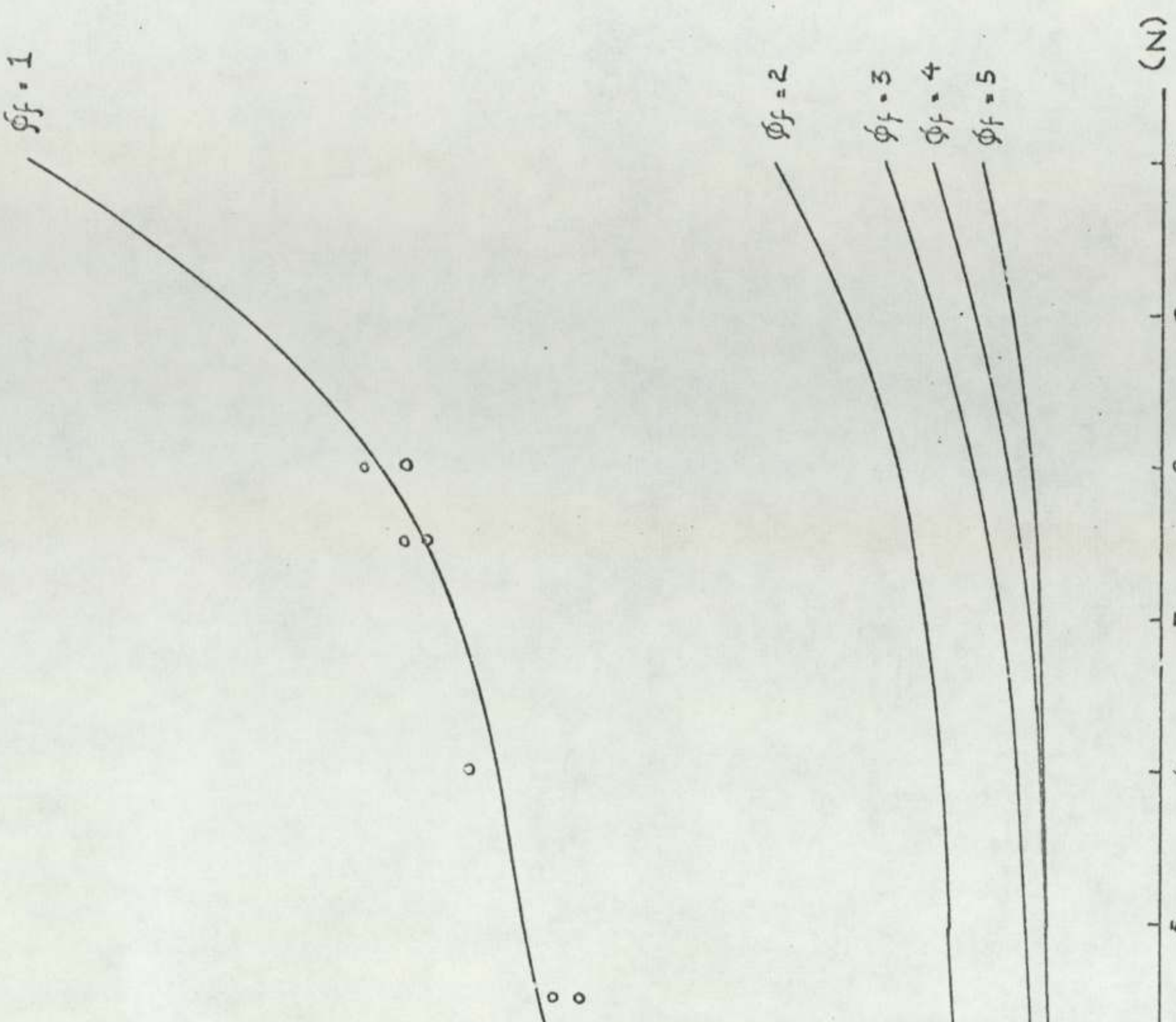

φf = 1
φf = 2
φf = 3
φf = 4
φf = 5
DEPTH / WIDTH RATIO
(N)
0
1
2
3
4
5
6
7
8
9
10
0.0
1.0
2.0
3.0

Figure . 8 .

Excavation Rate Subroutine

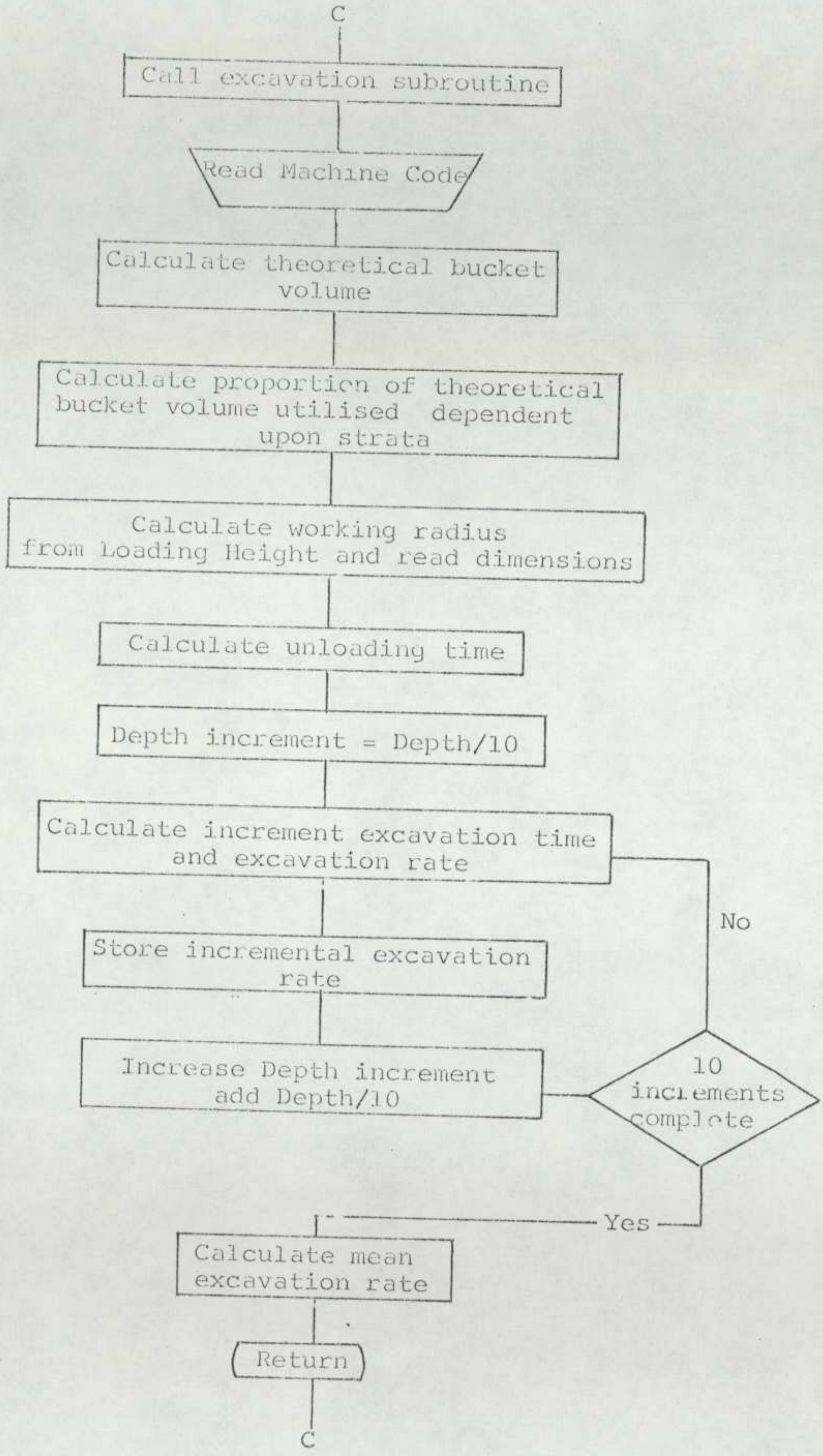


FIGURE. 9 .

Standard Trench Shape

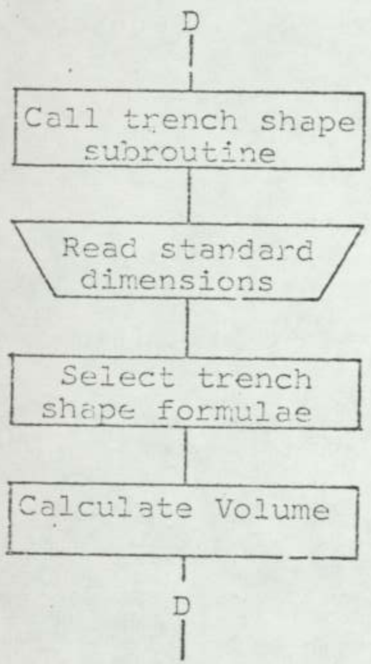


FIGURE.10.

Unique Trench Shape

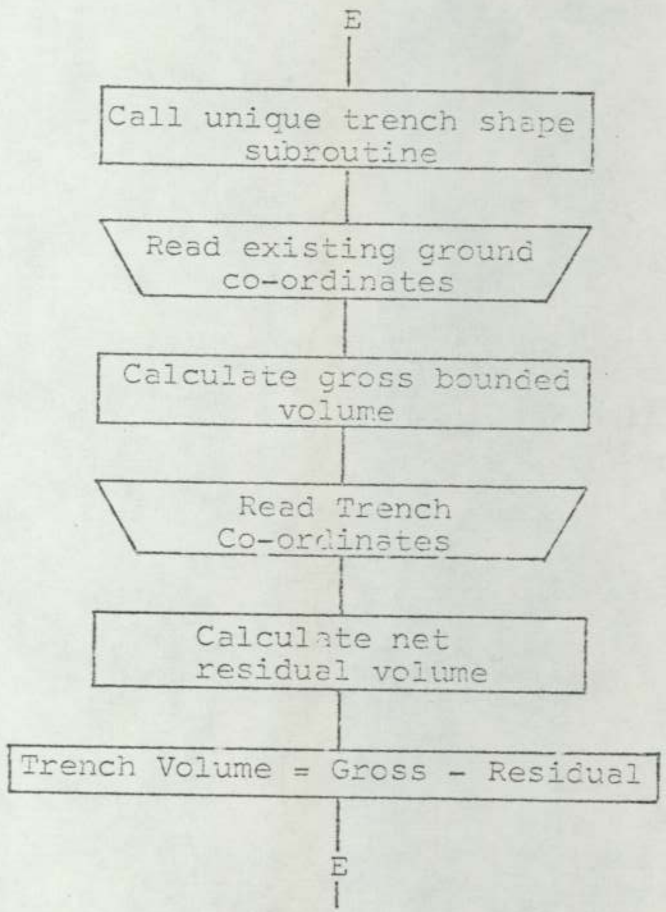


FIGURE.11.

Apparent Earth Pressure Subroutine

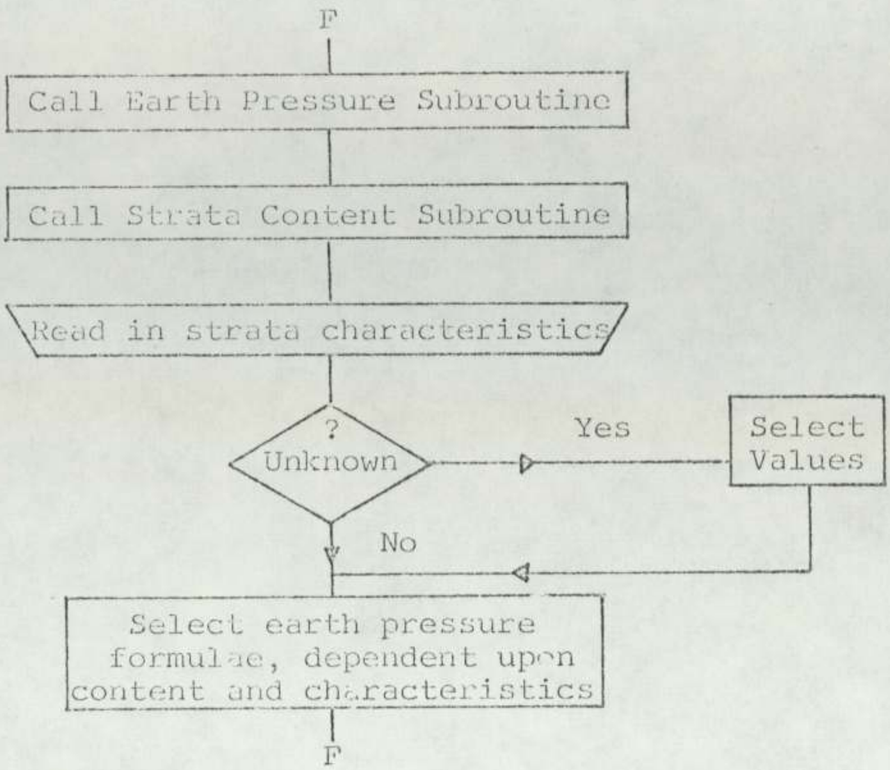


FIGURE.12.

Trench Support Structure

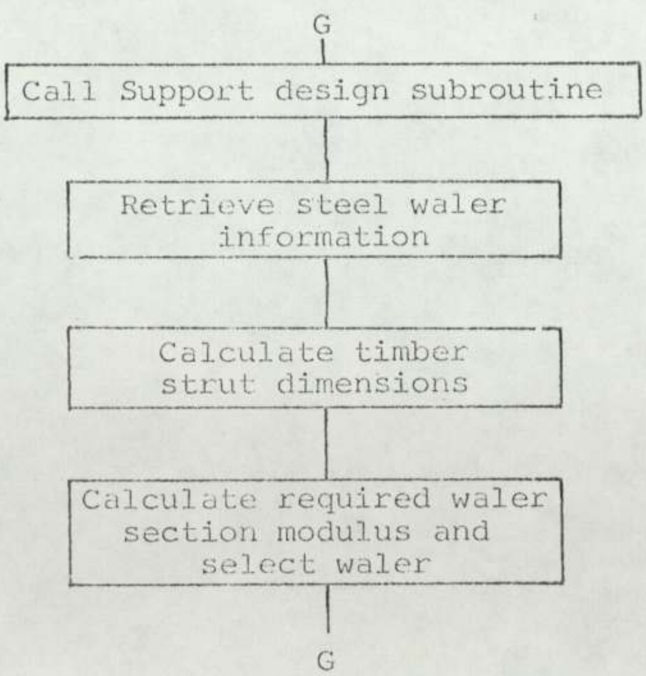


Figure.13.

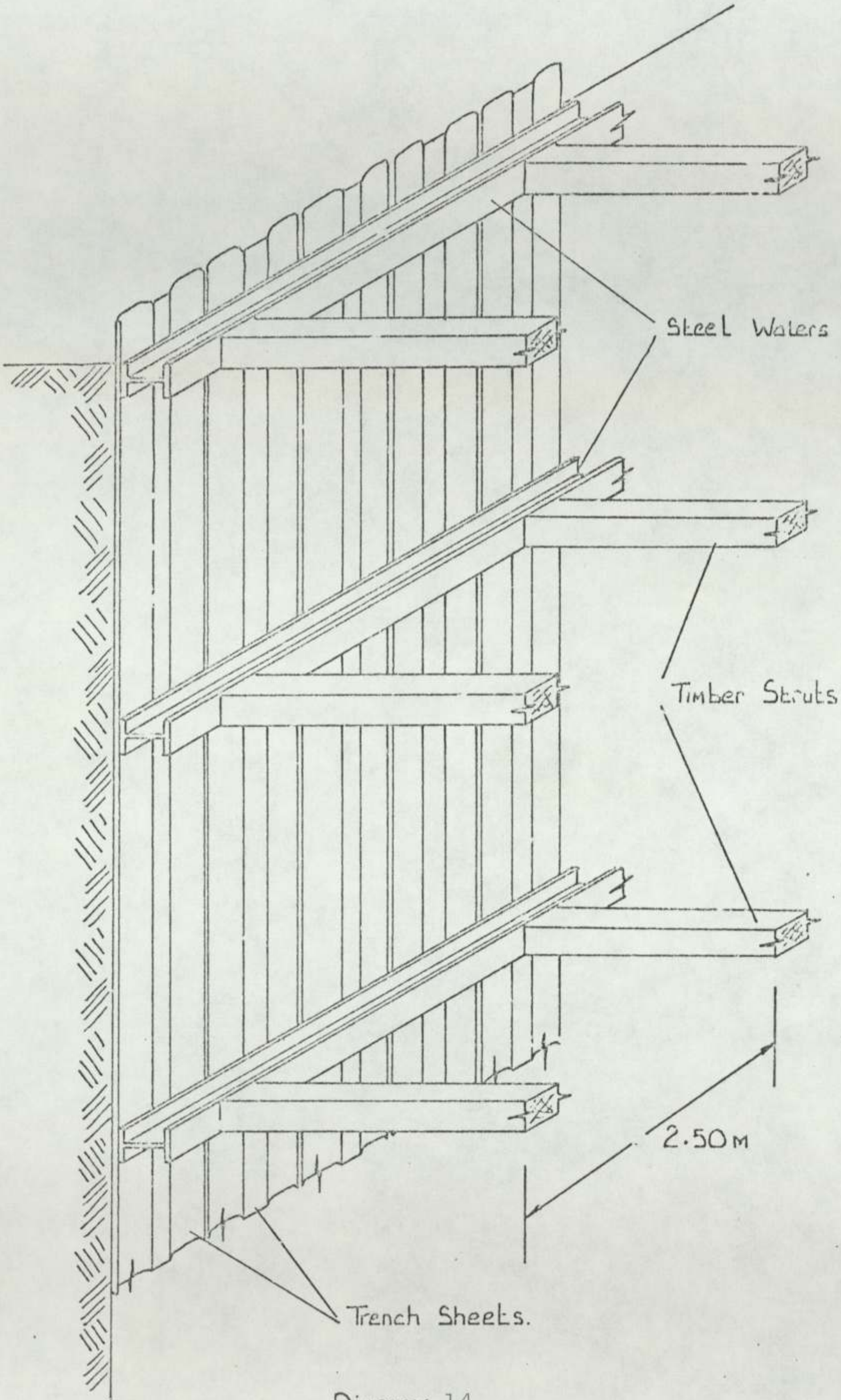


Diagram. 14.

4.3.1 Apparent Earth Pressure Element Subroutine

The apparent earth pressure (Ap) is calculated using:-

$$Ap = C. K_A . \gamma . D \qquad ....(4)$$

The element subroutine (Figure.12) permits the user to specify which strata grading (Table.1.) is predominant. However, it is permissible to combine gradings to produce a more accurate representation of a strata which may possess several characteristics.

The pressure distributions are assumed to be rectangular. If the density, cohesion and angle of internal friction are unknown, values of 2082.6 kg/m^3, 1400.0 kg/m^2 and 25 degs. are assumed by the element subroutine.

4.3.2 Support Structure Design Element Subroutine (Figure.13.)

The element subroutine produces several feasible design structures. Starting with a vertical strut/waler spacing of 0.5 m increasing in increments of 0.5m to the maximum permissible, the designs being intended for estimating and planning purposes only. A basic structural configuration (Figure.14) is hypothesised based on the following design theory and assumptions:-

(a) B.S.P. type T5 trench sheets are used
width = 0.33 M
Section Modulus = 56×10^{-6} M^3
Allowable Bending Stress = 165 MN/M^2

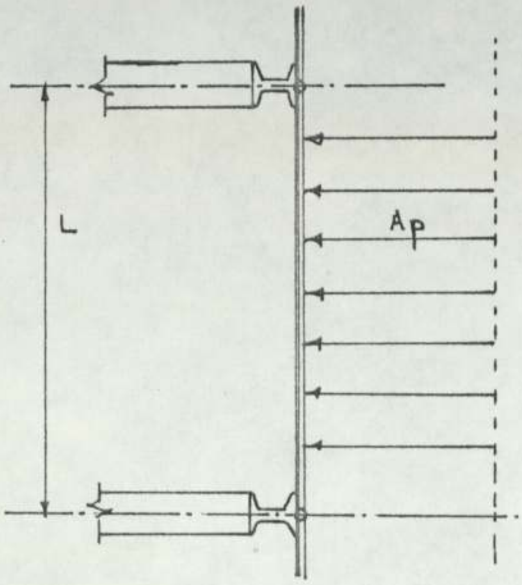
(b) The horizontal strut spacing is 2.5m (the length of one pipe).

(c) Each 2.5M structural unit is independently assembled.

(d) Grade 43 steel walers are used.

(e) Grade 2 square section struts are used.

4.3.3 Maximum Vertical Waler Spacing (L)



Maximum Bending Moment $M = \frac{ApL^2}{8}$

$$M = f.Z$$

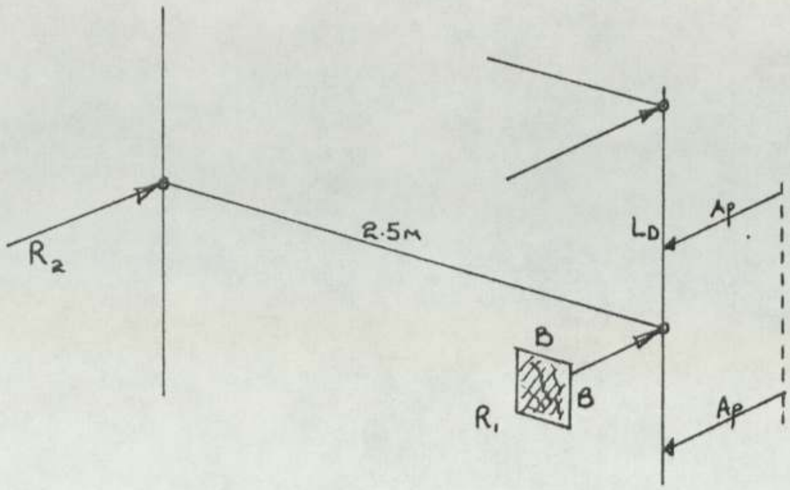
per trench sheet $\frac{0.33ApL^2}{8} = f.Z$

$$\frac{0.33ApL^2}{8} = 56 \times 10^{-6}.165 \times 10^3$$

$$L^2 = \frac{56 \times 165 \times 10^{-3} \times 8}{0.33 \times Ap}$$

$$L = 15.43 / \sqrt{Ap} \quad -(M) \qquad \ldots\ldots\ldots\ldots(5)$$

4.3.4 Magnitude of the Timber Struts



$$R_1 = R_2 = R$$

$$R_1 + R_2 = Ap.L_D.2.5$$

$$R = Ap.L_D.1.25 \qquad ....(6)$$

let applied compressive stress = Ca

Allowable compressive stress = Cp

From C.P.112

$$\frac{Ca}{K_5\ Cp} \leq 0.90$$

where $K_5 = 0.61$ (for $l/r = 90$)

$Cp = 5.516\ MN/M^2$

Standard used in the company is given by

$$\frac{Ca}{Cp} = 0.429$$

$$\underline{Ca = 0.429 \times 10^3 \times 5.516}\ \ KN/M^2 \ ....(7)$$

Now $Ca = \frac{R}{B^2}$ ....(8)

Therefore substituting (6) and (7) into (8)

$$B^2 = \frac{Ap.L_D.1.25}{429 \times 5.516}$$

$$B^2 = Ap.L_D.528.236 \text{ ---}(MM^2)$$

$$\underline{\underline{B = 22.9833 \sqrt{Ap.L_D}}}$$ ....(9)

To satisfy slenderness, irrespective of stress.

$$I = B^4/12 \quad \text{and} \quad A = B^2$$

$$\therefore \quad r^2 = B^2/12$$

$$r = B / \sqrt{12}$$

from Cp 112

$$l/r = 90 \quad \text{let } l = \text{trench width}$$

$$\frac{w\sqrt{12}}{B} = 90$$

$$\therefore \quad \underline{\underline{B = 0.03849.w}}$$ ....(10)

Hence $\underline{\underline{B \geqslant 22.9833 \sqrt{Ap.L_D} \geqslant 0.03849.w}}$

4.3.5 Magnitude of Steel Waler

$$M = f.Z$$

$$M = Ap.L_D.\frac{2.5^2}{8} \text{ -----KNM}$$

$$f = 165 \text{ MN/M}^2$$

Trench Support Construction Time

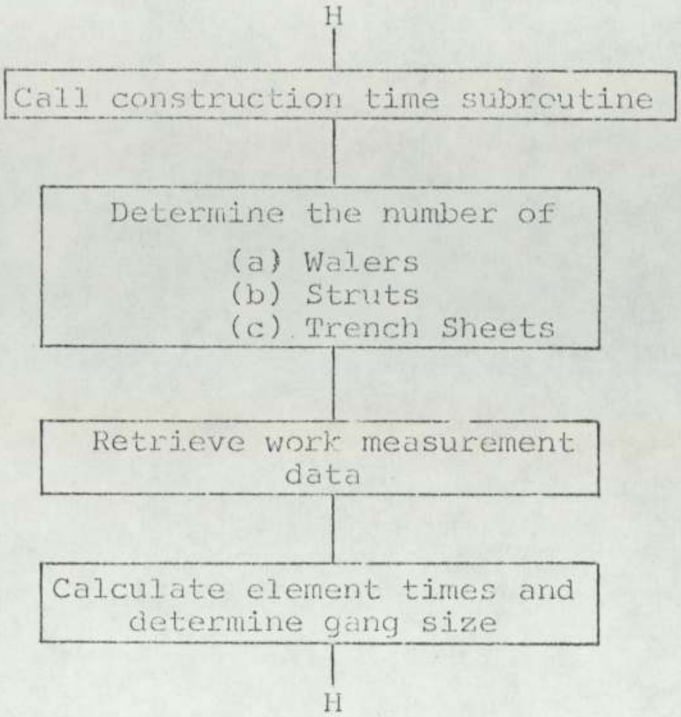


FIGURE.15.

Pipe Laying Time

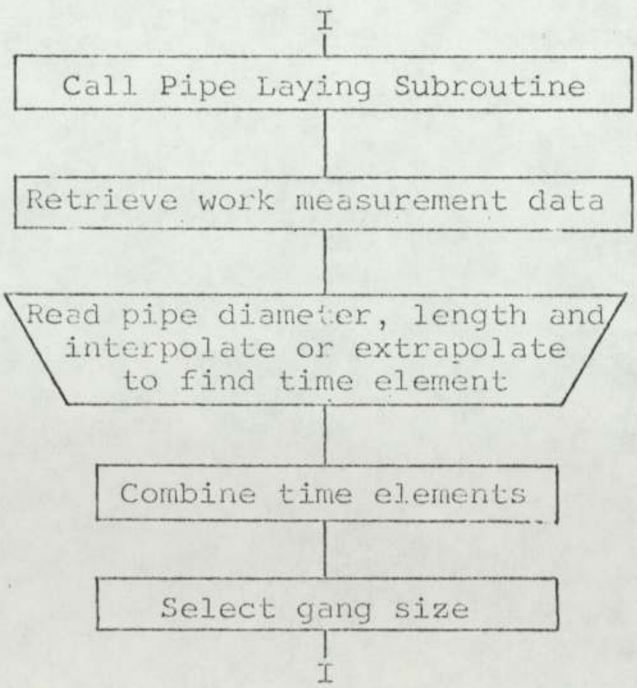


FIGURE.16.

$$\therefore \quad Ap.L_D.\frac{2.5^2}{8} = 165.10^3.Z$$

$$Z = Ap.L_D.\frac{2.5^2.10^6}{8.165.10^3} \quad CM^3$$

$$A = 4.734.Ap.L_D \qquad \ldots\ldots\ldots\ldots\ldots(11)$$

4.3.6 Erection Time, Gang and Plant Requirements Element Subroutine

This subroutine (Figure.15) uses the various design configurations produced by the design subroutine. It calculates the number of structural members required and uses stored work measurement data (Appendix 1) to determine the standard erection time and resources req irements. The user then selects the design configuration to be used in the total pipeline operation analysis.

4.2 Pipelaying Sub-Programme

This (Figure.16) stores the work measurement information (Appendix 1) for 16 different elements of the pipelaying operation. It calculates the construction time for any number of pipes, for pipe diameters ranging from 100 to 2100 mm and any pipe length specified. The times and gang sizes produced depend on the diameter of the pipes and the depth to which they are laid. A detailed summary is produced for each pipe analysed culminating in an intermediate summary at the end of the pipe laying element.

4.5 Pipe Bedding Sub-Programme

Two 'element subroutines' deal with this construction element. The first, (Figure.17.) calculates the volume of material to be used (excluding wastage) and the second, (Figure.18.) calculates the construction time and gang size required. The material volumes calculated are based on 8 (Table.3.) structural shapes most commonly used. The construction time and gang size calculations depend on the material used and the depth at which it is laid. One of three material types are considered:-

(1) Concrete

(2) Granular

(3) Selected Backfill

The user can input specific bedding structure dimensions based on the shapes available or use the standard minimum dimensions given in Table.3.

The output produced details the information required for each pipe. A general summary is produced when all bedding structures have been processed.

4.6 Backfill Sub-Programme

This sub-programme contains one 'element subroutine' (Figure.19.) which calculates the volume of the backfill material and produces four backfill methods, one of which is selected by the user. The construction time is calculated for each gang and is based on the thickness of the compaction layers. Individual summaries are produced, the main items of information being stored to produce an overall pipeline operation summary on completion of the analysis.

4.7 Overall Standard Output and Resources for the Pipeline Operation (Figure.20.)

After processing the individual elements of the pipeline operation, the construction times and gang sizes are stored. The user specifies which Road Breakout, Excavation Support and Backfill method is to be used. The programme then calculates the overall standard output and the resources required. A single gang is assumed.

The programme processes only the main construction elements of pipeline operation, hence the resultant gang size is based on the actual productive work anticipated. In practice, many minor ancillary operations take place which are non-productive, tidying up, removing the occasional obstacle, checking the excavator etc. These occur infrequently and are, to a certain extent, allowed for when standardising the work meas rement data. However, site observations indicate that the flexibility produced by not minimising the waiting time is necessary.

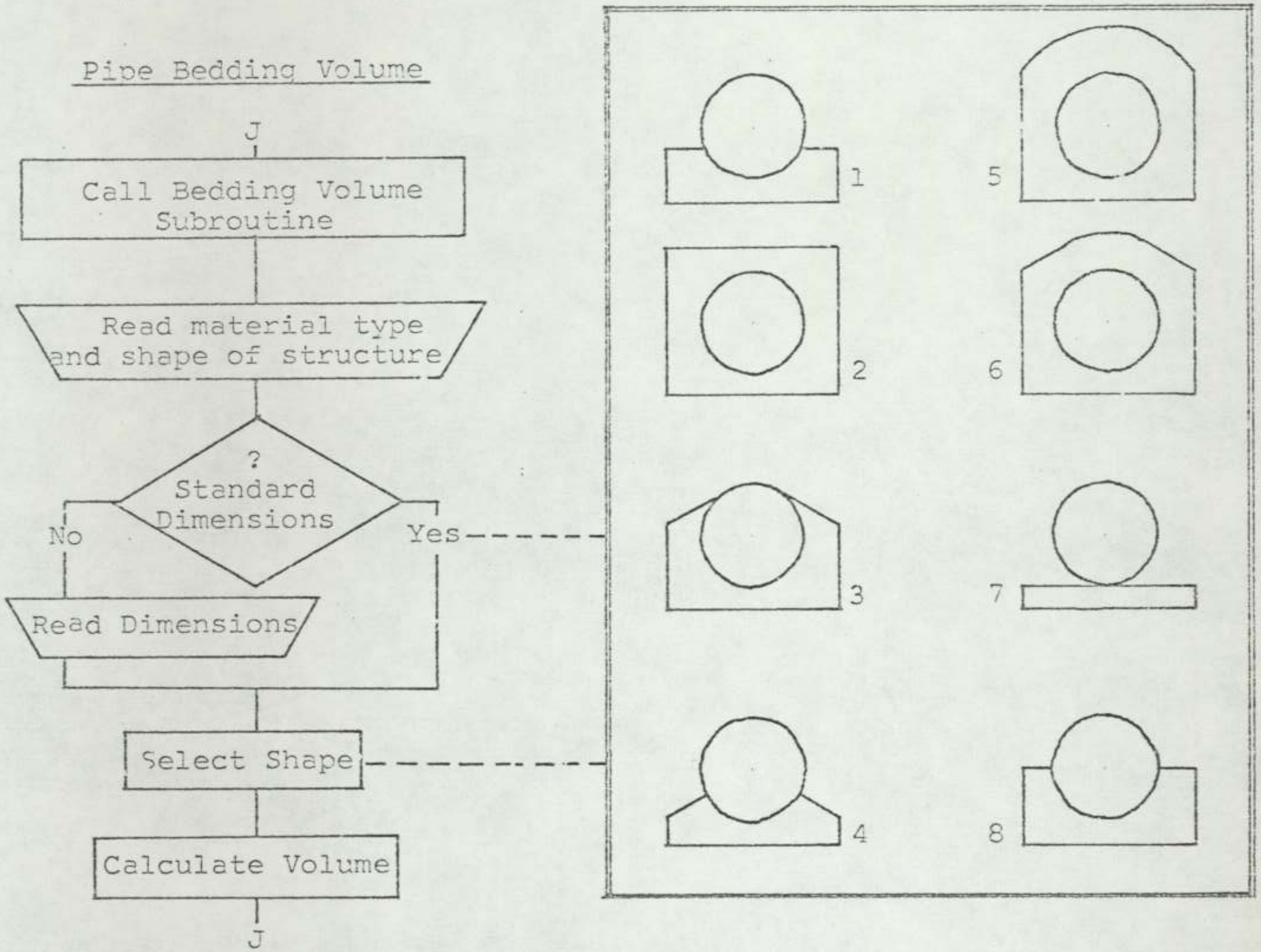


FIGURE.17.

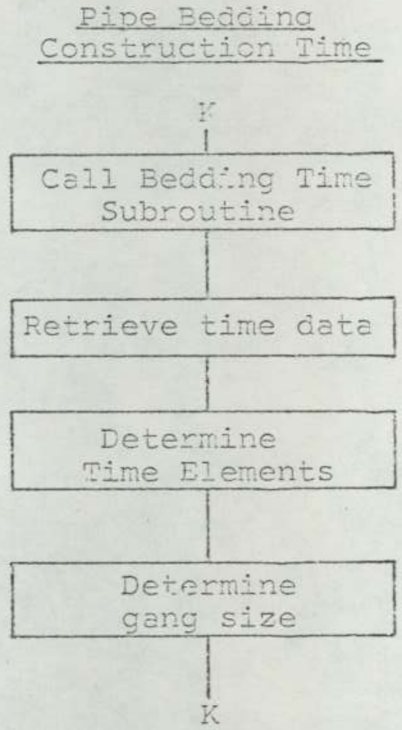
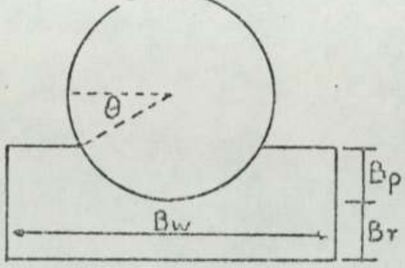
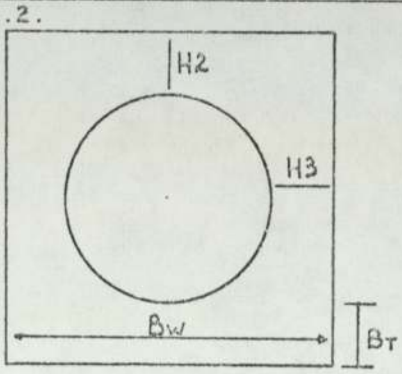
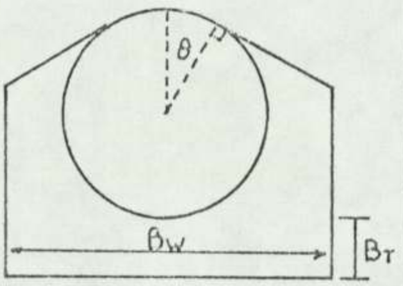
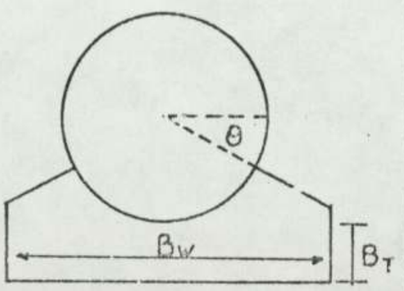
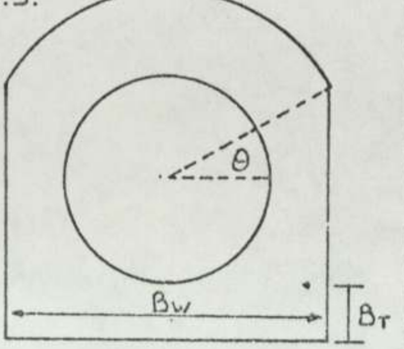


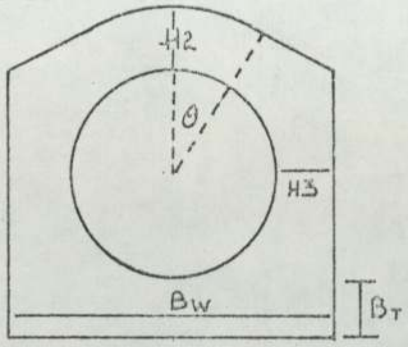
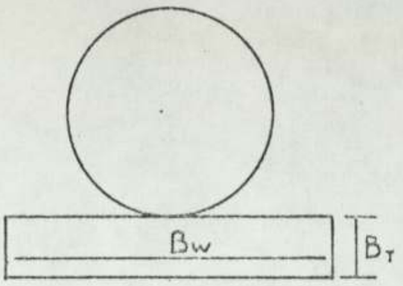
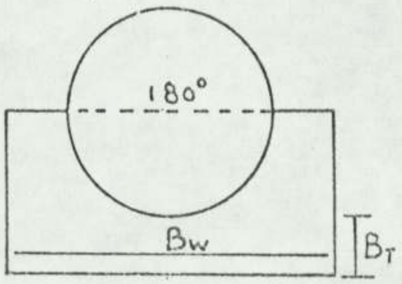
FIGURE.18.

TABLE. 3.

STANDARD BEDDING STRUCTURES

<table>
<tr><th>TYPE</th><th>STANDARD DIMENSIONS</th></tr>
<tr><td></td><td>D = Internal diameter of pipe
Bc = External diameter of pipe</td></tr>
<tr><td>TYPE.1.
</td><td>Bp = 0·25 Bc
BT = 0·25 D (100MM min)
BW = 1·25 Bc or Bc + 200MM (which ever is greater)
θ = 30°</td></tr>
<tr><td>TYPE.2.
</td><td>H3 = (BW - Bc)/2·0
H2 = H3
BT = 0·25 D (100 MM min)
BW = 1·25 Bc or Bc + 200 MM</td></tr>
<tr><td>TYPE.3.
</td><td>BT = 0·25 D (100 MM min)
BW = 1·25 Bc or Bc + 200 MM
θ = 30°</td></tr>
<tr><td>TYPE.4.
</td><td>BT = 0·25 D (100 MM min)
BW = 1·25 Bc or Bc + 200 MM
θ = 30°</td></tr>
<tr><td>TYPE.5.
</td><td>BT = 0·25 D (100 mm min)
BW = 1·25 Bc or Bc + 200 MM
θ = 30°</td></tr>
</table>

continued overleaf.

TYPE.6. 	$H3 = (Bw - Bc)/2.0$ $H2 = H3$ $B_T = 0.25D$ (100MM min) $Bw = 1.25\ Bc$ or $Bc + 200$ mm $\theta = 30°$
TYPE.7. 	$B_T = 0.25D$ (100 mm min) $Bw = 1.25\ Bc$ or $Bc + 200$ mm
TYPE.8. 	$B_T = 0.25D$ (100 mm min) $Bw = 1.25\ Bc$ or $Bc + 200$ mm.

Backfill Volume and Construction Time

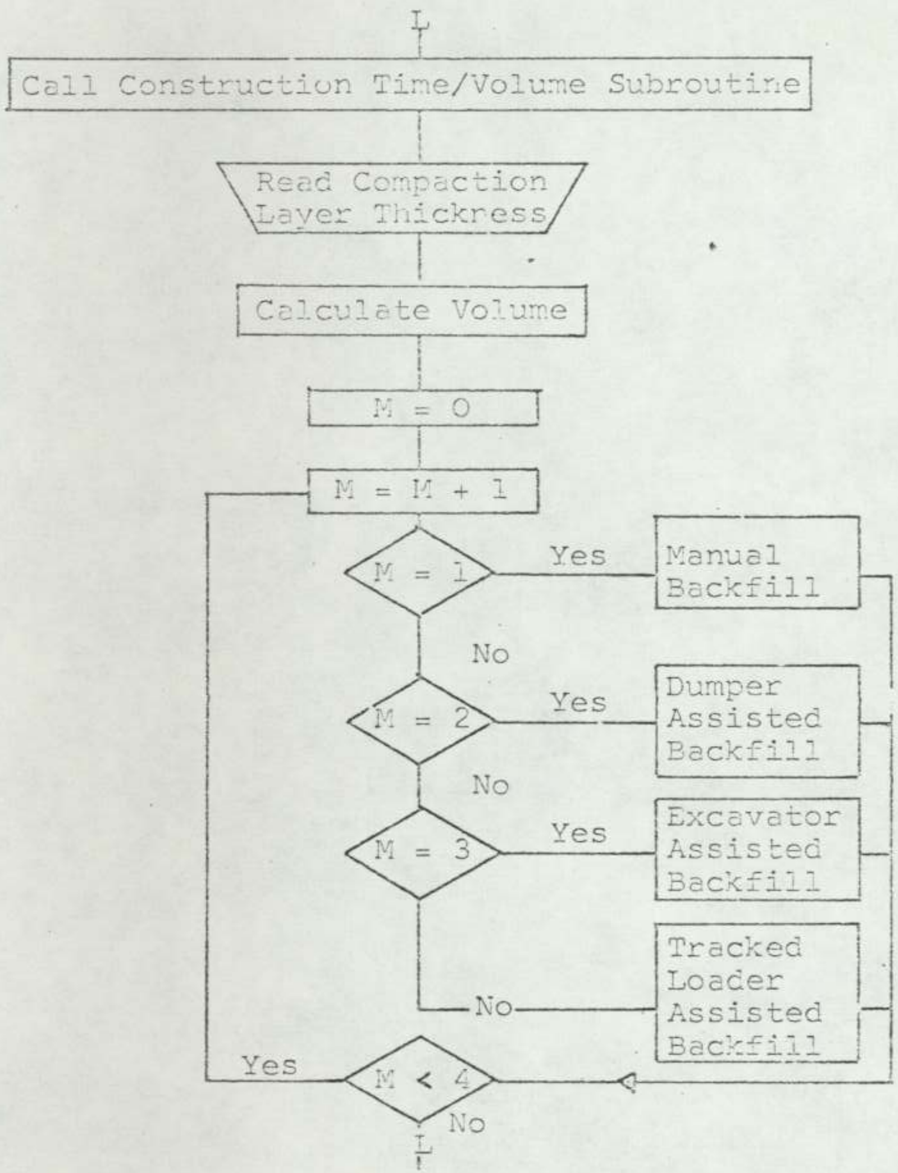


FIGURE.19.

Summary Preparation

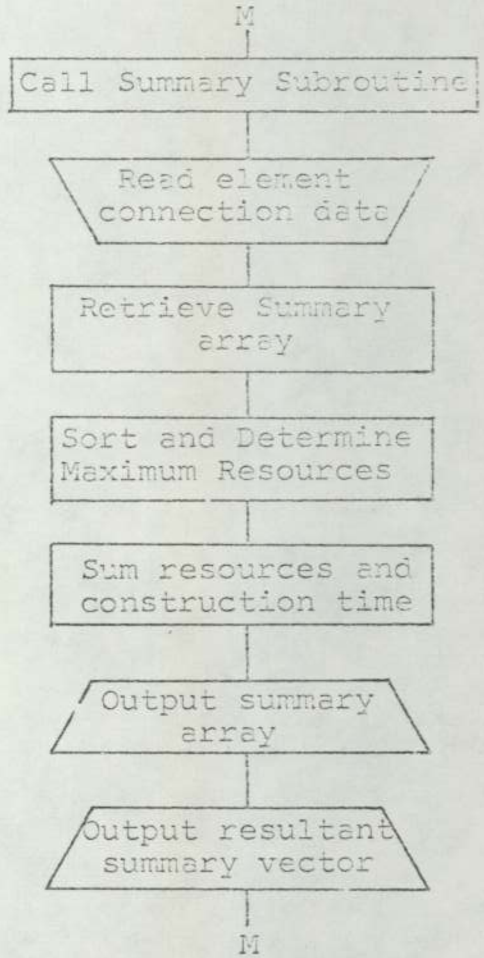


FIGURE.20.

SECTION 5

PIPELINE

USER MANUAL

CONTENTS

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5.2	General Information Input	41
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5.1 Restrictions

(a) All dimensions must be metric.

(b) Data must be entered for all sections unless stipulated otherwise.

(c) All column numbers are inclusive in the field specification.

(d) Data must be entered 'right bias' (the last figure of the item of data should be entered in the right most column).

(e) * In the field specification signifies that there is no column restriction.

5.2 General Information Input

Card Number	Field	Input Description
1	*	Number of pipeline items to be analysed.
2	1 to 24	Job description.
3	1 to 4	Bill Number.
4	1 to 4	Page Number.
5	1 to 4	Item Number.
6	1 to 5	Diameter of largest pipe in millimeters.
	6 to 13	Class of pipe.
	14 to 21	Class of Bedding material.
	22 to 26	Mean depth to invert in metres to 3 decimal places.
	27 to 31	Maximum depth to invert in metres to 3 decimal places.

Card Number	Field	Input Description
	32 to 39	Length of pipeline in metres to 3 decimal places.

5.3 Road Breakout

Card Number	Field	Input Description
1	*	If road breakout is not to be included enter 0. If it is to be included, enter 1.

(carry on with tis section only if 1 was entered previously. If 0 was entered, start section 4)

Card Number	Field	Input Description
2	1	Enter 1 if road is concrete. Enter 0 if road is Tarmac-cadam.
3	1 to 5	Width to be broken out in metres to 3 decimal places.
	6 to 10	Thickness to be broken out in millimetres.
	11 to 18	Length to be broken out in metres to 3 decimal places.

5.4. Machine Selection and Excavation Input

Card Number	Field	Input Description
1	*	Machine bucket width in millimetres.
	*	Maximum digging depth in millimetres.

Card Number	Field	Input Description
	*	Strata Grading (see table 1)
2	*	Obstruction Grading (see table 2).
3	*	Width of excavation in metres.
4	*	Horizontal reach required in metres.
	*	Vertical unloading height required in metres.
5	*	0 if the volume of the excavation is to be calculated by co-ordinates. 1 if the volume of the excavation is to be calculated from standard shapes.

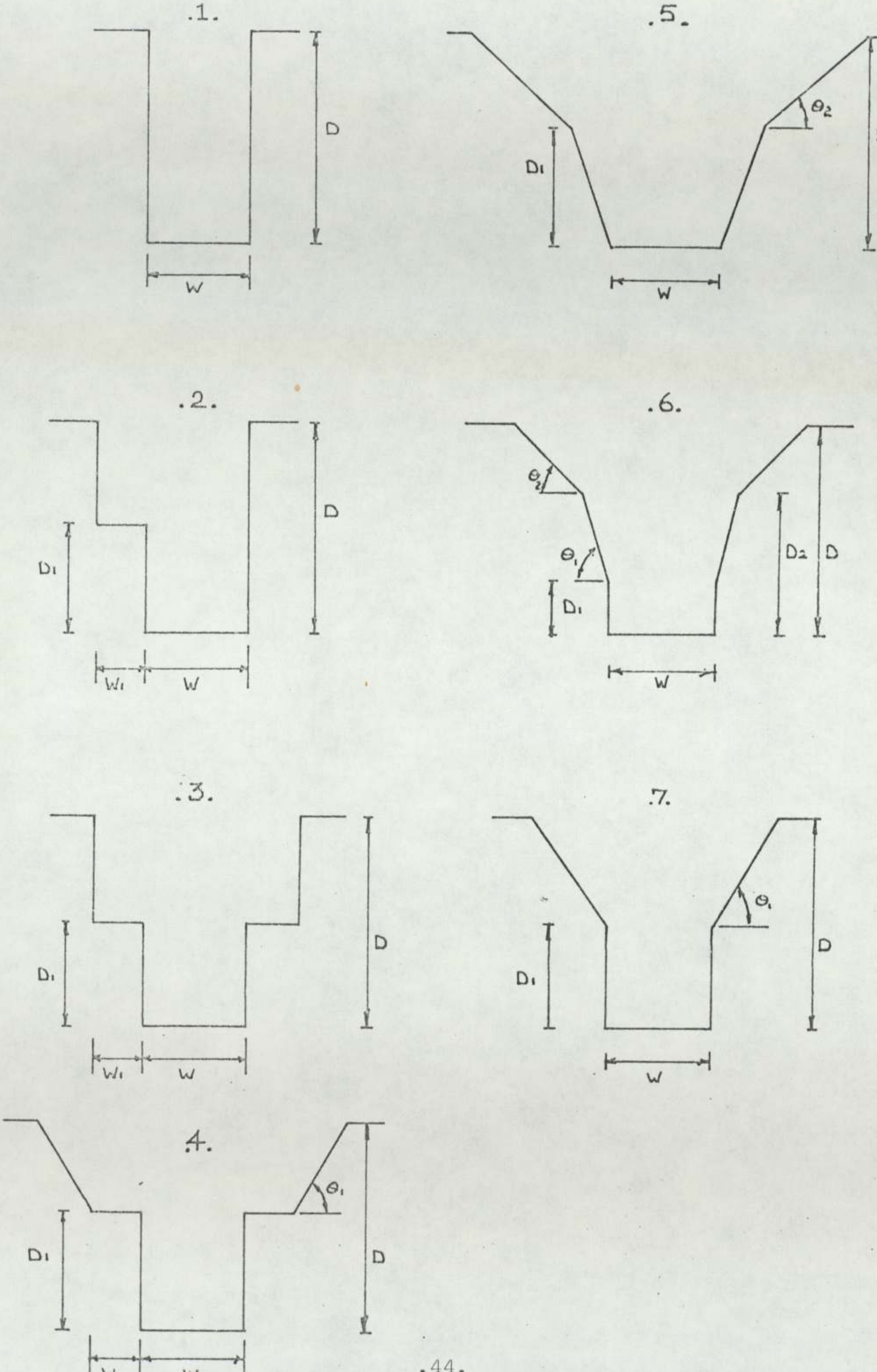
(If 0 was entered, go to section 5.4.2, if 1 was entered, carry on with section 5.4.1).

5.4.1 Standard Trench Shape

Card Number	Field	Input Description
1	*	Trench shape from table 4.
2	1 to 10	Total depth (D) in metres to 3 decimal places.
	11 to 20	Prime width (W) in metres to 3 decimal places.
	21 to 30	Secondary depth (D_1) in metres to 3 decimal places.

TABLE .4.

STANDARD TRENCH SHAPES



Card Number	Field	Input Description
	31 to 40	Secondary width (W_1) in metres to 3 decimal places.
	41 to 50	Third depth (D_2) in metres to 3 decimal places.
	51 to 55	Primary Angle (θ_1) in degrees.
	56 to 60	Secondary Angle (θ_2) in degrees.

(If the shape applicable does not contain the variables specified above, leave the field width blank). Having completed section 5.4.1, start section 5.5.

5.4.2 Co-ordinate Trench Shape

Existing Ground Level Co-ordinates

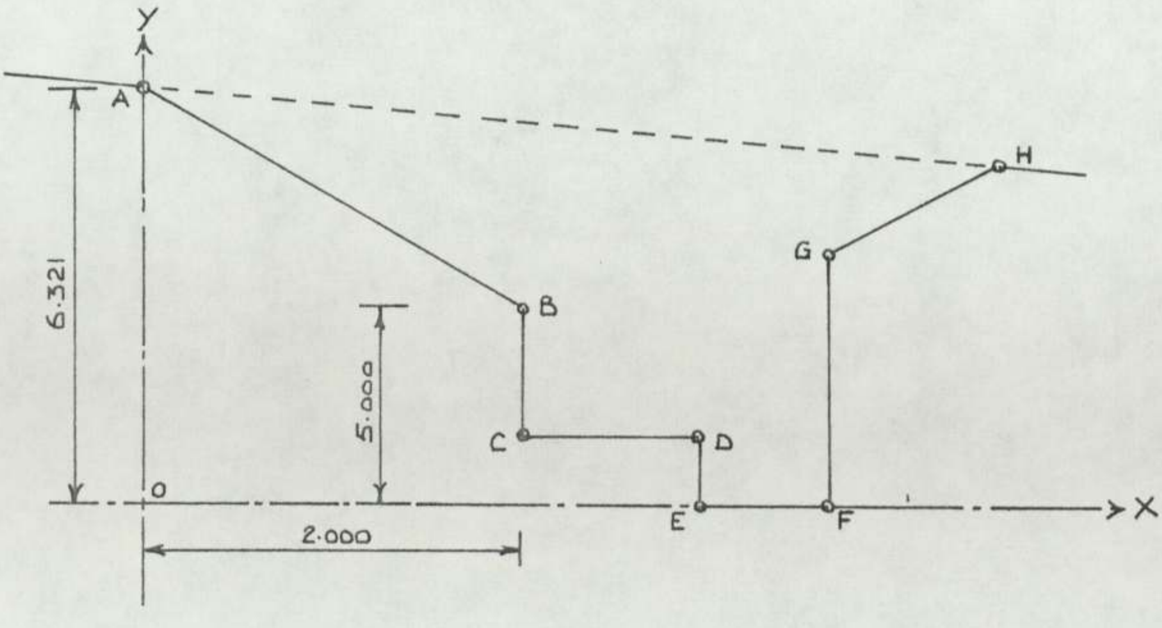
Card Number	Field	Input Description
1	*	Enter 0.
2	1 to 10	Enter the horizontal co-ordinates of the existing ground in metres to 3 decimal places.
	11 to 20	Enter the vertical co-ordinate of the existing ground in metres to 3 decimal places.
	21	Enter 0 if there are more existing ground co-ordinates to follow. Enter 1 if there are no more to follow.
3	*	Enter 1.

Excavation Co-ordinates

Card Number	Field	Input Description
4	1 to 10	Enter the horizontal co-ordinate of the trench to be excavated. They should be in metres to 3 decimal places.
	11 to 20	Enter the vertical co-ordinates of the trench to be excavated. They should be in metres to 3 decimal places.
	21	Enter 0 if there are more co-ordinates to follow. Enter 1 if there are no more to follow.

There are as many card 6's and card 8's as there are changes in the line and level.

Example showing the input of cards '5' to '8' inclusive:-



Procedure

(a) Construct axes X and Y on the sketch at the <u>lowest</u> and the most <u>left</u> extremities of the excavation.

(b) Note all the points on the diagram where changes in line or level occur (A,B,C,D,E,F, G,H). All the change points must be references to the X and Y axes.

Example

The co-ordinates of change point A are:-

X = 0.000

Y = 6.321

The co-ordinates of change point B are:-

X = 2.000

Y = 5.000

How to fill in cards 5 to 8 inclusive:-

(i) Consider the existing ground <u>only</u>.

(ii) Enter '0' in column '5' of card 5 (this tells the computer that the existing ground level co-ordinates will follow.

(iii) Enter the 'X' and 'Y' co-ordinates of point 'A' between columns 1 to 10 and 11 to 20 respectively of card 6. Enter '0' in column '21' of card 6 to indicate that point 'H' has still to be referenced.

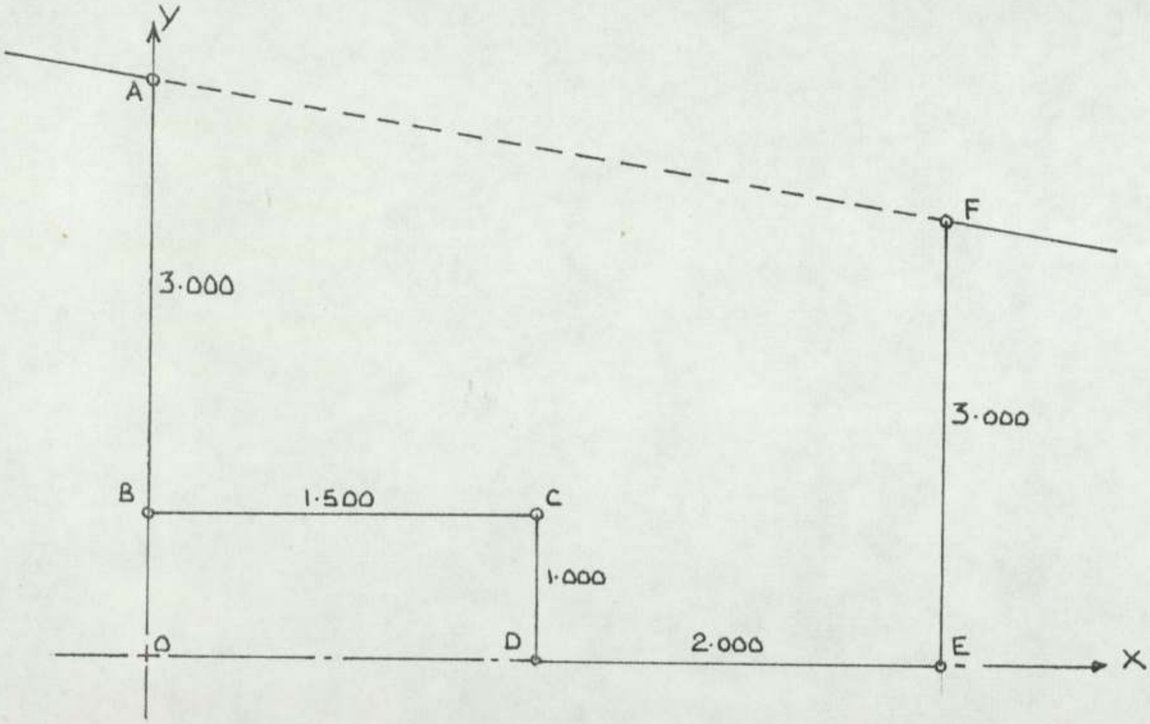
(iv) Enter the 'X' and 'Y' co-ordinates of point 'H' between columns 1 to 10 and 11 to 20 respectively, but enter '1' in column 21 to show that it is the last existing ground co-ordinate to be entered.

(v) Consider the Excavation only.

(vi) Enter '1' in column 5 of card 7 (this tells the computer that the excavation is now being considered and the trench co-ordinates will follow).

(vii) Card 8, enter the 'X' and 'Y' co-ordinates of points 'A' to 'H' (inclusive in columns 1 to 10 and 11 to 20. Enter '0' in column 21 of every card 8 except the last when '1' should be entered.

Worked Example



See the following data sheet for solution.

			INTERSECTION POINT	CARD Nº.
0				5
	0.000	4.0000	A	6
	3.500	3.0001	F	
1				7
	0.000	4.0000	A	
	0.000	1.0000	B	
	1.500	1.0000	C	8
	1.500	0.0000	D	
	3.500	0.0000	E	
	3.500	3.0001	F	

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5.5. Trench Support Design and Construction

Card Number	Field	Input Description
1	*	O if support is not re-required, 1 is support is required.

(If O was entered, go to section 5.6)

Card Number	Field	Input Description
2	5	Enter 1 if the strata to be supported contains sand. Enter O if not.
	10	Enter 1 if the strata to be supported contains clay. Enter O if not.
	15	Enter 1 if the strata contains stiff fissured clay. Enter O if not.
	16 to 25	Enter the depth of the strata to be supported in metres to 3 deciman places.
	26 to 35	Enter the width of the trench to be supported in metres to 3 decimal places.
3	1 to 10	Enter the density of the strata in kg/m^3 to 1 decimal place. If it is unknown, put 99.0

Card Number	Field	Input Description
3	11 to 15	Enter the Angle of Internal Friction of the Strata, in degrees to 1 decimal place. If it is unknown, put 99.0.
	16 to 25	Enter the value of cohesion for the strata in kg/m^2 to one decimal place. If it is unknown, put 99.0.
4	*	1 if close sheeted support. 2 if medium sheeted support. 3 if open sheeted support.

5.6. Pipe Laying Input

Card Number	Field	Input Description
1	*	Enter the number of pipes in the trench (on cross section).
2	1 to 5	Enter pipe diameter in millimeters. (refer to table 5).
	6 to 10	Enter pipe length in metres to 3 decimal places. (refer to table 5).
	11 to 15	Enter the depth to which the pipe is laid in metres

TABLE.5.

Diameter (mm)	Length (m)			Overall Wall Thickness (mm)
100		1.83		26
150		1.83		26
225		1.83		30
300		1.83		34
375		1.83		38
450		1.83	2.44	41
525		1.83	2.44	48
600		1.83	2.44	52
675		1.83	2.44	56
750		1.83	2.44	60
825		1.83	2.44	64
900		1.83	2.44	67
975		1.83	2.44	71
1050		1.83	2.44	78
1125		1.83	2.44	82
1200		1.83	2.44	86
1275		1.83	2.44	86
1350		1.83	2.44	93
1425		1.83	2.44	97
1500		1.83	2.44	101
1575		1.83	2.44	114
1650		1.83	2.44	115
1725		1.83	2.44	115
1800	1.22	1.83	2.44	116
1875	1.22	1.83	2.44	123
1950	1.22	1.83	2.44	130
2025	1.22	1.83	2.44	137
2100	1.22	1.83	2.44	144

to 3 decimal places.

Card number 2 should be repeated as many times as there are pipes in the trench.

5.7. Bedding Structure Input

Card Number	Field	Input Description
1	*	Enter the number of pipes in the trench (on cross section).
2	*	Enter 1 if the bedding material is concrete. Enter 2 if the bedding water is granular fill. Enter 3 if the bedding material is selected backfill.
2	*	Enter the bedding structure type to be analysed. (See table 3).
4	1 to 5	Enter the inside barrel diameter of the pipe in millimetres.
	6 to 10	Enter the wall thickness of the pipe in millimetres (refer to table 5).
	15	Enter 0 if you wish to specify your own bedding structure dimensions. Enter

1 if you wish to use standard dimensions. (Table 3).

If '0' was entered in column 15 of card 4, carry on to card number 5 in this section. If '1' was entered, repeat from card 2 for the next pipe in the trench. However, if there are no more, go on to section 5.8.

Select the bedding structure type from table 6.

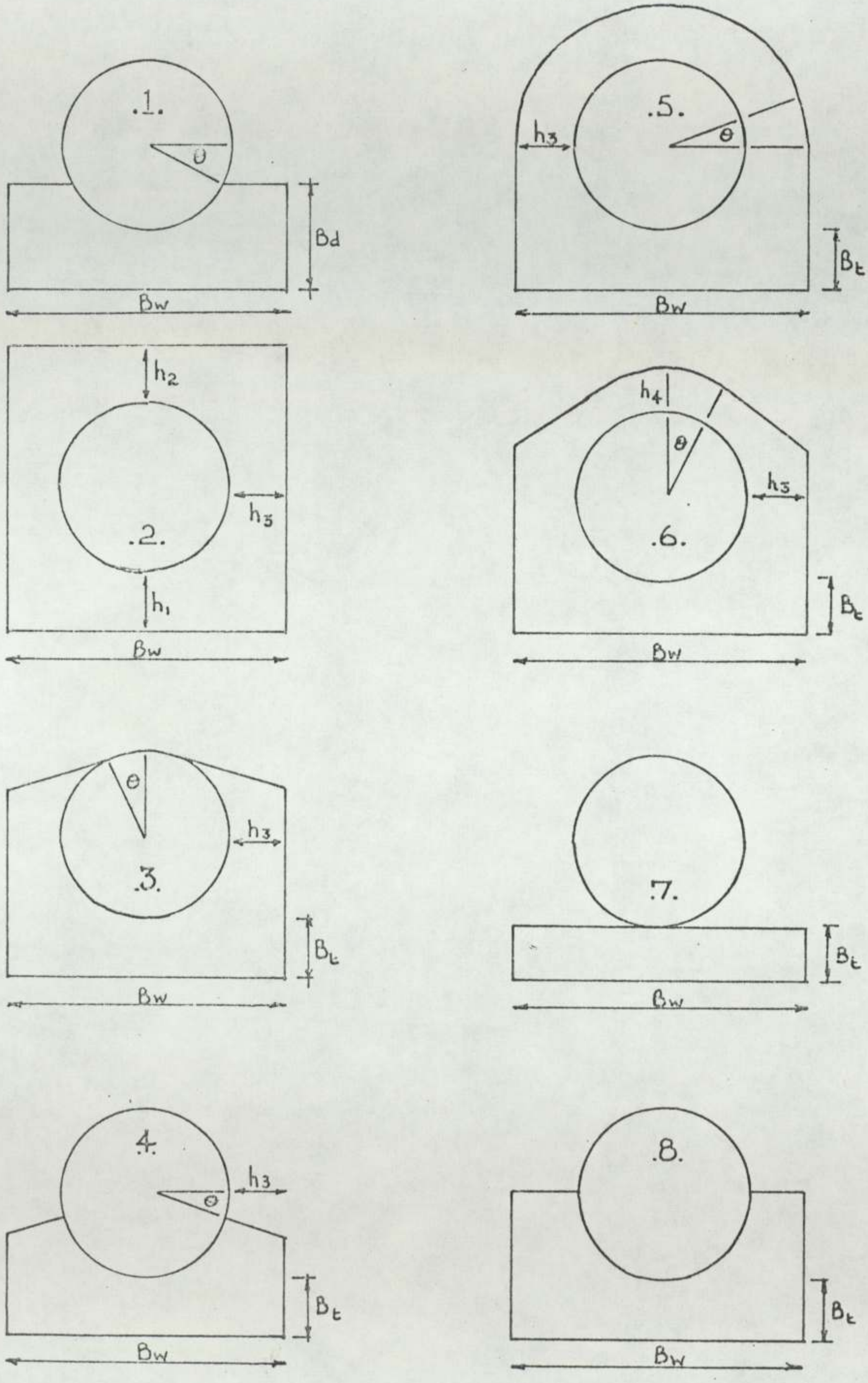
Card Number	Field	Input Description
5	1 to 5	Bed width (Bw) in millimetres.
	6 to 10	Bed thickness (B_t) in millimetres.
	11 to 15	Bed depth (Bd) in millimetres.
	16 to 20	Bottom cover (h_1) in millimetres.
	21 to 25	Top cover (h_2) in millimetres.
	26 to 30	Side cover (h_3 in millimetres.
	31 to 35	Angle top cover (h_4) in millimetres.
	36 to 40	Angular displacement (θ) in degrees.

Leave the field widths blank if the variables specified are not relevant to the shape selected.

Repeat from card 2 for the next pipe in the trench. However, if there are no more, go on to section 5.8.

TABLE. 6.

PIPE BEDDING STRUCTURE



5.8. Backfill

Card Number	Field	Input Description
1	*	The compaction layer thickness in millimetres.

5.9. Summary Input (Refer to Table.7.)

Card Number	Field	Input Description
1	1 to 5	Road breakout method number.
	6 to 10	Trench support method number.
	11 to 15	Backfill method number.

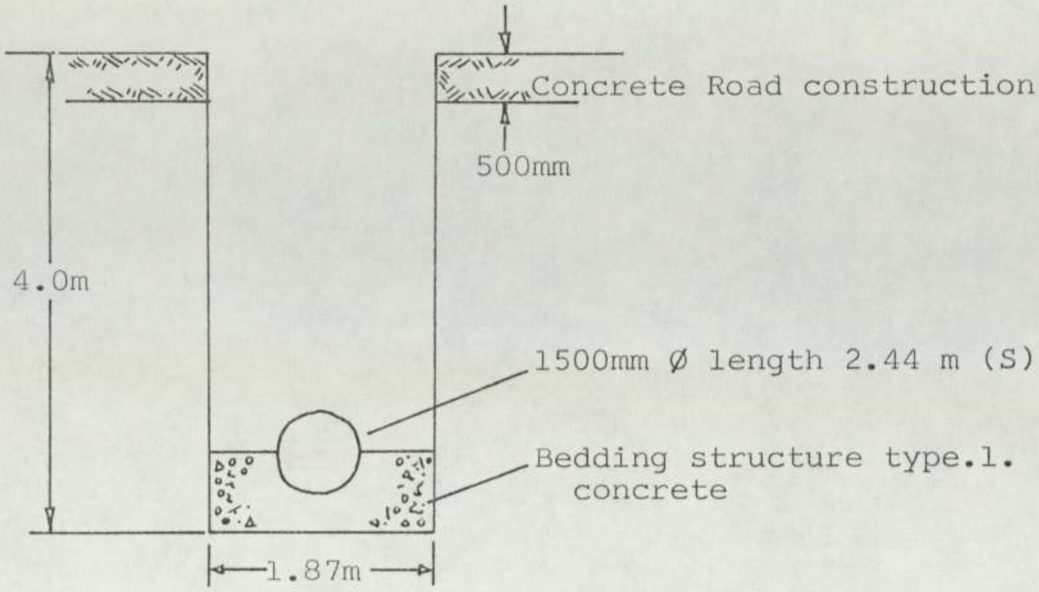
Table 7

Method Number Table

Description	Method	Method Number
Road Breakout	Medium breaker	1
Road Breakout	I.P.H.	2
Trench support	0.5 m Waler spacing	4
	1.0 m " "	5
	1.5 m " "	6
	2.0 m " "	7
	2.5 m " "	8
	3.0 m " "	9
	3.5 m " "	10
	4.0 m " "	11
Backfill	Manual	22
	Dumper assisted	23
	Excavator assisted	24
	Tracked loader	25

Repeat from section 2, card 3 for subsequent pipeline items.

5.10 Example Input and Output



Assume a strata grading of 7 and an obstruction grading of 5. The trench is to be supported with an open support configuration. The strength of the strata is unknown. See figure.21. for input format and page 59 to 71 for output.

```
1
DRATEPIP TEST 3
   8
   8
   8
 1500       S       A4.0004.000 100.000
1
1
1.870  500  10.000
1300 4000 7
5
1.870
2.000 2.000
1
1
     4.000     1.870
1
    1    1    0     4.000      1.870
      99.0 99.0      99.0
3
1
 15002.4403.750
1
1
1
 1500  101    1
150
    1    7   24
```

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Figure.21.

BILL ITEM TIME ANALYSIS

****

CONTRACT DESCRIPTION

****

DRATEPIP TEST 3

BILL NUMBER 8

PAGE NUMBER 8

ITEM NUMBER 8

PIPE INTERNAL DIAMETER	=	1500. MM
CLASS OF PIPE	=	S
CLASS OF BED	=	A
MEAN DEPTH OF TRENCH	=	4.000 M
MAXIMUM DEPTH OF TRENCH	=	4.000 M
LENGTH OF RUN	=	100.000M

ROAD BREAKOUT

****

CONCRETE ROAD CONSTRUCTION

****

WIDTH OF BREAKOUT	=	1.870 M
THICKNESS OF ROAD	=	500. MM
LENGTH OF BREAKOUT	=	10.00M
VOLUME OF BREAKOUT	=	0.935M3/MLIN

TWO ALTERNATIVE GANGS
****

GANG NUMBER.1..
NUMBER OF COMPRESSORS = 1.
NUMBER OF LABOURERS = 2.
STANDARD MANHOURS = 4.656HRS/MLIN
STANDARD DURATION = 2.328HRS/MLIN

GANG NUMBER.2..
NUMBER OF MACHINES(IPH) = 1.
NUMBER OF LABOURERS = 1.
STANDARD MANHOURS = 1.440HRS/MLIN
STANDARD DURATION = 0.720HRS/MLIN

MACHINE EXCAVATION RATE
****

MACHINES CONSIDERED
****

CODE	MACHINE NAME
1	JCB 3
2	JCB 3C
3	JCB 3D
4	JCB 5C
5	JCB 7B
6	HY-MAC 580
7	JCB 6C
8	JCB 6D
9	JCB 7C
10	RH 6

EXCAVATION DETAILS

****

STRATA GRADING	=	7.
OBSTRUCTION GRADING	=	5.
BUCKET WIDTH	=	1300.MM
LOADING HEIGHT	=	2.000M
REQUIRED REACH	=	2.000M
USE MACHINE TYPE	=	6
STANDARD OUTPUT	=	39.613M3/HR
TRENCH DEPTH	=	4.00M
TRENCH BASE WIDTH	=	1.870M
VOLUME OF EXCAVATION	=	7.480M3/M
STANDARD DURATION	=	0.189HRS/M

TRENCH SUPPORT SYSTEM DESIGN

****

TRENCH DETAILS: DEPTH=4.000 M

WIDTH=1.870 M

SOIL DETAILS: ANGLE OF INTERNAL FRICTION (PHI)=25.00 DEGS

COHESION (COH)=1400.00 KG/M2

SPECIFIC WEIGHT (GAMA)=2082.60 KG/M3

TRENCH SHEET DETAILS:

B.S.P. TYPE.T5. ELASTIC MODULUS=56.0CM3

WIDTH=0.33M

STRUT DETAILS: HORIZONTAL SPACING=2.50M

WALTER DETAILS:

SECTION NOTATION	SECTION SHAPE	SECTION WEIGHT (KG/M)	D (MM)	B (MM)	T (MM)	ELASTIC MODULUS (ZXX) (CM3)
1	I	13.38	127	76	7.6	75.12
2	I	17.10	152	89	8.3	115.90
3	I	20.82	178	76	10.3	150.40
4	I	23.80	203	76	11.2	192.00
5	I	25.00	203	133	7.8	231.00
6	I	30.00	207	134	9.6	279.00
7	I	31.00	251	146	8.6	352.00
8	I	43.00	260	147	12.7	504.00
9	I	31.00	307	166	11.8	646.00 ,

OPEN SHORING CONSTRUCTION DETAILS
****

VERTICAL WALER/STRUT SPACING = 0.500 M
****

NO OF TRENCH SHEETS	=	6./2.5M
LENGTH OF TRENCH SHEETS	=	4.333 M
NO OF TRENCH STRUTS	=	18./2.5M
LENGTH OF STRUTS	=	1.870 M
THICKNESS/WIDTH OF STRUTS	=	93. MM
NO OF WALERS	=	18./2.5M
USE WALER TYPE	=	2
WEIGHT OF WALER	=	17.10 KG/M
NUMBER OF MEN	=	4.
NUMBER OF MACHINES +DRIVERS	=	1.
STANDARD DURATION	=	0.907 HR/M
STANDARD MANHOURS	=	4.537 HR/M

OPEN SHORING CONSTRUCTION DETAILS
****

VERTICAL WALER/STRUT SPACING = 1.000 M
****

NO OF TRENCH SHEETS	=	6./2.5M
LENGTH OF TRENCH SHEETS	=	4.333 M
NO OF TRENCH STRUTS	=	10./2.5M
LENGTH OF STRUTS	=	1.870 M
THICKNESS/WIDTH OF STRUTS	=	131. MM
NO OF WALERS	=	10./2.5M
USE WALER TYPE	=	4
WEIGHT OF WALER	=	23.80 KG/M
NUMBER OF MEN	=	4.
NUMBER OF MACHINES + DRIVERS	=	1.
STANDARD DURATION	=	0.690 HR/M
STANDARD MANHOURS	=	3.448 HR/M

OPEN SHORING CONSTRUCTION DETAILS
****

VERTICAL WALER/STRUT SPACING = 1.500 M
****

NO OF TRENCH SHEETS	=	6./2.5M
LENGTH OF TRENCH SHEETS	=	4.333 M
NO OF TRENCH STRUTS	=	7./2.5M
LENGTH OF STRUTS	=	1.870 M
THICKNESS/WIDTH OF STRUTS	=	161. MM
NO OF WALERS	=	7./2.5M
USE WALER TYPE	=	6
WEIGHT OF WALER	=	30.00 KG/M
NUMBER OF MEN	=	4.
NUMBER OF MACHINES +DRIVERS	=	1.
STANDARD DURATION	=	0.608 HR/M
STANDARD MANHOURS	=	3.041 HR/M

OPEN SHORING CONSTRUCTION DETAILS
****

VERTICAL WALER/STRUT SPACING = 2.000 M
****

NO OF TRENCH SHEETS	=	6./2.5M
LENGTH OF TRENCH SHEETS	=	4.333 M
NO OF TRENCH STRUTS	=	6./2.5M
LENGTH OF STRUTS	=	1.870 M
THICKNESS/WIDTH OF STRUTS	=	186. MM
NO OF WALERS	=	6./2.5M
USE WALER TYPE	=	7
WEIGHT OF WALER	=	31.00 KG/M
NUMBER OF MEN	=	4.
NUMBER OF MACHINES +DRIVERS	=	1.
STANDARD DURATION	=	0.588 HR/M
STANDARD MANHOURS	=	2.941 HR/M

OPEN SHORING CONSTRUCTION DETAILS
****

VERTICAL WALER/STRUT SPACING = 2.500 M
****

NO OF TRENCH SHEETS	= 6./2.5M
LENGTH OF TRENCH SHEETS	= 4.333 M
NO OF TRENCH STRUTS	= 5./2.5M
LENGTH OF STRUTS	= 1.870 M
THICKNESS/WIDTH OF STRUTS	= 208. MM
NO OF WALERS	= 5./2.5M
USE WALER TYPE	= 8
WEIGHT OF WALER	= 43.00 KG/M
NUMBER OF MEN	= 4.
NUMBER OF MACHINES +DRIVERS	= 1.
STANDARD DURATION	= 0.605 HR/M
STANDARD MANHOURS	= 3.023 HR/M

OPEN SHORING CONSTRUCTION DETAILS
****

VERTICAL WALER/STRUT SPACING = 2.699 M
****

NO OF TRENCH SHEETS	= 6./2.5M
LENGTH OF TRENCH SHEETS	= 4.333 M
NO OF TRENCH STRUTS	= 4./2.5M
LENGTH OF STRUTS	= 1.870 M
THICKNESS/WIDTH OF STRUTS	= 216. MM
NO OF WALERS	= 4./2.5M
USE WALER TYPE	= 8
WEIGHT OF WALER	= 43.00 KG/M
NUMBER OF MEN	= 4.
NUMBER OF MACHINES +DRIVERS	= 1.
STANDARD DURATION	= 0.514 HR/M
STANDARD MANHOURS	= 2.568 HR/M

PIPE LAYING

****

PIPE NUMBER.1.	
PIPE DIAMETER	= 1500.MM
PIPE LENGTH	= 2.440M
DEPTH OF PIPE	= 3.750M
NO OF EXCAVATORS	= 0.
NO OF CRANES	= 1.
NO OF MEN	= 3
STANDARD DURATION	= 1.074HRS/PIP/
STANDARD DURATION	= 0.440HRS/MLIN

TOTAL FOR MULTIPLE PIPE TRENCH

****

COMBINED STANDARD DURATION	= 0.440HRS/MLIN
NO OF PIPES IN TRENCH	= 1

BEDDING CONDITIONS

****

BEDDING CLASS A (CONCRETE STRUCTURE)

****

D	T	BW	BT					
INTERNAL DIAMETER (MM)	WALL THICKNESS (MM)	BED WIDTH (MM)	BED THICKNESS (MM)	H1 (MM)	H2 (MM)	H3 (MM)	THETA (DEG)	VOLUME OF BEDDING MATERIAL FOR CONSTRUCTION TYPE.1. (M3/M LIN)
150.	10.	370.	100.	143.	0.	100.	30.	0.0483

NUMBER OF GANGERS 1.

NUMBER OF GENERAL LABOURERS = 2.

NUMBER OF PEGSON RAMMERS = 0.

STANDARD MAN HOURS = 0.1115 HRS/ML

STANDARD DURATION = 0.0372 HRS/ML

TOTAL DETAILS

****

VOLUME OF BEDDING MATERIAL	= 0.0483M3/MLIN
TOTAL STANDARD MAN-HOURS	= 0.1115HRS/MLN
STANDARD DURATION	= 0.0372HRS/MLN

TRENCH BACKFILL

****

BACKFILL VOLUME	= 7.409 M3/M LIN
GANG NUMBER	= 1.
NO OF PEGSON RAMMERS	= 1.
NO OF MEN	= 2.
STANDARD MANHOURS	= 8.205 HRS/MLIN
STANDARD DURATION	= 4.103 HRS/MLIN
GANG NUMBER	= 2.
NO OF PEGSON RAMMERS	= 1.
NUMBER OF MEN	= 2.
NO OF DUMPERS	= 1.
STANDARD MANHOURS	= 1.037 HRS/MLIN
STANDARD DURATION	= 0.519 HRS/MLIN
GANG NUMBER	= 3.
NO OF PEGSON RAMMERS	= 1.
NUMBER OF MEN	= 2.
NO OF MACHINES(JCB 3C)	= 1.
STANDARD MANHOURS	= 0.852 HRS/MLIN
STANDARD DURATION	= 0.284 HRS/MLIN
GANG NUMBER	= 4.
NO OF LOADERS(DROTT175)	= 1.
NO OF PEGSON RAMMERS	= 1.
NUMBER OF MEN	= 2.
STANDARD MANHOURS	= 0.630 HRS/MLIN
STANDARD DURATION	= 0.210 HRS/MLIN

```
                         ANALYSIS SUMMARY
                         ****************

    DESCRIPTION= DRATEPIP TEST 3              PIPE DIAMETER  =  1500. MM
    BILL NO    = 8                             PIPE CLASS    =        S
    PAGE NO    = 8                             BED CLASS     =        A
    ITEM NO    = 8                             MEAN DEPTH    =  4.000 M
                                               MAX DEPTH     =  4.000 M
                                               LENGTH OF RUN =   1.00.00 M

OPERATION * M    W     V   E   C   D   D   R   M   I   G   L     L      S      T
          * E    A     O   X   R   R   U   O   E   P   A   A     E      T      D
          * T    L     L   C   A   O   M   L   D   H   N   B     N      D      T
          * H    E     U   A   N   T   P   L   I       G   O     G             A
          * O    R     M   V   E   T   E   E   U       E   U     T      D      L
          * D          E   A   S   S   R   R   M       R   R     H      U
          *      S         T           S   S           S   E            R      D
          * N    P         O                   B           R     O      A      U
          * O    A         R                   R           S     F      T      R
          *      C                             E                        I      A
          *      I         T                   A                 R      O      T
          *      N         Y                   K                 U      N      I
          *      G         P                   E                 N             O
          *                E                   R                               N
          *                                    S

          *    (M)  M3/M                                        (M)   HR/M   (HRS)
          ***********************************************************************
```

Continued

```
ROAD BRK
          * 1. 0.00  0.93 0.  0.  0.  0.  0.  1.  0.  0.  2.  10.00  2.33  23.28
          * 2. 0.00  0.93 0.  0.  0.  0.  0.  0.  1.  0.  1.  10.00  0.72   7.20
EXCAVATION***********************************************************************
          * 3. 0.00  7.48 1.  0.  0.  0.  0.  0.  0.  0.  0. 100.00  0.19  18.88
TRENCH SPT***********************************************************************
          * 4. 0.50  0.00 1.  0.  0.  0.  0.  0.  0.  1.  3. 100.00  0.91  90.74
          * 5. 1.00  0.00 1.  0.  0.  0.  0.  0.  0.  1.  3. 100.00  0.69  68.97
          * 6. 1.50  0.00 1.  0.  0.  0.  0.  0.  0.  1.  3. 100.00  0.61  60.82
          * 7. 2.00  0.00 1.  0.  0.  0.  0.  0.  0.  1.  3. 100.00  0.59  58.82
          * 8. 2.50  0.00 1.  0.  0.  0.  0.  0.  0.  1.  3. 100.00  0.60  60.45
          * 9. 2.70  0.00 1.  0.  0.  0.  0.  0.  0.  1.  3. 100.00  0.51  51.35
PIPE LAY  ***********************************************************************
          * 0. 0.00  0.00 0.  0.  0.  0.  0.  0.  0.  1.  2. 100.00  0.44  44.03
     TOTAL***********************************************************************
          *20. 0.00  0.00 0.  1.  0.  0.  0.  0.  0.  1.  2. 100.00  0.44  44.03
PIPE BED  ***********************************************************************
          * 0. 0.00  0.05 0.  0.  0.  0.  0.  0.  0.  1.  2. 100.00  0.04   3.72
     TOTAL***********************************************************************
          *21. 0.00  0.05 0.  0.  0.  0.  0.  0.  0.  1.  2. 100.00  0.04   3.72
          ***********************************************************************
```

Continued

BACKFILL															
	*22.	0.00	7.41	0.	0.	0.	0.	1.	0.	0.	0.	2.	100.00	4.10	410.27
	*23.	0.00	7.41	0.	0.	0.	1.	1.	0.	0.	0.	2.	100.00	0.52	51.86
	*24.	0.00	7.41	1.	0.	0.	0.	1.	0.	0.	0.	2.	100.00	0.28	28.40
	*25.	0.00	7.41	0.	0.	1.	0.	1.	0.	0.	0.	2.	100.00	0.21	20.99

****

SUMMARY **

	* 8.			1.	1.	0.	0.	1.	1.	0.	1.	3.	100.00	1.77	177.13

****

SECTION 6

PIPELINE ANALYSIS PROGRAMME

LISTING

```
      LIST (LP)
      PROGRAM (FXXX)
      INPUT  1 = CRO
      OUTPUT 2 =LPO
      COMPRESS INTEGER AND LOGICAL
      EXTENDED
      END


      MASTER
      DIMENSION SUMRY (25,15)
      REAL LD,L,MENZ,LB,LPP,LS,LT1,LJ,J1
      INTEGER RDTYPE
      CALL DRTA(NNN)
      COUNT2=0.0
    2 CONTINUE
      COUNT2=COUNT2+1.0
      CALL DRTB(DESC,DESD,DESE,DESF,DESG,DESH)
      CALL DRTC(BILL,PAGE,TEM)
      CALL DRTD(DESC,DESD,DESE,DESF,DESG,DESH,BILL,PAGE,TEM)
      CALL DRTE(D,CLASS,CLASR,TBED,TBDE,ZMEAND,ZMAXD,ZLENGTH)
 9002 CONTINUE
      CALL DRTF(D,CLASS,CLASR,TBED,TBDF,ZMEAND,ZMAXD,ZLENGTH)
      CALL SUMMARY(1,DESC,DESD,DESE,DESF,DESG,DESH,BILL,PAGE,
     1TEM,D,CLASS,CLASE,TBED,TBDE,ZMEAND,SUMRY)
      CALL SUMMARY(2,ZMAXD,ZLENGTH,COUNT2,0.0,0.0,0.0,0.0,0.
     10,0.0,0.0,0.0,0.0,0.0,0.0,0.0,SUMRY)
      CALL DRTG(JROAD)
      IF(JROAD.EQ.O) GO TO 5018
      CALL DRTH(RDTYPE,RWIDTH,RTHICK,RLENGTH)
 9004 CONTINUE
      CALL ROD(RDTYPE,RWIDTH RTHICK,RLENGTH,ZGN1,ZMAC1,GANG1,
     1RATE1,OVR1,RVOLU)
      CALL ROD1(RDTYPE,RWIDTH,RTHICK,RLENGTH,ZGN2,ZMAC2,
     1GANG2,RATE2,OVR2,RVOLU)
      CALL DRTI
      IF(RDTYPE.EQ.1) TO TO 5021
      CALL DRTJ
      GO TO 5023
 5021 CONTINUE
      CALL DRTK
 5023 CONTINUE
      CALL DRTL(RWIDTH,RTHICK,RLENGTH,RVOLU,ZGN1,ZMAC1,
     1GANG1,RATE1,OVR1,ZGNZ,ZMAC2,GANG2,RATE2,OVR2)
      OVRA=OVR1*RLENGTH
      CALL SUMMARY(3,1.0,0.0,RVOLU,0.0,0.0,0.0,0.0,0.0,ZMAC1,
     10.0,0.0,GANG1,RLENGTH,OVR1,OVRA,SUMRY)
      OVRB=OVR2*RLENGTH
      CALL SUMMARY(4,2.0,0.0,RVOLU,0.0,0.0,0.0,0.0,0.0,0.0,
     1ZMAC2,0.0,GANG2,RLENGTH,OVR2,OVRB,SUMRY)
      M=5
      GO TO 3
 5018 RVOLU=0.0
      M=3
    3 CONTINUE
      CALL DRTM
      CALL EXDATA(B,DPT,W,OF,S,R,H)
```

```
      CALL MCSEL(B,DPT,H,R,TYPE)
      CALL DRTO
      I=IFIX(TYPE)
      CALL EXRAT(S,I,B,DPT,OF,W,R,H,RS)
      CALL DRTP(S,OF,DPT,W,B,H,R,I,RS)
      CALL DRTQ(IDO)
      IF(IDO.EQ.O) GO TO 8881
      CALL EXSHAPE(ISHAPE,ZZD,ZZW,AREAEXC,RATE,RS)
      CALL DRTR(ZZD,ZZW)
      GOTO 8882
 8881 CONTINUE
      CALL EXCAL(RS,AREAEXC,RATE)
 8882 CONTINUE
      CALL DRTS(AREAEXC,RATE)
      RATEZ=ZLENGTH*RATE
      CALL SUMMARY(M,3.0,0.0,AREAEXC,1.0,0.0,0.0,0.0,0.0,0.
     10,0.0,0.0,0.0,ZLENGTH,RATE,RATEZ,SUMRY)
      CALL DRTT
      CALL DRTU(ISING)
      IF(ISING.EQ.0) TO TO 2225
      CALL DRTV
      CALL DES(H,W,GAMA,PHI,COH,APA)
      CALL DRTW(H,W,PHI,COH,GAMA)
      CALL DRTX(IA,ID,IE,IF,IG,IH,II,IM,IN,IO,IP,IT,IU,IV,IIP)
      L=15.43/SQRT(APA)
      ZMTD=3.0
      19=M
      SUM=0.0
  999 LD=0.5+SUM
      19=19+1
      ZMTD=ZMTX+1.0
      CALL DESA(APA,WGT,B,LD,IS,L,W)
      CALL TZME(W,B,WGT,H,LD,YY,SMTH,G,SL,GI,IA,ID,IF,IF,IG,
     1IH,II,IM,IN,I0,IP,IT,IU,IV,IIP,YS,XN,WN)
      IF(IIP.EQ.1) GO TO 4901
      IF(IIP.EQ.2) GO TO 4902
      CALL DRTY
      GOTO 4903
 4901 CONTINUE
      CALL DRTZ
      GOTO 4903
 4902 CONTINUE
      CALL DRAA
 4903 CONTINUE
      CALL DRAB(YS,SL,XN,W,B,WN,IS,WGT,LD,G,GI,YY,SMTH)
      YY1=YY*ZLENGTH
      G1=G-1.0
      CALL SUMMARY(I9,ZMTD,LD,0.0,GI,0.0,0.0,0.0,0.0,0.0,0.
     10,1.0,G1,ZLENGTH,YY,YY1,SUMRY)
      IF(LD.EQ.L) GO TO 2221
      IF(LD.GE.4.0) GO TO 2221
      SUM=LD
      GO TO 999
 2225 19=5
 2221 CONTINUE
      CALL DRAC(ICOM)
      IIN+ICOM
```

```
      ZSUM=0.0
      M=0
      L9=19
 3913 CONTINUE
      CALL DRAD(DI,PIPEL,PDEPTH)
 9020 CONTINUE
      19=19+1
      M=M+1
      CALL PIPE(DI,PIPEL,PDEPTH,PDUR,DURM,EX,CR,MENZ )
      CALL DRAE(M,DI,PIPEL,PDEPTH,EX,CR,MENZ,PDUR,DURM)
      ENZ1=MENZ-1.0
      DURM1=ZLENGTH*DURM
      CALL SUMMARY(L9,0.0,0.0;0.0,EX,CR,0.0,0.0,0.0,0.0,0.
     10,1.0,ENZ1,ZLENGTH,DURM,DURM1,SUMRY)
      ZSUM=ZSUM+DURM
      ICOM=ICOM-1
      IF(ICOM.GE.1) GO TO 3913
      L8=L9+1
      CALL DRAF (ZSUM,IIN)
      ENZ2=MENZ-1.0
      SZUM1=ZSUM*ZLENGTH
      CALL SUMMARY (L8,20.,0.0,0.0,EX,CR,0.0,0.0,0.0,0.0,0.
     10,1.0,ENZ2,ZLENGTH,ZSUM,SZUM1,SUMRY)
      CALL DRAG(IDUAL)
      CALL DRAH
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      SUM4=0.0
      L7=L8
   80 CALL BED(IBDT,IBDS,D,T,JSELECT,BW,BT,H1,H2,H3,THETA,
     1H4,BD,AT)
      CALL BEDTME(D,IBDT,AT,SMHM,SDM,GB,GL,PL,SMHML,SDML,ZZD)
      L7=L7+1
      CALL DRAI(GB,GL,PL,SMHML, SDML)
      SDML1=SDML*ZLENGTH
      CALL SUMMARY(17,0.0,0.0,AT,0.0,0.0,0.0,0.0,PL,0.0,0.0,
     1GB,GL,ZLENGTH,SDML,SDML1,SUMRY)
      AT1=SUM1+AT
      BC1=(D+2.0*T)/1000.0
      ARPIPE=3.142*BC1*BC1/4.0
      AT2=SUM4+AT+ARPIPE
      SMHML2=SUM2+SMHML
      SDML3=SUM3+SDML
      SUM1=AT1
      SUM2=SMHML2
      SUM3=SMDL3
      SUM4=AT2
      JL=IDUAL-1
      IDUAL=JL
      L6=L7+1
      IF(JL.GE.1) GO TO 80
      CALL DRAJ(IDUAL,SUM1,SUM2,SUM3)
      SUM31=SUM3*ZLENGTH
      CALL SUMMARY(L6,21.,0.0,SUM1,0.0,0.0,0.0,0.0 PL,0.0,
     10.0 GB,GL,ZLENGTH,SUM3,SUM31,SUMRY)
      CALL DRAK(ZLAYER)
```

```
      CALL DRAL
      PIG=21.0
      I=0
      L5=L6
 9014 I=I+1
      L5=L5+1
      PIG=PIG+1.0
      CALL BACK(AREAEXC,SUM4,RVOLU,ZLAYER,I,DROT,PR,ZMEN,
     1CBJ,DMP,GNBR,YSMH,XSMH,VBKF )
      CALL DRAM(VBKF,GNBR,DROT,PR,ZMEN,CBJ,DMP,YSMH,XSMH)
      XSMH1=XSMH*ZLENGTH
      CALL SUMMARY(L5,PIG,O.O,VBKF,CBJ,O.O,DROT,DMP.PR,O.
     1O,O.O,O.O,ZMEN,ZLENGTH,XSMH,XSMH1,SUMRY)
      IF(I.LT.4) GOTO 9014
      MMM=NNN-1
      NNN=MMM
      CALL OUTSY1(SUMRY,K9,I9,L8,L7,L6,L5,JROAD,L9)
      M5=L5
      CALL OVERATE(M5,SUMRY)
      IF(MMM.GE.1) TO TO 2
      STOP
      END


      SUBROUTINE DRTA(NNN)
      READ(1,1) NNN
    1 FORMAT(I0)
      RETURN
      END


      SUBROUTINE DRTB(DESC,DESD,DESE,DESF,DESG.DESH)
    2 READ(1,5000) DESC,DESD,DESE,DESF,DESG,DESH
 5000 FORMAT( 6A4 )
      RETURN
      END


      SUBROUTINE DRTC(BILL,PAGE,TEM)
      READ(1,5003) BILL
      READ(1,5003) PAGE
      READ(1,5003) TEM
 5003 FORMAT(A4)
      RETURN
      END


      SUBROUTINE DRTD(DESC,DESD,DESE,DESF,DESG,DESH,BILL.
     1PAGE,TEM)
      WRITE(2,5002)
 5002 FORMAT(1H1,20X,23HBILL ITEM TIME ANALYSIS,/)
      WRITE(2,5003)
 5003 FORMAT(1H ,20X,23H***********************)
      WRITE(2,5004)
 5004 FORMAT(1H ,20X,20HCONTRACT DESCRIPTION,/)
      WRITE(2,5005)
 5005 FORMAT(1H ,20X,20H********************,/////)
      WRITE(2,5006) DESC,DESD,DESE,DESF,DESG,DESH
```

```
5006 FORMAT(1H ,20X,6A4,///)
     WRITE(2,5007) BILL
5007 FORMAT(1H ,20X,11HBILL NUMBER,3X,A4,//)
     WRITE(2,5008) PAGE
5008 FORMAT(1H ,20X,11HPAGE NUMBER,3X,A4,//)
     WRITE(2,5009) TEM
5009 FORMAT(1H ,20X,11HITEM NUMBER,3X,A4,//)
     RETURN
     END


     SUBROUTINE DRTE(D,CLASS,CLASR,TBED,TBDE,ZMEAND,
    1ZMAXD,ZLENGTH)
     READ(1,5010) D,CLASS,CLASR,TBED,TBDE,ZMEAND,ZMAXD,
    1ZLENGTH
5010 FORMAT( F5.0,4A4,F5.3,F5.3,F8.3 )
     RETURN
     END


     SUBROUTINE DRTF(D,CLASS CLASR,TBED,TBDE,ZMEAND,
    1ZMAXD,ZLENGTH)
     WRITE(3,5011) D
5011 FORMAT(1H ,20X,26HPIPE INTERNAL DIAMETER = ,F5.0,3X,
    12HMM,//)
     WRITE(2,5012) CLASS,CLASR
5012 FORMAT(1H ,20X,26HCLASS OF PIPE           = ,2A4,//)
     WRITE(2,5013) TBED,TBDE
5013 FORMAT(1H ,20X,26HCLASS OF BED            = ,2A4,//)
     WRITE(2,5014) ZMEAND
5014 FORMAT(1H ,20X,26HMEAN DEPTH OF TRENCH    = ,F5.3,3X,
    11HM,//)
     WRITE(2,5015) ZMAXD
5015 FORMAT(1H ,20X,26HMAXIMUM DEPTH OF TRENCH = ,F5.3,3X,
    11HM,//)
     WRITE(2,5016) ZLENGTH
5016 FORMAT(1H ,20X,26HLENGTH OF RUN  = ,F8.2,1HM)
     RETURN
     END


     SUBROUTINE DRTG(JROAD)
     READ(1,5017) JROAD
5017 FORMAT(IO)
     RETURN
     END


     SUBROUTINE DRTH(RDTYPE,RWIDTH,RTHICK,RLENGTH)
     INTEGER RDTYPE
     READ(1,6000) RDTYPE
6000 FORMAT( I1 )
     READ(1,6001) RWIDTH,RTHICK,RLENGTH
6001 FORMAT( F5.3,F5.0,F8.3)
     RETURN
     END
```

```
      SUBROUTINE ROD(RDTYPE,RWIDTH,RTHICK,RLENGTH,ZGN1,
     1ZMAC1,GANG1,RATE1,OVR1,RVOLU)
      INTEGER RDTYPE
      RVOLU=RWIDTH*RTHICK/1000.
      RVOLT=RVOLU*RLENGTH
      IF(RDTYPE.EQ.1) GO TO 6002
      ZGN1=1.0
      ZMAC1=1.0
      GANG1=2.0
      RATE1=2.5*RVOLU
      OVR1=RATE1/2.0
      GO TO 6003
 6002 7GN1=1.0
      ZMAC1=1.0
      GANG1=2.0
      RATE1=4.98*RVOLU
      OVR1=RATE1/2.0
 6003 RETURN
      END

      SUBROUTINE ROD1(RDTYPE,RWIDTH,RTHICK,RLENGTH,ZGN2,
     1ZMAC2,GANG2,RATE2,OVR2,RVOLU)
      INTEGER RDTYPE
      RVOLU=RWIDTH*RTHICK/1000.0
      RVOLT=RVOLU*RLENGTH
      IF(RDTYPE.EQ.1) GO TO 6002
      ZGN2=2
      ZMAC2=1.0
      GANG2=1.0
      RATE2=1.15*RVOLU
      OVR2=RATE2/2.0
      WRITE(2,6004) RVOLU,RATE2,OVR2
 6004 FORMAT(1H ,10X,F8.3,10X,F8.3,13X,F8.3,//)
      GO TO 6003
 6002 ZGN2=2.0
      ZMAC2=1.0
      GANG2=1.0
      RATE2=1.54*RVOLU
      OVR2=RATE2/2.0
 6003 RETURN
      END

      SUBROUTINE DRTI
      WRITE(2.5019)
 5019 FORMAT(1H1,20X,13HROAD BREAKOUT)
      WRITE(2,5020)
 5020 FORMAT(1H ,20X,13H*************,//)
      RETURN
      END

      SUBROUTINE DRTJ
      WRITE(2,5022)
 5022 FORMAT (1H ,20X,26HFLEXIBLE ROAD CONSTRUCTION)
      WRITE(2,5023)
```

```
5023 FORMAT(1H ,20X,'****************************',//)
     RETURN
     END


     SUBROUTINE DRTK
     WRITE(2,5024)
5024 FORMAT(1H ,20X,26HCONCRETE ROAD CONSTRUCTION)
     WRITE(2,5023)
5023 FORMAT(1H ,20X,'****************************',//)
     RETURN
     END


     SUBROUTINE DRTL(RWIDTH,RTHICK,RLENGTH,RVOLU,ZGN1,ZMAC1,
    1GANG1,RATE1,OVR1,ZGN2,ZMAC2,GANG2,RATE2,OVR2)
     WRITE(2,5025) RWIDTH
5025 FORMAT(1H ,20X,26HWIDTH OF BREAKOUT = ,F5.3,3X,1HM,/)
     WRITE(2,5026) RTHICK
5026 FORMAT(1H ,20X,26HTHICKNESS OF ROAD = ,F5.0,3X,2HMM,/)
     WRITE(2,5027) RLENGTH
5027 FORMAT(1H ,20X,26HLENGTH OF BREAKOUT = ,F8.3,1HM,/)
     WRITE(2,5555) RVOLU
5555 FORMAT(1H ,20X,26HVOLUME OF BREAKOUT = ,F8.3,7HM3/
    1MLIN,//)
     WRITE(2,5028)
5028 FORMAT(1H ,20X,'TWO ALTERNATIVE GANGS')
     WRITE(2,5021)
5021 FORMAT(1H ,20X,'*********************',//)
     WRITE(2,5029) ZGN1
5029 FORMAT(1H ,20X,12HGANG NUMBER.,F2.0,1H.,/)
     WRITE(2,5030) ZMAC1
5030 FORMAT(1H ,20X,26HNUMBER OF COMPRESSORS = ,F2.0,/)
     WRITE(2,5031) GANG1
5031 FORMAT(1H ,20X,26HNUMBER OF LABOURERS = ,F2.0,/)
     WRITE(2,5032) RATE1
5032 FORMAT(1H ,20X,26HSTANDARD MANHOURS = ,F8.3,8HHRS/
    1MLIN,/)
     WRITE(2,5033) OVR1
5033 FORMAT(1H ,20X,26HSTANDARD DURATION = ,F8.3,8HHRS/
    1MLIN,///)
     WRITE(2,5034) ZGN2
5034 FORMAT(1H ,20X,12HGANG NUMBER.,F2.0,1H.,/)
     WRITE(2,5035) ZMAC2
5035 FORMAT(1H ,20X,26HNUMBER OF MACHINES(IPH) = ,F2.0,/)
     WRITE(2,5036) GANG2
5036 FORMAT(1H ,20X,26HNUMBER OF LABOURERS = ,F2.0,/)
     WRITE(2,5037) RATE2
5037 FORMAT(1H ,20X,26HSTANDARD MANHOURS = ,F8.3,8HHRS/
    1MLIN,/)
     WRITE(2,5038) OVR2
5038 FORMAT(1H ,20X,26HSTANDARD DURATION = ,F8.3,8HHRS/
    1MLIN,/)
     RETURN
     END
```

```
      SUBROUTINE DRTM
      WRITE(2,30)
   30 FORMAT(1H1,20X,23HMACHINE EXCAVATION RATE )
      WRITE(2,31)
   31 FORMAT(1H ,20X,23H*********************** )
      WRITE(2,32)
   32 FORMAT(1H ,/ )
      WRITE(2,33)
   33 FORMAT(1H ,20X,19HMACHINES CONSIDERED)
      WRITE(2,331)
  331 FORMAT(1H ,20X,19H*******************,//)
      WRITE(2,34)
   34 FROMAT(1H ,19X,4HCODE,6X,12HMACHINE NAME,/ )
      WRITE(2,35)
   35 FORMAT(1H ,20X,1H1,9X,5HJCB 3,/,20X,1H2,10X,6HJCB 3C,
     1/,20X,1H3,10X,5HJCB 3D,/,20X,1H4,10X,6HJCB 5C,/,20X,
     21H5,10X,6HJCB 7B,/,20X,1H6,10X,10HHY-MAC 580,/,20X,
     31H7,10x,6HJCB 6C,/,20X,1H8,10X,6HJCB 6D,/,20X,1H9,10X,
     46HJCB 7C,/,20X,2H10,10X,4HRH 6,/ )
      RETURN
      END


      SUBROUTINE EXDATA(B,DPT,W,OF,S,R,H)
      READ(1,1) B,DPT,S
    1 FORMAT(3FO.O)
      READ(1,2) OF
      READ(1,2) W
    2 FORMAT(FO.O)
      READ(1,3) R,H
    3 FORMAT(2FO.O)
      RETURN
      END


      SUBROUTINE MCSEL(BB,DP,H,R,TYPE)
      DIMENSION D(10,6)
      DATA D/1.,2.,3.,4.,5.,6.,7.,8.,9.,10.,225.,225.,450.,
     1450.,400.,450.,450.,600.,600.,675.,675.,1200.,1200.,
     21350.,1300.,1300.,1300.,1300.,3.7,4.19,5.76,6.1,6.425,
     36.35,6.73,6.70,5.41,5.57,5.57,9.02,9.30,9.093,9.2,
     49.2,9.73,10.50,3.45,3.38,3.29,6.27,.54,5.358.6.05,6.10,
     53.0/
      DPP=DP/1000.0
      HH=H
      RR=R
      COUNT=0.0
  999 I=O
      COUNT=COUNT+1.0
      IF(COUNT.GE.10.0) GO TO 8
    2 I=I+1
      IF(BB.GE.D(I.2)) GO TO 3
      IF(I.LT.10) GO TO 2
      CALL ERROR1
      BB=450.0
      GO TO 999
    3 IF(BB.LE.D(I,3)) GO TO 4
```

```
      IF/I.LT.10) GO TO 2
      CALL ERROR2
      BB=1300.0
      GO TO 999
    4 IF(DPP.LE.D(I,4) GO TO 5
      IF(I.LT.10) GO TO 2
      CALL ERROR3
      DPP=DP/2.0
      GO TO 999
    5 IF(RR.LE.D(I,5)) GO TO 6
      IF(I.LT.10) GO TO 2
      CALL ERROR4
      RR=R/2.0
      GO TO 999
    6 IF(HH.LE.D(I,6)) GO TO 7
      IF(I.LT.10) GO TO 2
      CALL ERROR5
      HH=H/2.0
      GO TO 999
    8 I=9
    7 TYPE=D(I,1)
      RETURN
      END


      SUBROUTINE ERROR1
      WRITE(2,1)
    1 FORMAT(1H1,2X,'REQUIRED BUCKET WIDTH TOO SMALL')
      WRITE(2,2)
    2 FORMAT(1H ,2X,'450 MM WIDTH ASSUMED')
      RETURN
      END


      SUBROUTINE ERROR2
      WRITE(2,1)
    1 FORMAT(1H1,2X,'REQUIRED BUCKET WIDTH TOO LARGE')
      WRITE(2,2)
    2 FORMAT(1H ,2X,'1300 MM WIDTH ASSUMED')
      RETURN
      END


      SUBROUTINE ERROR3
      WRITE(2,1)
    1 FORMAT(1H1,2X,'REQUIRED DEPTH TOO LARGE')
      WRITE(2,2)
    2 FORMAT(1H ,2X,'DOUBLE EXCAVATE WITH JCB7C')
      RETURN
      END


      SUBROUTINE ERROR4
      WRITE(2,1)
    1 FORMAT(1H1,2X,'REQUIRED REACH TOO LARGE')
      WRITE(2,2)
    2 FORMAT(1H ,2X,'DOUBLE HANDLE WITH JCB 7C')
      RETURN
      END
```

```
      SUBROUTINE ERROR5
      WRITE(2,1)
    1 FORMAT(1H1,2X,'REQUIRED LOADING HIEGHT TOO LARGE')
      WRITE(2,2)
    2 FORMAT(1H ,2X,'DOUBLE HANDLE WITH JCB 7C')
      RETURN
      END


      SUBROUTINE DRTO
      WRITE(2,24)
   24 FORMAT(1H ,20X,'EXCAVATION DETAILS')
      WRITE(2,241)
  241 FORMAT(1H ,20X,'******************',//)
      RETURN
      END


      SUBROUTINE EXRAT(S,ITMC,B,D,OF,W,R,H,RS)
      B=B/1000.0
      IF(ITMC.EQ.1) GO TO 15
      IF(ITMC.EQ.2) GO TO 16
      IF(ITMC.EQ.3) GO TO 17
      IF(ITMC.EQ.4) GO TO 18
      IF(ITMC.EQ.5) GO TO 19
      IF(ITMC.EQ.6) GO TO 20
      IF(ITMC.EQ.7) GO TO 21
      IF(ITMC.EQ.8) GO TO 22
      IF(ITMC.EQ.9) GO TO 23
      IF(ITMC.EQ.10) GO TO 24
      CALL DRAR
      GO TO 2222
   15 IF(B.LT.O.225) B=0.225
      IF(B.GT.O.675) B=0.675
      BC=0.3904*8-0.0128
      GO TO 3333
   16 IF(B.LT.O.225) B=0.225
      IF(B.GT.O.675) B=0.675
      BC=0.3714*B+0.0465
      GO TO 3333
   17 IF(B.LT.O.225) B=0.225
      IF(B.GT.O.675) B=0.675
      BC=0.371*B+0.0465
      GO TO 3333
   18 IF(B.LT.O.450) B=0.450
      IF(B.GT.1.200) B=1.200
      BC=0.2866*B+0.1961
      GO TO 3333
   19 IF(B.LT.O.450) B=0.450
      IF(B.GT.1.200) B=1.200
      BC=0.46*B+0.1181
      GO TO 3333
   20 IF(B.LT.O.400) B=0.400
      IF(B.GT.1.350) B=1.350
      BC=0.28*B+0.1920
      GO TO 3333
   21 IF(B.LT.O.450) B=0.450
```

```
      IF(B.GT.1.300) B=1.300
      BC=0.1941*B+0.2377
      GO TO 3333
   22 IF(B.LT.0.450) B=0.450
      IF(B.GT.1.300) B=1.300
      BC=0.1941*B+o.2377
      GOTO 3333
   23 IF(B.LT.0.600) B=0.600
      IF(B.GT.1.300) B=1.300
      BC=0.8*B+0.0200
      GO TO 3333
   24 IF(B.LT.0.600) B=0.600
      IF(B.GT.1.300) B=1.300
      BC=0.8*B+0.0200
 3333 CONTINUE
      BIC=0.13531*S-0.0047672*S*S-0.32589
      QE=BC*BIC
      R2=R*R
      H2=H*H
      T2=R2+H2
      T=SQRT(T2)
      IF(ITMC.LE.3) UT=0.0055278-0.010534*T+0.039124*T*T-0.
     10042776*T*T*T
      IF(ITMC.GT.3) UT=0.0174370+0.038475*T+0.0027197*T*T-0.
     1000249*T*T*T
      SUM=0.0
      D=D/1000.0
      ZINC=D/10.0
      TAG=0.0
  777 TAG=TAG+1.0
      ZN=ZINC*TAG/W
      IF(OF.EQ.1.) ET=0.051219+0.8015*ZN-0.1397*ZN*ZN+0.0088
     195*ZN*ZN*ZN
      IF(OF.EQ.2.) ET=0.022858+0.2703*ZN-0.0480*ZN*ZN+0.0031
     138*ZN*ZN*ZN
      IF(OF.EQ.3.) ET=0.041371+0.1366*ZN-0.0216*ZN*ZN+0.0012
     141*ZN*ZN*ZN
      IF(OF.EQ.4.) ET=0.020984+0.1402*ZN-0.0252*ZN*ZN+0.0016
     156*ZN*ZN*ZN
      IF(OF.EQ.5.) ET=0.026574+0.1285*ZN-0.0215*ZN*ZN+0.0013
     149*ZN*ZN*ZN
      RSINC=50.7099*QE/(UT+ET)
      DEPTH=ZINC*TAG
      WRITE(2,88) DEPTH,RSINC
   88 FORMAT(1H ,2F12.4)
      SUM=SUM+RSINC
      IF(TAG.LT.10.) GO TO 777
      RS=SUM/10.0
      ITMC=ITMC
 2222 CONTINUE
      RETURN
      END


      SUBROUTINE DRTP(S,OF,HI,W,B,H,R,I,RS)
      WRITE(2,36) S
   36 FORMAT(1H ,20X,'STRATA GRADING =',F3.0)
```

```
      WRITE(2,37) OF
   37 FORMAT(1H ,20X,'OBSTRUCTION GRADING =',F3.0)
      B=B*1000.
      WRITE(2,39) B
   39 FORMAT(1H ,20X,'BUCKET WIDTH =',F6.),'MM')
      WRITE(2,40) H
   40 FORMAT(1H ,20X,'LOADING HIEGHT = ',F6.3,'M')
      WRITE(2,41) R
   41 FORMAT(1H ,20X,'REQUIRED REACH = ',F6.3,'M',//)
      WRITE(2,42) I
   42 FORMAT(1H ,20X,'USE MACHINE TYPE = ',I2)
      WRITE(2,43) RS
   43 FORMAT(1H ,20X,'STANDARD OUTPUT = ',F7.3,'M3/HR',//)
      RETURN
      END


      SUBROUTINE DRTQ(IDO)
      READ(1,9995) IDO
 9995 FORMAT(IO)
      RETURN
      END


      SUBROUTINE DRAR
      WRITE(2,25)
   25 FORMAT(1H1,6HERROR:,4X,23HCHECK MACHINE TYPE DATA)
      RETURN
      END


      SUBROUTINE EXSHAPE(ISHAPE,ZZD,ZZW,AREAEXC,RATE,RS)
      CALL DRAT(ISHAPE)
      CALL DRAU(ZZD,ZZW,ZZD1,ZZW1,ZZD2,TH1,TH2)
 9010 CONTINUE
      IF(ISHAPE.EQ.1) GO TO 2
      IF(ISHAPE.EQ.2) GO TO 3
      IF(ISHAPE.EQ.3) GO TO 4
      IF(ISHAPE.EQ.4) GO TO 5
      IF(ISHAPE.EQ.5) GO TO 6
      IF(ISHAPE.EQ.6) GO TO 7
      IF(ISHAPE.EQ.7) GO TO 8
      ZVOL=ZZD*ZZW
      TH1=0.0174533*TH1
      ZA1=ZZD/TAN(TH1)
      ZVOL1=ZA1*ZZD
      ZVOLT=ZVOL+ZVOL1
      GO TO 10
    2 CONTINUE
      ZVOLT=ZZD*ZZW
      GO TO 10
    3 CONTINUE
      ZVOL=ZZD*ZZW
      ZVOL1=ZZD-ZZD1
      ZVOL1-ZVOL1*ZZW1
      ZVOLT=ZVOL+ZVOL1
      GO TO 10
    4 CONTINUE
```

```
      ZVOL=ZZD*ZZW
      ZVOL1-ZZD-ZZD1
      ZVOL1=2.0*ZVOL1*ZZW1
      ZVOLT=ZVOL+ZVOL1
      GO TO 10
    5 CONTINUE
      ZVOL=ZZW*ZZD
      ZVOL2=ZZD-ZZD1
      ZVOL1=2.0*ZVOL2*ZZW1
      TH1=0.0174533*TH1
      ZA1=ZVOL2/TAN(TH1)
      ZVOL3=ZA1*ZVOL2
      ZVOLT=ZVOL+ZVOL1+ZVOL3
      GO TO 10
    6 CONTINUE
      ZVOL=ZZD*ZZW
      TH1=0.0174533*TH1
      ZA1=ZZD1/TAN(TH1)
      ZVOL1=ZZD1*ZA1
      ZVOLA=ZZD-ZZD1
      ZVOL2=ZA1*ZVOLA*2.0
      TH2=0.0174533*TH2
      ZA2=ZVOLA/TAN(TH2)
      ZVOL3=ZA2*ZVOLA
      ZVOLT=ZVOL+ZVOL1+ZVOL2+ZVOL3
      GO TO 10
    7 CONTINUE
      ZVOL=ZZD*ZZW
      ZVOLA=ZZD2-ZZD1
      TH1=0.0174533*TH1
      ZA1=ZVOLA/TAN(TH1)
      ZVOL1=ZA1*ZVOLA
      ZVOLB=ZZD-ZZD2
      ZVOL2=ZVOLB*ZA1*2.0
      TH2=0.0174533*TH1
      ZA2=ZVOLB/TAN(TH2)
      ZVOL3=ZVOLB*ZA2
      ZVOLT=ZVOL+ZVOL1+ZVOL2+ZVOL3
      GO TO 10
    8 CONTINUE
      ZZVL=ZZD*ZZW
      ZVOLA=ZZD-ZZD1
      TH1=0.0174533*TH1
      ZA1=ZVOLA/TAN(TH1)
      ZVOL1=ZA1*ZVOLA
      ZVOLT=ZZVL+ZVOL1
   10 AREAEXC=ZVOLT
      RATE=AREAEXC/RS
      RETURN
      END


      SUBROUTINE DRTR(ZZD,ZZW)
      WRITE(2,1190) ZZD
 1190 FORMAT(1H ,20X,'TRENCH DEPTH = ',F7.3,'M')
      WRITE(2,1191)ZZW
 1191 FORMAT(1H ,20X,'TRENCH BASE WIDTH =',F7.3,'M')
      RETURN
      END
```

```
      SUBROUTINE DRAT(ISHAPE)
      READ(1,1) ISHAPE
    1 FORMAT(IO)
      RETURN
      END


      SUBROUTINE DRAU(ZZD,ZZW,ZZD1,ZZW1,ZZD2,TH1,TH2)
      READ(1,9)ZZD,ZZW,ZZD1,ZZW1,ZZD2,TH1,TH2)
    9 FORMAT( 5F10.3,2F5.O)
      RETURN
      END


      SUBROUTINE EXCAL(RS,AREAEXC,RATE)
      DIMENSION XG(100)
      DIMENSION YG(100)
      DIMENSION XD(100)
      DIMENSION YD(100)
   17 CONTINUE
      CALL DRAV(JS)
C     O OR 1 IF GROSS OR DEDUCT COORDINATES FOLLOW
      IF(JS.EQ.1) GO TO 12
      SUM=O.O
      I=O
   14 CONTINUE
      CALL DRAW(X,Y,IS)
 9012 CONTINUE
      I=I+1
      XG(I)=X
      YG(I)=Y
      IF(IS.EQ.O) GO TO 14
      IN=I
      DO 444 I=1,IN,1
      K=I+1
      IF(K.GT.IN) GO TO 15
      A=(YG(I)+YG(K))/2.0
      B=(XG(K)=XG(I))
      GO TO 16
   15 A=O.O
      B=O.O
   16 SUM=SUM+(*B)
  444 CONTINUE
      AREAGROSS=SUM
      GOTO 17
   12 SUM=O.O
      J=O
   19 CONTINUE
      CALL DRA1(X,Y,IS)
 9014 CONTINUE
      J=J+1
      XD(J)=X
      YD(J)=Y
      IF(IS.EQ.O) GO TO 19
      JN=J
      DO 555 J=1,JN,1
      L=j+1
```

```
      IF(L.GT.JN) GO TO 20
      A=(YD(J)+YD(L))/2.0
      B=(XD(L)-XD(J))
      GO TO 21
   20 A=0.0
      B=0.0
   21 SUM=SUM+(A*B)
  555 CONTINUE
      AREADEDUCT=SUM
      AREAEXC=AREAGROSS-AREADEDUCT
C     RATE IN HOURS/METRE LIN
      RATE=AREAEXC/RS
      RETURN
      END


      SUBROUTINE DRTS(AREAEXC,RATE)
      WRITE(2,1515) AREAEXC
 1515 FORMAT(1H ,20X,'VOLUME OF EXCAVATION =',F7.3,'M3/
     1M',//)
      WRITE(2,1555) RATE
 1555 FORMAT(LH ,20X,'STANDARD DURATION =',F7.3,'HRS/M')
      RETURN
      END


      SUBROUTINE DRTT
      WRITE(2,3333)
 3333 FORMAT(1H1)
      RETURN
      END


      SUBROUTINE DRTU(ISING)
      READ(1,4951) ISING
 4951 FORMAT(IO)
      RETURN
      END


      SUBROUTINE DRTV
      WRITE(2,700)
  700 FORMAT(1H ,24X,28HTRENCH SUPPORT SYSTEM DESIGN)
      WRITE(2,701)
  701 FORMAT(1H ,21X,34H********************************** )
      RETURN
      END


      SUBROUTINE DRAV(JS)
      READ(1,11) JS
   11 FORMAT(IO)
      RETURN
      END
```

```
      SUBROUTINE DRAV(JS)
      READ(1,11) JS
   11 FORMAT(IO)
      RETURN
      END

      SUBROUTINE DRAW(X,Y,IS)
      READ(1,13) X,Y,IS
   13 FORMAT( F10.3,F10.3,I1 )
      RETURN
      END


      SUBROUTINE DRA1(X,Y,IS)
      READ(1,18) X,Y,IS
   18 FORMAT( F10.3,F10.3,I1)
      RETURN
      END


      SUBROUTINE DES(H,W,GAMA,PHI,COH,APA)
      CALL DRAX(IS1,IS2,IS3,H,W)
 9016 CONTINUE
      K1=IS1*2
      K1=K1+IS2
      K2=K1*2
      K2=K2+IS3
      CALL DRAY(GAMA, PHI,COH)
 9018 CONTINUE
      IF(K2.EQ.4) GO TO 11
      IF(K2.EQ.2) GO TO 12
      IF(K2.EQ.O) GO TO 13
      IF(K2.EQ.1) GO TO 14
      IF(K2.EQ.3) GO TO 15
      IF(K2.EQ.5) GO TO 16
      IF(K2.EQ.6) GO TO 17
      IF(K2.EQ.7) GO TO 18
   11 CONTINUE
      IF(GAMA.EQ.99.) GAMA=2082.6
      IF(GAMA.NE.99.) GAMA=GAMA
      IF(PHI.EQ.99.) PHI=15.0
      IF(PHI.NE.99.) PHI=PHI
      IF(COH.EQ.99.) COH=0.0
      IF(COH.NE.99.) COH=0.0
      THT=0.0174533*PHI
      A=1.0-SIN(THT)
      B=1.0+SIN(THT)
      BKA=A/B
      APA=0.65*GAMA*BKA*H
      APA=APA*0.00980665
      GO TO 21
   12 CONTINUE
      IF(GAMA.EQ.99.) GAMA=2082.6
      IF(GAMA.NE.99.) GAMA=GAMA
      IF(PHI.EQ.99.) PHI=0.0
      IF(PHI.NE.99.) PHI=0.0
      IF(COH.EQ.99.) COH=1400.0
```

```
      IF(COH.NE.99.) COH=COH
      AN=GAMA*H/COH
      IF(AN.LE.4.0) GO TO 23
      APA=0.4*GAMA*H
      APA=APA*0.00980665
      GO TO 21
   23 A=4.0*COH
      B=GAMA*H
      A=A/B
      BKA=1.0-A
      IF(BKA.LE.0.0) BKA=0.40
      APA=BKA*GAMA*H
      APA=APA*0.00980665
      GOTO 21
   13 CONTINUE
      IF(GAMA.EQ.99.) GAMA=2082.6
      IF(GAMA.NE.99.) GAMA=GAMA
      APA=0.4*GAMA*H
      APA=APA*0.00980665
      GO TO 21
   14 CONTINUE
      IF(GAMA.EQ.99.) GAMA=2082.6
      IF(GAMA.NE.99.) GAMA=GAMA
      APA=0.4*GAMA*H
      APA=APA*0.0098665
      GO TO 21
   15 CONTINUE
      IF GAMA.EQ.99.) GAMA=2082.6
      IF(GAMA.NE.99) GAMA=GAMA
      IF(PHI.EQ.99.) PHI=15.0
      IF(PHI.NE.99.) PHI=PHI
      IF(COH.EQ.99.) COH=1400.0
      IF(COH.NE.99.) COH=COH
      APA1=0.4*GAMA*H
      AN=GAMA*H/COH
      IF(AN.LE.4.0) GO TO 27
      APA2=0.4*GAMA*H
      GO TO 28
   27 A=4.0*COH
      B=GAMA*H
      A=A/B
      BKA=1.0-A
      IF(BKA.LE.0.0) BKA=0.40
      APAZ=BKA*GAMA*H
   28 CONTINUE
      IF(APA2.GE.APA1) APA=APA2*0.00980665
      IF(APA2.LT.APA1) APA=APA1*0.00980665
      GO TO 21
   16 CONTINUE
      IF(GAMA.EQ.99.)GAMA=2082.6
      IF(GAMA.NE.99.) GAMA=GAMA
      IF(PHI.EQ.99.) PHI=15.0
      IF(PHI.NE.99.) PHI=PHI
      IF(COH.EQ.99.) COH=1400.0
      IF(COH.NE.99.) COH=COH
      THT=0.0174533*PHI
      A=1.0-SIN(THT)
```

```
      B=1.0+SIN(THT)
      BKA=A/B
      APA1=0.65*GAMA*BKA*H
      APA2=0.4*GAMA*H
      IF(APA1.GE.APA1) APA=APA2*0.00980665
      IF(APA2.LT.APA1) APA=APA1"0.00980665
      GO TO 21
   17 CONTINUE
      IF(GAMA.EQ.99.) GAMA=2082.6
      IF(GAMA.NE.99.) GAMA=GAMA
      IF(PHI.EQ.99.) PHI=15.0
      IF(PHI.NE.99.) PHI-PHI
      IF(COH.EQ.99.) COH=1400.0
      IF(COH.NE.99.) COH=COH
      THT=0.0174533*PHI
      A=1.0-SIN(THT)
      B=1.0+SIN(GHT)
      BKA=A/B
      APA1=0.65*GAMA*BKA*H
      AN=GAMA*H/COH
      IF(AN.LE.4.0) GO TO 31
      APA2=0.4*GAMA*H
      GO TO 32
   31 A=4.0*COH/(GAMA*H)
      BKA=1.0-A
      IF(BKA.LE.0.0) BKA=0.40
      APA2=BKA*GAMA*H
   32 CONTINUE
      IF(APA2.GE.APA1) APA=APA2*0.00980665
      IF(APA2.LT.APA1) APA=APA1*0.0980665
      GOTO 21
   18 CONTINUE
      IF(GAMA.EQ.99.) GAMA=2082.6
      IF(GAMA.NE.99.) GAMA=GAMA
      IF(PHI.EQ.99.) PHI=15.0
      IF(PHI.NE.99.) PHI=PHI
      IF(COH.EQ.((.) COH=1400.0
      IF(COH.NE.99.) COH=COH
      THT=0.0174533*PHI
      A=1.0-SIN(THT)
      B=1.0+SIN(THT)
      BKA=A/B
      APA1=0.65*GAMA*BKA*H
      AN=GAMA*H/COH
      IF(AN.LE.4.0) GO TO 34
      APA2=0.4*GAMA*H
      GO TO 35
   34 A=4.0*COH
      B=GAMA*H
      A=A/B
      BKA=1.0-A
      IF(BKA.LE.0.0) BKA=0.40
      APA2=BKA*GAMA*H
   35 APA3=0.4*GAMA*H
      IF(APA2.GE.APA1) APA4=APA2
      IF(APA2.LT.APA1) APA4=APA1
      IF(APA4.GE.APA3) APA=APA4*0.00980665
```

```
      IF(APA4.LT.APA3) APA=APA3*0.00980665
   21 CONTINUE
      RETURN
      END


      SUBROUTINE DRTW(H,W,PHI,COH,GAMA)
      WRITE(2,702) H
  702 FORMAT(1H ,5X ,15HTRENCH DETAILS:,47X,6HDEPTH=,F5.3,
     11X,1HM)
      WRITE(2,703) W
  703 FORMAT(1H ,67X,6HWIDTH=,F5.3,1X,1HM )
      WRITE(2,704) PHI
  704 FORMAT(1H ,5X,13HSOIL DETAILS:,22X,33HANGLE OF INTERNAL
     1FRICTION (PHI)=,F5.2,1X,4HDEGS )
      WRITE(2,705) COH
  705 FORMAT(1H ,58X,15HCOHESION (COH)=,F7,2,1X,5HKG/M2)
      WRITE(2,706) GAMA
  706 FORMAT(1H ,50X23HSPECIFIC WIEGHT (GAMA)=,F7.2,1X,5HKG/
     1M3)
      WRITE(2,707)
  707 FORMAT(1H ,5X ,21HTRENCH SHEET DETAILS:,14X,14HB.S.P.
     1TYPE.T5.,3X,23HELASTIC MODULUS=56.0CM3)
      WRITE(2,708)
  708 FORMAT(1H ,67X,11HWIDTH=0.33M )
      WRITE(2,709)
  709 FORMAT(1H ,5X ,14HSTRUT DETAILS:,35X,25HHORIZONTAL
     1SPACING=2.50 M)
      WRITE(2,710)
  710 FORMAT(1H ,5X ,14HWALER DETAILS:,// )
      WRITE(2,711)
  711 FORMAT(1H ,20X,60HSECTION  SECTION  SECTION  D  B  T
     1ELASTIC MODULUS )
      WRITE(2,712)
  712 FORMAT(1H ,20X,58HNOTATION  SHAPE  WIEGHT  (MM)  (MM)
     1(MM)  (ZXX) (CM3) )
      WRITE(2,713)
  713 FORMAT(1H ,41X,6H(KG/M),//)
      WRITE(2,714)
  714 FORMAT(1H ,22X,1H1,9X,  47HI  13.38  127  76  7.6  7
     15.12  ,/,23X,57H2  I  17.10  152  89  8.3  1  15.90
     2,/,23X,1H3,9X,  47H    20.82  178  76  10.3  150.40
     3,/,23X,57H4  [  23.80  203  76  11.2  192.00  ,/)
      WRITE(2,777)
  777 FORMAT(1H ,22X,1H5,9X,  35HI  25.00  203  133  7.8
     1,2X,10H231.00  ,/,23X,57H6  I  30.00  207  134  9.6
     2279.00  ,/,23X,57H7  I  31.00  251  146  8.6  352.00
     3,/,23X,57H8  I  43.00  260  147  12.7  504.00  ,/)
      WRITE(2,778)
  778 FORMAT(1H ,22X,1H9,9X,  47HI  31.00  307  166  11.8
     164  6.00  ,/)
      RETURN
      END

      SUBROUTINE DRTX(IA,ID,IE,IF,IG,IH,II,IM,IN,IO,IP,IT,
     1IU,IV,IIP)
      IA=0
      ID=0
```

```
      IE=O
      IF=O
      IG=O
      IH=1
      II=O
      IM=1
      IN=0
      IO=0
      IP=0
      IT=1
      IU=O
      IV=O
      READ(1,1414) IIP
 1414 FORMAT(IO)
      RETURN
      END

      SUBROUTINE DRAX(IS1,IS2,IS3,H,W)
      READ(1,10) IS1,IS2,IS3,H ,W
   10 FORMAT( I5,I5,I5,F10.3,F10.3 )
      RETURN
      END

      SUBROUTINE DRAY(GAMA,PHI,COH)
      READ(1,20) GAMA,PHI,COH
   20 FORMAT( F10.1,F5.1,F10.1 )
      RETURN
      END

      SUBROUTINE DESA(APA,WGT,B,LD,IS,L,W)
      REAL  L,  LD,  LP
      DIMENSION Z(9 )
      DATA Z/75.12,115.90,150.40,192.00,231.00,279.00,352.00,
     1504.00,646.00/
C     TO CALCULATE THE VERTICAL STRUT SPACING PERMISSIBLE (L)
      IF(LD.LT.L) GO TO 38
      LD=L
   38 B1=38.4*W
      B2=14.36*SQRT(APA)*SQRT(LD)
      IF(B1.GE.B2) B=B1
      IF(b1.LT.B2) B=B2
      ZR=2.367*APA*LD
      ICOUNT=O
   39 I=1+ICOUNT
      IF(I.LE.9) GO TO 40
      CALL DRAZ(ZR)
      WGT=0.0
      B=O.O
      LD=0.0
      IS=O
      GO TO 2222
   40 CONTINUE
      IF(ZR.LT.Z(I)) GO TO 42
      ICOUNT=I
      GOTO 39
```

```
   42 IS=I
      ZX=Z(I)
      IF(IS.EQ.1) WGT=13.38
      IF(IS.EQ.2) WGT=17.10
      IF(IS.EQ.3) WGT=20.82
      IF(IS.EQ.4) WGT=23.80
      IF(IS.EQ.5) WGT=25.00
      IF(IS.EQ.6) WGT=30.00
      IF(IS.EQ.7) WGT=31.00
      IF(IS.EQ.8) WGT=43.00
      IF(IS.EQ.9) WGT=31.00
 2222 CONTINUE
      RETURN
      END


      SUBROUTINE DRAZ(ZR)
      WRITE(2,41) ZR
   41 FORMAT(1H1, 8X, 50HSECTION MODULUS NOT AVAILABLE SEE
     1TABLES FOR ZR= ,F10.2, 2X 3HCM3)
      RETURN
      END


      SUBROUTINE TZME(STL,B,WGT,H,ZLD,YY,SMTH,G,SL,GI,IA,ID,
     1IE,IF,IG,IH,II,IM,IN,IO,IP,IT,IU,IV,IIP,YS,XN,WN)
      SL=H+0.333
      WL=2.500
C     TRENCH SHEETS
C     **************
      TA=0.12925*SL+0.0745
      TB=0.121*SL+0.13025
      TC=0.4025
      TD=0,129*SL+0.176
      TE=0.003*SL+1.0232
      TF=0.02925*SL+0.57325
C     TIMBER STRUTS
C     **************
      B2=B/100.
      B2=B2*B2
      AG=-0.0045276+0.017435*B2
      AH=-0.0156+0.057902*B2
      AI=-0.051737+0.047466*B2
      AJ=0.029488+0.025636*B2
      AK=0.34389+0.037109*B2
      AL=0.23583+0.013164*B2
      AM=0.13054+0.0017042*B2
      AN=0.14083+0.022655*B2
      AO=0.059572+0.025717*B2
      CG=0.18887-0.0027834*B2
      CH=0.97452+0.62216*B2
      CI=0.49723+0.26224*B2
      CJ=0.254+0.0017595*B2
      CK=0.77333+0.084156*B2
      CL=0.38558+0.12197"B2
      CM=0.044055+0.1137*B2
      CN=0.23427+0.0231*B2
```

```
      CO=0.21614+0.023599*B2
      TG=AG*STL+CG
      TH=AH*STL+CH
      TI=AI*STL+CI
      TJ=AJ*STL+CJ
      TK=AK*STL+CK
      TL=AL*STL+CL
      TM=AM*STL+CM
      TN=AN*STL+CN
      CO=AO*STL+CO
C     STEELWALERS
C     *************
      AP=0.4785-0.011725*WGT
      AQ=0.071+0.004175*WGT
      AR=0.039+0.002875*WGT
      AS=0.145-0.00025*WGT
      AT=-0.39366+0.019683*WGT
      AU=0.1745-0.002225*WGT
      AV=0.158-0.0034*WGT
      CP=-0.59475+0.018975*WGT
      CQ=-0.16975+0.00795*WGT
      CR=-0.39775+0.04325*WGT
      CS=-0.26970+0.04161*WGT
      CT=0.010689-0.03332*WGT
      CU=-0247+0.023475*WGT
      CV=-0.303+0.026400*WGT
      TP=AP*WL+CP
      TQ=AQ*WL+CQ
      TR=AR*WL+CR
      TS=AS*WL+CS
      TT=AT*WL+CT
      TU=AU*WL+CU
      TV=AV*WL+CV
      IF(IIP.EQ.1) YS=14.0
      IF(IIP.EQ.2) YS=8.0
      IF(IIP.EQ.3) YS=6.0
      XN=(H/ZLD+1.0)*2.0
      XN=AINT(XN)
      WN=XN
      IF(IA.EQ.1) TA= TA
      IF(IA.NE.1) TA=0.0
      IF(ID.EQ.1) GO TO 20
      IF(IE.EQ.1) GO TO 21
      IF(IF.EQ.1) GO TO 22
   20 TD=TD
      TE=0.0
      TF=0.0
      GO TO 1111
   21 TE=TE
      TD=0.0
      TF=0.0
      GO TO 1111
   22 TF=TF
      TD=0.0
      TE=0.0
 1111 CONTINUE
      IF(IG.EQ.1) TG=TG
```

```
      IF(IG.NE.1) TG=O.O
      IF(IH.EQ.1) GO TO 24
      IF(II.EQ.1) GO TO 25
   24 TH=TH
      TI=O.O
      GO TO 2222
   25 TI=TI
      TH=O.O
 2222 CONTINUE
      IF(IM.EQ.1) GO TO 27
      IF(IN.EQ.1) GO TO 28
      IF(IO.EQ.1) GO TO 29
   27 TM=TM
      TN=O.O
      TO=O.O
      GO TO 3333
   28 TN=TN
      TM=O.O
      TO=O.O
      TO TO 3333
   29 TO=TO
      TM=O.O
      TN=O.)
 3333 CONTINUE
      IF(IP.EQ.1) TP=TP
      IF(IP.NE.1) TP=O.O
      IF(IU.EQ.1) GO TO 32
      IF(IT.EQ.1) GO TO 31
      IF(IV.EQ.1) GO TO 33
   31 TT=TT
      TU=O.O
      TV=O.O
      GO TO 4444
   32 TU=TU
      TT=O.O
      TV=O.O
      GO TO 4444
   33 TV=TV
      TT=O.O
      TU=O.O
 4444 CONTINUE
      T1=YS*(TA+TB+TC+TD+TE+TF)
      T2=XN*(TG+TH+TI+TJ+TK+TL+TM+TN+TO)
      T3=WN*(TP+TQ+TR+TS+TT+TU+TV)
C     OVERALL DURATION IN BASIC MINS
      T=T1+T2+T3
C     OVERALL DURATION IN STD MINS
      TSTD=T*1.02*1.16
C     OVERALL DURATION IN STD HOURS
      TSTDH=TSTD/60.0
C     OVERALL DURATION IN STD MINS/M
      XX=TSTD/2.500
C     OVERALL DURATION IN STD HOURS/M
      YY=TSTDH/2.500
C     STD MAN MINS/M
      IF(H.LE.3.0) GO TO 35
      SMT=XX*5.0
      G=4.0
```

```
      GI=1.0
      SMTH=YY*5.0
      GO TO 5555
   35 SMT=XX*4.0
      SMTH=YY*4.0
      G=4.0
      GI=0.0
 5555 CONTINUE
      RETURN
      END


      SUBROUTINE DRTY
      WRITE(2,2900)
 2900 FORMAT(1H1,5X,33HOPEN SHORING CONSTRUCTION DETAILS)
      WRITE(2,1001)
 1001 FORMAT(1H ,5X,33H*********************************)
      RETURN
      END


      SUBROUTINE DRTZ
      WRITE(2,4904)
 4904 FORMAT(1H1,5X,34HCLOSE SHORING CONSTRUCTION DETAILS)
      WRITE(2,4905)
 4905 FORMAT(1H ,5X,34H**********************************)
      RETURN
      END


      SUBROUTINE DRAA
      WRITE(2,4906)
 4906 FORMAT(1H1,5X,35HMEDIUM SHORING CONSTRUCTION DETAILS)
    . WRITE(2,4907)
 4907 FORMAT(1H ,5X,35H***********************************)
      RETURN
      END


      SUBROUTINE DRAB(YS,SL,XN,W,B,WN,IS,WGT,LD,G,GI,YY,
     1SMTH)
      REAL LD
      WRITE(2,1007) LD
 1007 FORMAT(1H ,22X,31VERTICAL WALER/STRUT SPACING = ,F5.3,
     12H M )
      WRITE(2,1017)
 1017 FORMAT(1H ,22X,'**************************************
     1*',/)
      WRITE(2,4908) YS
 4908 FORMAT(1H ,22X,31HNO OF TRENCH SHEETS = ,F5.0,5H/2.5M)
      WRITE(2,1002) SL
 1002 FORMAT(1H ,22X,31HLENGTH OF TRENCH SHEETS = ,F5.3, 2H M )
      WRITE(2,4909) XN
 4909 FORMAT(1H ,22X,31HNO OF TRENCH STRUTS = ,F5.0,5H/2.5M)
      WRITE(2,1003) W
 1003 FORMAT(1H ,22X,31HLENGTH OF STRUTS = ,F5.3, 2H M )
      WRITE(2,1004) B
```

```
1004 FORMAT(1H ,22X,31HTHICKNESS/WIDTH OF STRUTS = ,F5.
    10,3H MM )
     WRITE(2,4910) WN
4910 FORMAT(1H ,22X,31HNO OF WALERS = ,F5.0,5H/2.5M)
     WRITE(2,1005) IS
1005 FORMAT(1H ,22X,31HUSE WALER TYPE = ,I1)
     WRITE(2,1006) WGT
1006 FORMAT(1H ,22X,31HWIEGHT OF WALER = ,F5.2,5H KG/M )
     WRITE(2,1008) G
1008 FORMAT(1H ,22X,31HNUMBER OF MEN = ,F2.0)
     WRITE(2,1009) GI
1009 FORMAT(1H ,22X,31HNUMBER OF MACHINES + DRIVERS =
    1,F2.0 )
     WRITE(2,2901) YY
2901 FORMAT(1H ,22X,31HSTANDARD DURATION = ,F10.3,SH HR/M )
     WRITE(2,1011) SMTH
1011 FORMAT(1H ,22X,31HSTANDARD MANHOURS = ,F10.3,5H HR/M )
     RETURN
     END


     SUBROUTINE DRAC(ICOM)
     READ(1,3900) ICOM
3900 FORMAT(IO)
     RETURN
     END


     SUBROUTINE DRAD(DI,PIPEL,PDEPTH)
     READ(1,3901) DI,PIPEL ,PDEPTH
3901 FORMAT( F5.0,f£.3,F5.3)
     RETURN
     END


     SUBROUTINE PIPE(DI,PIPEL,PDEPTH,PDUR,DURM,EX,CR,MENZ)
     REAL MENZ,LB,LPP,LS,LT1,LJ,J1
     DIMENSION P(17,8)
     DATAP/100.,0.40,0.22,2.00,0.44,0.40,0.12,0.25,0.40,0.
    145,0.14,0.14,1.16,0.10,0.10,0.50,0.14,300.,1.15,0.95,
    25.60,0.94,1.15,0.33,0.80,1.16,1.25,0.36,0.38,1.16,0.
    330,0.40,0.90,0.38,600.,2.30,1.20,6.80,1.36,2.28,0.66,
    41.57,2.35,2.43,0.72,0.75,1.16,0.58,1.00,1.24,0.75,90
    50.,3.30,1.20,6.95,1.60,3.42,0.99,2.37,3.50,3.64,1.06,
    61.12,1.16,0.86,1.90,1.44,1.12,1200.,3.90,1.20,6.95,1.
    776,4.55,1.34,3.17,4.69,4.8,1.42,1.49,1.16,1.16,3.10,
    81.60,1.49,1500.,4.25,1.20,6.95,1.92,5.70,1.67,3.95,5.
    985,6.05,1.78,1.86,1.16,1.45,4.30,1.76,1.86,1800.,4.4
    15,1.20,6.95,2.08,6.82,2.00,4.75,7.03,7.25,2.13,2.23,
    21.16,1.74,5.35,1.92,2.23,2100.,4.50,1.20,6.95,2.23,7
    3.95,2.33,5.60,8.20,8.45,2.48,2.61,1.16,2.02,5.40,2.08
    4,2.61/
     J=0
   1 J=J+1
     IF(DI.LE.P(1,J))GO TO 2
     GO TO 1
   2 PB=P(2,J)-P(2,(J-1))
```

```
      LB=P(3,J)-P(3,(J-1))
      PLB=P(4,J)-P(4,(J-1))
      PSP=P(5,J)-P(5,(J-1))
      LPP=P(6,J)-P(6,(J-1))
      PG=P(7,J)-P(7,(J-1))
      LS=P(8,J)-P(8,(J-1))
      SJ=P(9,J)-P(9,(J-1))
      J1=P(10,J)-P(10,(J-1))
      RJ=P(11,J)-P(11,(J-1))
      LT1=P(12,J)-P(12,(J-1))
      B=P(13,J)-P(13,(J-1))
      LT=P(14,J)-P(14,(J-1))
      AP=P(15,J)-P(15,(J-1))
      RS=P(16,J)-P(16,(J-1))
      CLS=P(17,J)-P(17,(J-1))
      DDIF=P(1,J)-P(1,(J-1))
      DDF=DI-P(1,(J-1))
      RATIO=DDF/DDIF
      PB=P(2,(J-1))+PB*RATIO
      LB=P(3,(J-1))+LB*RATIO
      LB=LB*PDEPTH/2.0
      PLB=P(4,(J-1))+PLB*RATIO
      PSP=P(5,(J-1))+PSP*RATIO
      LPP=P(6,(J-1))+LPP*RATIO
      LPPP=LPP
      GRUMP=PDEPTH-DI/1000.0
      LPP=LPP*(GRUMP+0.0001)/2.0
      IF(LPP.LT.LPPP) LPP=LPPP
      PG=P(7,(J-1))+PG*RATIO
      LS=P(8,(J-1))+LS*RATIO
      SJ=P(9,(J-1))+SJ*RATIO
      J1=P(10,(J-1))+J1*RATIO
      RJ=P(11,(J-1))+RJ*RATIO
      LT1=P(12,(J-1))+LT1*RATIO
      B=P(13,(J-1))+B*RATIO
      LT=P(14,(J-1))+LT*RATIO
      AP=P(15,(J-1))+AP*RATIO
      RS=P(16,(J-1))+RS*RATIO
      CLS=P(17,(J-1))+CLS*RATIO
      IF(PIPEL.LT.1.44) GO TO 3
      ZMULT=PIPEL/2.440
      GOTO4
    3 ZMULT=1.0
    4 PB=PB*ZMULT
      LB=LB*ZMULT
      PLB=PLB*ZMULT
      CLS=CLS*ZMULT
      BMPP=PB+LB+PLB+PSP+LPP+PG+LS
      BMPP=BMPP+SJ+J1+RJ+LT1+B+LT+AP+RS+CLS
      BWC=BMPP*1.18
      TWC=BWC*1.02
      PDUR-TWC*1.01/60.0
      DURM=PDUR/PIPEL
      IF(PDEPTH.LE.3.0) GO TO 5
      IF(PDEPTH.LE.5.0) GO TO 6
      EX=0.0
      CR=1.0
```

```
      MENZ=3.0
      GO TO 7
    5 CONTINUE
      IF(DI.LT.600.) GO TO 8
      EX=0.0
      CR=1.0
      MENZ=3.0
      GO TO 7
    6 CONTINUE
      IF(DI.LT.525) GO TO 9
      EX=0.0
      CR=1.0
      MENZ=3.0
      GO TO 7
    8 CONTINUE
      IF(DI.LT.375.) GO TO 10
      EX=1.0
      CR=0.0
      MENZ=3.0
      GO TO 7
    9 EX=1.0
      CR=0.0
      MENZ=3.0
      GO TO 7
   10 EX=0.0
      CR=0.0
      MENZ=3.0
    7 RETURN
      END


      SUBROUTINE DRAE(M,DI,PIPEL,PDEPTH,EX,CR,MENZ,PDUR,
     1DURM)
      REAL MENZ
      WRITE(2,3902)
 3902 FORMAT(1H1,20X,11HPIPE LAYING)
      WRITE(2,3903)
 3903 FORMAT(1H ,20X,11H***********,////)
      WRITE(2,3904) M
 3904 FORMAT(1H ,20X,12HPIPE NUMBER.,I1,1H.,//)
      WRITE(2,3905) DI
 3905 FORMAT(1H ,20X,26HPIPE DIAMETER = ,F5.0,2HMM,/)
      WRITE(2,3906) PIPEL
 3906 FORMAT(1H ,20X,26HPIPE LENGTH = ,F5.3,1HM,/)
      WRITE(2,3907) PDEPTH
 3907 FORMAT(1H ,20X,26HDEPTH OF PIPE = ,F5.3,1HM,/)
      WRITE(2,3908) EX
 3908 FORMAT(1H ,20X,27HNO OF EXCAVATORS = ,F2.0,/)
      WRITE(2,3909) CR
 3909 FORMAT(1H ,")X,26HNO OF CRANES = ,F2.0,/)
      WRITE(2,3910) MENZ
 3910 FORMAT(1H ,20X,26HNO PF MEN = ,F2.0,/)
      WRITE(2,3911) PDUR
 3911 FORMAT(1H ,20X,26HSTANDARD DURATION = ,F5.3,8HHRS/
     1PIPE,/)
      WRITE(2,3912) DURM
 3912 FORMAT(1H ,20X,26HSTANDARD DURATION = ,F5.3,8HHRS/
     1MLIN,///)
```

```
      RETURN
      END

      SUBROUTINE DRAF(ZSUM,IIN)
      WRITE(2,3914)
 3914 FORMAT(1H1,20X,30HTOTAL FOR MULTIPLE PIPE TRENCH)
      WRITE(2,3915)
 3915 FORMAT(1H ,20X,30H******************************,//)
      WRITE(2,3916) ZSUM
 3916 FORMAT(1H ,20X,29HCOMBINED STANDARD DURATION = ,F5.
     13,8HHRS/MLIN,/)
      WRITE(2,3917) IIN
 3917 FORMAT(1H ,20X,29HNO OF PIPES IN TRENCH = ,I£)
      RETURN
      END

      SUBROUTINE DRAG(IDUAL)
      READ(1,77) I DUAL
   77 FORMAT(IO)
      RETURN
      END

      SUBROUTINE DRAH
      WRITE(2,78)
   78 FORMAT(1H1,20X,18HBEDDING CONDITIONS)
      WRITE(2,79)
   79 FORMAT(1H ,20X,18H******************,//)
      RETURN
      END

      SUBROUTINE BED(IBDT,IBDS,D,T,JSELECT,BW,BT,H1,H2,H3,
     1THETA,H4,BD,AT)
   10 CONTINUE
      CALL DAAA(IBDT)
   12 CONTINUE
      CALL DAA1(IBDS)
      IF(IBDT.LT.2) GO TO 14
      IF(IBDT.LT.3) GO TO 15
      CALL DAAB
      GO TO 16
   14 CONTINUE
      CALL DAAC
      GO TO 16
   15 CONTINUE
      CALL DAAD
   16 CONTINUE
      CALL DAAF(D,T,JSELECT)
 9022 CONTINUE
      IF(JSELECT.EQ.O) GO TO 9030
      GO TO 9031
 9030 CONTINUE
      CALL DAAH(BW,BT,BD,H1,H2,H3,H4,THETA)
 9031 CONTINUE
```

```
      CALL DAAE(IBDS)
      IF(IBDS.LT.3) GO TO 17
      IF(IBDS.LT.4) GO TO 18
      IF(IBDS.LT.6) GO TO 19
      IF(IBDS.LT.8) GO TO 20
   24 CONTINUE
      IF(JSELECT.EQ.O) GO TO 21
      IF(D.LE.400.0) BT=100.0
      IF(D.GT.400.0) BT=D*O.25
      BC=D+2.0*T
      IF(BC.LE.800.0) BW=BC+200.0
      IF(BC.GT.800.0) BW=BC*1.25
      A1=3.142/8.0
      A2=BC*BC
      A2=A1*A2
      A3=BT+T+O.5*D
      A3=BW*A3
      AT=A/=A2
      H1=BT
      H2=O.OO
      H3=(BW-BC)/2.0
      THETA=0.00
      AT=AT/1000000.0
      CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
      GO TO 60
   21 CONTINUE
      A1=3.142/8.0
      BC=D+1.0*T
      A2=BC*BC
      A2=A1*A2
      A3=BT+T+O.5*D
      A3=BW*A3
      H1=BT
      H2=O.OO
      H3=(BW-BC)/2.0
      THETA=O.OO
      AT=A3-A2
      AT=AT/1000000.0
      CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
      GO TO 60
   17 IF(IBDS.LT.2) GO TO 25
   27 CONTINUE
      IF(JSELECT.EQ.O) GO TO 26
      IF(D.LE.400.0) BT=100.0
      IF(D.GT.400.0) BT=D*O.25
      BC=D+2.O*T
      IF(BC.LE.800.0) BW=BC+200.0
      IF(BC.GT.800.0) BW=BC*1.25
      A1=BW-BC
      A1-A1/2.0
      H2=A1
      BC=A1+BC+BT
      A1=BW*BD
      A2=BC*BC
      A3=3.142/4.0
      A3=A3*A2
      H1=BT
```

```
      H3=H2
      THETA=0.00
      AT=A1-A3
      AT=AT/1000000.0
      CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
      GO TO 60
   26 CONTINUE
      BW=D+2.0*T+".0*H3
      BD=D+2.0*T+H1+H2
      A1=BW*BD
      BC=D+1.0*T
      A2=BC*BC
      A3=3.142/4.0
      A3=A2*A3
      BT=H1
      THETA=0.0
      AT=A1=A3
      AT=AT/1000000.0
      CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
      GO TO 60
   18 CONTINUE
      IF(JSELECT.EQ.0) GOTO 30
      IF(D.LE.400.0) BT=100.0
      IF(D.GT.400.0) BT=D*0.25
      BC=D+1.0*T
      IF(BC.LE.800.0) BW=BC+200.0
      IF(BC.GT.800.0) BW=BC*1.25
      BD=BT+BC
      A1=BD*BW
      A2=BC*BC
      A3=3.142/4.0
      A3=A3*A2
      A4=BC/2.0
      A5=A4/0.5
      A6=BW/2.0
      A7=A5-A6
      A7=0.5773503*A7
      A8=A4-A7
      A8=A8*A8
      A8=A8/0.5773503
      A9=3.142/24.0
      A10=BC*BC
      A10=A9*A10
      A11=A2/2.0
      A11=0.2679492*A11
      A12=A11=A10
      H1=BT
      H2=0.0
      H3=(BW-BC)/2.0
      THETA=30.0
      AT=A1-A3-A8-A12
      AT=AT/1000000.0
      CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
      GO TO 60
   30 CONTINUE
      THT=0.0174533*THETA
      BC=D+2.0*T
```

```
      BD=BT+BC
      BW=BC+2.0*H3
      A1=BD*BW
      A2=BC*BC
      A3=3.142/4.0
      A3=A3*A2
      A4=BC/2.0
      A5=A4/SIN(THT)
      A6=BW/2.0
      A7=A5-A6
      A7=A7*TAN(THT)
      A8=A4-A7
      A8=A8*A8
      A8=A8/TAN(THT)
      A9=THETA/360.0
      A9=A9*3.142/4.0
      A10=BC*BC
      A10=A9*A10
      A10=2.0*A10
      A11=A2/2.0
      HLF=THT/2.0
      A11=A11*TAN(HLF)
      A12=A11=A10
      H1=BT
      H2=0.0
      AT=A1-A3-A8-A12
      AT=AT/1000000.0
      CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
      GOTO 60
   19 IF(IBDS.LT.5) GOTO 34
   36 CONTINUE
      IF(JSELECT.EQ.0) GO TO 35
      IF(D.LE.400.0) BT=100.0
      IF(D.GT.400.0) BT=D*0.25
      BC=D+2.0*T
      IF(BC.LE.800.0) BW=BC+200.0
      IF(BC.GT.800.0) BW=BC*1.25
      A1=BT+T+0.5*D
      A1=BW*A1
      A2=BW*BW
      A2=0.25*A2*0.5773503
      A3=3.142/3.0
      A3=A3*0.25
      A3=A3/(0.8660254*0.8660254)
      A4=BW*BW
      A4=A3*A4
      A5=BC*BC
      A6=3.142/4.0
      A6=A6*A5
      H1=BT
      H2=0.5*BW/0.8660254
      H2=H2-0.5*BC
      H3=(BW-BC)/2.0
      THETA=30.0
      AT=A1+A2+A4-A6
      AT=AT/1000000.0
      CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
```

```
   TO TO 60
35 CONTINUE
   BC=D+2.0*T
   BW=BC+2.0*H3
   BN=BC/2.0
   BN=BN+BT
   THT=0.0174533*THETA
   A1=BW*BN
   A2=BW*BW
   A3=0.25*A2*TAN(THT)
   A4=180,0-2.0*THETA
   A4=A4/360.0
   A5=3.142*0.25*A2
   A6=COS(THT)*COS(THT)
   A5=A5/A6
   A7=A4*A5
   A8=3,142/4.0
   A9=BC*BC
   A9=A8*A9
   H1=BT
   H2=0.5* BW/COS(THT)
   AT=A1+A3+A7-A9
   AT=AT/1000000.0
   CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
   GOTO 60
20 IF(IBDS.LT.7) GO TO 39
40 CONTINUE
   IF(JSELECT.EQ.0) GO TO 42
   IF(D.LE.400.0) BT=100.0
   IF(D.GT.400.0) BT=D*0.25
   BC=D+2.0*T
   IF(BC.LE.800.0) BW=BC+200.0
   IF(BC.GT.800.0) BW=BC*1.25
   H1=BT
   H2=0.0
   H3=(BW-BC)/2.0
   THETA=0.0
   AT=BW*BT
   AT=AT/1000000.0
   CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
   GO TO 60
42 CONTINUE
   H1=BT
   H2=0.0
   BC=D+0.5*T
   H3=(BW-BC/2.0
   THETA=0.0
   AT=BW*BT
   AT=AT/1000000.0
   CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
   GO TO 60
34 CONTINUE
   IF(JSELECT.EQ.0) GO TO 44
   IF(D.LE.400.0) BT=100.0
   IF(D.GT.400.0) BT=D*0.25
   BC=D+2.0*T
   IF(BC.LE.800.0) BW=BC+200.0
```

```
      IF(BC.GT.800.0) BW=BC*1.25
      BD=BT+).5*BC
      A1=BW*BD
      A2=BC*BC
      A3=3.142/8.0
      A3=A3*A2
      A4=BW*BW
      A4=0.25*A4
      A5=0.5773503*A4
      A6=3.142/24.0
      A6=A6*A2
      A7=A5-A6
      H1=BT
      H2=0.0
      H3=(BW-BC)/2.0
      THETA=30.0
      AT=A1-A3-A7
      AT=AT/1000000.0
      CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
      GO TO 60
   44 CONTINUE
      BC=D+2.0*T
      BW=BC+2.0*H3
      BD=BT+0.5*BC
      A1=BW*BD
      A2=BC*BC
      A3=3.142/8.0
      A3=A3*A2
      A4=BW*BW
      A4=0.25*A4
      THT=0.0174533*THETA
      A5=A4*TAN(THT)
      A6=THETA*3.142
      A6=A6/720.0
      A6=A6*A2
      A7=A5-A6
      H1=BT
      H2=O.O
      AT=A1-A3-A7
      AT=AT/1000000.0
      CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
      GO TO 60
   39 CONTINUE
      IF(JSELECT.EQ.O) GO TO 47
      IF(D.LE.400.0) BT=100.0
      IF(D.GT.400.0) BT=D*O.25
      BC=D+2.0*T
      IF(BC.LE.800.0) BW=BC+200.0
      IF(BC.GT.800.0) BW=BC*1.25
      H3=(BW-BC)/2.0
      BD=BT+BC+H3
      A1=BD*BW
      R=O.5*BC+H3
      AB=R*O.2679492
      A2=2.0*R*AB
      A3=3.142/4.0
      R2=R*R
```

```
      A3=A3*R2
      A4=A2-A3
      DB=0.5*BW-AB
      DE=0.5773503*DB
      A5=DE*DB
      A6=3.142/4.0
      A7=A6*BC*BC
      H1=BT
      H2=H3
      THETA=30.0
      AT=A1-A4-A5-A7
      AT=AT/1000000.0
      CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
      GO TO 60
   47 CONTINUE
      PHI=THETA
      RADPHI=PHI*0.0174533
      BC=D+2.0*T
      BW=BC+2.0*H3
      BD=BT+BC+H4
      A1=BD*BW
      R2=R*R
      THT2=RADPHI/2.0
      AB=R*TAN(THT2)
      A2=2.0*R*AB
      A3=2.0"PHI/360.0
      A3=A3*3.142*R2
      A4=A2-A3
      DB=0.5*BW-AB
      DE=DB*TAN(RADPHI)
      A5=DE*DB
      A6=3.142/4.0
      A7=A6*BC*BC
      H1=BT
      H2=H4
      THETA=PHI
      AT=A1-A4-A5-A7
      AT=AT/1000000.0
      CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
      GO TO 60
   25 CONTINUE
      IF(JSELECT.EQ.0) GOTO 50
      IF(D.LE.400.0) BT=100.0
      IF(D.GT.400.0) BT=D*0.25
      BC=D+2.0*T
      IF(BC.LE.800.0) BW=BC+200.0
      IF(BC.GT.800.0) BW=BC*1.25
      BD=0.25*BC+BT
      A1=BD*BW
      A2=3.142/12.0
      A2=A2*BC*BC
      A3=BC/2.0
      THT=60.0*0.0174533
      A4=A3*SIN(THT)
      A5=BT+A3-BD
      A6=A4*A5
      H1-BD
      H2=0.0
```

```
      H3=(BW-BC) /2.0
      THETA=30.0
      AT=A1-A2+A6
      AT=AT/1000000.0
      CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
      GO TO 60
   50 CONTINUE
      BC=D+2.0*T
      A1=BW*BD
      A2=BC*BC
      A3=(180.0-2*THETA)*3.142
      A3=A3/(360.0*4.0)
      A4=A2*A3
      A5=BC/2.0
      THT2=(180.0-2.0*THETA)/2.0
      RAD=THT2*0.0174533
      A6=A5*SIN(RAD)
      A7=0.5*BC*COS(RAD)
      A8=A6*A7
      BT=BD+A7-0.5*BC
      H1=BD
      H2=0.0
      H3=(BW-BC)/2.0
      AT=A1-A4+A8
      AT=AT/1000000.0
      CALL DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
   60 CONTINUE
      RETURN
      END


      SUBROUTINE (DAAA(IBDT)
      READ(1,11) IBDT
   11 FORMAT(I0)
      RETURN
      END


      SUBROUTINE DAA1(IBDS)
      READ(1,13) IBDS
   13 FORMAT(I0)
      RETURN
      END


      SUBROUTINE DAAB
      WRITE(2,111)
  111 FORMAT(1H ,20X,'BEDDING CLASS C ( SELECTED BACKFILL )')
      WRITE(2,1)
    1 FORMAT(1H ,20X,'*************************************
     1',//)
      RETURN
      END


      SUBROUTINE DAAC
      WRITE (2,112)
```

```
112 FORMAT(1H ,20X,'BEDDING CLASS A ( CONCRETE STRUCTURE )')
    WRITE(2,1)
  1 FORMAT(1H ,20X,'*************************************
   1',//)
    RETURN
    END


    SUBROUTINE DAAD
    WRITE(2,113)
113 FORMAT(1H ,20X,'BEDDING CLASS B ( GRANUALR STRUCTURE )')
    WRITE(2,1)
  1 FORMAT(1H ,20X,'*************************************
   1',//)
    RETURN
    END


    SUBROUTINE DAAE(IBDS)
    WRITE(2,777)
777 FORMAT(1H ,4X,1HD, 12X,1HT,9X,2HBW,8X,2HBT,26X,1H*/
   165X,1H* )
    WRITE(2,778)
778 FORMAT(1H , 8HINTERNAL,7X,4HWALL,7X,3HBED,7X,3HBED,
   125X,1H*)
    WRITE(2,779)
779 FORMAT(1H , 8HDIAMETER,5X,9HTHICKNESS,3X,5HWIDTH,3X,
   19HTHICKNESS,2X,2HH1,3X,2HH2,2HH3,2X,5HTHETA,1X,27H*
   2VOLUME OF BEDDING MATERIAL )
    WRITE(2,780) IBDS
780 FORMAT(1H ,3X,4H(MM),9X,4H(MM),7X,4H(MM),5X,4H(MM),4X,
   14H(MM),1X,4H(MM),1X,4H(MM),1X,5H(DEG),1X,23H*FOR CON
   2STRUCTION TYPE.,I1,1H.)
    WRITE(2,781)
781 FORMAT(1H ,65X,16H*   (M3/M LIN))
    WRITE(2,782)
782 FORMAT(1H ,65X,1H*)
    WRITE(2,783)
783 FORMAT(1H ,65X,1H*)
    RETURN
    END


    SUBROUTINE DAAF(D,T,JSELECT)
    READ(1,22) D,T   ,JSELECT
 22 FORMAT( F5.),F5.0,  I5)
    RETURN
    END


    SUBROUTINE DAAG(D,T,BW,BT,H1,H2,H3,THETA,AT)
    WRITE(2,59) D,T,BW,BT,H1,H2,H3,THETA,AT
 59 FORMAT(1H ,3X,F5.0,8X,f@.0,6X,F5.),4X,F5.0,3X,F5.0,
   11X,F4.0,1X,F4.0,2X,F4.0,1X,1H*,7X,F6.4)
    RETURN
    END
```

```
      SUBROUTINE DAAH(BW,BT,BD,H1,H2,H3,H4,THETA)
      READ(1,23) BW,BT,BD,H1,H2,H3,H4,THETA
   23 FORMAT(8F5.0)
      RETURN
      END


      SUBROUTINE BEDTME(D,IBDT,AT,SMHM,SDM,GB,GL,PL,SMHML,
     1SDML,ZZD)
      DIMENSION C(28,3)
      DIMENSION G(28,3)
      DATA C/100.,150.,225.,300.,375.,450.,525.,600.,750.,
     1825.,900.,975.,1050.,1125.,1200.,1275.,1350.,1425.,
     21500.,1575.,1650.,1725.,1800.,1875.,1950.,2025.,2100.,
     31.20,1.20,1.20,1.20,1.05,1.05,1.05,1.05,0.99.0.99,
     40.99,0.99,0.90,0.90.0.90,0.84,0.84,0.84,0.84,0.78,0.78,
     50.78,0.78,0.78,0.78,0.78,0.78,0.40,0.40,0.40,0.40,0.35,
     60.35,0.35,0.35.0.35,0.33,0.33,0.33,0.33,0.30,0.30,0.30,
     70.28,0.28,0.28,0.28,0.26,0.26,0.26,0.26,0.26,0.26,0.26,
     80.26/
      DATA G/100.,150.,225.,300.,375.,450.,525.,600.,675.,
     1750.,825.,900.,975.,1050.,1125.,1200.,1275.,1350.,1425
     2.,1500.,1575.,1650.,1725.,1800.,1875.,1950.,2025.,2100
     3.,0.90,0.90,0.90,0.90,0.78,0.78,0.78,0.78,0.78,0.72,0.
     472,0.72,0.72,0.63,0.63,0.63,0.57,0.57,0.57,0.57,0.51,
     50.51,0.51,0.51.0.51,0.51,0.51.0.51,0.30,0.30,0.30,0.30,
     60.26,0.26,0.26,0.26,0.26,0.24,0.24,0.24,0.24,0.21,0.21,
     70.21,0.19,0.19,0.19,0.19,0.17,0.17,0.17,0.17,0.17,0.17,
     80.17,0.17/
      IF(IBDT.EQ.1) GO TO 90
      IF(IBDT.EQ.2) GO TO 91
      SMHM=0.12
      SDM=0.04
      PL=1.0
      GO TO 92
   90 I=0
   93 I=I+1
      IF(D.LE.C(I,1)) GO TO 94
      GO TO 93
   94 DFF=C(I,1)-C((I-1),1)
      DF1=D-C((I-1),1)
      RATIO=DF1/DFF
      DF2=C(I,2)-C((I-1),2)
      DF3=C(I,3)-C((I-1),3)
      SMHM=C((I-1),2)+RATIO*DF2
      SDM=C((I-1),3)+RATIO*DF3
      PL=0.0
      GO TO 92
   91 I=0
   95 I=I+1
      IF(D.LE.G(I,1)) GO TO 96
      GO TO 95
   96 DFF=G(I,1)-G((I-1),1)
      DF1=D-G((I-1),1)
      RATIO=DF1/DFF
      DF2=G(I,3)-G((I-1),2)
      DF3=G(I,3)-G((I-1),3)
```

```
      SMHM=G((I-1),2)+RATIO*DF2
      SDM=G((I-1),3)+RATIO*DF3
      PL=0.0
   92 SMHML=SMHM*AT
      SDML=SDM*AT
      CRAP1=SDML
      CRAP=SMHML
      GRUM=ZZD-D/1000.0
      SMHML=SMHML*(GRUM+0.0001)/2.0
      IF(SMHML.LT.CRAP) SMHML=CRAP
      SDML=SDML*(GRUM+0.0001)/2.0
      IF(SDML.LT.CRAP1) SDML=CRAP1
      GB=1.0
      GL=2.0
      RETURN
      END

      SUBROUTINE DRAI(GB,GL,PL,SMHML,SDML)
      WRITE(2,7777)
 7777 FORMAT(1H ,/// )
      WRITE(2,81) GB
   81 FORMAT(1H ,20X,31HNUMBER OF GANGERS = ,F2.0)
      WRITE(2,82) GL
   82 FORMAT(1H ,20X,31HNUMBER OF GENERAL LABOURERS = ,F2.0)
      WRITE(2,83) PL
   83 FORMAT(1H ,20X,31HNUMBER OF PEGSON RAMMERS = ,F2.0)
      WRITE(2,84) SMHM
   84 FORMAT(1H ,20X,31HSTANDARD MAN HOURS = ,F7.4,7H HRS/ML)
      WRITE(2,85) SDML
   85 FORMAT(1H ,20X,31HSTANDARD DURATION = ,F7.4,7H HRS/ML,/
     1/////////)
      RETURN
      END

      SUBROUTINE DRAJ(IDUAL,SUM1,SUM2,SUM3)
      WRITE(2,86)
   86 FORMAT(1H1,20X,13HTOTAL DETAILS)
      WRITE(2,87)
   87 FORMAT(1H ,20X,13H*************,//)
      WRITE(2,89)SUM1
   89 FORMAT(1H ,20X,32HVOLUME OF BEDDING MATERIAL = ,F7.4,
     17HM3/MLIN)
      WRITE(2,90) SUM2
   90 FORMAT(1H ,20X,32HTOTAL STANDARD MAN-HOURS = ,F7.4,7
     1HHRS/MLN)
      WRITE(2,91) SUM3
   91 FORMAT(1H ,20X,32HTOTAL STANDARD DURATION = ,F7.4,7H
     1HRS/MLN)
      RETURN
      END

      SUBROUTINE DRAK(ZLAYER)
      READ(1,8999) ZLAYER
 8999 FORMAT(F0.0)
      RETURN
      END
```

```
      SUBROUTINE DRAL
      WRITE(2,9000)
 9000 FORMAT(1H1,20X,15HTRENCH BACKFILL)
      WRITE(2,9001)
 9001 FORMAT(1H ,20X,15H***************,///)
      RETURN
      END


      SUBROUTINE BACK(AREAEXC,SUM4,RVOLU,ZLAYER,I,DROT,PR,
     1ZMEN,CBJ,DMP,GNBR,YSMH,XSMH,VBKF)
      VBKF=AREAEXC-SUM4
      IF(I.EQ.1) GOTO 1000
      IF(I.EQ.2) GOTO 1001
      IF(I.EQ.3) GOTO 1002
      DROT=1.0
      PR=1.0
      ZMEN=2.0
      CBJ=0.0
      DMP=0.0
      GNBR=4.0
      IF(ZLAYER.LT.500.) ZSMH=0.10-0.0001*ZLAYER
      IF(ZLAYER.GE.500.) ZSMH=0.05
      YSMH=VBKF*ZSMH
      XSMH=YSMH/3.0
      GO TO 1100
 1000 DROT=0.0
      PR=1.0
      SMEN=2.0
      CBJ=0.0
      DMP=0.0
      GNBR=1.0
      IF(ZLAYER.LT.307.) ZSMH=1.8575-0.005*ZLAYER
      IF(ZLAYER.GE.307.) ZSMH=0.32
      YSMH=VBKF*ZSMH
      XSMH=YSMH/2.0
      GO TO 1100
 1001 DROT=0.0
      PR=1.0
      ZMEN=2.0
      CBJ=0.0
      DMP=1.0
      GNBR=2.0
      IF(ZLAYER.LT.500.) ZSMH=0.155-0.0001*ZLAYER
      IF(ZLAYER.GE.500.) ZSMH=0.105
      YSMH=VBKF*ZSMH
      XSMH=YSMH/2.0
      GO TO 1100
 1002 DROT=0.0
      PR=1.0
      ZMEN=2.0
      CBJ=1.0
      DMP=0.0
      GNBR=3.0
      IF(ZLAYER.LT.500.) ZSMH=0.13-0.0001*ZLAYER
      IF(ZLAYER.GE.500.) ZSMH=0.08
      YSMH=VBKF*ZSMH
```

```
      XSMH=YSMH/3.0
 1100 RETURN
      END


      SUBROUTINE DRAM(VBKF,GNBR,DROT,PR,ZMEN,CBJ,DMP,YSMH,
     1XSMH)
      IF(GNBR.GT.1.0) GO TO 9999
      WRITE(2,9002) VBKF
 9002 FORMAT(1H ,20X,27HBACKFILL VOLUME = ,F7.3,9H M3/M
     1LIN,/)
 9999 WRITE(2,9003) GNBR
 9003 FORMAT(1H ,20X,27HGANG NUMBER = ,F3.0)
      IF(DROT.EQ.0.0) GOTO 9004
      WRITE(2,9005)DROT
 9005 FORMAT(1H ,20X,27HNO OF LOADERS(DROTT175) = ,F3.0)
 9004 WRITE(2,9006)PR
 9006 FORMAT(1H ,20X,27HNO OF PEGSON RAMMERS = ,F3.0 )
      WRITE(2,9007) ZMEN
 9007 FORMAT(1H ,20X,27HNUMBER OF MEN = ,F3.0 )
      IF(CBJ.EQ.0.0) GOTO 9008
      WRITE(2,9009) CBJ
 9009 FORMAT(1H ,20X,27HNO OF MACHINES(JCB 3C) = ,F3.0 )
 9008 IF(DMP.EQ.0.0) GOTO 9010
      WRITE(2,9011) DMP
 9011 FORMAT(1H ,20X,27HNO OF DUMPERS = ,F3.0 )
 9010 WRITE(2,9012) YSMH
 9012 FORMAT(1H ,20X,27HSTANDARD MANHOURS = ,F6.3,9H HRS/
     1MLIN)
      WRITE(2,9013) XSMH
 9013 FORMAT(1H ,20X,27HSTANDARD DURATION = ,F6.3,9H HRS/
     1MLIN,//)
      RETURN
      END


      SUBROUTINE OUTSY1(SUMRY,K9,I9,L8,L7,L6,L5,JROAD,L9)
      DIMENSION SUMRY(25,15)
      WRITE(2,1)
    1 FORMAT(1H1,25X,16HANALYSIS SUMMARY,/)
      WRITE(2,2)
    2 FORMAT(1H ,25X,16H****************)
      WRITE(2,3)
    3 FORMAT(1H ,//)
      WRITE(2,4) SUMRY(1,1),SUMRY(1,2),SUMRY(1,3),SUMRY(
     11,5),SUMRY(1,6),SUMRY(1,10)
    4 FORMAT(1H ,5X,12HDESCRIPTION=,2X,6A4,6X18HPIPE DIAM
     1ETER = ,F5.0,1X,2HMM,/)
      WRITE(2,5) SUMRY(1,7),SUMRY(1,11),SUMRY(1,12)
    5 FORMAT(1H ,5X,14HBILL NO = ,A4,27X,17HPIPE CLASS =
     1,2A4,/)
      WRITE(2,6) SUMRY(1,8),SUMRY(1,13),SUMRY(1,14)
    6 FORMAT(1H ,5X,14HPAGE NO = ,A4,27X,17HBED CLASS =
     1,2A4,/)
      WRITE(2,7) SUMRY(1,9),SUMRY(1,15)
    7 FORMAT(1H ,5X,14HITEM NO = ,A4,27X,17HMEAN DEPTH =
     1,F5.3,1X,1HM,/)
```

```
   WRITE(2,8) SUMRY(2,1)
 8 FORMAT(H1H ,50X,17HMAX DEPTH = ,F5.3,1X,1HM,/)
   WRITE(2,9) SUMRY(2,2)
 9 FORMAT(1H ,50X,17HLENGTH OF RUN = ,F.3,1X,1HM,/)
   WRITE(2,10)
10 FORMAT(1H ,////)
   WRITE(2,11)
11 FORMAT(1H ,78HOPRATION  *  M  W  V  E  C  D  D  R  M  I
  1  G   L     L    S        T)
   WRITE(2,12)
12 FORMAT(1H ,78H          *  E  A  O  X  R  R  U  O  E  P
  1  A   A     E    T        O)
   WRITE(2,13)
13 FORMAT(1H ,78H          *  T  L  L  C  A  O  M  L  D  H
  1  N   B     N    D        T)
   WRITE(2,14)
14 FORMAT(1H ,78H          *  H  E  U  A  N  T  P  L  I
  1  G   O     G             A)
   WRITE(2,15)
15 FORMAT(1H ,78H          *  O  R  M  V  E  T  E  E  U
  1  E   U     T    D        L)
   WRITE(2,16)
16 FORMAT(1H ,78H          *  D     E  A  S  S  R  R  M
  1  R   R     H    U         )
   WRITE(2,17)
17 FORMAT(1H ,78H          *     S     T        S  S
  1  S   E          R        D)
   WRITE(2,18)
18 FORMAT(1H ,78H          *  N  P     O              B
  1      R     O    A        U)
   WRITE(2,19)
19 FORMAT(1H ,78H          *  O  A     R              R
  1      S     F    T        R)
   WRITE(2,20)
20 FORMAT(1H ,78H          *     C                    E
  1                 I        A)
   WRITE(2,21)
21 FORMAT(1H ,78H          *     I     T              A
  1            R    O        I)
   WRITE(2,22)
22 FORMAT(1H ,78H          *     N     Y              K
  1            U    N        I)
   WRITE(2,23)
23 FORMAT(1H ,78H          *     G     P              E
  1            N             O)
   WRITE(2,24)
24 FORMAT(1H ,78H          *           E              R
  1                          N)
   WRITE(2,25)
25 FORMAT(1H ,78H          *                          S
  1                           ,/)
   WRITE(2,26)
26 FORMAT(1H ,80H          *    (M) M3/M
  1           (M) HR/M    (HRS))
   IF(JROAD.EQ.O) GO TO 100
   WRITE(2,27)
27 FORMAT(1H ,11HROAD BRK *)
   WRITE(2,70)
```

```
 70 FORMAT(1H+,11X,69H***************************************
   1***************************)
    WRITE(2,177) ((SUMRY(M9,J),J=1,15),M9=3,4)
177 FORMAT(1H ,10X,1H*,F3.0    ,1X,F4.2,1X,F5.2,1X,F2.0,2X
   1,F2.0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F20,2X,F2.0,
   22X,F2.0,1X,F6.2,1X,F5.2,1X,F6.2)
    WRITE(2,160)
160 FORMAT(1H )
116 CONTINUE
    M9=5
    GO TO 101
100 CONTINUE
    M9=3
101 WRITE(2,28)
 28 FORMAT(1H ,11HEXCAVATION*)
    WRITE(2,71)
 71 FORMAT(1H+,11X,69H***************************************
   1***************************)
    WRITE(2,800) ((SUMRY(I,J),J=1,15),I=M9,M9)
800 FORMAT(1H ,10X,1H*,F3.0    ,1X,F4.2,1X,F5.2,1X,F2,0,2X,
   1F2.0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.0,
   22X,F2.0,1X,F6.2,1X,F5.2,1X,F6.2)
    WRITE(2,159)
159 FORMAT(1H )
    IF(19.EQ.5) GO TO 102
    WRITE(2,29)
 29 FORMAT(1H ,11HTRENCH SPT*)
    WRITE(2,72)
 72 FORMAT(1H+,11X,69H***************************************
   1***************************)
    M5=M9+1
    WRITE(2,811) ((SUMRY(M9,J),J=1,15),M9=M5,I9)
811 FORMAT(1H ,10X,1H*,F3.0    ,1X,F4.2,1X,F5.2,1X,F2.0,2X,
   1F2.0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.0,
   22X,F1.0,1X,F6.2,1X,F5.2,1X,F6.2)
    WRITE(2,158)
158 FORMAT(1H )
224 CONTINUE
    19=19+1
    GO TO 222
102 CONTINUE
    I9=I9+1
222 CONTINUE
    WRITE(2,30)
 30 FORMAT(1H ,11HPIPE LAY *)
    WRITE(2,73)
 73 FORMAT(1H+,11X,69H***************************************
   1***************************)
    WRITE(2,822) ((SUMRY(I,J),J=1,15),I=M9,L9)
822 FORMAT(1H ,10X,1H*,F3.0    ,1X,F4.2,1X,F5.2,1X,F2.0,2X
   1,F2.0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.0
   2,2X,F2.0,1X,F6.2,1X,F5.2,1X,F6.2)
    WRITE(2,157)
157 FORMAT(1H )
228 CONTINUE
    WRITE(2,31)
 31 FORMAT(1H ,11H   TOTAL*)
    WRITE(2,74)
```

```
 74 FORMAT(1H+,11X,69H***********************************
   1**************************)
    M9=L8
    WRITE(2,833) ((SUMRY(I,J),J=1,15),I=M9,M9)
833 FORMAT(1H ,10X,1H*,F3.0    ,1X,F4.2,1X,F5.2,1X,F2.,0.2
   1X,F2,0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.),2X,F2.),2X,F2.
   2),2X,F2.0,1X,F5.2,1X,F5.2,1X,F6.2)
    WRITE(2,156)
156 FORMAT(1H )
    WRITE(2,32)
 32 FORMAT(1H ,11HPIPE BED  *)
    WRITE(2,75)
 75 FORMAT(1H+,11X,69H***********************************
   1**************************)
    L8=L8+1
    WRITE(2,844) ((SUMRY(M9,J),J=1,15),M9=L8,L7)
844 FORMAT(1H ,10X,1H*,F3.O    ,1X,F4.2,1X,F5.2,1X,F2.0,2X,
   1F2.0,2X,F2.0,2X,F2.0,2X,F2.),2X,F2.),2X,F2.O,2X,F2.0,
   22X,F2.O,1X,F5.2,1X,F5.2,1X,F6.2)
    WRITE(2,155)
155 FORMAT(1H )
 36 CONTINUE
    WRITE(2,33)
 33 FORMAT(1H ,11H   TOTAL*)
    WRITE(2,76)
 76 FORMAT(1H+,11X,69H***********************************
   1**************************)
    M9=L7+1
    WRITE(2,855) ((SUMRY(I,J),J=1,15),I=M9,M9)
855 FORMAT(1H ,10X,1H*,F3.0    ,1X,F4.2,1X,F5.2,1X,F2.0,2X
   1,F2.0,2X,F2.),2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.0
   2,2X,F2.0,1X,F6.2,1X,F5.2,1X,F6,2)
    WRITE(2,154)
154 FORMAT(1H )
    WRITE(2,34)
 34 FORMAT(1H ,11HBACKFILL  *)
    WRITE(2,77)
 77 FORMAT(1H+,11X,69H***********************************
   1**************************)
    M8=L6+1
    WRITE(2,866) ((SUMRY(M9,J),J=1,15),M9=M8,L5)
866 FORMAT(1H ,10X,1H*,F3.0    ,1X,F4.2,1X,F5.2,1X,F2.0,2X,
   1F2.0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.0,2X,F2.0,
   22X,F2.0,1X,F6.2,1X,F5.2,1X,F6.2)
    WRITE(2,153)
153 FORMAT(1H )
    WRITE(2,78)
 78 FORMAT(1H+.10X,70H***********************************
    ***************************)
 45 CONTINUE
    RETURN
    END

    SUBROUTINE SUMMARY(I,A,B,C,D,E,F,G,H,P,R,S,T,U,V,W,
   1SUMRY)
    DIMENSION SUMRY(25,15)
```

```
      SUMRY(I,1)=A
      SUMRY(I,2)=B
      SUMRY(I,3)=C
      SUMRY(I,4)=D
      SUMRY(I,5)=E
      SUMRY(I,6)=F
      SUMRY(I,7)=G
      SUMRY(I,8)=H
      SUMRY(I,9)=P
      SUMRY(I,10)=R
      SUMRY(I,11)=S
      SUMRY(I,12)=T
      SUMRY(I,13)=U
      SUMRY(I,14)=V
      SUMRY(I,15)=W
      RETURN
      END

      SUBROUTINE OVERATE(L5,A)
      DIMENSION A(25,15),B(25,15)
      CALL RELATION(Z1,Z2,Z3)
    1 CONTINUE
      J=0
      J=J+1
      I=2
      I=I+1
      IF(A(I,J).EQ.3.0 GO TO 2
    3 CONTINUE
      IF(A(I,J).EQ.Z1) GO TO 4
      I=I+1
    4 CONTINUE
C ROAD BREAKOUT INCLUDED
      L=1
      CALL BFORM(L,I,A,B)
      I=5
      L=2
C EXCAVATION
      CALL BFORM(L,I,A,B)
      GO TO 5
    2 CONTINUE
C NO ROAD BREAKOUT
      L=1
      CALL BFORM(L ,I,A,B)
    5 CONTINUE
      I=I+1
      IF(A(I,J).EQ.20.0) GO TO 6
      K=I
    7 CONTINUE
      IF(A(I,J).EQ.Z2) GO TO 8
      IF(A(I,J).EQ.20.0) GO TO 9
      I=I+1
      GO TO 7
    9 Z2=Z2-1.0
      I=K
      GO TO 7
    8 CONTINUE
```

```
C TRENCH SUPPORT INCLUDED
      L=L+1
      CALL BFORM(L,I,A,B)
    6 CONTINUE
      I=0
   10 I=I+1
      IF(A(I,J).EQ.20.0) GO TO 11
      GO TO 10
   11 L=L+1
C PIPE LAY TOTAL
      CALL BFORM(L,T,A,B)
   15 I=I+1
      IF(A(I,J).EQ.21.0) GO TO 14
      GO TO 15
   14 L=L+1
C BEDDING TOTAL
      CALL BFORM(L,I,A,B)
   12 I=I+1
      IF(A(I,J).EQ.Z3) GO TO 13
      GO TO 12
   13 CONTINUE
C BACKFILL
      L=L+1
      CALL BFORM(L,I,A,B)
      CALL UTBFORM(B,L,A)
      RETURN
      END


      SUBROUTINE RELATION(Z1,Z2,Z3)
      READ(1.1) Z1,Z2,Z3
    1 FORMAT(3F5.0)
      RETURN
      END


      SUBROUTINE BFORM(L,I,A,B)
      DIMENSION A(25,15),B(25,15)
      DO 1 J=1,15
      B(1,J)=A(I,J)
    1 CONTINUE
      RETURN
      END


      SUBROUTINE UTBFORM(B,L,A)
      DIMENSION A(25,15),B(25,15),C(1,9)
      SUM=0.0
      J=3
    1 J=J+1
      REG=0.0
      I=0
    2 I=I+1
      IF(B(I,J).GE.REG) GO TO 3
      IF(I.LT.L) GO TO 2
      GO TO 4
    3 REG=B(I,J)
      IF(I.LT.L) GO TO 2
```

```
 4 C(1,J-3) =REG
   IF(J.LT.12) GO TO 1
   SUM=0.0
   DO 5 I=1,L
   SUM=B(I,15)+SUM
 5 CONTINUE
   ZLENGTH=A(2,2)
   SUMPU=SUM/ZLENGTH
   WRITE(2,62)
62 FORMAT(1H ,11HSUMMARY  *)
   WRITE(2,63)
63 FORMAT(1H+,11X,69H*************************************
  1**************************)
   WRITE(2,6) A(2,3),C(1,1),C(1,2),C(1,3),C(1,4),C(1,5),
  1C(1,6),C(1,7),C(1,8),C(1,9),ZLENGTH,SUMPU,SUM
 6 FORMAT(1H ,10X,1H*,F3.0,12X,F2.0,2X,F2.0,2X,F2.0,2X,
  1F2,0.2X,F2.0,2X,F2.0 2X,F2.0,2X,F2.0,2X,F2.0,1X,F5.2
  2,1X,F5.2,1X,F6.2)
   WRITE(2,64)
64 FORMAT(1H ,10X,70H*************************************
  1***************************)
   RETURN
   END

   FINISH
```

APPENDIX 3

MANHOLE ANALYSIS PROGRAMME

MANHOLE

CONTENTS

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3	Hardware Configuration	1
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4.2	Pre-Cast Concrete Ring Manhole Analysis	4
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1. Introduction

This programme analyses manhole construction. It produces material quantities, labour and plant requirements and the construction time at standard performance. Both brick and pre-cast concrete ring manholes may be analysed. Insitu reinforced concrete manholes are not considered.

2. Software Language

FORTRAN

3. Hardware Configuration

1905E Central Processing Unit with hardware floating point

96K words of 1.8 μsec store (K = 1024, word = 24 bits)

Operators' console

Input: 2101 card reader, 2000 cards/minute

1916 paper tape reader, 1000 characters/second

Output: 1933 lineprinter, 1350 lines/minute, 120 characters/line

1925 paper tape punch, 110 characters/second

1934 graph plotter, 30" wide, 300 steps/second, step size 0.005"

Magnetic Tapes:

4 magnetic tape decks using 0.5" magnetic tapes. Information is stored across 7 tracks at a density of 556 characters/inch. The maximum transfer rate is 20,800 characters/second.

2 magnetic tape decks using 0.5" magnetic tape. Information is stored across 9 tracks at a density of 1600 characters/inch. The maximum transfer rate is 160,000 characters/second.

Magnetic Discs:

4 exchangeable disc drives, each drive holding 8,192,000 characters stored on 200 tracks. The transfer rate is 208,000 characters/second.

3 exchangeable disc drives, each drive holding 60,000,000 characters.

Magnetic Drum:

1 drum with a storage capacity of 512K (K=1024) words. The maximum transfer rate is 100,000 characters/second.

7007 Multiplexor

7008 Telegraph Data terminals

7010 Telephone Data terminal

In the Main Building, room 416, the following equipment is installed.

7022 Card reader, 300 cards/minute

7021 Lineprinter, 300 lines/minute

Operators' console

418A teletype terminals

4. Programme Configuration and Theory

This programme (Figure.1.) contains eleven sub-programmes, each of which analyse different manhole construction operations. Each sub-programme contains one or more 'element subroutines' to calculate material quantities, gang sizes and construction times, data input and output being controlled by 'ancillary subroutines'.

The sub-programmes are:-

(1) Road Breakout

(2) Excavation

(3) Excavation Support

(4) Base Binding

(5) Channel Construction

(6) Pre-Cast Concrete Ring Manhole Analysis

(7) Brick Manhole Analysis

(8) Insitu Concrete Slab Construction

(9) Concrete Surround

(10) Benching and Finishing

(11) Backfill

The sub-programmes which analyse the road breakout, excavation support and backfill are similar to those presented earlier (Appendix 2) for pipeline analysis.

Work measurement information (Appendix 1) is stored within each sub-programme and detailed analyses of each construction element is output after each is processed. Although the object of this programme is primarily to produce gang sizes and construction times, a great deal of emphasis is placed on calculating the net material quantities (excluding wastage).

Each sub-programme contained in the manhole analysis programme will now be discussed in more detail.

4.1 Base Blinding, Channel Construction and Benching

Although these sub-programmes deal with different construction elements, their individual structures are similar.

Each sub-programme contains one element sub-routine which calculates the material quantity, gang size and construction time at standard performance from stored work measurement data and the relevant dimensions provided by ancillary sub-routines. A detailed output is produced after each is processed, the main items being stored so that an overall summary of the manhole construction can be produced.

4.2 Pre-Cast Concrete Ring Manhole Analysis

This sub-programme (Figure.2.) contains six element subroutines, each dealing with separate structural elements.

(1) Chamber Rings

(2) Straight Backed Tapers

(3) Shaft Rings

(4) 75 mm Flat Slabs

(5) 150 mm Flat Slabs

(6) Base Units

Any combination of the various structural elements may be specified. If pre-cast base units are used, the channel analysis sub-programme (described in 4.1) is omitted from the analysis.

4.3 Brick Manholes Analysis

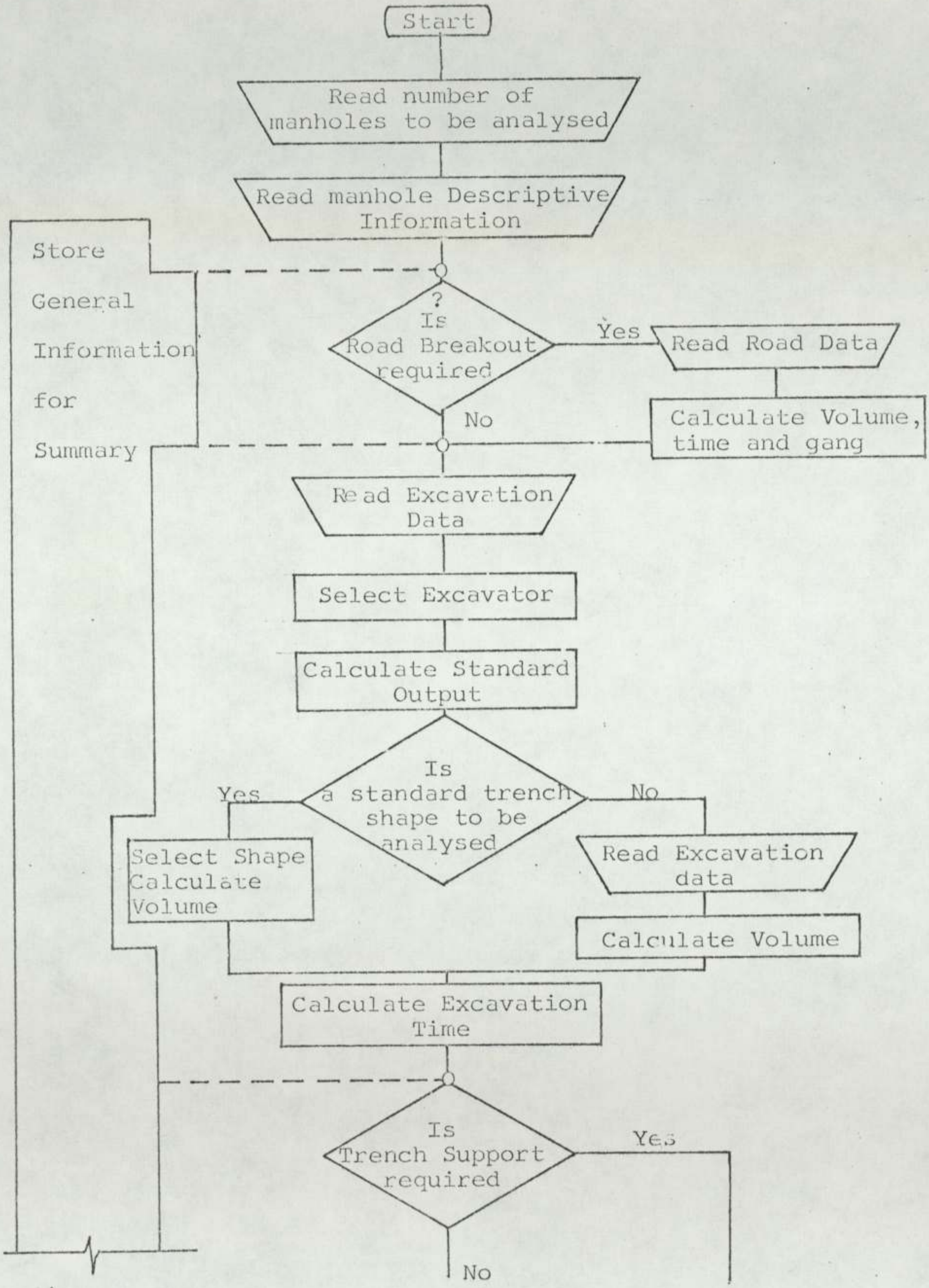
From manhole dimensions obtained either from the Bills of Quantity or Detail Drawings, this group of element subroutines calculates the number of bricks, step irons, volume of mortar, construction time and gang size. The sub-programme (Figure.3.) is capable of analysing single or dual chamber manholes. All material quantities calculated do not include wastage and the construction time is based on standard work measurement data (Appendix 1).

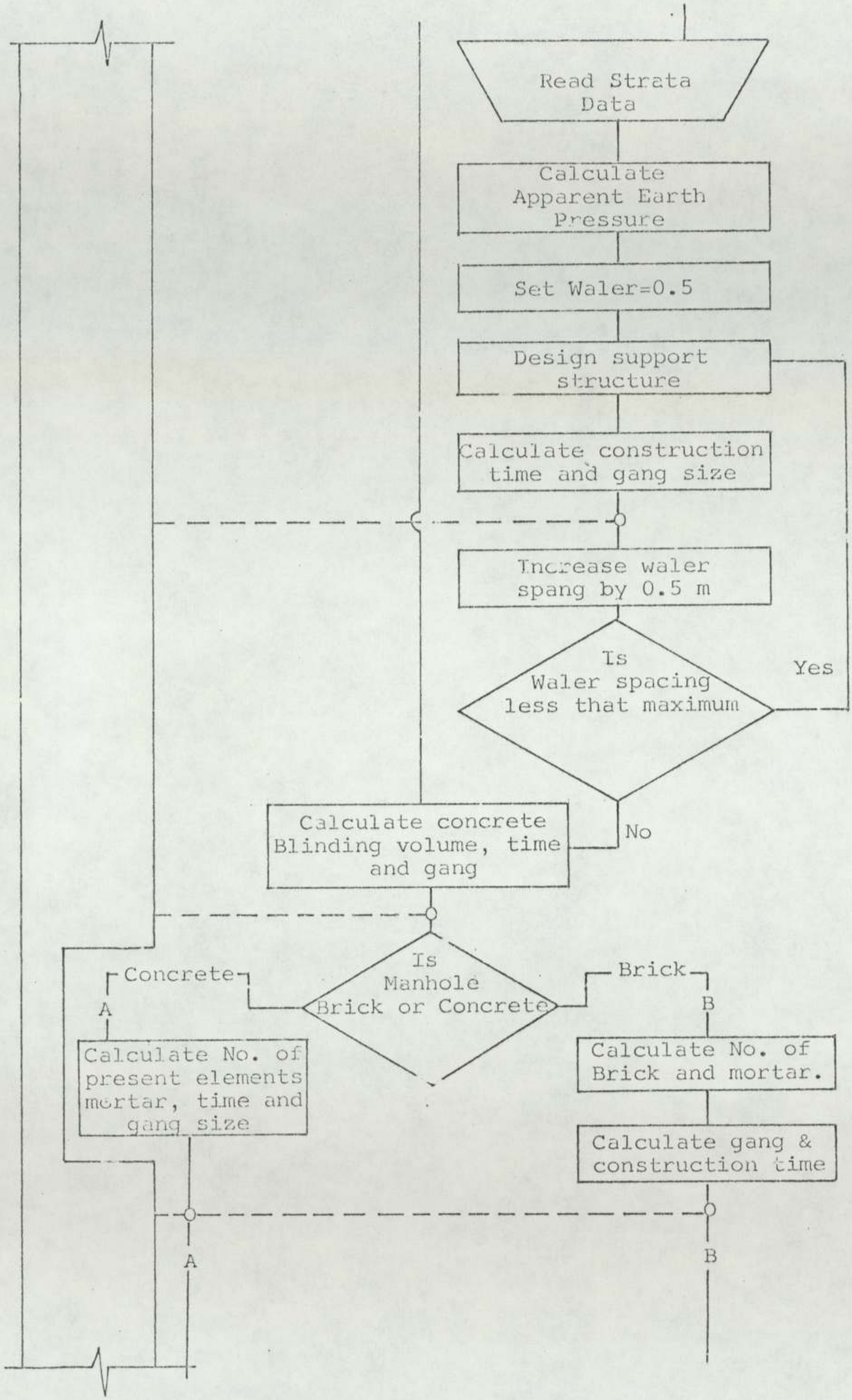
4.4 Insitu Concrete Slabs and Surround Analysis

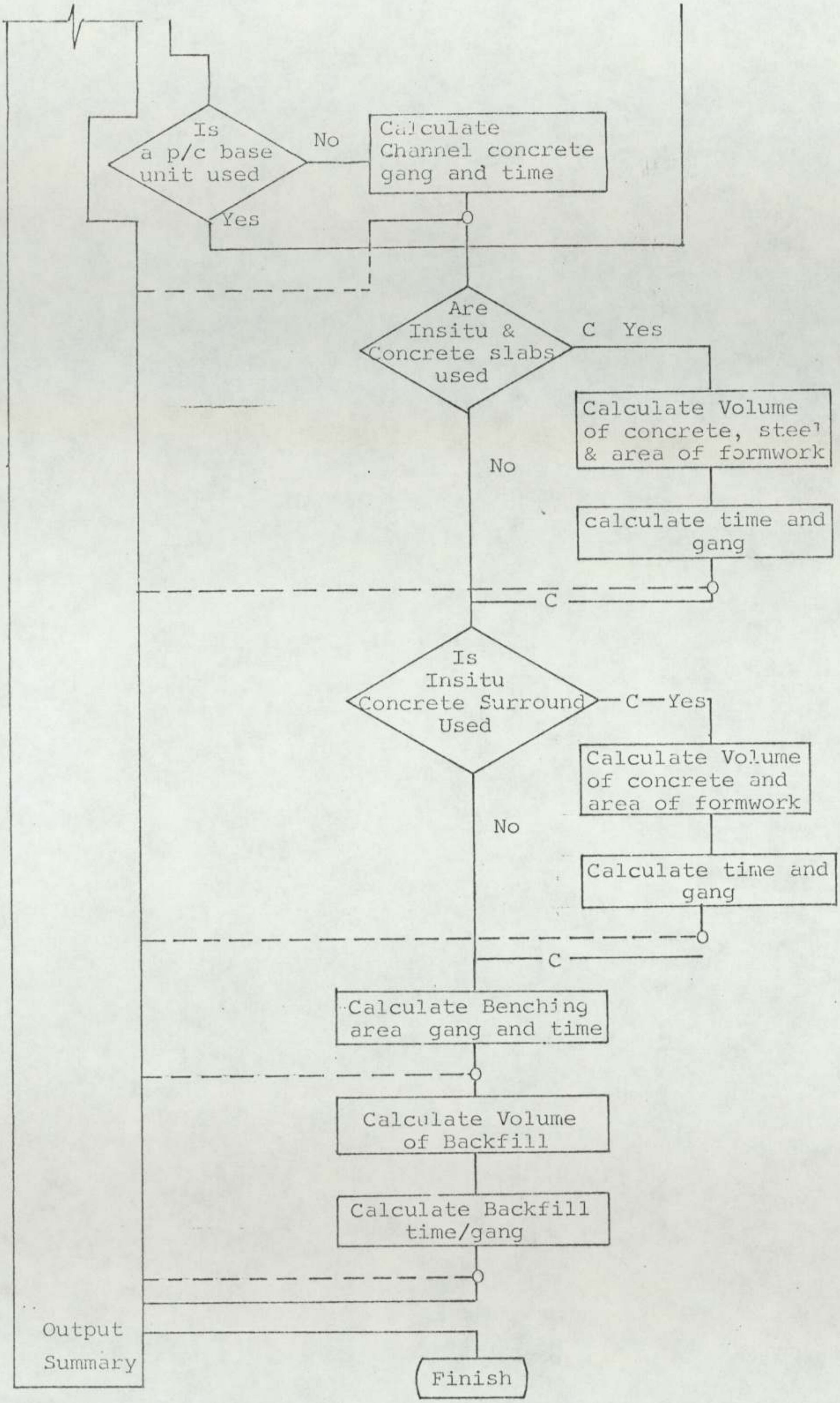
These sub-programmes (Figure 4) contain two element subroutines. One calculates the material quantities and the area of formwork required. The second element subroutine determines the construction time and gang size necessary. Both sub-programmes are optional.

FIGURE. 1 .

Structure of Master Segment




Read Strata Data
Calculate Apparent Earth Pressure
Set Waler=0.5
Design support structure
Calculate construction time and gang size
Increase waler spang by 0.5 m
Is Waler spacing less that maximum
Yes
No
Calculate concrete Blinding volume, time and gang
Is Manhole Brick or Concrete
Concrete
Brick
A
B
Calculate No. of present elements mortar, time and gang size
Calculate No. of Brick and mortar.
Calculate gang & construction time
A
B


Is a p/c base unit used
No
Yes
Calculate Channel concrete gang and time
Are Insitu & Concrete slabs used
C Yes
No
Calculate Volume of concrete, steel & area of formwork
calculate time and gang
C
Is Insitu Concrete Surround Used
C
Yes
No
Calculate Volume of concrete and area of formwork
Calculate time and gang
C
Calculate Benching area gang and time
Calculate Volume of Backfill
Calculate Backfill time/gang
Output Summary
Finish

Pre-Cast Concrete Ring Manholes

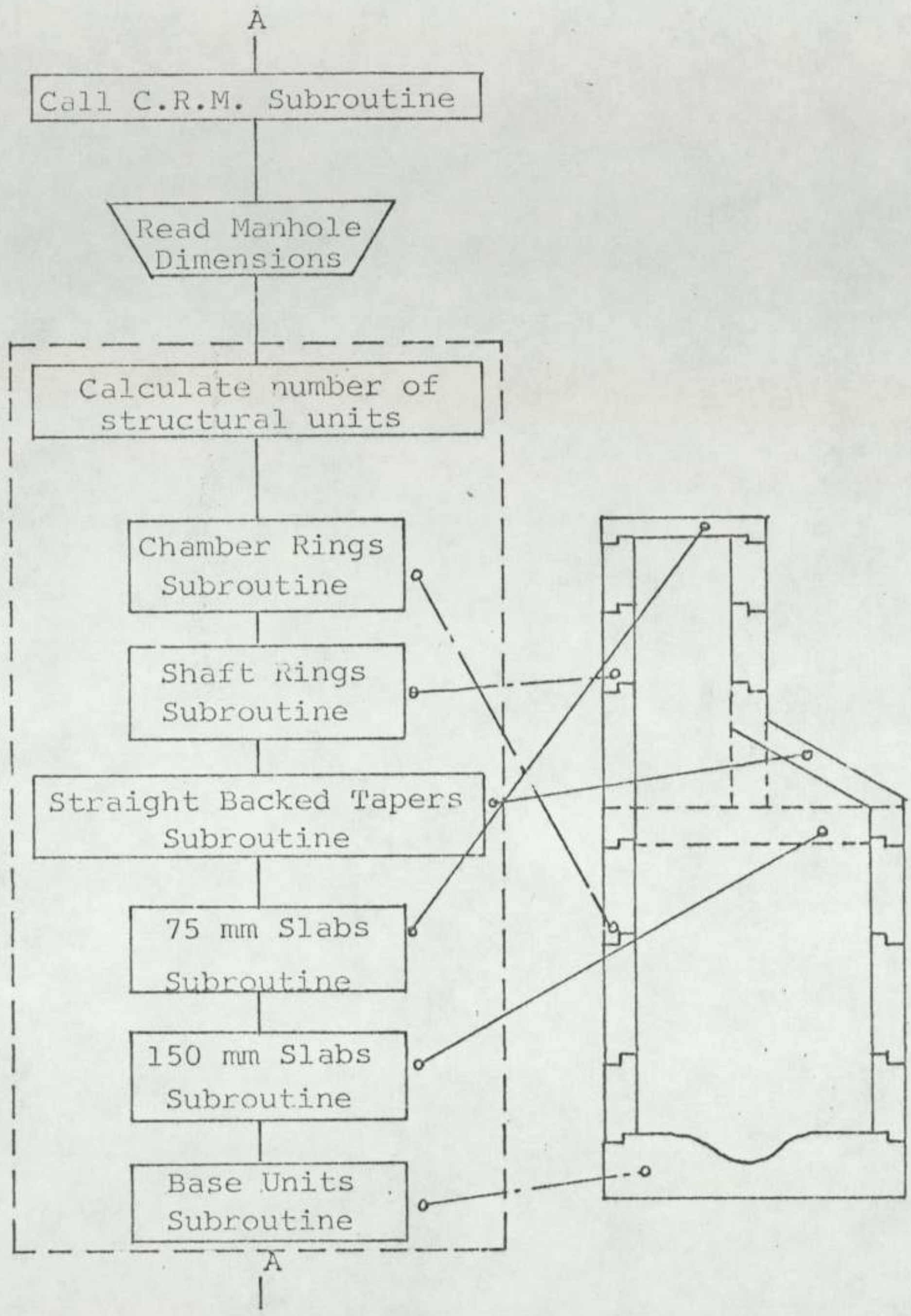


FIGURE. 2 .

Brick Manholes

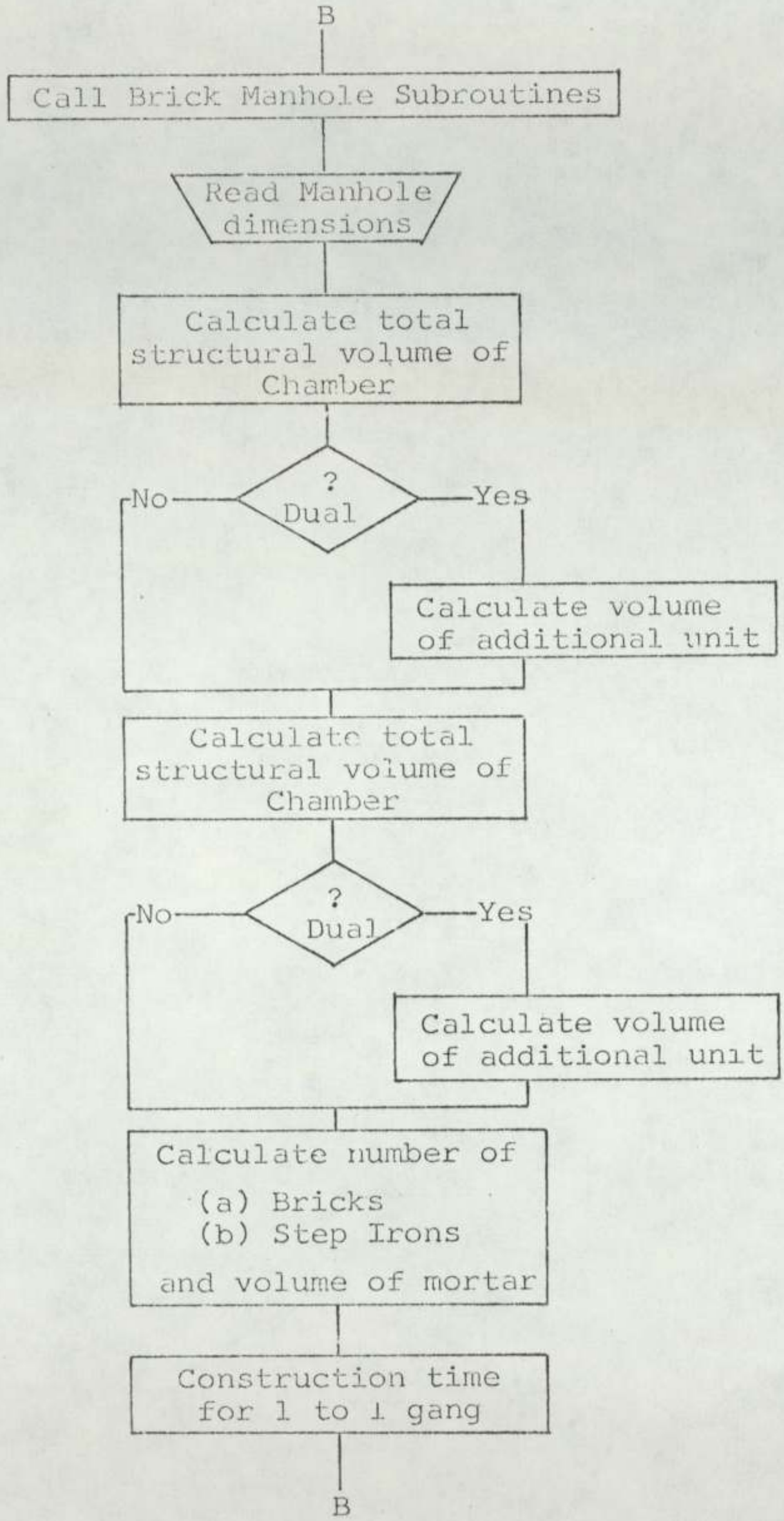


FIGURE. 3 .

Insitu Concrete Slabs and Surround

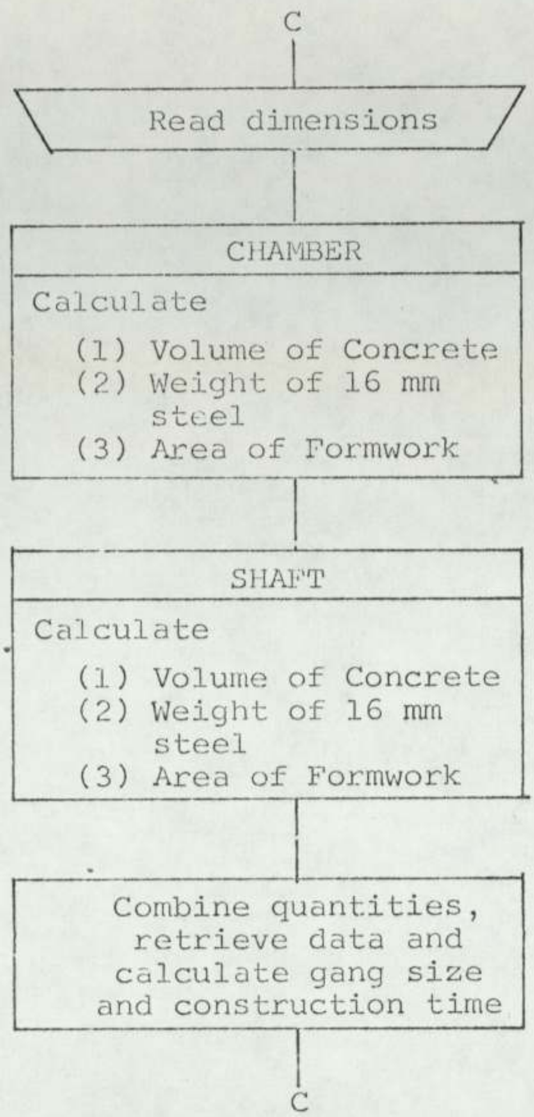


FIGURE. 4 .

SECTION 5

MANHOLE ANALYSIS

USER MANUAL

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5.1. Restrictions

(a) All dimensions must be metric.

(b) Data must be entered for all sections unless stipulated otherwise.

(c) All column numbers are inclusive in the field specifications.

(d) Data must be entered 'right bias' (the last figure of the item of data should be entered in the right most column).

(e) * In the field specification signifies that there is no column restriction.

5.2. General Information Input

Card Number	Field	Input Description
1	*	Number of manhole items to be analysed.
2	1 to 24	Job description.
3	1 to 4	Bill number.
4	1 to 4	Page number.
5	1 to 4	Item number.
6	*	1 if Brick manhole, 0 if Pre-cast concrete Ring manhole.
7	*	External width in metres.
	*	External length in metres.
	*	Depth of manhole in metres.

5.3. Road Breakout Input

Card Number	Field	Input Description
1	*	1 if Road Breakout required, 0 if Road Breakout not required.

If 0 was entered, start section 4.

Card Number	Field	Input Description
2	*	1 If concrete road construction, 2 if Tarmacadam road construction.
3	*	Road breakout thickness in millimetres.

5.4. Machine Selection and Excavation Input

Card Number	Field	Input Description
1	*	Machine Bucket width in millimetres.
	*	Strata Grading. (Table 1)
	*	Construction Grading. (Table 2)
	*	Horizontal reach in metres.
	*	Vertical unloading height in metres.
2	*	Required trench shape. (Table 3)

Table 3

Trench Shape

Trench Shape 1

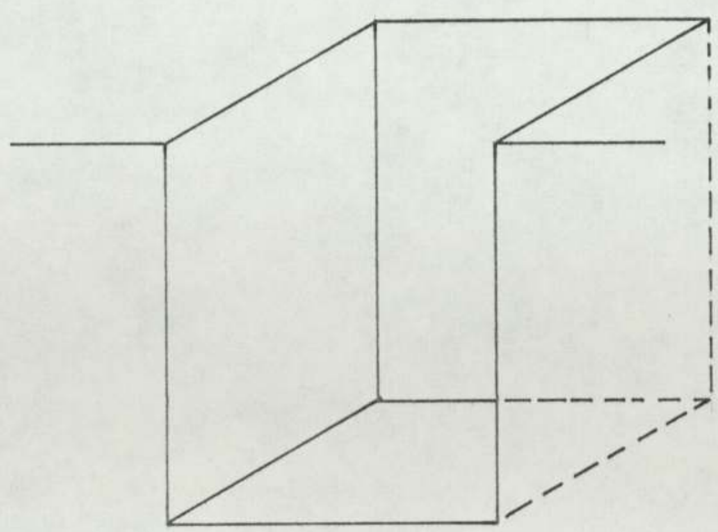


TABLE. 1 .

STRATA GRADING

DESCRIPTION	GRADING
'ROCK' shall mean those geological strata and individual boulders exceeding 6 cubic feet (0.17m) in size or other masses of hard material outside those strata which necessitate the use of blasting or approved pneumatic tools for their removal.*	1
'MEDIUM ROCK' As 'A' above but not exceed-ind 6 cubic feet (0.17m) but exceeding 1 cubic foot (0.028m).	2
'SOFT ROCK' As 'B' but not exceeding 1 cubic foot (0.028m) and possessing bedding plains to allow breakage.	3
'SOFT LAMINATED ROCK' As 'C' but with excess laminations or bedding plains (slate, soft sandstone, shale).	4
'COHESIVE SOIL' (stiff) includes clays and marls with up to 20 per cent of gravel having a moisture content not less than the value of the plastic limit (BS 1377) minus 4; also chalk having a saturation moisture content of 20 per cent or greater.*	5-6
'SOFT COHESIVE SOIL' (medium) As '5-6' but excluding marls and including all clays and approximately 10 per cent sand or below.	7
Well-graded granular and dry cohesive soils, include clays or marls containing more than 20 per cent gravel.*	8
Well-graded sand and gravels with uniform-ity coefficient exceeding 10, also clinker and spent domestic refuse.	9
Uniformity graded material includes sands and gravels with uniformity coefficient of 10 or less, all silts and pulverised fuel ashes.*	10

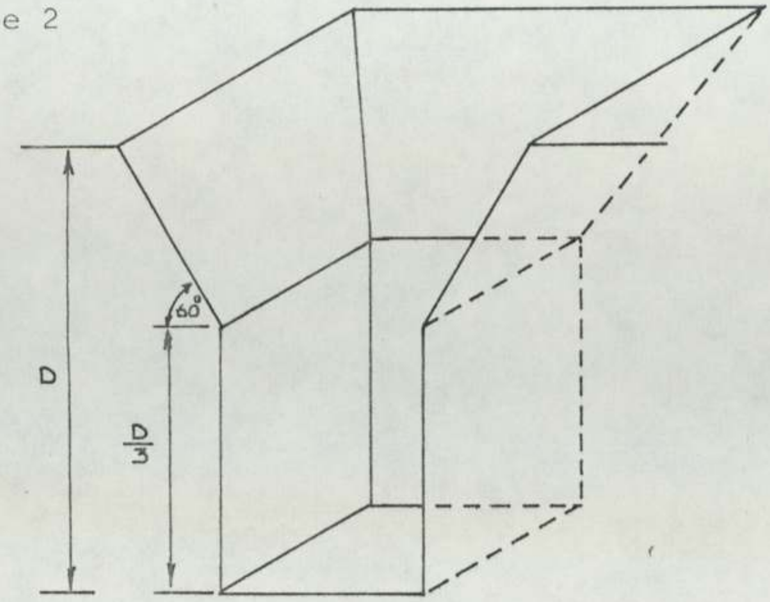
* "Specification for Road and Bridge Works". 1969. Clause 601, 1.(iv), 2.(i), 2.(ii), 2.(iii).

TABLE. 2 .

OBSTRUCTION GRADING

DESCRIPTION	GRADING
Excavation involving the breaking out of metalled road surfaces or other such obstructions situated on top of frequently occurring services.	1
Excavating in ground possessing frequently occurring major services and house connection.	2
(a) Excavating in ground possessing infrequent major services but frequently occurring house services. (b) Excavating in ground possessing infrequent major services and infrequent minor services. (c) Excavating in ground possessing infrequent minor services and for tree roots etc.	3
Excavating in ground possessing minor obstructions only, i.e. tree roots, small quantities of hard core, etc.	4
Excavating in ground possessing no obstructions other than those which are an integral part of the strata.	5

Trench Shape 2



5.5. Trench Support System Input

Card Number	Field	Input Description
1	*	1 If trench support required, 0 if trench support not required.

If 0 was entered, start section 6.

Card Number	Field	Input Description
2	*	1 If strata contains sand, 0 if not.
	*	1 If strata contains clay, 0 if not.
	*	1 If strata contains fissured clay, 0 if not.
3	*	Density of the strata in kg/m^3, if unknown, enter 99.0.
	*	Angle of internal friction in degrees for strata, if unknown enter 99.0.
	*	Cohesion in kg/m^2,if unknown enter 99.0.
4	*	1 If close support required, 2 if medium support required, 3 if open support required.

5.6. Base Blinding

Card Number	Field	Input Description
1	*	Thickness of blinding in millimetres.

If the manhole being analysed is <u>Brick</u> start section 5.7.

If the manhole being analysed is <u>Pre-Cast Concrete Ring</u>, start section 5.8.

5.7. Brick Manhole Input

Card Number	Field	Input Description
1	*	1 If the manhole is dual, 0 if the manhole is single.
2	*	Chamber wall thickness in millimetres.
	*	Chamber height in metres.
3	*	Shaft wall thickness in millimetres.
	*	Shaft height in metres.
	*	Shaft internal width in metres.
	*	Shaft internal length in metres.

If the manhole being analysed is Brick, start section 5.9.

5.8. Pre-Cast Concrete Ring Manhole Input

Card Number	Field	Input Description
1	*	Chamber internal diameter in millimetres.
	*	Shaft internal diameter in millimetres.
2	*	Length of chamber rings in metres.

Card Number	Field	Input Description
	*	Number of straight backed tapers.
	*	Length of shaft rings in metres.
	*	Number of 75 mm cover slabs.
	*	Number of 150 mm cover slabs.
	*	Number of pre-cast base units.

If pre-cast concrete base units are used, start section 5.10.

5.9. Channel Construction Input

Card Number	Field	Input Description
1	*	Manhole outlet diameter in millimetres.

5.10. Insitu Slab Construction Input

Card Number	Field	Input Description
1	*	1 If insitu slabs are required, 0 if insitu slabs not required.

If 0 was entered, start section 5.11.

Card Number	Field	Input Description
2	*	Shaft slab thickness in millimetres.
	*	Chamber slab thickness in millimetres.

5.11. Insitu Concrete Surround Input

Card Number	Field	Input Description
1	*	1 If concrete surround is required, 0 if concrete surround is not required.

If 0 was entered start section 5.12.

Card Number	Field	Input Description
2	*	Concrete surround thickness in millimetres.

5.12. Backfill Input

Card Number	Field	Input Description
1	*	Compaction layer thickness in millimetres.

5.13. Construction Method Input

Card Number	Field	Input Description
		Refer to table 4.
1	*	Road Breakout method number.
	*	Trench Support method number.
	*	Backfill method number.

If the methods are not included in the analysis, enter 0 in the appropriate fields.

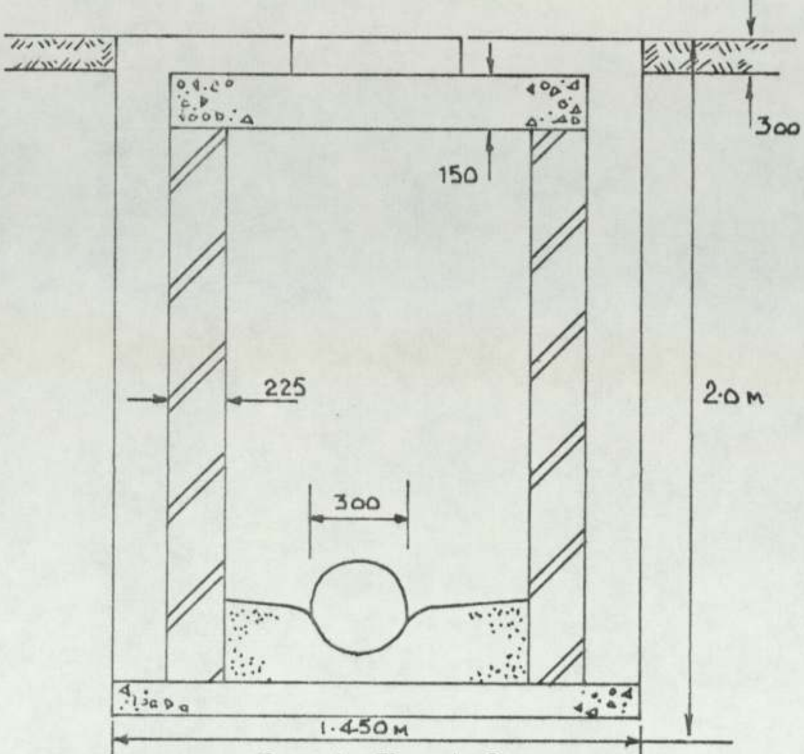
Table 4
Construction Method Numbers

Operation	Method Description	Method Number
Road Breakout	Medium Breaker	1
Road Breakout	I.P.H.	2
Trench Support	0.5 vertical waler spacing	4
" "	1.0 " " "	5
" "	1.5 " " "	6
" "	2.0 " " "	7
" "	2.5 " " "	8
" "	3.0 " " "	9
" "	3.5 " " "	10
" "	4.0 " " "	11
Backfill	Hand backfill	90
"	Dumper assisted	91
"	Excavator assisted	92
"	Tracked Loader	93

Re-start at section5.2,card number 3, for subsequent manhole analyses.

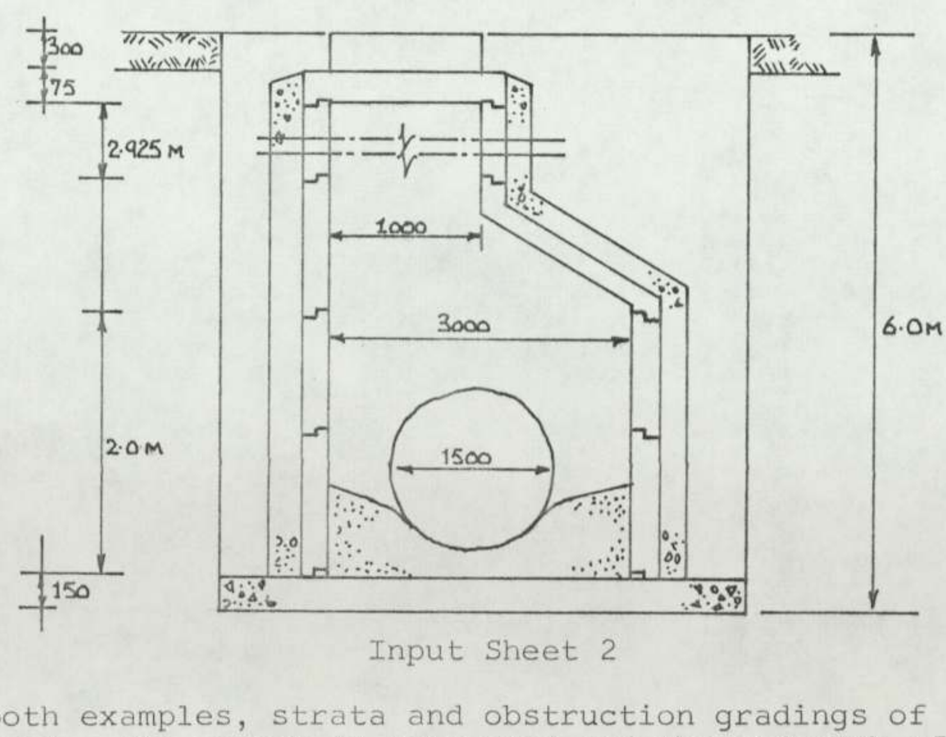
5.14. Example Input and Output

(a) Brick Manhole Analysis



Input Sheet 1

(b) Pre-cast Concrete Ring Manhole Analysis



Input Sheet 2

In both examples, strata and obstruction gradings of 5 are assumed. The trench is supported and the strength of the strata is unknown.

INPUT SHEET 1

```
1
DRATEMAN  TEST 1  BRICK
1
1
1
1
1.450   1.450  2.000
1
2
300
600.0  5.0  5.0  2.0  2.0
1
1
1   1   0
99.0  99.0  99.0
1
150
0
225  1.700
225  0.150   1.0   1.0
300
1
0.0  150.0
0
150
1.0  7.0  92.0
```

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THE UNIVERSITY OF ASTON IN BIRMINGHAM

PAPER TAPE OR CARD DATA LAYOUT SHEET

BILL ITEM TIME ANALYSIS

****

CONTRACT DESCRIPTION

****

DRATEMAN TEST 1 BRICK

BILL NUMBER 1

PAGE NUMBER 1

ITEM NUMBER 1

ROAD BREAKOUT

****

FLEXIBLE ROAD CONSTRUCTION

****

WIDTH OF BREAKOUT	=	2.950 M
THICKNESS OF ROAD	=	300. MM
LENGTH OF BREAKOUT	=	2.950M
VOLUME OF BREAKOUT	=	2.611M3

TWO ALTERNATIVE GANGS

****

GANG NUMBER.1..

NUMBER OF COMPRESSORS	=	1.
NUMBER OF LABOURERS	=	2.
STANDARD MANHOURS	=	6.527HRS
STANDARD DURATION	=	3.263HRS

GANG NUMBER.2..

NUMBER OF MACHINES(IPH)	=	1.
NUMBER OF LABOURERS	=	1.
STANDARD MANHOURS	=	3.002HRS
STANDARD DURATION	=	1.501HRS

MACHINE EXCAVATION RATE
****

MACHINES CONSIDERED
****

CODE	MACHINE NAME
1	JCB 3
2	JCB 3C
3	JCB 3D
4	JCB 5C
5	JCB 7B
6	HY-MAC 580
7	JCB 6C
8	JCB 6D
9	JCB 7C
10	RH 6

EXCAVATION DETAILS
****

STRATA: =TYPE. 5..
OBSTRUCTION GRADING =TYPE. 5..
TRENCH DEPTH = 2.000 M
TRENCH WIDTH = 2.950 M
BUCKET WIDTH = 600.MM
LOADING HEIGHT = 2.000 M
REACH = 2.000 M
USE MACHINE TYPE = 1
STANDARD OUTPUT = 9.964 M3/HR
VOLUME OF EXCAVATION = 17.405M3
STANDARD DURATION = 1.747HRS

TRENCH SUPPORT SYSTEM DESIGN

****

TRENCH DETAILS: DEPTH=2.000 M

WIDTH=2.950 M

SOIL DETAILS: ANGLE OF INTERNAL FRICTION (PHI)=25.00 DEGS

COHESION (COH)=1400.00 KG/M2

SPECIFIC WEIGHT (GAMA)=2082.60 KG/M3

TRENCH SHEET DETAILS:

B.S.P TYPE.T5. ELASTIC MODULUS=56.OCM3

WIDTH=0.33M

STRUT DETAILS: HORIZONTAL SPACING=2.50 M

WALER DETAILS:

SECTION NOTATION	SECTION SHAPE	SECTION WEIGHT (KG/M)	D (MM)	B (MM)	T (MM)	ELASTIC MODULUS (ZXX) (CM3)
1	I	13.38	127	76	7.6	75.12
2	I	17.10	152	89	8.3	115.90
3	I	20.82	178	76	10.3	150.40
4	I	23.80	203	76	11.2	192.00
5	I	25.00	203	133	7.8	231.00
6	I	30.00	207	134	9.6	279.00
7	I	31.00	251	146	8.6	352.00
8	I	43.00	260	147	12.7	504.00
9	I	31.00	307	166	11.8	646.00

CLOSE SHORING CONSTRUCTION DETAILS
****

VERTICAL WALER/STRUT SPACING = 0.500 M
****

NO OF TRENCH SHEETS	=	33
LENGTH OF TRENCH SHEETS	=	2.333 M
NO OF TRENCH STRUTS	=	24.
LENGTH OF STRUTS	=	2.950 M
THICKNESS/WIDTH OF STRUTS	=	113. MM
NO OF WALERS	=	24.
USE WALER TYPE	=	1.
WEIGHT OF WALER	=	13.38 KG/M
NUMBER OF MEN	=	4.
NUMBER OF MACHINES +DRIVERS	=	0.
STANDARD DURATION	=	1.602 HRS
STANDARD MANHOURS	=	6.409 HRS

CLOSE SHORING CONSTRUCTION DETAILS
****

VERTICAL WALER/STRUT SPACING = 1.000 M
****

NO OF TRENCH SHEETS	=	33.
LENGTH OF TRENCH SHEETS	=	2.333 M
NO OF TRENCH STRUTS	=	14.
LENGTH OF STRUTS	=	2.950 M
THICKNESS/WIDTH OF STRUTS	=	113. MM
NO OF WALERS	=	14.
USE WALER TYPE	=	1
WEIGHT OF WALER	=	13.38 KG/M
NUMBER OF MEN	=	4.
NUMBER OF MACHINES +DRIVERS	=	0.
STANDARD DURATION	=	1.096 HRS
STANDARD MANHOURS	=	4.384 HRS

```
CLOSE SHORING CONSTRUCTION DETAILS
**********************************
VERTICAL WALER/STRUT SPACING = 1.500 M
**************************************
NO OF TRENCH SHEETS           =   33.
LENGTH OF TRENCH SHEETS       = 2.333 M
NO OF TRENCH STRUTS           =    9.
LENGTH OF STRUTS              = 2.950 M
THICKNESS/WIDTH OF STRUTS     =  113. MM
NO OF WALERS                  =    9.
USE WALER TYPE                = 2
WEIGHT OF WALER               = 17.10 KG/M
NUMBER OF MEN                 = 4.
NUMBER OF MACHINES +DRIVERS   = 0.
STANDARD DURATION             =       0.878 HRS
STANDARD MANHOURS             =       3.511 HRS


CLOSE SHORING CONSTRUCTION DETAILS
**********************************
VERTICAL WALER/STRUT SPACING = 2.000 M
**************************************
NO OF TRENCH SHEETS           =   33.
LENGTH OF TRENCH SHEETS       = 2.333 M
NO OF TRENCH STRUTS           =    9.
LENGTH OF STRUTS              = 2.950 M
THICKNESS/WIDTH OF STRUTS     =  113. MM
NO OF WALERS                  =    9.
USE WALER TYPE                = 2
WEIGHT OF WALER               = 17.10 KG/M
NUMBER OF MEN                 = 4.
NUMBER OF MACHINES +DRIVERS   = 0.
STANDARD DURATION             =       0.878 HRS
STANDARD MANHOURS             =       3.511 HRS
```

BASE BLINDING

****

THICKNESS OF BLINDING = 150.MM
VOLUME OF BLINDING = 1.31M3
NUMBER OF LABOURERS = 2.
NUMBER OF GANGERS = 1.
STANDARD DURATION = 0.43 HRS

BRICK MANHOLE

****

NUMBER OF BRICKS =1025.NO
VOLUME OF MORTAR = 0.43M3
NUMBER OF STEP IRONS = 6.NO
NUMBER OF MIXERS = 1.NO
NUMBER OF LABOURERS = 1.
NUMBER OF BRICKLAYERS = 1.
STANDARD DURATION =13.49HRS

CHANNEL LAYING

****

OUTLET DIAMETER = 3.00.MM
NUMBER OF LABOURERS = 1.
NUMBER OF GANGERS = 0.
STANDARD DURATION = 0.75HRS

INSITU SLABS

****

VOLUME OF CONCRETE = 0.32M3
WEIGHT OS STEEL = 0.09T
AREA OF FORMWORK = 5.07M2
NUMBER OF LABOURERS = 1.
NUMBER OF TRADESMEN = 0.
NUMBER OF GANGERS = 1.
STANDARD DURATION = 4.91HRS

BENCHING

****

AREA OF BENCHING = 2.10M2

NUMBER OF LABOURERS = 2.

STANDARD DURATION = 2.10HRS

TRENCH BACKFILL

****

BACKFILL VOLUME = 13.173 M3

GANG NUMBER = 1.

NO OF PEGSON RAMMERS = 1.

NUMBER OF MEN = 2.

STANDARD MANHOURS =14.590 HRS

STANDARD DURATION = 7.295 HRS

GANG NUMBER = 2.

NO OF PEGSON RAMMERS = 1.

NUMBER OF MEN = 2.

NO OF DUMPERS = 1

STANDARD MANHOURS = 1.844 HRS

STANDARD DURATION = 0.922 HRS

GANG NUMBER = 3.

NO OF PEGSON RAMMERS = 1.

NUMBER OF MEN = 2.

NO OF MACHINES(JCB 3C) = 1.

STANDARD MANHOURS = 1.515 HRS

STANDARD DURATION = 0.505 HRS

GANG NUMBER = 4.

NO OF LOADERS(DROTT175) = 1.

NO OF PEGSON RAMMERS = 1.

NUMBER OF MEN = 2.

STANDARD MANHOURS = 1.120 HRS

STANDARD DURATION = 0.373 HRS

ANALYSIS SUMMARY
****

```
DESCRIPTION =DRATEMAN TEST 1 BRICK                          MANHOLE TYPE = BRICK
BILL NO     =1                      LENGTH      = 1.45M
PAGE NO     =1                      WIDTH       = 1.45M
ITEM NO     =1                      DEPTH       = 2.00M

OPERATION * M   W   V   A   E N N N N M I N N   N N   S
          * E   A   O   R   X O O O O E . O O   O O   T
          * T   L   L   E   C         D P             D
          * H   E   U   A   A O O O O I . O O   O O
          * O   R   M   S   V F F F F U H F F   F F   D
          * D       E   /   A         M                U
          *     S   S   B   T C D D R     M G   T L   R
          * N   P       R   O R R U O B   I A   R A   A
          * U   A       I   R A O M L R   X N   A B   T
          * M   C       C     N T P L E   E G   D O   I
          * B   I       K   T E T E E A   R E   E U   O
          * E   N       S   Y S S R R K   S R   S R   N
          * R   G           P     S S E     S   M E
          *                 E         R         E R
          *                           S         N S
          *    (M)     (M3) (M2)NO                    HRS
            ****************************************************************
```

Continued

```
ROAD BRK
           * 1.  0.00    2.61   0.00 0.  0. 0. 0. 0. 1. 0. 0. 0.  0.  2.    3.26
           * 2.  0.00    2.61   0.00 0.  0. 0. 0. 0. 0. 1. 0. 0.  0.  1.    1.50
           *
EXCAVATION**************************************************************************
           * 3.  0.00   17.40   0.00 1.  0. 0. 0. 0. 0. 0. 0. 0.  0.  0.    1.75
           *
TRENCH SPT**************************************************************************
           * 4.  0.50    0.00   0.00 0.  0. 0. 0. 0. 0. 0. 0. 1.  0.  3.    1.60
           * 5.  1.00    0.00   0.00 0.  0. 0. 0. 0. 0. 0. 0. 1.  0.  3.    1.10
           * 6.  1.50    0.00   0.00 0.  0. 0. 0. 0. 0. 0. 0. 1.  0.  3.    0.88
           * 7.  2.00    0.00   0.00 0.  0. 0. 0. 0. 0. 0. 0. 1.  0.  3.    0.88
           *
BASE BLIND**************************************************************************
           *20.  0.00    1.31   0.00 0.  0. 0. 0. 0. 0. 0. 0. 1.  0.  2.    0.43
           *
MANHOLE    *************************************************************************
           *40.  0.00    0.43 1025.  0.  0. 0. 0. 0. 0. 0. 1. 0.  1.  1.   13.49
           *
CHANNEL    *************************************************************************
           *50.  0.00    0.00   0.00 0.  0. 0. 0. 0. 0. 0. 0. 0.  0.  1.    0.75
           *
           *************************************************************************
```

Continued

```
INSITU SLB
          *60.  0.00    0.32   5.07  0.   0. 0. 0. 0. 0. 0. 0. 1.  0.  1.    4.91
          *
BENCHING  ************************************************************************
          *80.  0.00    0.00   0.00  0.   0. 0. 0. 0. 0. 0. 0. 0.  0.  2.    7.29
          *
BACKFILL  ************************************************************************
          *90.  0.00   13.17   0.00  0.   0. 0. 0. 1. 0. 0. 0. 0.  0.  2.    7.29
          *91.  0.00   13.17   0.00  0.   0. 0. 1. 1. 0. 0. 0. 0.  0.  2.    0.92
          *92.  0.00   13.17   0.00  1.   0. 0. 0. 1. 0. 0. 0. 0.  0.  2.    0.50
          *93.  0.00   13.17   0.00  0.   0. 1. 0. 1. 0. 0. 0. 0.  0.  2.    0.37
          *
SUMMARY   ************************************************************************
                                     1.   0. 0. 0. 1. 1. 0. 1. 1.  1.  3.   28.07
          ************************************************************************
          ************************************************************************
```

INPUT SHEET 2

```
1
DRATEMAN PRE-CAST TEST 1
12
12
12
0
3.4 3.4 6.0
1
2
300
1200. 5.0 5.0 2.0 2.0
1
1
1 1 0
99.0 99.0 99.0
1
150
3000. 1000.
2.000 1.0 2.925 1.0 0.0 0.0
1500.
0
1
150.0
150.0
1.0 9.0 92.0
```

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THE UNIVERSITY OF ASTON IN BIRMINGHAM

PAPER TAPE OR CARD DATA LAYOUT SHEET

BILL ITEM TIME ANALYSIS
****
CONTRACT DESCRIPTION
****
DRATEMAN PRE-CAST TEST 1
BILL NUMBER   12
PAGE NUMBER   12
ITEM NUMBER   12

ROAD BREAKOUT
****
FLEXIBLE ROAD CONSTRUCTION
****
WIDTH OF BREAKOUT   = 4.900   M
THICKNESS OF ROAD   = 300.   MM
LENGTH OF BREAKOUT   =   4.900M
VOLUME OF BREAKOUT   =   7.203M3
TWO ALTERNATIVE GANGS
****
GANG NUMBER.1..
NUMBER OF COMPRESSORS   = 1.
NUMBER OF LABOURERS   = 2.
STANDARD MANHOURS   =   18.007HRS
STANDARD DURATION   =   9.004HRS
GANG NUMBER.2..
NUMBER OF MACHINES(IPH) = 1.
NUMBER OF LABOURERS   = 1.
STANDARD MANHOURS   =   8.283HRS
STANDARD DURATION   =   4.142HRS

MACHINE EXCAVATION RATE

****

MACHINES CONSIDERED

****

CODE	MACHINE NAME
1	JCB 3
2	JCB 3C
3	JCB 3D
4	JCB 5C
5	JCB 7B
6	HY-MAC 580
7	JCB 6C
8	JCB 6D
9	JCB 7C
10	RH 6

EXCAVATION DETAILS

****

STRATA: =TYPE. 5..
OBSTRUCTION GRADING = TYPE. 5..
TRENCH DEPTH = 6.000 M
TRENCH WIDTH = 4.900 M
BUCKET WIDTH =1200.MM
LOADING HEIGHT = 2.000 M
REACH = 2.000 M
USE MACHINE TYPE = 5
STANDARD OUTPUT = 33.000 M3/HR
VOLUME OF EXCAVATION = 144.060M3
STANDARD DURATION = 4.365HRS

TRENCH SUPPORT SYSTEM DESIGN

****

TRENCH DETAILS: DEPTH=6.000 M

WIDTH=4.900 M

SOIL DETAILS: ANGLE OF INTERNAL FRICTION (PHI)=25.00 DEGS

COHESION (COH)=1400.00 KG/M2

SPECIFIC WEIGHT (GAMA)=2082.60 KG/M3

TRENCH SHEET DETAILS:

B.S.P. TYPE.T5. ELASTIC MODULUS=56.OCM3

WIDTH=0.33M

STRUT DETAILS: HORIZONTAL SPACING=2.50 M

WALER DETAILS:

SECTION NOTATION	SECTION SHAPE	SECTION WEIGHT (KG/M)	D (MM)	B (MM)	T (MM)	ELASTIC MODULUS (ZXX) (CM3)
1	I	13.38	127	76	7.6	75.12
2	I	17.10	152	89	8.3	115.90
3	I	20.82	178	76	10.3	150.40
4	I	23.80	203	76	11.2	192.00
5	I	25.00	203	133	7.8	231.00
6	I	30.00	207	134	9.6	279.00
7	I	31.00	251	146	8.6	352.00
8	I	43.00	260	147	12.7	504.00
9	I	31.00	307	166	11.8	646.00 ,

```
CLOSE SHORING CONSTRUCTION DETAILS
**********************************
VERTICAL WALER/STRUT SPACING = 0.500 M
**************************************
NO OF TRENCH SHEETS          =   55.
LENGTH OF TRENCH SHEETS      = 6.333 M
NO OF TRENCH STRUTS          =  102.
LENGTH OF STRUTS             = 4.900 M
THICKNESS/WIDTH OF STRUTS    =  188. MM
NO OF WALERS                 =  102.
USE WALER TYPE               = 3
WEIGHT OF WALER              = 20.82 KG/M
NUMBER OF MEN                = 4.
NUMBER OF MACHINES +DRIVERS  = 1.
STANDARD DURATION            =     11.532 HRS
STANDARD MANHOURS            =     57.661 HRS

CLOSE SHORING CONSTRUCTION DETAILS
**********************************
VERTICAL WALER/STRUT SPACING = 1.000 M
**************************************
NO OF TRENCH SHEETS          =   55.
LENGTH OF TRENCH SHEETS      = 6.333 M
NO OF TRENCH STRUTS          =   55.
LENGTH OF STRUTS             = 4.900 M
THICKNESS/WIDTH OF STRUTS    =  188. MM
NO OF WALERS                 =   55.
USE WALER TYPE               = 6
WEIGHT OF WALER              = 30.00 KG/M
NUMBER OF MEN                = 4.
NUMBER OF MACHINES +DRIVERS  = 1.
STANDARD DURATION            =      7.167 HRS
STANDARD MANHOURS            =     35.836 HRS
```

CLOSE SHORING CONSTRUCTION DETAILS

****

VERTICAL WALER/STRUT SPACING = 1.500 M

****

NO OF TRENCH SHEETS	=	55.
LENGTH OF TRENCH SHEETS	=	6.333 M
NO OF TRENCH STRUTS	=	39.
LENGTH OF STRUTS	=	4.900 M
THICKNESS/WIDTH OF STRUTS	=	197. MM
NO OF WALERS	=	39
USE WALER TYPE	=	7
WEIGHT OF WALER	=	31.00 KG/M
NUMBER OF MEN	=	4.
NUMBER OF MACHINES +DRIVERS	=	1.
STANDARD DURATION	=	5.612 HRS
STANDARD MANHOURS	=	28.061 HRS

CLOSE SHORING CONSTRUCTION DETAILS

****

VERTICAL WALER/STRUT SPACING = 2.000 M

****

NO OF TRENCH SHEETS	=	55.
LENGTH OF TRENCH SHEETS	=	6.333 M
NO OF TRENCH STRUTS	=	31.
LENGTH OF STRUTS	=	4.900 M
THICKNESS/WIDTH OF STRUTS	=	228. MM
NO OF WALERS	=	31.
USE WALER TYPE	=	8
WEIGHT OF WALER	=	43.00 KG/M
NUMBER OF MEN	=	4.
NUMBER OF MACHINES +DRIVERS	=	1.
STANDARD DURATION	=	5.576 HRS
STANDARD MANHOURS	=	27.879 HRS

CLOSE SHORING CONSTRUCTION DETAILS

****

VERTICAL WALER/STRUT SPACING = 2.204 M

****

NO OF TRENCH SHEETS = 55.
LENGTH OF TRENCH SHEETS = 6.333 M
NO OF TRENCH STRUTS = 27.
LENGTH OF STRUTS = 4.900 M
THICKNESS/WIDTH OF STRUTS = 239. MM
NO OF WALERS = 27.
USE WALER TYPE = 9
WEIGHT OF WALER = 31.00 KG/M
NUMBER OF MEN = 4.
NUMBER OF MACHINES +DRIVERS = 1.
STANDARD DURATION = 4.860 HRS
STANDARD MANHOURS = 24.299 HRS

BASE BLINDING

****

THICKNESS OF BLINDING = 150.MM
VOLUME OF BLINDING = 3.60M3
NUMBER OF LABOURERS = 2.
NUMBER OF GANGERS = 1.
STANDARD DURATION = 1.98HRS

PRECAST RING MANHOLE
****

CHAMBER DIAMETER =3000.MM
SHAFT DIAMETER =1000.MM
CHAMBER HEIGHT = 2.00M
SHAFT HEIGHT = 2.92M
STRAIGHT BACKED TAPERS= 1.NO
COVER SLABS (75MM) = 1.NO
COVER SLABS (150MM) = 0.NO
BASE UNITS = 0.NO
MACHINE +DRIVER = 1.
NUMBER OF LABOURERS = 1.
NUMBER OF PIPELAYERS = 1.
NUMBER OF GANGERS = 1.
TOTAL VOLUME OF MORTAR= 0.08M3
STANDARD DURATION =25.77HRS

CHANNEL LAYING
****

OUTLET DIAMETER =1500.MM
NUMBER OF LABOURERS = 1.
NUMBER OF GANGERS = 1.
STANDARD DURATION = 3.75HRS

CONCRETE SURROUND
****

VOLUME OF CONCRETE = 5.40M3
AREA OF FORMWORK =38.29M2
NUMBER OF LABOURERS = 1.
NUMBER OF TRADESMEN = 1.
NUMBER OF GANGERS = 1.
STANDARD DURATION =23.14HRS

BENCHING
****

AREA OF BENCHING = 7.07M2
NUMBER OF LABOURERS = 2.
STANDARD DURATION = 7.07HRS

TRENCH BACKFILL
****

BACKFILL VOLUME = 99.711 M3
GANG NUMBER = 1.
NO OF PEGSON RAMMERS = 1.
NUMBER OF MEN = 2.
STANDARD MANHOURS = *110.430 HRS
STANDARD DURATION = 55.215 HRS

GANG NUMBER = 2.
NO OF PEGSON RAMMERS = 1.
NUMBER OF MEN = 2.
NO OF DUMPERS = 1.
STANDARD MANHOURS = 13.960 HRS
STANDARD DURATION = 6.980 HRS

GANG NUMBER = 3.
NO OF PEGSON RAMMERS = 1.
NUMBER OF MEN = 2.
NO OF MACHINES(JCB 3C) = 1.
STANDARD MAHOURS = 11.467 HRS
STANDARD DURATION = 3.822 HRS

GANG NUMBER = 4.
NO OF LOADERS(DROTT175) = 1.
NO OF PEGSON RAMMERS = 1.
NUMBER OF MEN = 2.
STANDARD MANHOURS = 8.475 HRS
STANDARD DURATION = 2.825 HRS

ANALYSIS SUMMARY

```
                     ANALYSIS SUMMARY
                    ******************

DESCRIPTION =DRATEMAN PRE-CAST TEST 1  MANHOLE TYPE  = CONCRETE RING
BILL NO     =12                        LENGTH        = 3.40M
PAGE NO     =12                        WIDTH         = 3.40M
ITEM NO     =12                        DEPTH         = 6.00M

OPERATION * M  W    V    A  E N N N N M I N  N  N  N   S
          * E  A    O    R  X O O O O E . O  O  O  O   T
          * T  L    L    E  C         D P              D
          * H  E    U    A  A O O O O I . O  O  O  O
          * O  R    M    S  V F F F F U H F  F  F  F   D
          * D       E    /  A         M                U
          *    S    S    B  T C D D R       M  G  T  L   R
          * N  P         R  O R R U O B     I  A  R  A   A
          * U  A         I  R A O M L R     X  N  A  B   T
          * M  C         C    N T P L E     E  G  D  O   I
          * B  I         K  T E T E E A     R  E  E  U   O
          * E  N         S  Y S S R R K     S  R  S  R   N
          * R  G            P     S S E        S  M  E
          *                 E         R           E  R
          *                           S           N  S
          *   (M)    (M3) (M2)NO                         HRS
          *****************************************************
```

Continued

```
ROAD BRK
          * 1. 0.00     7.20    0.00  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  2.    9.00
          * 2. 0.00     7.20    0.00  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  1.    4.14
EXCAVATION*******************************************************************************
          * 3. 0.00   144.06    0.00  5.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.    4.37
          *
TRENCH SPT*******************************************************************************
          * 4. 0.50     0.00    0.00  1.  0.  0.  0.  0.  0.  0.  0.  1.  0.  3.   11.53
          * 5. 1.00     0.00    0.00  1.  0.  0.  0.  0.  0.  0.  0.  1.  0.  3.    7.17
          * 6. 1.50     0.00    0.00  1.  0.  0.  0.  0.  0.  0.  0.  1.  0.  3.    5.61
          * 7. 2.00     0.00    0.00  1.  0.  0.  0.  0.  0.  0.  0.  1.  0.  3.    5.58
          * 8. 2.20     0.00    0.00  1.  0.  0.  0.  0.  0.  0.  0.  1.  0.  3.    4.86
          *
BASE BLIND*******************************************************************************
          *20. 0.00     3.60    0.00  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  2.    1.98
          *
MANHOLE   *******************************************************************************
          *30. 0.00     0.00    0.00  1.  0.  0.  0.  0.  0.  0.  0.  1.  1.  1.   25.77
          *
CHANNEL   *******************************************************************************
          *50. 0.00     0.00    0.00  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.    3.75
          *******************************************************************************
```

Continued

```
SURROUND
          *70. 0.00     5.40  38.29  0.   0.  0.  0.  0.  0.  0.  0.  1.  1.  1.   23.14
          *
BENCHING  ********************************************************************
          *80. 0.00     0.00   0.00  0.   0.  0.  0.  0.  0.  0.  0.  0.  0.  2.    7.07
          *
BACKFILL  ********************************************************************
          *90. 0.00    99.71   0.00  0.   0.  0.  0.  1.  0.  0.  0.  0.  0.  2.   55.21
          *91. 0.00    99.71   0.00  0.   0.  0.  1.  1.  0.  0.  0.  0.  0.  2.    6.98
          *92. 0.00    99.71   0.00  1.   0.  0.  0.  1.  0.  0.  0.  0.  0.  2.    3.82
          *93. 0.00    99.71   0.00  0.   0.  1.  0.  1.  0.  0.  0.  0.  0.  2.    2.83
          *
SUMMARY   ********************************************************************
                                 1.   0.  0.  0.  1.  1.  0.  0.  1.  1.  3.   82.34
          ********************************************************************
          ********************************************************************
```

SECTION 6

MANHOLE ANALYSIS PROGRAMME

LISTING

```
 LIST (LP)
 PROGRAM (FXXX)
 INPUT 1 = CRO
 OUTPUT2 = LPO
 COMPRESS INTEGER AND LOGICAL
 EXTENDED
 TRACE 2
 END


 MASTER
 DIMENSION S(25,16)
 REAL LD,L,MENZ,LB,LPP,LS,LT1,LJ,J1
 INTEGER RDTYPE
 CALL DRTA(NNN)
 COUNT=0.0
 CALL DRTB(DESC,DESD,DESE,DESF,DESG,DESH)
2 CONTINUE
 CALL ZEROS(S)
 COUNT=COUNT+1.0
 CALL DRTC(BILL,PAGE,TEM)
 CALL DRTD(DESC,DESD,DESE,DESF,DESG,DESH,BILL,PAGE,TEM)
 CALL DRTE(IB,WDT,ZLNG,DPT)
 PIB=FLOAT(IB)
 CALL SUMMARY(1,DESC,DESD,DESE,DESF,DESG,DESH,BILL,
1PAGE,TEM,PIB,WDT,ZLNG,DPT,0.0,0.0,0.0,S)
 WDT=WDT+1.50
 SLNG=ZLNG+1.50
 CALL DRTG(JROAD)
 IF(JROAD.EQ.0.) GO TO 3
 CALL DRTH(RDTYPE,RTHICK)
 CALL ROD(RDTYPE,WDT,RTHICK,ZLNG,ZGN1,ZMAC1,GANG1,
1RATE1,OVR1,RVOLT)
 CALL SUMMARY(2,1.0 ,0.0,RVOLT,0.0,0.0,0.0,0.0,0.0,0.0,
1ZMAC1,0.0,0.0,0.0,0.0,GANG1,OVR1,S)
 CALL ROD1(RDTYPE,WDT,RTHICK,ZLNG,ZGN2,ZMAC2,GANG2,
1RATE2,OVR2,RVOLT)
```

```
      CALL SUMMARY(3,2,0,0.0,RVOLT,O.O,O.O,O.O,O.O,O.O,O.
     1O,O.O,ZMAC2,O.O,O.O,O.O,GANG2,OVR2,S)
      CALL DRTI
      IF(RDTYPE.EQ.1) GO TO 4
      CALL DRTJ
      GO TO 5
    4 CONTINUE
      CALL DRTK
    5 CONTINUE
      CALL DRTL(WDT,RTHICK,ZLNG,RVOLT,ZGN1,ZMAC1,GANG1,
     1RATE1,OVR1,ZGN2,ZMAC2,GANG2,RATE2,OVR2)
      GO TO 3000
    3 CONTINUE
      RVOLT=0.0
 3000 CALL DRTM
      CALL EXDATA(B,OF,SS,R,H)
      CALL MCSEL(B,DPT,H,R,TYPE)
      CALL DRTO
      I=IFIX(TYPE)
      CALL EXRAT(SS,I,B,DPT,OF,WDT,R,H,RS)
      CALL DRTP(SS,OF,DPT,WDT,B,H,R,I,RS)
      CALL EXSHAPE(ISHAPE,DPT,WDT,AREAEXC,RATE,RS,ZLNG)
      CALL DRTS(AREAEXC,RATE)
      ZMI=FLOAT(I)
      CALL SUMMARY(4,3,0,0.0,AREAEXC,O.O,ZMI,O.O,O.O,O.O,O.
     1O,O.O,O.O,O.O,O.O,O.O,O.O,RATE,S)
      M=4
      ZM=3.0
      CALL DRTT
      CALL DRTU(ISING)
      IF(ISING.EQ.O) GO TO 11
      CALL DRTV
      CALL DES(DPT,WDT,GAMA,PHI,COH,APA)
      CALL DRTW(DPT,WDT,PHI,COH,GAMA)
      CALL DRTX(IA,ID,IE,IF,IG,IH,II,IM,IN,IO,IP,IT,IU,IV,
     1IIP)
      L=15.43/SQRT(APA)
```

```
      ZMTD=0.0
      SUM=).)
  999 LD=0.5+SUM
      ZMTD=ZMTD+1.0
      M=M+1
      ZM=ZM+1.0
      CALL DESA(APA,WGT,B,LD,IS,L,WDT)
      IF(WGT.EQ.0.0) GO TO 11
      CALL TZME(WDT,B,WGT,DPT,LD,YY,SMTH,G,SL,GI,IA,ID,IE,
     1IF,IG,IH,II,IM,IN,IO,IP,IT,IU,IV,IIP,YS,XN,WN,ZLNG)
      IF(IIP.EQ.1) GO TO 8
      IF(IIP.EQ.2) GO TO 9
      CALL DRTY
      GO TO 10
    8 CONTINUE
      CALL DRTZ
      GO TO 10
    9 CONTINUE
      CALL DRAA
   10 CONTINUE
      CALL DRAB(YS,SL,XN,WDT,B,WN,IS,WGT,LD,G,GI,YY,SMTH)
      ZGANG=G-1.0
      CALL SUMMARY(M,ZM,LD,0.0,0.0,GI,0.0,0.0,0.0,0.0,0.0,
     10.0,0.0,1.0,0.0,ZGANG,YY,S)
      IF(LD.EQ.L) GO TO 11
      IF(LD.GE.4.0) GO TO 11
      IF(LD.GE.DPT) GO TO 11
      SUM=LD
      GO TO 999
   11 CONTINUE
      CALL BLINDC(DPT,WDT,ZLNG,THICK,CVOL,SD,ZLAB,GANG)
      CALL OUTBLINDC(THICK,CVOL,SD,ZLAB,GANG)
      M=15
      CALL SUMMARY(M,20.0,0.0,CVOL,0.0,0.0,0.0,0.0,0.0,0.
     10,0.0,0.0,0.0,GANG,0.0,ZLAB,SD,S)
      IF(IB.EQ.1) GO TO 12
```

```
      CALL PRERINGS(CR,SBT.,SR,CS75,CS150,BU,VM1,SD1,
     1ZMC,ZLAB,PL,GANG,DS,DC)
      CALL    OUTRINGS(CR,SBT,SR,CS75,CS150,BU,DS,DC,VM1,
     1SD1,ZMC,ZLAB,PL,GANG)
      M=16
      CALL SUMMARY(M,30.0,0.0,0.0,0.0,ZMC,0.0,0.0,0.0,0.0,
     10.0,0.0,0.0,GANG,PL,ZLAB,SD1,S)
      IF(BU.GT.0.0) GO TO 13
  113 CONTINUE
      CALL CHANNEL(OUTDIA,SD,ZLAB,GANG)
      CALL OUTCHANNEL(OUTDIA,SD,ZLAB,GANG)
      M=18
      CALL SUMMARY(M,50.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.
     10,0.0,0.0,0.0,GANG,0.0,ZLAB,SD,S)
      GO TO 13
   12 CONTINUE
      CALL BRICKCAL(WDT,ZLNG,CWT,CH,SWT,SH,SLNG,SWDT,TB,
     1TMV,TBC,TBS)
      CALL TIMBERICK(TBC,TBS,CWT,SWT,CH,SH,SD,ZLAB,ZTRADE,
     1ZMC,ZNSI)
      CALL OUTBRICK(TB,TMV,ZNSI,ZLAB,ZTRADE,ZMC,SD)
      M=17
      CALL SUMMARY(M,40.0,0.0,TMV,TB,0.0,0.0,0.0,0.0,0.0,
     10.0,0.0,ZMC,0.0,ZTRADE,ZLAB,SD,S)
      TO TO 113
   13 READ(L,14)ISL
   14 FORMAT(IO)
      IF(ISL.EQ.1) GO TO 15
      VISC=0.0
   16 READ(1,17)IS
   17 FORMAT(IO)
      IF(IS.EQ.1) GO TO 18
      TCONCV=0.0
   19 CALL BENCHING(IB,DC,WDT,ZLNG,ZLAB,AB,TB,BU)
      CALL OUTBENCH(ZLAB,AB,TB)
      M=21
      CALL SUMMARY(M,80.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.
     10,0.0,0.0,0.0,0.0,0.0,ZLAB,RB,S)
```

```
      GO TO 20
   15 CALL INSITUSLAB(IB,VISC,TWS,ASH,SBT,DC,DS,ZLNG,WDT,
     1SWDT,SLNG,SWT)
      CALL SLABTIME(VISC,TWS,ASH ,SD,GANG,ZLAB,ZTRADE)
      CALL OUTSLAB(VISC,TWS,ASH,ZLAB ,GANG,SD,ZTRADE)
      M=19
      CALL SUMMARY(M,60.0,0.0,VISC,ASH,0.0,0.0,0.0,0.0,
     10.0,0.0,0.0,0.0,GANG,ZTRADE,ZLAB,SD,S)
      TO TO 16
   18 CALL CONSURD(IB,CR,DC,SR,DS,WDT,ZLNG,CH,SWT,SH,SLNG,
     1SWDT,ZLAB,GANG,CTIME,FTIME,TCONCV,TASH,SD ,TRADE)
      CALL OUTSURD(TCONCV,TASH,ZLAB,GANG ,TRADE,SD)
      M=20
      CALL SUMMARY(M,70.0,0.0,TCONCV,TASH,0.0,0.0,0.0,0.
     10,0.0,0.0,0.0,0.0,GANG,TRADE,ZLAB,SD,S)
      GO TO 19
   20 CONTINUE
      CALL BACKPREP(CVOL,IB,CR,DC,SR,DS,TCONCV,WDT,ZLNG,
      SWT,SLNG,SWDT,ZMANV,VISC,SBT)
      CALL DRAK(ZLAYER)
      CALL DRAL
      I=0
      ZM=89.0
      M=21
 9014 I=I+1
      ZM=ZM+1.0
      M=M+1
      CALL BACK(AREAEXC,ZMANV,RVOLT,ZLAYER,I,DROT,PR,ZMEN,
     1CBJ,DMP,GNBR,YSMH,XSMH,VBKF)
      CALL DRAM(VBKF,GNBR,DROT,PR,ZMEN,CBJ,DMP,YSMH,XSMH)
      CALL SUMMARY(M,ZM,0.0,VBKF,0.0,CBJ,0.0,DROT,DMP,PR,
     10.0,0.0,0.0,0.0,0.0,ZMEN,XSMH,S)
      M1=M
      IF(I.LT.4) GO TO 9014
      MMM=NNN-1
      NNN=MMM
      CALL OUTSUMRY(S,M1)
```

```
      IF(MMM.GE.1) GO TO 2
      STOP
      END


      SUBROUTINE DRTA(NNN)
      READ(1,1) NNN
    1 FORMAT(IO)
      RETURN
      END


      SUBROUTINE DRTB(DESC,DESD,DESE,DESF,DESG,DESH)
    2 READ(1,5000) DESC,DESD,DESE,DESF,DESG,DESH
 5000 FORMAT( 6A4)
      RETURN
      END


      SUBROUTINE ZEROS(S)
      DIMENSION S(25,16)
      DO 1 I=1,25
      DO 1 J=1,16
      S(I,J)=0.0
    1 CONTINUE
      RETURN
      END


      SUBROUTINE DRTC(BILL,PAGE,TEM)
      READ(1,5003) BILL
      READ(1,5003) PAGE
      READ(1,5003) TEM
 5003 FORMAT(A4)
      RETURN
      END
```

```
      SUBROUTINE DRTD(DESC,DESD,DESE,DESF,DESG,DESH,BILL,
     1PAGE,TEM)
      WRITE(2,5002)
 5002 FORMAT(1H1, 2X,23HBILL ITEM TIME ANALYSIS,/)
      WRITE(2,5003)
 5003 FORMAT(1H , 2X,23H***********************)
      WRITE(2,5004)
 5004 FORMAT(1H , 2X,20CONTRACT DESCRIPTION,/)
      WRITE(2,5005)
 5005 FORMAT(1H , 2X,20H********************,/////)
      WRITE(2,5006) DESC,DESD,DESE,DESF,DESG,DESH
 5006 FORMAT(1H , 2X,6A4,///)
      WRITE(2,5007) BILL
 5007 FORMAT(1H , 2X,11HBILL NUMBER,3X,A4,//)
      WRITE(2,5008) PAGE
 5008 FORMAT(1H , 2X,11HPAGE NUMBER,3X,A4,//)
      WRITE(2,5009) TEM
 5009 FORMAT(1H , 2X,11HITEM NUMBER,3X,A4 )
      RETURN
      END


      SUBROUTINE DRTE(IB,WDT,ZLNG,DPT)
      READ(1,1) IB
    1 FORMAT(IO)
      READ(1,2)WDT,ZLNG,DPT
    2 FORMAT(3FO.O)
      RETURN
      END


      SUBROUTINE DRTG(JROAD)
      READ(1,5017) JROAD
 5071 FORMAT(IO)
      RETURN
      END
```

```
      SUBROUTINE DRTH(RDTYPE,RTHICK)
      INTEGER RDTYPE
      READ(1,1)RDTYPE
    1 FORMAT(IO)
      READ(1,2) RTHICK
    2 FORMAT(FO.O)
      RETURN
      END


      SUBROUTINE ROD(RDTYPE,RWIDTH,RTHICK,RLENGTH,ZGN1,ZM
     1AC1,GANG1,RATE1,OVR1,RVOLT)
      INTEGER RDTYPE
      RVOLU=RWIDTH*RTHICK/1000.
      RVOLT=RVOLU*RLENGTH
      IF(RDTYPE.EQ.1) GO TO 6002
      ZGN1=1.0
      ZMAC1=1.0
      GANG1=2.0
      RATE1=2.5*RVOLT
      OVR1=RATE1/2.0
      GO TO 6003
 6002 ZGN1=1.0
      ZMAC1=1.0
      GANG1=2.0
      RATE1=4.98*RVOLT
      OVR1=RATE1/2.0
 6003 RETURN
      END


      SUBROUTINE ROD1(RDTYPE,RWIDTH,RTHICK,RLENGTH,ZGN2,
     1ZMAC2,GANG2,RATE2,OVR2,RVOLT)
      INTEGER RDTYPE
      RVOLU=RWIDTH*RTHICK/1000.0
      RVOLT=RVOLU*RLENGTH
      IF(RDTYPE.EQ.1) GO TO 6002
```

```
      ZGN2=2.0
      ZMAC2=1.0
      GANG2=1.0
      RATE2=1.15*RVOLT
      OVR2=RATE2/2.0
      GO TO 6003
 6002 ZGN2=2.0
      ZMAC2=1.0
      GANG2=1.0
      RATE2=1.54*RVOLT
      OVR2=RATE2/2.0
 6003 RETURN
      END


      SUBROUTINE DRTI
      WRITE(2,5019)
 5019 FORMAT(1H1, 2X,13HROAD BREAKOUT)
      WRITE(2,5020)
 5020 FORMAT(1H , 2X,13H*************,//)
      RETURN
      END


      SUBROUTINE DRTJ
      WRITE(2,5022)
 5022 FORMAT(1H , 2X,26HFLEXIBLE ROAD CONSTRUCTION)
      WRITE(2,5023)
 5023 FORMAT(1H ,2X,'**************************',///)
      RETURN
      END


      SUBROUTINE DRTK
      WRITE(2,5024)
 5024 FORMAT(1H , 2X,26HCONCRETE ROAD CONSTRUCTION)
```

```
      WRITE(2,5025)
 5025 FORMAT(1H ,2X,'****************************',///)
      RETURN
      END


      SUBROUTINE DRTL(RWIDTH,RTHICK,RLENGTH,RVOLT,ZGN1,
     1ZMAC1,GANG1,RATE1,OVR1,ZGN2,ZMAC2,GANG2,RATE2,OVR2)
      WRITE(2,5025) RWIDTH
 5025 FORMAT91H , 2X,26HWIDTH OF BREAKOUT          = ,F5.3,3X,
     11HM,/)
      WRITE(2,5026) RTHICK
 5026 FORMAT(1H , 2X,26HTHICKNESS OF ROAD          = ,F5.0,3X,
     12HMM,/)
      WRITE(2,5027) RLENGTH
 5027 FORMAT(1H ,2X,26HLENGTH OF BREAKOUT          = ,F8.3,1HM,
     1/)
      WRITE(2,5555) RVOLT
 5555 FORMAT(1H , 2X,26HVOLUME OF BREAKOUT         =,F8,3,2HM
     13    ,//)
      WRITE(2,5028)
 5028 FORMAT(1H ,2X,21HTWO ALTERNATIVE GANGS)
      WRITE(2,5039)
 5039 FORMAT(1H ,2X,'**********************',//)
      WRITE(2,5029) ZGN1
 5029 FORMAT(1H , 2X,12HGANG NUMBER.,F2.o,1H.,/)
      WRITE(2,5030) ZMAC1
 5030 FORMAT(1H , 2X,26HNUMBER OF COMPRESSORS   = ,F2.O,/)
      WRITE(2,5031) GANG1
 5031 FORMAT(1H , 2X,26HNUMBER OF LABOURERS      = ,F2.O,/)
      WRITE(2,5032) RATE1
 5032 FORMAT(1H , 2X,26HSTANDARD MANHOURS         + ,F8,3,3H
     1HRS     ,/)
      WRITE(2,5033) OVR1
 5033 FORMAT(1H , 2X,26HSTANDARD DURATION         = ,F8.3,3H
     1HRS     ,///)
      WRITE(2,5034) ZGN2
```

```
5034 FORMAT(1H , 2X,12HGANG NUMBER.,F2.0,1H.,/)
     WRITE(2,5035) ZMAC2
5035 FORMAT(1H , 2X,26HNUMBER OF MACHINES(IPH) = ,F2.0,/)
     WRITE(2,5036) GANG2
5036 FORMAT(1H , 2X,26HNUMBER OF LABOURERS      = ,F2.0,/)
     WRITE(2,5037) RATE2
5037 FORMAT(1H , 2X,26HSTANDARD MANHOURS        = ,F8.3,3HHRS
    1,/)
     WRITE(2,5038) OVR2
5038 FORMAT(1H ,2X,26HSTANDARD DURATION         = ,F8.3,3HHRS
    1,/)
     RETURN
     END


     SUBROUTINE DRTM
     WRITE(2,30)
  30 FORMAT(1H1,2X,'MACHINE EXCAVATION RATE')
     WRITE
  31 FORMAT(1H , 2X,23H*********************** )
     WRITE(2,32)
  32 FORMAT(1H ,/ )
     WRITE(2,33)
  33 FORMAT(1H , 2X,19HMACHINES CONSIDERED)
     WRITE(2,331)
 331 FORMAT(1H , 2X,19H*******************,//)
     WRITE(2,34)
  34 FORMAT(1H ,    4HCODE,6X,12HMACHINE NAME,/ )
     WRITE(2,35)
  35 FORMAT(1H , 1X,1H1,9X,5HJCB 3,/, 2X,1H2,10X,6HJCB 3C
    1,/, 2X,1H3,10XBRA12200,6HJCB 3D,/, 2X,1H4,10X,6HJCB
    25C,/, 2X,1H5,10X,6HJCB 7B,/, 2X,1H6,BRA1230010X,10HH
    3Y-MAC 580,/, 2X,1H7,10X,6HJCB 6C,/, 2X,1H8,10X,6HJCB
    46C,/, 2X,1H8,10X,6HJCB 6D,/,BRA12400 2X,1H9,10X,6HJC
    5B 7C,/, 2X,2H10,10X,4HRH 6,///)
     RETURN
     END
```

```
      SUBROUTINE EXDATA(B,OF,S,R,H)
      READ(1,1) B,OF,S,R,H
    1 FORMAT(5F0.0)
      RETURN
      END


      SUBROUTINE MCSEL(BB,DP,H,R,TYPE)
      DIMENSION D(10,6)
      DATA D/1.,2.,3.,4.,5.,6.,7.,8.,9.,10.,225.,225.,225.,
     1450.,450.,400.,450.,450.,600.,675.,675.,675.,1200.,12
     200.,1350.,1300.,1300.,1300.,1300.,3.7,4.19,4.19,5.76,
     36.1,6.425,6.35,5.35,6.73,6.70,5.41,5.57,5.57,9.02,9.3
     40,9.093,9.2,9.73,10.50,3.545,3.38.3.29,6.27,5.54,5.35
     58,6.05,6.05.10,3.06/
      DPP=DP
      HH=H
      RR=R
      COUNT=0.0
  999 I=0
      COUNT=COUNT+1.0
      IF(COUNT.GE.10.0) GO TO 8
    2 I=I+1
      IF(BB.GE.D(I.2)) GO TO 3
      IF(I.LT.10) GO TO 2
      CALL ERROR1
      BB=450.0
      GO TO 999
    3 IF(BB.LE.D(I,3)) GO TO 4
      IF(I.LT.10) GO TO 2
      CALL ERROR2
      BB=1300.0
      GO TO 999
    4 IF(DPP.LE.D(I,4)) GO TO 5
      IF(I.LT.10) GO TO 2
```

```
      CALL ERROR3
      DPP=DP/2.0
      GO TO 999
    5 IF(RR.LE.D(I,5)) GO TO 6
      IF(I.LT.10) GO TO 2
      CALL ERROR4
      RR=R/2.0
      GO TO 999
    6 IF(HH.LE.D(I,6)) GO TO 7
      IF(I.LT.10) GO TO 2
      CALL ERROR5
      HH=H/2.0
      GO TO 999
    8 I=9
    7 TYPE=D(I,1)
      RETURN
      END


      SUBROUTINE ERROR1
      WRITE(2,1)
    1 FORMAT(1H1,2X,'REQUIRED BUCKET WIDTH TOO SMALL')
      WRITE(2,2)
    2 FORMAT(1H ,2X,'450 MM WIDTH ASSUMED')
      RETURN
      END


      SUBROUTINE ERROR2
      WRITE(2,1)
    1 FORMAT(1H1,2X,'REQUIRED BUCKET WIDTH TOO LARGE')
      WRITE(2,2)
    2 FORMAT(1H ,2X,'1300 MM WIDTH ASSUMED')
      RETURN
      END
```

```
      SUBROUTINE ERROR3
      WRITE(2,1)
    1 FORMAT(1H1,2X,'REQUIRED DEPTH TOO LARGE')
      WRITE(2,2)
    2 FORMAT(1H ,2X,'DOUBLE EXCAVATE WITH JCB 7C')
      RETURN
      END


      SUBROUTINE ERROR4
      WRITE(2,1)
    1 FORMAT(1H1,2X,'REQUIRED REACH TOO LARGE')
      WRITE(2,2)
    2 FORMAT(1H ,2X,'DOUBLE HANDLE WITH JCB 7C')
      RETURN
      END


      SUBROUTINE ERROR5
      WRITE(2,1)
    1 FORMAT(1H1,2X,'REQUIRED LOADING HEIGHT TOO LARGE')
      WRITE(2,2)
    2 FORMAT(1H ,2X,'DOUBLE HANDLE WITH JCB 7C')
      RETURN
      END


      SUBROUTINE DRTO
      WRITE(2,24)
   24 FORMAT(1H ,2X,'EXCAVATION DETAILS')
      WRITE(2,241)
  241 FORMAT(1H ,2X,'******************',//)
      RETURN
      END
```

```
      SUBROUTINE EXRAT(S,ITMC,B,D,OF,W,R,H,RS)
      B=B/1000.0
      IF(ITMC.EQ.1) GO TO 15
      IF(ITMC.EQ.2) GO TO 16
      IF(ITMC.EQ.3) GO TO 17
      IF(ITMC.EQ.4) GO TO 18
      IF(ITMC.EQ.5) GO TO 19
      IF(ITMC.EQ.6) GO TO 20
      IF(ITMC.EQ.7) GO TO 21
      IF(ITMC.EQ.8) GO TO 22
      IF(ITMC.EQ.9) GO TO 23
      IF(ITMC.EQ.10) GO TO 24
      CALL DRAR
      GO TO 2222
   15 IF(B.LT.O.225) B=0.225
      IF(B.GT.O.675) B=0.675
      BC=0.3904*B-0.0128
      GO TO 3333
   16 IF(B.LT.O.225) B=0.225
      IF(B.GT.O.675) B=0.675
      BC=0.3714*B+0.0465
      GO TO 3333
   17 IF(B.LT.O.225) B=0225
      IF(B.GT.O.675) B=0.675
      BC=0.3714*B+0.0465
      GO TO 3333
   18 IF(B.LT.O.450) B=0.450
      IF(B.GT.1.200) B=1.200
      BC=0.2866*B+0.1961
      GO TO 3333
   19 IF(B.LT.O.450) B=0.450
      IF(B.GT.1.200) B=1.200
      BC=0.46*B+0.1181
      GO TO 3333
   20 IF(B.LT.O.400) B=0.400
      IF(B.GT.1.350) B-1.350
```

```
      BC=0.28*B+0.1920
      GO TO 3333
   21 IF(B.LT.0.450) B=0.450
      IF(B.GT.1.300) B=1.300
      BC=0.1941*B+0.2377
      GO TO 3333
   22 IF(B.LT.0.450) B=0.450
      IF(B.GT.1.300) B=1.300
      BC=0.1941*B+0.2377
      GO TO 3333
   23 IF(B.LT.0.600) B=0.600
      IF(B.GT.1.300) B=1.300
      BC=0.8*+BO.0200
      GO TO 3333
   24 IF(B.LT.0.600) B=0.600
      IF(B.GT.1.300) B=1.300
      BC=0.8*B+0.0200
 3333 CONTINUE
      BIC=0.13531*S-o.oo47672*S*S-0.32589
      QE=BC*BIC
      R2=R*R
      H2=H*H
      T2=R2+H2
      T=SQRT(T2)
      IF(ITMC.LE.3) UT=0.0055278-0.010534*T+0.039124*T*T-O.
     10042776*T*T*T
      IF(ITMC.GT.3) UT=0.0174370+0.038475*T+0.0027197*T*T-O
     1.000249*T*T*T
      SUM=0.0
      ZINC=D/10.0
      TAG=0.0
  777 TAG=TAG+1.0
      ZN=ZINC*TAG/W
      IF(OF.EQ.1.) ET=0.051219+0.8015*ZN-0.1397*ZN*ZN+0.00
     18895*ZN*ZN*ZN
```

```
      IF(OF.EQ.2.) ET=0.022858+0.2703*ZN-0.0480*ZN*ZN+0.003
     1138*ZN*ZN*ZN
      IF(OF.EQ.3.) ET=0.041371+0.1366*ZN-0.0216*ZN*ZN+0.001
     1241*ZN*ZN*ZN
      IF(OF.EQ.4.) ET=0.020984+0.1402*ZN-0.0252*ZN*ZN+0.001
     1656*ZN*ZN*ZN
      IF(OF.EQ.5.) ET=0.026574+0.1285*ZN-0.0215*ZN*ZN+0.001
     1349*ZN*ZN*ZN
      RSING=50.7099*QE/(UT+ET)
      DEPTH=ZINC*TAG
      WRITE(2,88) DEPTH,RSINC
   88 FORMAT(1H ,2F12.4)
      SUM=SUM+RSINC
      IF(TAG.LT.10.) GO TO 777
      RS=SUM/10.0
      ITMC=ITMC
 2222 CONTINUE
      RETURN
      END


      SUBROUTINE DRTP(S,OF,HI,W,B,H,R,I,RS)
      WRITE(2,36) S
   36 FORMAT(1H , 2X,7HSTRATA:,13X,6H=TYPE.,F3.0,1H.,/ )
      WRITE(2,37) OF
   37 FORMAT(1H , 2X,26HOBSTRUCTION GRADING =TYPE.,F3.0,1H
     1.,/ )
      WRITE(2,38) HI
   38 FORMAT(1H , 2X,19HTRENCH DEPTH       =,F6.3,2H M,/ )
      WRITE(2,381 ) W
  381 FORMAT(1H , 2X,19HTRENCH WIDTH       =,F6.3,2H M,/ )
      B=B*1000.
      WRITE(2,39) B
   39 FORMAT(1H , 2X,19HBUCKET WIDTH       =,F5.0,2HMM,/ )
      WRITE(2,40) H
   40 FORMAT(1H , 2X,20HLOADING HEIGHT     =,F6.3,2H M,/ )
```

```
      WRITE(2,41) R
   41 FORMAT(1H , 2X,20HREACH               =,F6.3,2H M,/ )
      WRITE(2,42) I
   42 FORMAT(1H , 2X,20HUSE MACHINE TYPE  =,I2,/ )
      WRITE(2,43) RS
   43 FORMAT(1H , 2X,20HSTANDARD OUTPUT   =,F7.3,6H M3/HR
     1,/)
      RETURN
      END


      SUBROUTINE DRAR
      WRITE(2,25)
   25 FORMAT(1H1,6HERROR:,4X,23HCHECK MACHINE TYPE DATA )
      RETURN
      END


      SUBROUTINE DRAS
      WRITE(2,26)
   26 FORMAT(1H1,6HERROR:,4X,61HBUCKET WIDTH TOO SMALL OR
     1TOO LARGE FOR THE MACHINE SELECTED. )
      RETURN
      END


      SUBROUTINE EXSHAPE(ISHAPE,DPT,WDT,AREAEXC,RATE,RS,Z
     1LNG)
      W=WDT
      ZLG=ZLNG
      CALL DRAT(ISHAPE)
      IF(ISHAPE.EQ.1) GO TO 1
      V1=0.34*DPT*W*ZLG
      A1=W*ZLG
      W1=2.)*).57735*0.66*DPT
      W2=W+W1
      W3=ZLG+W1
```

```
      A2=W2*W3
      A3=(A1+A2)/2.0
      V2=A3*0.66*DPT
      ZVOLT=V1+V2
      GO TO 3
    1 CONTINUE
      ZVOLT=W*DPT*ZLG
    3 AREAEXC=AVOLT
      RATE=AREAEXC/RS
      RETURN
      END


      SUBROUTINE DRAT(ISHAPE)
      READ(1,1) ISHAPE
    1 FORMAT(IO)
      RETURN
      END


      SUBROUTINE DRTS(AREAEXC,RATE)
      WRITE(2,1515) AREAEXC
 1515 FORMAT(1H , 2X,26HVOLUME OF EXCAVATION    = ,F10.3,2
     1HM3     ,/)
      WRITE(2,1555) RATE
 1555 FORMAT(1H , 2X,26HSTANDARD DURATION       = ,F10.3,3
     1HHRS     )
      RETURN
      END


      SUBROUTINE DRTT
      WRITE(2,3333)
 3333 FORMAT(1H1)
      RETURN
      END
```

```
      SUBROUTINE DRTU(ISING)
      READ(1,4951) ISING
 4951 FORMAT(IO)
      RETURN
      END


      SUBROUTINE DRTV
      WRITE(2,700)
  700 FORMAT(1H ,24X,28HTRENCH SUPPORT SYSTEM DESIGN )
      WRITE(2,701)
  701 FORMAT(1H ,21X,34H*********************************
     1* )
      RETURN
      END


      SUBROUTINE DES(H,W,GAMA,PHI,COH,APA)
      CALL DRAX(IS1,IS2,IS3)
 9016 CONTINUE
      K1=ISI*2
      K1=K1+IS2
      K2=K1*2
      K2=K2+IS3
      CALL DRAY(GAMA, PHI,COH)
 9018 CONTINUE
      IF(K2.EQ.4) GO TO 11
      IF(K2.EQ.2) GO TO 12
      IF(K2.EQ.O) GO TO 13
      IF(K2.EQ.1) GO TO 14
      IF(K2.EQ.3) GO TO 15
      IF(K2.EQ.5) GO TO 16
      IF(K2.EQ.6) GO TO 17
      IF(K2.EQ.7) GO TO 18
   11 CONTINUE
      IF(GAMA.EQ.99.) GAMA=2082.6
      IF(GAMA.NE.99.) GAMA=GAMA
      IF(PHI.EQ.99.) PHI=25.0
```

```
      IF(PHI.NE.99.) PHI=PHI
      IF(COH.EQ.99.) COH=0.0
      IF(COH.NE.99.) COH=0.0
      THT=0.0174533*PHI
      A=1.0-SIN(THT)
      B=1.0+SIN(THT)
      BKA=A/B
      APA=0.65*GAMA*BKA*H
      APA=APA*0.00980665
      GO TO 21
   12 CONTINUE
      IF(GAMA.EQ.99.) GAMA=2082.6
      IF(GAMA.NE.99.) GAMA=GAMA
      IF(PHI.EQ.99.) PHI=0.0
      IF(PHI.NE.99.) PHI=0.0
      IF(COH.EQ.99.) COH=1400.)
      IF(COH.NE.99.) COH=COH
      AN=GAMA*H/COH
      IF(AN.LE.4.0) GO TO 23
      APA=0.4*GAMA*H
      APA=APA*0.00980665
      GO TO 21
   23 A=4.0*COH
      B=GAMA*H
      A=A/B
      BKA=1.0-A
      APA=BKA*GAMA*H
      APA=APA*0.00980665
      GOTO 21
   13 CONTINUE
      IF(GAMA.EQ.99.) GAMA=2082.6
      IF(GAMA.NE.99.) GAMA=GAMA
      APA=0.4*GAMA*H
      APA=APA*0.00980665
      GO TO 21
   14 CONTINUE
      IF(GAMA.EQ.99.) GAMA=2082.6
      IF(GAMA.NE.99.) GAMA=GAMA
```

```
      APA=0.4*GAMA*H
      APA=APA*0.00980665
      GO TO 21
   15 CONTINUE
      IF(GAMA.EQ.99.) GAMA=2082.6
      IF(GAMA.NE.99.) GAMA=GAMA
      IF(PHI.EQ.99.) PHI=25.0
      IF(PHI.NE.99.)  PHI=PHI
      IF(COH.EQ.99.)  COH=1400.0
      IF(COH.NE.99.)  COH=COH
      APA1=0.4*GAMA*H
      AN=GAMA*H/COH
      IF(AN.LE.4.0) GO TO 27
      APA2=0.4*GAMA*H
      GO TO 28
   27 A=4.0*COH
      B=GAMA*H
      A=A/B
      BKA=1.0-A
      APA2=BKA*GAMA*H
   28 CONTINUE
      IF(APA2.GE.APA1) APA=APA2*0.00980665
      IF(APA2.LT.APA1) APA=APA1*0.00980665
      GO TO 21
   16 CONTINUE
      IF(GAMA.EQ.99.)GAMA=2082.6
      IF(GAMA.NE.99.) GAMA=GAMA
      IF(PHI.EQ.99.) PHI=25.0
      IF(PHI.NE.99.) PHI=PHI
      IF(COH.EQ.99.) COH=1400.0
      IF(COH.NE.99.) COH=COH
      THT=0.0174533*PHI
      A=1.0-SIN(THT)
      B=1.0+SIN(THT)
      BKA=A/B
      APA1=0.65*GAMA*BKA*H
      APA2=0.4*GAMA*H
      IF(APA2.GE.APA1) APA=APA2*0.00980665
```

```
      IF(APA2.LT.APA1) APA=APA1*0.00980665
      GO TO 21
   17 CONTINUE
      IF(GAMA.EQ.99.) GAMA=2082.6
      IF(GAMA.NE.99.) GAMA=GAMA
      IF(PHI.EQ.99.) PHI=25.0
      IF(PHI.NE.99.)  PHI=PHI
      IF(COH.EQ.99.)  COH=1400.0
      IF(COH.NE.99.)  COH=COH
      THT=0.0174533*PHI
      A=1.0-SIN(THT)
      B=1.0+SIN(THT)
      BKA=A/B
      APA1=0.65*GAMA*BKA*H
      AN=GAMA*H/COH
      IF(AN.LE.4.0) GO TO 31
      APA2=0.4*GAMA*H
      GO TO 32
   31 A=4.0*COH/(GAMA*H)
      BKA=1.0-A
      APA2-BKA*GAMA*H
   32 CONTINUE
      IF(APA2.GE.APA1) APA=APA2*0.00980665
      IF(APA2.LT.APA1) APA-APA1*0.00980665
      GOTO 21
   18 CONTINUE
      IF(GAMA.EQ.99.) GAMA-2082.6
      IF(GAMA.NE.99.) GAMA=GAMA
      IF(PHI.EQ.99.) PHI=25.0
      IF(PHI.NE.99.)  PHI=PHI
      IF(COH.EQ.99.)  COH=1400.0
      IF(COH.NE.99.) COH=COH
      THT=0.174533*PHI
      A=1.0-SIN(THT)
      B=1.0*SIN(THT)
      BKA=A/B
      APA1=0.65*GAMA*BKA*H
      AN=GAMA*H/COH
```

```
      IF(AN.LE.4.0) GO TO 34
      APA2=0.4*GAMA*H
      GO TO 35
   34 A=4.0*COH
      B=GAMA*H
      A=A/B
      BKA=1.0-A
      APA2=BKA*GAMA*H
   35 APA3=0.4*GAMA*H
      IF(APA2.GE.APA1) APA4=APA2
      IF(APA2.LT.APA1) APA4=APA1
      IF(APA4.GE.APA3) APA=APA4*0.00980665
      IF(APA4.LT.APA3) APA=APA3*0.00980665
   21 CONTINUE
      RETURN
      END


      SUBROUTINE DRAX(IS1,IS2,IS3)
      READ(1,1)IS1,IS2,IS3
    1 FORMAT(3I0)
      RETURN
      END


      SUBROUTINE DRAY(GAMA,PHI,COH)
      READ(1,1) GAMA,PHI,COH
    1 FORMAT(3F0.0)
      RETURN
      END


      SUBROUTINE DRTW(H,W,PHI,COH,GAMA)
      WRITE(2,702) H
  702 FORMAT(1H ,5X ,15HTRENCH DETAILS:,47X,6HDEPTH=,F5.3
     1,1X,1HM  )
      WRITE(2,703) W
  703 FORMAT(1H ,67X,6HWIDTH=,F5.3,1X,1HM    )
```

```
      WRITE(2,704) PHI
  704 FORMAT(1H ,5X,13HSOIL DETAILS:,22X,33HANGLE OF INTE
     1RNAL FRICTION (PHI)=,F5.2,1X,4HDEGS   )
      WRITE(2,705) COH
  705 FORMAT(1H ,58X,15HCOHESION (COH)=,F7.2,1X,5HKG/M2 )
      WRITE(2,706) GAMA
  706 FORMAT(1H ,50X,23HSPECIFIC WEIGHT (GAMA)=,F7.2,1X,5
     1HKG/M3 )
      WRITE(2,707)
  707 FORMAT(1H ,5X ,21HTRENCH SHEET DETAILS:,14X,14HB.S.
     1P TYPE.T5.,3X,23HELASTIC MODULUS=56.0CM3)
      WRITE(2,708)
  708 FORMAT(1H ,67X,11HWIDTH=0.33M )
      WRITE(2,709)
  709 FORMAT(1H ,5X ,14HSTRUT DETAILS:,35X,25HHORIZONTAL S
     1PACING=2.50 M)
      WRITE(2,710)
  710 FORMAT(1H ,5X ,14HWALER DETAILS:,// )
      WRITE(2,711)
  711 FORMAT(1H ,20X,60HSECTION    SECTION   SECTION    D
     1 D     T     ELASTIC MODULUS )
      WRITE(2,712)
  712 FORMAT(1H ,20X,58HNOTATION    SHAPE     WEIGHT   (MM)
     1(MM) (MM)     (ZXX) (CM3) )
      WRITE(2,713)
  713 FORMAT(1H ,41X,6H(KG/M),/
      WRITE(2,714)
  714 FORMAT(1H ,22X,1H1,9X,  47HI       13.38     127    76
     1  7.6          75.12      ,/,23X,57H2            I
     2  17.10    152    89    8.3         115.90      ,/,23
     3X,1H3,9X,     47H          20.82   178   76   10.3
     4   150.40     ,/,23X,57H4               23.80   203
     5 76   11.2        192.00    ,/)
      WRITE(2,777)
  777 FORMAT(1H ,22X,1H5,9X,  35HI       25.00   203   133
     1  133  7.8      ,2X,10H231.00     ,/,23X,57H6
     2I          30.00   207   134  9.6       279.00      ,/
     3,23X,57H7          I        31.00   251   146  8.6
```

```
   4  352.00    ,/,23X,57H8         U         43.00   260
   5147 12.7        504.00     ,/)
    WRITE(2,778)
 778 FORMAT(1H ,22X,1H9,9X,  47HI          31.00   307   1
   166 11.8         646.00    ,/)
    RETURN
    END


    SUBROUTINE DRTX(IA,ID,IE,IF,IG,IH,II,IM,IN,IO,IP,IT
   1,IU,IV,IIP)
    IA=O
    ID=O
    IE=O
    IF=O
    IG=O
    IH=1
    II=O
    IM=1
    IN=O
    IO=O
    IP=O
    IT=O
    IU=O
    IV=O
    READ(1,1414) IIP
1414 FORMAT(IO)
    RETURN
    END


    SUBROUTINE DESA(APA,WGT,B,LD,IS,L,W)
    REAL  L, LD, LP
    DIMENSION Z(i )
    DATA Z/75.12.115.90,150.40.192.00,231.00,279.00,352
   1.00,504.00,646.00/
C    TO CALCULATE THE VERTICAL STRUT SPACING PERMISSIBLE
    (L)
```

```
      IF(LD.LT.L) GO TO 38
      LD=L
   38 B1=38.4*W
      B2=22.9833*SQRT(APA)*SQRT(LD)
      IF(B1.GE.B2) B=B1
      IF(B1.LT.B2) B=B2
      ZR=4.734*APA*LD
      ICOUNT=O
   39 I=1+ICOUNT
      IF(I.LE.9) GO TO 40
      CALL DRAZ(ZR)
      WGT=O.O
      B=O.O
      LD=O.O
      IS=O
      GO TO 2222
   40 CONTINUE
      IF(ZR.LT.Z(I)) GO TO 42
      ICOUNT=I
      GOTO 39
   42 IS=I
      ZX=Z(I)
      IF(IS.EQ.1) WGT=13.38
      IF(IS.EQ.2) WGT=17.10
      IF(IS.EQ.3) WGT=20.82
      IF(IS.EQ.4) WGT=23.80
      IF(IS.EQ.5) WGT=25.))
      IF(IS.EQ.6) WGT=30.00
      IF(IS.EQ.7) WGT=31.))
      IF(IS.EQ.8) WGE=43.))
      IF(IS.EQ.9) WGT=31.00
 2222 CONTINUE
      RETURN
      END


      SUBROUTINE DRAZ(ZR)
      WRITE(2,41) ZR
```

```
   41 FORMAT(1H1, 8X,  50HSECTION MODULUS NOT AVAILABLE S
     1EE TABLES FOR ZR= ,F10.2, 2X, 3HCM3 )
      RETURN
      END


      SUBROUTINE TZME(STL,B,WGT,H,ZLD,YY,SMTH,G,SL,GI,IA,
     1ID,IE,IF,IG,IH,II,IM,IN,IO,IP,IT,IU,IV,IIP,YS,XN,WN
     2,W1)
      SL=H+0.333
      WL=2.500
C     TRENCH SHEETS
C     *************
      TA=0.12925*SL+0.0745
      TB=0.121*SL+0.13025
      TC=0.4025
      TD=0.129*SL+0.176
      TE=0.003*SL+1.0232
      TF=0.02925*SL+0.57325
C     TIMBER STRUTS
C     *************
      B2=B/100.
      B2=B2*B2
      AG=0.0045276+0.017435*B2
      AH=-0.0156+0.057902*B2
      AI=-0.051737+0.047466*B2
      AJ=0.029488+0.025636*B2
      AK=0.34389+0.037109*B2
      AL=0.23583+0.013164*B2
      AM=0.13054+0.0017042*B2
      AN=0.14083+0.022655*B2
      AO=0.059572+0.025717*B2
      CG=0.18887-0.0027834*B2
      CH=0.97452+0.62216*B2
      CI=0.49723+0.26224*B2
      CJ=0.254+0.00017595*B2
      CK=0.77333+0.084156*B2
      CL=0.38558+0.12197*B2
```

```
      CM=0.044055+0.1137*B2
      CN=0.23427+0.023103*B2
      CO=0.21614+0.023599*B2
      TG=AG*STL+CG
      TH=AH*STL+CH
      TI=AI*STL+CI
      TJ=AJ*STL+CJ
      TK=AK*STL+CK
      TL=AL*STL+CL
      TM=AM*STL+CM
      TN=AN*STL+CN
      TO=AO*STL+CO
C     STEELWALERS
C     ***********
      AP=0.4785-0.011725*WGT
      AQ=0.071+0.004175*WGT
      AR=0.039+0.002875*WGT
      AS=0.145-0.00025*WGT
      AT=-0.39366+0.019683*WGT
      AU=0.1745-0.002225*WGT
      AV=0.158-0.0034*WGT
      CP=-0.59475+0.018975*WGT
      CQ=-0.16975+0.00795*WGT
      CR=-0.39775+0.04325*WGT
      CS=-0.26970+0.041615*WGT
      CT=0.010689-0.03332*WGT
      CU=-0.247+0.023475*WGT
      CV=-0.303+0.026400*WGT
      TP=AP*WL+CP
      TQ=AQ*WL+CQ
      TR=AR*WL+CR
      TS=AS*WL+CS
      TT=AT*WL+CT
      TU=AU*WL+CU
      TV=AV*WL+CV
      IF(IIP.EQ.1) YS=14.0
      IF(IIP.EQ.2) YS=8.0
      IF(IIP.EQ.3) YS=6.0
```

```
      XN=(H/ZLD+1.0)*2.0
      XN=AINT(XN)
      WN=XN
      ZLG=STL+W1
      YS=ZLG*YS/2.50
      XN=ZLG*XN/2.50
      WN=XN
      IF(IA.EQ.1) TA= TA
      IF(IA.NE.1) TA=0.0
      IF(ID.EQ.1) GO TO 20
      IF(IE.EQ.1) GO TO 21
      IF(IF.EQ.1) GO TO 22
   20 TD=TD
      TE=0.0
      TF=0.0
      GO TO 1111
   21 TE=TE
      TD=0.0
      TF=0.0
      GO TO 1111
   22 TF=TF
      TD=0.0
      TE=0.0
 1111 CONTINUE
      IF(IG.EQ.1) TG=TG
      IF(IG.NE.1) TG=0.0
      IF(IH.EQ.1) GO TO 24
      IF(II.EQ.1) GO TO 25
   24 TH=TH
      TI=0.0
      GO TO 2222
   25 TI=TI
      TH=0.0
 2222 CONTINUE
      IF(IM.EQ.1) GO TO 27
      IF(IN.EQ.1) GO TO 28
      IF(IO.EQ.1) GO TO 29
```

```
   27 TM=TM
      TN=0.0
      TO=0.0
      GO TO 3333
   28 TN=TN
      TM=0.0
      TO=0.0
      GO TO 3333
   29 TO=TO
      TM=0.0
      TN=0.0
 3333 CONTINUE
      IF(IP.EQ.1) TP=TP
      IF(IP.NE.1) TP=0.0
      IF(IU.EQ.1) GO TO 32
      IF(IT.EQ.1) GO TO 31
      IF(IV.EQ.1) GO TO 33
   31 TT=TT
      TU=0.0
      TV=0.0
      GO TO 4444
   32 TU=TU
      TT=0.0
      TV=0.0
      GO TO 4444
   33 TV=TV
      TT=0.0
      TU=0.0
 4444 CONTINUE
      T1=YS*(TA+TB+TC+TD+TE+TF)
      T2=XN*(TG+TH+TI+TJ+TK+TL+TM+TN+TO)
      T3=WN*(TP+TQ+TR+TS+TT+TU+TV)
C     OVERALL DURATION IN BASIC MINS
      T=T1+T2+T3
C     OVERALL DURATION IN STD MINS
      TSTD=T*1.02*1.16
C     OVERALL DURATION IN STD HOURS
      TSTDH=TSTD/60.0
```

```
C     OVERALL DURATION IN STD MINS/M
      XX=TSTD/2.500
C     OVERALL DURATION IN STD HOURS/M
      YY=TSTDH/2.500
C     STD MAN MINS/M
      IF9H.LE.3.)) GO TO 35
      SMT=XX*5.0
      G=4.0
      GI=1.0
      SMTH=YY*5.0
      GO TO 5555
   35 SMT=XX*4.0
      SMTH=YY*4.0
      G=4.0
      GI=0.0
 5555 CONTINUE
      RETURN
      END


      SUBROUTINE DRTY
      WRITE(2,2900)
 2900 FORMAT(1H1,2X,33HOPEN SHORING CONSTRUCTION DETAILS)
      WRITE(2,1001)
 1001 FORMAT(1H ,2X,33H*********************************,
     1//)
      RETURN
      END


      SUBROUTINE DRTZ
      WRITE(2,4904)
 4904 FORMAT(1H1,2X,34HCLOSE SHORING CONSTRUCTION DETAILS)
      WRITE(2,4905)
 4905 FORMAT(1H ,2X,34H**********************************,
     1//)
      RETURN
      END
```

```
      SUBROUTINE DRAA
      WRITE(2,4906)
 4906 FORMAT(1H1,2X,35HMEDIUM SHORTING CONSTRUCTION DETAI
     1LS)
      WRITE(2,4907)
 4907 FORMAT(1H ,2X,35H*********************************
     **,//)
      RETURN
      END


      SUBROUTINE DRAB(YS,SL,XN,W,B,WN,IS,WGT,LD,G,GI,YY,S
     1MTH)
      REAL LD
      WRITE(2,1007) LD
 1007 FORMAT(1H , 2X,31HVERTICAL WALER/STRUT SPACING = ,F
     15.3, 2H M )
      WRITE(2,1017)
 1017 FORMAT(1H ,2X,'*************************************
     1**',//)
      WRITE(2,4908) YS
 4908 FORMAT(1H , 2X,31HNO OF TRENCH SHEETS            = ,F
     15.0)
      WRITE(2,1002) SL
 1002 FORMAT(1H , 2X,31HLENGTH OF TRENCH SHEETS        = ,F
     15.3, 2H M )
      WRITE(2,4909) XN
 4909 FORMAT(1H , 2X,31HNO OF TRENCH STRUTS            = ,F
     15.0)
      WRITE(2,1003) W
 1003 FORMAT(1H , 2X,31HLENGTH OF STRUTS               = ,F
     15.3, 2H M )
      WRITE(2,1004) B
 1004 FORMAT(1H , 2X,31HTHICKNESS/WIDTH OF STRUTS      = ,F
     1.5.0,3H MM )
      WRITE(2,4910) WN
 4910 FORMAT(1H , 2X,31HNO OF WALERS                   = ,F
     15.0)
```

```
      WRITE(2,1005) IS
 1005 FORMAT(1H , 2X,31HUSE WALER TYPE                 =,I1)
      WRITE(2,1006) WGT
 1006 FORMAT(1H , 2X,31HWEIGHT OF WALER                = ,F
     15.2,5H KG/M )
      WRITE(2,1008) G
 1008 FORMAT(1H , 2X,31HNUMBER OF MEN                  = ,F
     12.0)
      WRITE(2,1009) GI
 1009 FORMAT(1H , 2X,31HNUMBER OF MACHINES +DRIVERS    = ,F
     12.0 )
      WRITE(2,2901) YY
 2901 FORMAT(1H , 2X,31HSTANDARD DURATION              = ,F
     110.3,4H HRS)
      WRITE(2,1011) SMTH
 1011 FORMAT(1H , 2X,31HSTANDARD MANHOURS              = ,F
     110.3,4H HRS)
      RETURN
      END


      SUBROUTINE BLINDC(DPT,WDT,ZLNG,THICK,CVOL,SD,ZLAB,G
     1ANG)
      READ(1,1) THICK
    1 FORMAT(F0.0)
      WDT1=WDT
      ZLNG1=ZLNG
      CVOL=WDT1*ZLNG1*THICK/1000.0
      IF(DPT.LE.3.0) GO TO 2
      SD=CVOL*0.55
      GO TO 3
    2 SD=CVOL*0.33
    3 ZLAB=2.0
      GANG=1.0
      RETURN
      END
```

```
      SUBROUTINE OUTBLINDC(THICK,CVOL,SD,ZLAB,GANG)
      WRITE(2,1)
    1 FORMAT(1H1,2X,13HBASE BLINDING)
      WRITE(2,2)
    2 FORMAT(1H ,2X,13H*************)
      WRITE(2,3) THICK
    3 FORMAT(1H ,2X,23HTHICKNESS OF BLINDING =,F5.0,2HMM,
     1/)
      WRITE(2,4) CVOL
    4 FORMAT(1H ,2X,23HVOLUME OF BLINDING    =,F5.2,2HM3,/)
      WRITE(2,5) ZLAB
    5 FORMAT(1H ,2X,23HNUMBER OF LABOURERS   =,F5.0,/)
      WRITE(2,6) GANG
    6 FORMAT(1H ,2X,23HNUMBER OF GANGERS     =,F5.0,/)
      WRITE(2,7) SD
    7 FORMAT(1H ,2X,23HSTANDARD DURATION     =,F5.2,3HHRS)
      RETURN
      END


      SUBROUTINE CHANNEL(OUTDIA,SD,ZLAB,GANG)
      READ(1,1) OUTDIA
    1 FORMAT(F0.0)
      SD=0.75*OUTDIA/300.0
      IF(OUTDIA.LE.450.0) GO TO 2
      ZLAB=1.0
      GANG=1.0
      GO TO 3
    2 ZLAB=1.0
      GANG=0.0
    3 CONTINUE
      RETURN
      END


      SUBROUTINE OUTCHANNEL(OUTDIA,SD,ZLAB,GANG)
      WRITE(2,1)
    1 FORMAT(1H1,2X,14HCHANNEL LAYING)
```

```
      WRITE(2,2)
    2 FORMAT(1H ,2X,14H**************,//)
      WRITE(2,3) OUTDIA
    3 FORMAT(1H ,2X,23HOUTLET DIAMETER        =,F5.0,2HMM,/)
      WRITE(2,4) ZLAB
    4 FORMAT(1H ,2X,23HNUMBER OF LABOURERS    =,F5.0,/)
      WRITE(2,5) GANG
    5 FORMAT(1H ,2X,23HNUMBER OF GANGERS      =,F5.0,/)
      WRITE(2,6) SD
    6 FORMAT(1H ,2X,23HSTANDARD DURATION      =,F5.2,3HHRS)
      RETURN
      END


      SUBROUTINE PRERINGS(CR,SBT,SR,CS75,CS150,BU,VM1,SD1
     1,ZMC,ZLAB,PL,GANG,DS,DC)
      READ(1,1) DC,DS
    1 FORMAT(2F0.0)
      READ(1,2) CR,SBT,SR,CS75,CS150,BU
    2 FORMAT(6F0.0)
      VM1=0.0
      SD1=0.0
      CALL CHAMBER(CR,DC,VM,SD,ZMC,ZLAB,PL,GANG)
      VM1=VM+VM1
      SD1=SD+SD1
      CALL SBTAPER(SBT,DC,DS,VM,SD)
      VM1=VM+VM1
      SD1=SD+SD1
      CALL SHAFT(SR,VM,SD)
      VM1=VM+VM1
      SD1=SD+SD1
      CALL COVER75(CS75,DS,VM,SD)
      VM1=VM+VM1
      SD1=SD+SD1
      CALL COVER150(CS150,DC,VM,SD)
      VM1=VM+VM1
      SD1=SD+SD1
      CALL BASEU(BU,DC,VM,SD)
```

```
VM1=VM+VM1
SD1=SD+SD1
RETURN
END


SUBROUTINE CHAMBER(CR,DC,VM,SD,ZMC,ZLAB,PL,GANG)
SD=4.15*DC/1750.0
SD=SD*CR
VM=0.008*DC/914.0
VM=VM*CR
ZMC=1.0
ZLAB=1.0
PL=1.0
GANG=1.0
RETURN
END


SUBROUTINE SBTAPER (SBT,DC,DS,VM,SD)
SD=2.20*DC/1500.0
SD=SD*SBT
VM=0.003*DC/914.0
VM=VM*SBT
RETURN
END


SUBROUTINE SHAFT(SR,VM,SD)
SD=2.0*SR
VM=0.006*SR
RETURN
END


SUBROUTINE COVER75(CS75,DS,VM,SD)
SD=(1.63*DS/1500.0)+0.2
VM=0.003*DS/686.0
```

```
      SD=SD*CS75
      VM=VM*CS75
      RETURN
      END


      SUBROUTINE COVER150(CS150,DC,VM,SD)
      SD=(2.04*DC/1500.0)+0.1
      VM=0.003*DC/686.0
      SD=SD*CS150
      VM=VM*CS150
      RETURN
      END


      SUBROUTINE BASEU(BU,DC,VM,SD)
      SD=2.16*DC/1500.0
      VM=0.010*DC/686.0
      SD=SD*BU
      VM=VM*BU
      RETURN
      END


      SUBROUTINE OUTRINGS(CR,SBT,SR,CS75,CS150,BU,DS,DC,V
     1M1,SD1,ZMC,ZLAB,PL,GANG)
      WRITE(2,1)
    1 FORMAT(1H1.2X.20HPRECAST RING MANHOLE)
      WRITE(2,2)
    2 FORMAT(1H ,2X,20H********************)
      WRITE(2,3)DC
    3 FORMAT(1H ,2X,23HCHAMBER DIAMETER       =,F5.0,2HMM,/)
      WRITE(2,4)DS
    4 FORMAT(1H ,2X,23HSHAFT DIAMETER         =,F5.0,2HMM,/)
      WRITE(2,5)CR
    5 FORMAT(1H ,2X,23HCHAMBER HEIGHT         =,F5.2,1HM,/)
      WRITE(2,6)SR
    6 FORMAT(1H ,2X,23HSHAFT HEIGHT           =,F5.2,1HM,/)
```

```
      WRITE(2,7) SBT
    7 FORMAT(1H ,2X,23HSTRAIGHT BACKED TAPERS=,F5.0,2HNO,/)
      WRITE(2,8) CS75
    8 FORMAT(1H ,2X,23HCOVER SLABS (75MM)     =,F5.0,2HNO,/)
      WRITE(2,9) CS150
    9 FORMAT(1H ,2X,23HCOVER SLABS (150MM)    =,F5.0,2HNO,/)
      WRITE(2,10) BU
   10 FORMAT(1H ,2X,23HBASE UNITS             =,F5.0,2HNO,/)
      WRITE(2,11) ZMC
   11 FORMAT(1H ,2X,23HMACHINE +DRIVER        =,F5.0,/)
      WRITE(2,12) ZLAB
   12 FORMAT(1H ,2X,23HNUMBER OF LABOURERS    =,F5.0,/)
      WRITE(2,13) PL
   13 FORMAT(1H ,2X,23HNUMBER OF PIPELAYERS   =,F5.0,/)
      WRITE(2,14) GANG
   14 FORMAT(1H ,2X,23HNUMBER OF GANGERS      =,F5.0,/)
      WRITE(2,15) VM1
   15 FORMAT(1H ,2X,23HTOTAL VOLUME OF MORTAR=,F5.2,2HM3,/)
      WRITE(2,16) SD1
   16 FORMAT(1H ,2X,23HSTANDARD DURATION      =,F5.2,3HHRS)
      RETURN
      END


      SUBROUTINE BRICKCAL(WDT,ZLNG,CWT,CH,SWT,SH,SLNG,SWDT,
     1TB,TMV,TBC,TBSO
      WDT=WDT-1.50
      ZLNG=ZLNG-1.50
      READ(1,1) IDUAL
    1 FORMAT(IO)
      READ(1,2) CWT,CH
    2 FORMAT(2FO.O)
      CWT1=CWT/1000.0
      CBV=(ZLNG-2.0*CWT1)*CH*2.0*CWT1
      CBV=CBV+(WDT*CH*2.0*CWT1)
      IF(IDUAL.EQ.1) GO TO 3
    4 CONTINUE(1,5) SWT,SH,SLNG,SWDT
    5 FORMAT(4FO.O)
```

```
      GO TO 6
    3 CBV=CBV+WDT*CH*CWT1
      GO TO 4
    6 SWT1=SWT/1000.0
      SBV=(SLNG+2.0*SWT1)*SH*2.0*SWT1
      SBV=SBV*(SWDT*SH*2.0*SWT1)
      IF(IDUAL.EQ.1) GO TO 7
    8 TBV=CBV+SBV
      GO TO 9
    7 SBV=SBV+(SWDT*SH*SWT1)
      GO TO 8
    9 TBC=CBV*1000.0/1.99
      TBS=SBV*1000.0/1.99
      TB=TBC+TBS
      TMV=TB*O.4148/1000.0
      RETURN
      END


      SUBROUTINE TIMEBRICK(TBC,TBS,CWT,SWT,CH,SH,SD,ZLAB,
     1ZTRADE,ZMC,ZNSI)
      ZNSI=(CH+SH)/O.300
      ZNSI=AINT(ZNSI)
      BPSHC=(22.5*CWT/500.0)+67.O
      BPSHS=(22.5*SWT/500.0)+67.0
      SMC=TBC/BPSHC
      SMS=TBS/BPSHS
      DC=SMC
      DS=SMS
      SD=DC+DS+(2.0*ZNSI/60.0
      ZLAB=1.0
      ZTRADE=1.0
      SMC=1.0
      RETURN
      END


      SUBROUTINE OUTBRICK(TB,TMV,ZNSI,ZLAB,ZTRADE,ZMC,SD)
```

```
      WRITE(2,1)
    1 FORMAT(1H1,2X,13HBRICK MANHOLE)
      WRITE(2,2)
    2 FORMAT(1H ,2X,13H*************)
      WRITE(2,3) TB
    3 FORMAT(1H ,2X,23HNUMBER OF BRICKS      =,F5.0,2HNO,/)
      WRITE(2,4) TMV
    4 FORMAT(1H ,2X,23HVOLUME OF MORTAR      =,F5.2,2HMS,/)
      WRITE(2,5) ZNSI
    5 FORMAT(1H ,2X,23HNUMBER OF STEP IRONS =,F5.0,2HNO,/)
      WRITE(2,6) ZMC
    6 FORMAT(1H ,2X,23HNUMBER OF MIXERS      =,F5.0,2HNO,/)
      WRITE(2,7) ZLAB
    7 FORMAT(1H ,2X,23HNUMBER OF LABOURERS  =,F5.0,/)
      WRITE(2,8) ZTRADE
    8 FORMAT(1H ,2X,23HNUMBER OF BRICKLAYERS=,F5.0,/)
      WRITE(2,9) SD
    9 FORMAT(1H ,2X,23HSTANDARD DURATION     =,F5.2,3HHRS)
      RETURN
      END


      SUBROUTINE BENCHING(IB,DC,WDT,ZLNG,ZLAB,AB,TB,BU)
      ZLAB=2.0
      IF(IB.EQ.1) GO TO 1
      DC1=DC/1000.0
      DC2=DC1*DC1
      AB=3.142*DC2/4.0
      TB=AB*1.0
      IF(BU.GT.0.0) TB=TB/2.0
      GO TO 2
    1 CONTINUE
      AB=WDT*ZLNG
      TB=AB*1.0
    2 RETURN
      END
```

```
      SUBROUTINE OUTBENCH(ZLAB,AB,TB)
      WRITE(2,1)
    1 FORMAT(1H1,2X,8HBENCHING)
      WRITE(2,2)
    2 FORMAT(1H ,2X,8H********)
      WRITE(2,3) AB
    3 FORMAT(1H ,2X,23HAREA OF BENCHING       =,F5.2,2HM2,/)
      WRITE(2,4) ZLAB
    4 FORMAT(1H ,2X,23HNUMBER OF LABOURERS  =,F5.0,/)
      WRITE(2,5) TB
    5 FORMAT(1H ,2X,23HSTANDARD DURATION    =,F5.2,3HHRS)
      RETURN
      END


      SUBROUTINE INSITUSLAB(IB,VISC,TWS,ASH,SBT,DC,DS,ZLNG,
     1WDT,SWDT,SLNG,SWT)
      READ(1,1) ST,CST
    1 FORMAT(2F0.0)
      IF(IB.EQ.1) GO TO 2
      DC1=DC/1000.0
      DC2=DC1*DC1
      ST1=ST/1000.0
      CST1=CST/1000.0
      VCS=(3.142*DC2)/4.0
      VCS3=VCS*CST1
      VCS3=VCS3*(SBT=1.0)
      DS1=DS/1000.0
      DS2=DS1*DS1
      VCS1=(3.142*DS2)/4.0
      VCS2=VCS1*ST1
      VCS2=VCS2
C VOLUME OF CONCRETE =VISC
      VISC=VCS3+VCS2
      TLS=DC*2.0/150.0
      TLS=TLS*DC1
      TLS1=DS*2.0/150.0
      TLS1=TLS1*DS1
```

```
      TTLS=TLS+TLS1
      WPM=1.579/1000.0
      TWS=TTLS*WPM
C  TOTAL WEIGHT OF 16MM M.S. =TWS
      ASC=VCS+VCS1
      ASC1=3.142*DC1*CST1
      ASC2=3.142*DS1*ST1
      ASH=ASC+ASC1+ASC2
      GO TO 3
    2 CONTINUE
      ST1=ST/1000.0
      CST1=CST/1000.0
      VCS=ZLNG*WDT
      VCS3=VCS*CST1
      SWT1=SWT/1000.0
      VZ=2.0*SWT1
      VCS1=VZ+SWDT
      VCS2=VZ+SLNG
      VCS4=VCS1*VCS2
      VCS5=VCS4*ST1
C VOLUME OF CONCRETE =VISC
      VISC=VCS3+VCS5
      TLS=ZLNG*1000.0/150.0
      TLS1=WDT*1000.0/150.0
      TLS2=VCS1*1000.0/150.0
      TLS3=VCS2*1000.0/150.0
      TLS=TLS*ZLNG
      TLS1=TLS1* WDT
      TLS2=TLS2*VCS1
      TLS3=TLS3*VCS2
      TTLS=TLS+TLS1+TLS2+TLS3
      WPM=1.579/1000.0
C TOTAL WEIGHT OF 16MM M.S. =TWS
      TWS=TTLS*WPM
      ASC=VCS+VCS4
      ASC1=2.0*(ZLNG+WDT)
      ASC1=ASC1*CST1
      ASC2=2.0*(VCS1+VCS2)
```

```
      ASC2=ASC2*ST1
C AREA OF FORMWORK = ASH
      ASH=ASC+ASC1+ASC2
    3 RETURN
      END


      SUBROUTINE SLABTIME(VISC,TWS,ASH,SD,GANG,ZLAB,ZTRADE)
      TCUT=1.28*TWS
      TFIX=12.80*TWS
      TMFIX=1.130*ASH
      TMSTRIKE=0.538*ASH
      TFORM=TMFIX+TMSTRIKE
      TST=TCUT+TFIX
      TCONC=0.33*VISC
      TTIME=TST+TFORM+TCONC
      GANG=1.0
      ZLAB=1.0
      ZTRADE=0.25*    (ASH-4.0)
      ZTRADE=AINT(ZTRADE)
      TGANG=GANG+ZLAB+ZTRADE
      SD=TTIME/TGANG
      RETURN
      END


      SUBROUTINE OUTSLAB(VISC,TWS,ASH,ZLAB,GANG,SD,TRADE)
      WRITE(2,1)
    1 FORMAT(1H1,2X,12HINSITU SLABS)
      WRITE(2,2)
    2 FORMAT(1H ,2X,12H************)
      WRITE(2,3) VISC
    3 FORMAT(1H ,2X,23HVOLUME OF CONCRETE    = ,F5.2,2HM3,/)
      WRITE(2,4) TWS
    4 FORMAT(1H ,2X,23HWEIGHT OF STEEL       =,F5.2,1HT,/)
      WRITE(2,5) ASH
    5 FORMAT(1H ,2X,23HAREA OF FORMWORK      =,F5.2,2HM2,/)
      WRITE(2,6) ZLAB
```

```
    6 FORMAT(1H ,2X,23HNUMBER OF LABOURERS  =,F.0,/)
      WRITE(2,7) TRADE
    7 FORMAT(1H ,2X,23HNUMBER OF TRADESMEN  =,F5.0,/)
      WRITE(2,8) GANG
    8 FORMAT(1H ,2X,23HNUMBER OF GANGERS    =,F5.0,/)
      WRITE(2,9) SD
    9 FORMAT(1H ,2X,23HSTANDARD DURATION    =,F5.2,3HHRS)
      RETURN
      END


      SUBROUTINE CONSURD(IB,CR,DC,SR,DS,WDT,ZLNG,CH,SWT,S
     1H,SLNG,SWDT,ZLAB,GANG,CTIME,FTIME,TCONCV,TASH,SD,TR
     2ADE)
      READ(1,1) CTHICK
    1 FORMAT(F0.0)
      IF(IB.EQ.1) GO TO 2
      DC1=DC/1000.0
      EXTD=DC1+0.2*DC1
      EXTD2=EXTD*EXTD
      AC=3.142*EXTD2/4.0
      CTHICK1=CTHICK/1000.0
      OUTD=EXTD+2.0*CTHICK1
      OUTD2=OUTD*OUTD
      AS=3.142*OUTD2/4.0
      ACONC=AS-AC
C VOLUME OF CONCRETE = VCONC
      VCONC=ACONC*CR
      ASH=3.142*OUTD*CR
C AREA OF FORMWORK = ASH
      DS1=DS/1000.0
      EXTDS=DS1+0.2*DS1
      EXTDS2=EXTDS*EXTDS
      ASHAFT=3.142*EXTDS2/4.0
      OUTDS=EXTDS+2.0*CTHICK1
      OUTDS2=OUTDS*OUTDS
      AS1=3.142*OUTDS2/4.0
      ACONC1=AS1-ASHAFT
      VCONC1=ACONC1*SR
```

```
C VOLUME OF CONCRETE =VCONC1
      ASH1=3.142*OUTDS*SR
C AREA OF FORMWORK =ASH1
      TCONCV=VCONC+VCONC1
      TASH=ASH1+ASH
      ZLAB=1.0
      GANG=1.0
      TRADE=TASH/20.0
      IF(TRADE.LE.0.0)TRADE=0.0
      TRADE=AINT(TRADE)
      GANG1=ZLAB+GANG+TRADE
      CTIME=1.130*TASH/GANG1
      STIME=0.538*TASH/GANG1
      FTIME=FTIME+STIME
      SD=FTIME+CTIME
      GO TO 3
    2 CONTINUE
      AC=WDT*ZLNG
      CTHICK1=CTHICK/1000.0
      WDT1=WDT+2.0*CTHICK1
      ZLNG1=ZLNG+2.0*CTHICK1
      AS=WDT1*ZLNG1
      ACONC=AS-AC
      VCONC=ACONC*CH
      ASH=2.0*(WDT1+ZLNG1)*CH
      SWT1=SWT/1000.0
      SLNG1=SLNG+2.0*SWT1
      SWDT1=SWDT+2.0*SWT1
      AS1=SLNG1*SWDT1
      SLNG2=SLNG1+2.0*CTHICK1
      SWDT2=SWDT1+2.0*CTHICK1
      AC1=SLNG2*SWDT2
      ACONC1=AC1-AS1
      VCONC1=ACONC1*SH
      ASH1=2.0*(SLNG2+SWDT2)*SH
      TCONCV=VCONC+VCONC1
      TASH=ASH+ASH1
      ZLAB=1.0
      GANG=1.0
```

```
      TRADE=TASH/20.0
      IF(TRADE.LE.0.0) TRADE=0.0
      TRADE=AINT(TRADE)
      GANG1=ZLAB+GANG+TRADE
      CTIME=1.027*TCONCV/GANG1
      FTIME=1.130*TASH/GANG1
      STIME=0.538*TASH/GANG1
      FTIME=FTIME+STIME
      SD=CTIME+FTIME
    3 CONTINUE
      RETURN
      END


      SUBROUTINE OUTSURD(TCONCV,TASH,ZLAB,GANG,TRADE,SD)
      WRITE(2,1)
    1 FORMAT(1H1,2X,17HCONCRETE SURROUND)
      WRITE(2,2)
    2 FORMAT(1H ,2X,17H*****************)
      WRITE(2,3) TCONCV
    3 FORMAT(1H ,2X,23HVOLUME OF CONCRETE     =,F5.2,2HM3,/)
      WRITE(2,4) TASH
    4 FORMAT(1H ,2X,23HAREA OF FORMWORK       =,F5.2,2HM2,/)
      WRITE(2,5) ZLAB
    5 FORMAT(1H ,2X,23HNUMBER OF LABOURERS    =,F5.0,/)
      WRITE(2,6) TRADE
    6 FORMAT(1H ,2X,23HNUMBER OF TRADESMEN    =,F5.0,/)
      WRITE(2,7) GANG
    7 FORMAT(1H ,2X,23HNUMBER OF GANGERS      =,F5.0,/)
      WRITE(2,8) SD
    8 FORMAT(1H ,2X,23HSTANDARD DURATION      =,F5.2,3HHRS)
      RETURN
      END


      SUBROUTINE BACKPREP(CVOL,IB,CR,DC,SR,DS,TCONCV,WDT,
     1ZLNG,SWT,SLNG,SWDT,SMANV,VISC,SBT)
      (IF(IB.EQ.1) GO TO 1
      DC1=DC/1000.0
```

```
      EDC=DC1+0.2*DC1
      EDC2+EDC*EDC
      AC=3.142*EDC2/4.0
      VC=AC*CR
      DS1=DS/1000.0
      EDS=DS1+0.2*DS1
      EDS2=EDS*EDS
      AS=3.142*EDS2/4.0
      VS=AS*SR
      IF(SBT.LT.1.0) GO TO 3
      AC1=AC/3.0
      AS1=AS/3.0
      IF(DC.LE.1219.0)ZL1=0.610
      IF(DC.GT.1219.0)ZL1=0.914
      ZL=EDC*ZL1/(EDC-EDS)
      FCONEV=AC1*ZL
      HCONEV=AS1*(ZL-ZL1
      VSBT=FCONEV-HCONEV
      GO TO 4
    3 CONTINUE
      VSBT=0.0
    4 CONTINUE
      ZMANV=VC*VS+VSBT+CVOL+TCONCV+VISC
      GO TO 2
    1 CONTINUE
      AC=WDT*ZLNG
      VC=AC*CH
      SWT1=SWT/L000.0
      SLNG=SLNG+2.0*SWT1
      SWDT1=SWDT+2.0*SWT1
      AS=SLNG1*SWDT1
      VS=AS*SH
      ZMANV=VC+VS+CVOL+TCONCV+VISC
    2 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE DRAK(ZLAYER)
      READ(1,8999) ZLAYER
 8999 FORMAT(F0.0)
      RETURN
      END


      SUBROUTINE DRAL
      WRITE(2,9000)
 9000 FORMAT(1H1,20X,15HTRENCH BACKFILL)
      WRITE(2,9001)
 9001 FORMAT(1H ,20X,15H***************,///)
      RETURN
      END


      SUBROUTINE BACK(AREAEXC,SUM4,RVOLT,ZLAYER,I,DROT,PR
     1,ZMEN,CBJ,DMP,GNBR,YSMH,XSMH,VBKF)
      VBKF=AREAEXC-SUM4-RVOLT
      IF(I.EQ.1) GOTO 1000
      IF(I.EQ.2) GOTO 1001
      IF(I.EQ.3) GOTO 1002
      DROT=1.0
      PR=1.0
      ZMEN=2.0
      CBJ=0.0
      DMP=0.0
      GNBR=4.0
      IF(ZLAYER.LT.500.) ZSMH=0.10-0.0001*ZLAYER
      IF(ZLAYER.GE.500.) ZSMH=0.05
      YSMH=VBKF*ZSMH
      XSMH=YSMH/3.0
      GO TO 1100
 1000 DROT=0.0
      PR=1.0
      ZMEN=2.0
      CBJ=0.0
      DMP=0.0
      GNBR=1.0
```

```
      IF(ZLAYER.LT.307.) ZSMH=1.8575-0.005*ZLAYER
      IF(ZLAYER.GE.307.) ZSMH=0.32
      YSMH=VBKF*ZSMH
      XSMH=YSMH/2.0
      GO TO 1100
 1001 DROT=0.0
      PR=1.0
      ZMEN=2.0
      CBJ=0.0
      DMP=1.0
      GNBR=2.0
      IF(ZLAYER.LT.500.) ZSMH=0.155-0.0001*ZLAYER
      IF(ZLAYER.GE.500.) ZSMH=0.105
      YSMH=VBKF*ZSMH
      XSMH=YSMH/2.0
      GO TO 1100
 1002 DROT=0.0
      PR=1.0
      ZMEN=2.0
      CBJ=1.0
      DMP=0.0
      GNBR=3.0
      IF(ZLAYER.LT.500.) ZSMH=0.13-0.0001*ZLAYER
      IF(ZLAYER.GE.500.) ZSMH=0.08
      YSMH=VBKF*ZSMH
      XSMH=YSMH/3.0
 1100 RETURN
      END


      SUBROUTINE DRAM(VBKF,GNBR,DROT,PR,ZMEN,CBJ,DMP,YSMH
     1,XSMH)
      IF(GNBR.GT.1.0) GO TO 9020
      WRITE(2,9002) VBKF
 9002 FORMAT(1H , 2X,27HBACKFILL VOLUME           = ,F7.3,
     13H M3)
 9020 WRITE(2,9003) GNBR
 9003 FORMAT(1H ,2X,27HGANG NUMBER               = ,F3.0)
      IF(DROT.EQ.0.0) GOTO 9004
```

```
      WRITE(2,9005) DROT
 9005 FORMAT(1H , 2X,27HNO OF LOADERS(DROTT175)  = ,F3.0 )
 9004 WRITE(2,9006) PR
 9006 FORMAT(1H , 2X,27HNO OF PEGSON RAMMERS     = ,F3.0 )
      WRITE(2,9007) ZMEN
 9007 FORMAT(1H , 2X27HNUMBER OF MEN             = ,F3.0 )
      IF(CBJ.EQ.0.0) GOTO 9008
      WRITE(2,9009) CBJ
 9009 FORMAT(1H , 2X,27HNO OF MACHINES(JCB 3C)   = ,F3.0 )
 9008 IF(DMP.EQ.0.0) GOTO 9010
      WRITE(2,9011) DMP
 9011 FORMAT(1H , 2X27HNO OF DUMPERS             = ,F3.0 )
 9010 WRITE(2,9012) YSMH
 9012 FORMAT91H , 2X,27HSTANDARD MANHOURS        = ,F6.3,4
     1H HRS)
      WRITE(2,9013) XSMH
 9013 FORMAT(1H , 2X,27HSTANDARD DURATION        = ,F6,3,4
     1H HRS,//)
      RETURN
      END


      SUBROUTINE SUMMARY(I,A,B,C,D,E,F,G,H,P,Q,R,S1,T,U,V,
     1W,S)
      DIMENSION S(25,16)
      S(I,1)=A
      S(I,2)=B
      S(I,3)=C
      S(I,4)=D
      S(I,5)=E
      S(I,6)=F
      S(I,7)=G
      S(I,8)-H
      S(I,9)=P
      S(I,10)=Q
      S(I,11)=R
      S(I,12)=S1
```

```
      S(I,13)=T
      S(I,14)=U
      S(I,15)=V
      S(I,16)=W
      RETURN
      END


      SUBROUTINE OUTSUMRY(S,M1)
      DIMENSION S(25,16)
      WRITE(2,1)
    1 FORMAT(1H1,32X16HANALYSIS SUMMARY)
      WRITE(2,2)
    2 FORMAT(1H ,31X,18H****************,///)
      IF(S(1,10).EQ.1.0) GO TO 4
      WRITE(2,3) S(1,1),S(1,2),S(1,3),S(1,4),S(1,5),S(1,6)
    3 FORMAT(1H ,10X,13HDESCRIPTION =,6A4, 2X,29HMANHOLE T
     1YPE  = CONCRETE RING,/)
      GO TO 5
    4 WRITE(2,6) S(1,1),S(1,2),S(1,3),S(1,4),S(1,5),S(1.6)
    6 FORMAT(1H ,10X13HDESCRIPTION =,6A4,22X,29HMANHOLE TY
     1PE  = BRICK        ,/)
    5 WRITE(2,7) S(1,7),S(1,12)
    7 FORMAT(1H ,10X13HBILL NO     =, A4,22X,15HLENGTH
     1    =,F5.2,1HM,/)
      WRITE(2,8) S(1,8),S(1,11)
    8 FORMAT(1H ,10X,13HPAGE NO     =, A4,22X,15HDEPTH
     1    =,F5.2,1HM,/////)
      WRITE(2,10)
```

```
10 FORMAT(1H , 78HOPERATION * M   W   V   A   E  N  N  N  N
 1 M  I  N   N   N   N   S)
   WRITE(2,11)
11 FORMAT(1H , 78H         * E   A   O   R   X  O  O  O  O
    E  .  O   O   O   O   T)
   WRITE(2,12)
12 FORMAT(1H , 78H         * T   L   L   E   C
 1 D  P                   D)
   WRITE(2,13)
13 FORMAT(1H , 78H         * H   E   U   A   A  O  O  O  O
 1 I  .  O   O   O   O    )
   WRITE(2,14)
14 FORMAT(1H , 78H         * O   R   M   S   V  F  F  F  F
    U  H  F   F   F   F   D)
   WRITE(2,15)
15 FORMAT(1H , 78H         * D       E   /   A
 1 M                      U)
   WRITE(2,16)
16 FORMAT(1H , 78H         *     S   S   B   T  C  D  D  R
 1       M   G   T   L    R)
   WRITE(2,17)
17 FORMAT(1H , 78H         * N   P       R   O  R  R  U  O
 1 B     I   A   R   A    A)
   WRITE(2,18)
18 FORMAT(1H , 78H         * U   A       I   R  A  O  M  L
 1 R     X   N   A   B    T)
   WRITE(2,19)
19 FORMAT(1H , 78H         * M   C       C      N  T  P  L
 1 E     E   G   D   O    I)
   WRITE(2,20)
20 FORMAT(1H , 78H         * B   I       K   T  E  T  E  E
 1 A     R   E   E   U    O)
   WRITE(2,21)
21 FORMAT(1H , 78H         * E   N       S   Y  S  S  R  R
 1 K     S   R   S   R    N)
   WRITE(2,22)
22 FORMAT(1H , 78H         * R   G           P        S  S
 1 E         S   M   E     )
```

```
      WRITE(2,23)
   23 FORMAT(1H , 78H           *                   E
     1 R             E  R      )
      WRITE(2,24)
   24 FORMAT(1H , 78H           *
     1 S             N  S      )
      WRITE(2,25)
   25 FORMAT(1H , 79H           *    (M)  (M3) (M2)NO
     1                         HRS)
      WRITE(2,26)
   26 FORMAT(1H , 80H           *
     1                         )
      IF(S(2,1).EQ.0.0) GO TO 27
      WRITE(2,28)
      WRITE(2,261)
  261 FORMAT(1H ,10H ROAD BRK )
   28 FORMAT(1H+, 80H           ********************************
     1*****************************************)
      WRITE(2,29) ((S(I,J),J=1,16),I=2,3)
   29 FORMAT(1H ,10X1H*,F3.0,1X,F4.2,2X,F6.2,2X,F6.2,1X,F3.0,
     12X,F2.0,1X,F2.0,1X,F2.0,1X,F2.0,1X,F2.0,1X,F2.0,1X,F2.0
     2,1X,F2.0,1X,F2.0,2X,F2.0,2X,F6.2)
      WRITE(2,30)
   30 FORMAT(1H , 80H           *
     1                         )
   27 CONTINUE
      WRITE(2,271)
  271 FORMAT(1H ,10HEXCAVATION)
      WRITE(2,28)
      WRITE(2,29) (S(4,J),J=1,16)
      WRITE(2,30)
      IF(S(5,1).EQ.0.0) GO TO 31
      WRITE(2,32)
   32 FORMAT(1H ,10HTRENCH SPT)
      WRITE(2,28)
      I=5
  321 WRITE(2,29) (S(I,J),J=1,16)
```

```
      I=I+1
      IF(S(I,1).EQ.0.0) GO TO 33
      GO TO 321
   33 WRITE(2,30)
   31 WRITE(2,34)
   34 FORMAT(1H ,10HBASE BLIND)
      WRITE(2,28)
      WRITE(2,29) (S(15,J),J=1.16)
      WRITE(2,30)
      IF(S(16,1).EQ.0.0) GO TO 35
      WRITE(2,36)
   36 FORMAT(1H ,10HMANHOLE    )
      WRITE(2,28)
      WRITE(2,29) (S(16,J),J=1,16)
      WRITE(2,30)
      GO TO 37
   35 WRITE(2,38)
   38 FORMAT(1H ,10MANHOLE     )
      WRITE(2,28)
      WRITE(2,299)(S(17,J),J=1.16)
  299 FORMAT(1H ,10X,1H*,F3.0,1X,F4.2,2X,F6.2,2X,F6.o,1X,
     1F3.0,2X,F2.0,1X,F2.0,1X,F2.0,1X,F2.0,1X,F2.0,1X,F2.
     20,1X,F2.0,1X,F2.0,1X,F2.0,1X,F2.0,2X,F6.2)
      WRITE(2,30)
   37 CONTINUE
      IF(S(18,1).EQ.0.0) GO TO 39
      WRITE(2,40)
   40 FORMAT(1H ,10HCHANNEL    )
      WRITE(2,28)
      WRITE(2,29) (S(18,J),J=1.16)
      WRITE(2,30)
   39 CONTINUE
      IF(S(19,1).EQ.0.0) G  TO 41
      WRITE(2,42)
   42 FORMAT(1H ,10HINSITU SLB)
      WRITE(2,28)
```

```
      WRITE(2,29) (S(19,J),J=1,16)
      WRITE(2,30)
   41 CONTINUE
      IF(S(20,1).EQ.0.0) GO TO 43
      WRITE(2.44)
   44 FORMAT(1H ,10HSURROUND  )
      WRITE(2,28)
      WRITE(2,29) (S(20,J),J=1.16)
      WRITE(2,30)
   43 CONTINUE
      IF(S(21,1).EQ.0.0) GO TO 45
      WRITE(2,46)
   46 FORMAT(1H ,10HBENCHING  )
      WRITE(2,28)
      WRITE(2,29) (S(21,J),J=1.16)
      WRITE(2,30)
   45 CONTINUE
      WRITE(2.47)
   47 FORMAT(1H ,10HBACKFILL  )
      WRITE(2,28)
      WRITE(2,29) ((S(I,J),J=1.16),I=22,25)
      WRITE(2,30)
      WRITE(2,48)
   48 FORMAT(1H ,10HSUMMARY   )
      WRITE(2,28)
      READ(1,49) Z1,Z2,Z3
   49 FORMAT(3F0.0)
      I=1
   50 I=I+1
      IF(S(I,1).EQ.Z1) GO TO 51
      IF(I.LT.4) GO TO 50
      I1=0
      GO TO 52
   51 I1=I
   52 I=4
   53 I=I+1
```

```
      IF(S(I,1).EQ.0.0) GO TO 54
      IF(S(I,1).EQ.Z2) GO TO 55
      IF(I.LT.15) GO TO 53
      Z2=Z2=1.0
      GO TO 52
   54 I2=0
      GO TO 56
   55 I2=I
   56 I=21
   57 I=I+1
      IF(S(I,1).EQ.Z3) GO TO 58
      IF(I.LT.25) GO TO 57
      I3=0
      GO TO 59
   58 I3=I
   59 CALL RELDATA(S,I1,I2,I3)
      RETURN
      END


      SUBROUTINE RELDATA(S,I1,I2,I3)
      DIMENSION S(25,16),P(11,16)
      IF(I1,EQ.0) GO TO 1
      DO 1 J=1,16
      P(1,J)=S(I1,J)
    1 CONTINUE
      DO 2 J=1,16
      P(2,J)=S(4,J)
    2 CONTINUE
      IF(I2.EQ.0) GO TO 3
      DO 3 J=1.16
      P(3,J)=S(I2,J)
    3 CONTINUE
      DO 4 I=4,LO
      DO 4 J=1,16
      P(I,J)=S(I+11,J)
    4 CONTINUE
```

```
      DO 5 J=1,16
      P(11,J)=S(I3,J)
    5 CONTINUE
      CALL SUMTOT(P)
      RETURN
      END


      SUBROUTINE SUMTOT(P)
      DIMENSION P(11,16),C(1,16)
      J=5
      C(1,J)=1.0
    1 J=J+1
      REG=0.0
      I=0
    2 I=I+1
      IF(P(I,J).GE.REG) GO TO 3
      IF(I.LT.11) GO TO 2
      GO TO 4
    3 REG=P(I,J)
      IF(I.LT.11) GO TO 2
    4 C(1,J)=REG
      IF(J.LT.15) GO TO 1
      SUM=0.0
      DO 5 I=1,11
      SUM=P(I,16)+SUM
    5 CONTINUE
      C(1,16)=SUM
      WRITE(2,6) (C(1,J),J=5,16)
    6 FORMAT(1H ,26X,F3.0,2X,F2.0,1X,F2.0,1X,F2.0,1X,F2.
     10,1X,F2.0,1X,F2.0,1X,F2.0,1X,F2.0,1X,F2.0,1X,F2.0
     2,1X,F6.2)
      WRITE(2,7)
    7 FORMAT(1H , 80H             ****************************
     ********************************************)
```

```
WRITE(2,7)
RETURN
END

FINISH
```

APPENDIX 4

PROJECT SIMULATION PROGRAMME

CONTENTS

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NOTATION

		UNIT
r	Random Fraction	
x	Dependent Variant	
R_o	Positive Integer	
M	Positive Integer	
Q	Total Activity Quantity	
qm	Quantity produced in period 'm'	
ti	Time period increment 'i'	
Qm	Quantity left after 'm' periods	
n	Minimum Practical Gang Size	
Su	Standard man-hours per unit quantity	
Ø	Operative Performance Index	
S	Site Performance Index	
Z	Working day duration	hrs
pu	Productive unmeasured time	hrs
na	Actual Gang Size	
Ap	Actual productive man-hours	hrs
fw	Performance forced waiting time	hrs
Tfw	Total forced waiting time	hrs
α	Zero Production Coefficient	
Øfw	Overloading forced waiting time	hrs
b	Basic Rate	p/hr
p	Plus Rate	p/hr
g	Guaranteed Bonus	p/hr
c	Cost of Living Allowance	£/week
f	Fall Back Bonus	p/hr
w	Worked overtime	hrs

Symbol	Description	UNIT
s	Subsistence Allowance	£/week
t	Travelling Allowance	£/week
t^1	Tool Money Allowance	£/week
n^1	National Insurance Allowance	£/week
h	(H.W.P.) Allowance	£/week
p^1	(P.H.W.P.) Allowance	£/week
w^1	Wet time addition	%
pb	Total Productive Bonus	£
fb	Total Fall Back Bonus	£
gb	Total Guaranteed Bonus	£
z^1	Actual Attendance	hrs
Tc	Total Labour Cost	£
L	Labour cost for a given period	£
CPj	Total plant cost for a single weekly period	£
c_{pi}	Unit cost of plant type 'i'	£
Cmj	Total material cost for a single weekly period	£
cm_i	Unit cost of material type 'i'	£
Tm_i	Transport cost of material type 'i'	£
x_{ij}	Quantity of material type 'i' in activity 'j'	
bpi	Unit bonus for plant type 'i'	£
Cij	Number of Operatives type 'i' required for activity 'j'	
C′	Intercept Point	
c^1	Adjustments	
c^{11}	Operative class increase	%
m′	Slope	
Npij	Number of plant type 'i' in activity 'j'	
z^1	Actual Attendance	

1. Introduction

This suite of computer programmes is designed to combine planning and estimating into a single function. The programmes attempt to simulate a working project and in so doing, enable the user to estimate the cost of variation in operative and site performances, absenteeism and gang overloading. The suite is capable of quantifying anticipated fluctuations in labour, plant and material costs and of spreading the cost of preliminaries over the project activities. Although the suite of programmes is designed for use by contractors, it is flexible enough to fit many design situations which demand an unbiased cost estimate.

2. Software Language

FORTRAN

3. Development Hardware Configuration

1905E Central Processing Unit with hardware floating point 96K words of 1.8 μsec store (K = 1024, word = 24 bits) Operators' console.

Input: 2101 card reader, 2000 cards/minute.
1916 paper tape reader, 1000 characters/second.

Output: 1933 lineprinter, 1350 lines/minute, 120 characters/line.
1925 paper tape punch, 110 characters/second.
1934 graph plotter, 30" wide, 300 steps/second, step size 0.005".

Magnetic Tapes:
4 magnetic tape decks using 0.5" magnetic tapes. Information is stored across 7 tracks at a density

of 556 characters/inch. The maximum transfer rate is 20,800 characters/second.

2 magnetic tape decks using 0.5" magnetic tape. Information is stored across 9 tracks at a density of 1600 characters/inch. The maximum transfer rate is 160,000 characters/second.

Magnetic Discs:

4 exchangeable disc drives, each drive holding 8,192,000 characters stored on 200 trancs. The transfer rate is 208,000 characters/second.

3 exchangeable disc drives, each drive holding 60,000,000 characters.

Magnetic Drum:

1 drum with a storage capacity of 512K (K=1024) words. The maximum transfer rate is 100,000 characters/second.

7007 Multiplexor

7008 Telegraph Data terminals

7010 Telephone Data terminal

In the Main Building, room 416, the following equipment is installed:-

7022 Card reader, 300 cards/minute

7021 Lineprinter, 300 lines/minute

Operators' console

418A teletype terminals.

4. Programme Configuration and Theory

The suite (Figure.1) contains eight programmes, each of which deal with a different aspect of the project simulation. Information generated by each programme is entered and stored on ten data files which either output it to the lineprinter or retain it for future use. The information stored in each data file is given in Table.1.

TABLE.1.

File Name	Information Stored
DAYTA	(1) Day Number (2) Activity Number (3) Ideal Gang Size (4) Actual Gang Size (5) Productive Man-Hours (6) Operative Performance Index (7) Overloaded forced waiting man-hours (8) Performance forced waiting man-hours (9) Total forced waiting man-hours (10) Productive Unmeasured Hours (11) Site Performance Index (12) Quantity of Activity Produced (13) Quantity left to produce (14) Labour Cost
PERTA	(1) Lost daily period recorded
ACTRATE	(1) Activity Number (2) Man-hours per unit of production (3) Total number of units to be produced
COUNT	(1) Total number of different activities occurring each week
WEEK	(1) DAYTA information summarised and grouped into week numbers
LCOSTA	(1) WEEK information grouped into week numbers and activity numbers (2) Week number (3) Activity number (4) Quantity of activity produced (5) Labour cost

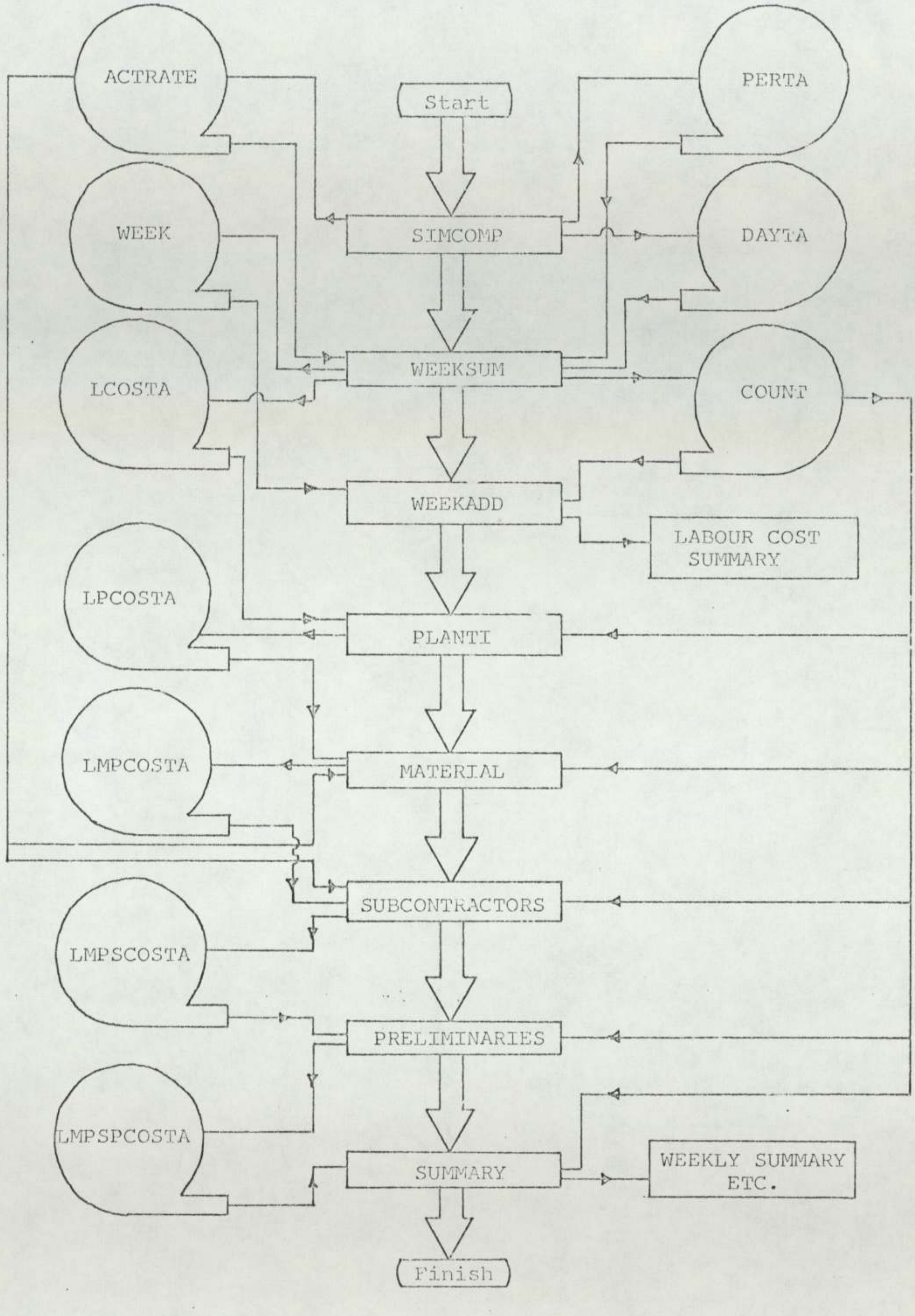

ACTRATE
Start
PERTA
WEEK
SIMCOMP
DAYTA
LCOSTA
WEEKSUM
COUNT
WEEKADD
LABOUR COST SUMMARY
LPCOSTA
PLANTI
LMPCOSTA
MATERIAL
SUBCONTRACTORS
LMPSCOSTA
PRELIMINARIES
LMPSPCOSTA
SUMMARY
WEEKLY SUMMARY ETC.
Finish

Figure. 1 .

LPCOSTA	(1) LCOSTA plus plant cost information
LMPCOSTA	(1) LPCOSTA plus material cost information
LMPSCOSTA	(1) LMPCOSTA plus sub-contractor cost information
LMPSPCOSTA	(1) LMPSCOSTA plus preliminaries cost information

4.1 Day by Day Project Simulation Programme (SIMCOMP)

The simulation is based on the interdependence exhibited by the various project activities. Consequently, it requires a Precidence Network for the project as a whole and standard man-hours, gang sizes and quantities for each project activity. Initially the project is simulated in daily increments (figure.2.) which are subsequently sorted into weekly summaries.

The programme configuration (figure.3.) contains three prime components:-

(a) Project Sequencing

(b) Variable Performance Selection and Manipulation

(c) Labour Cost

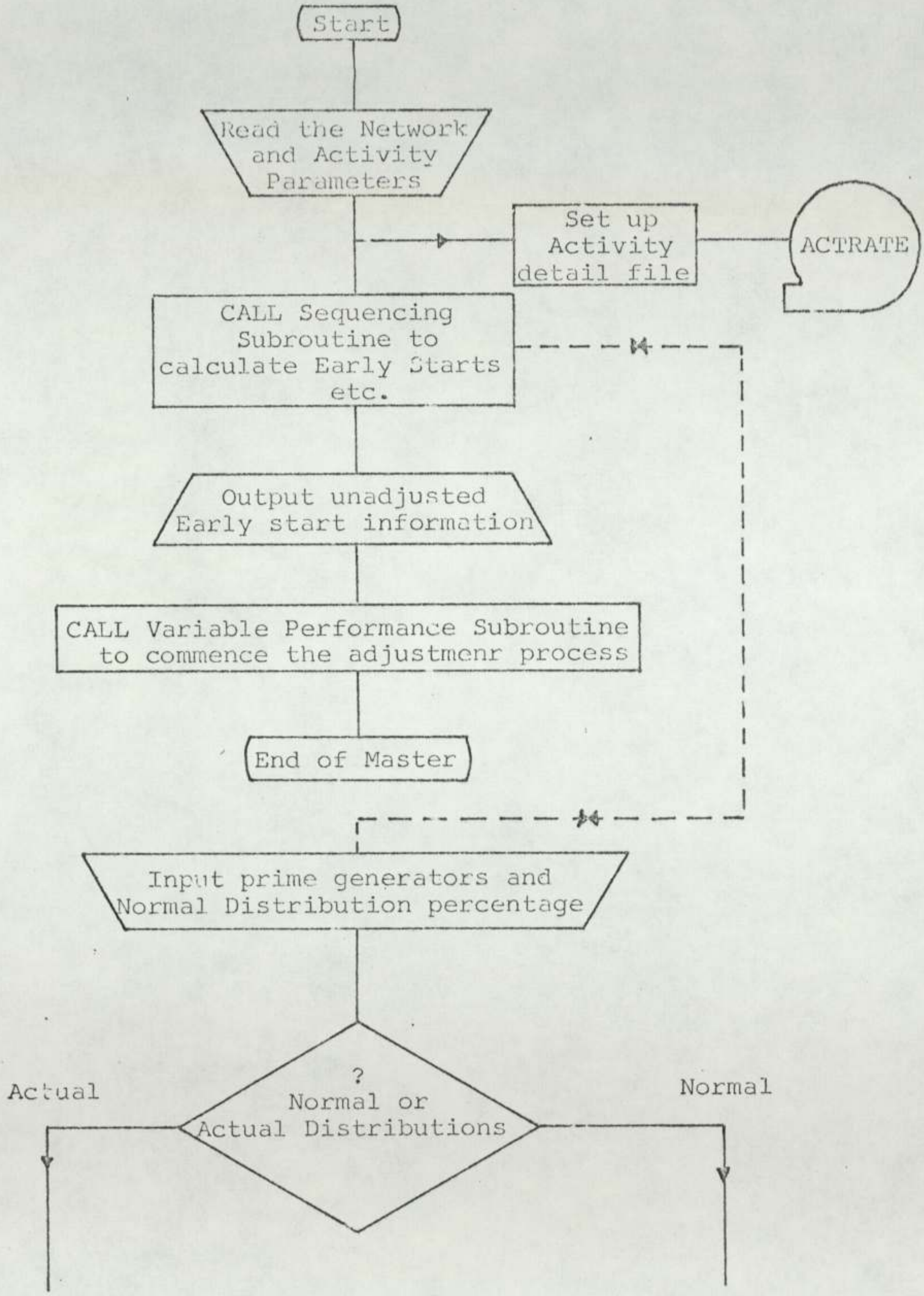
4.1.1 Project Sequencing Subprogramme

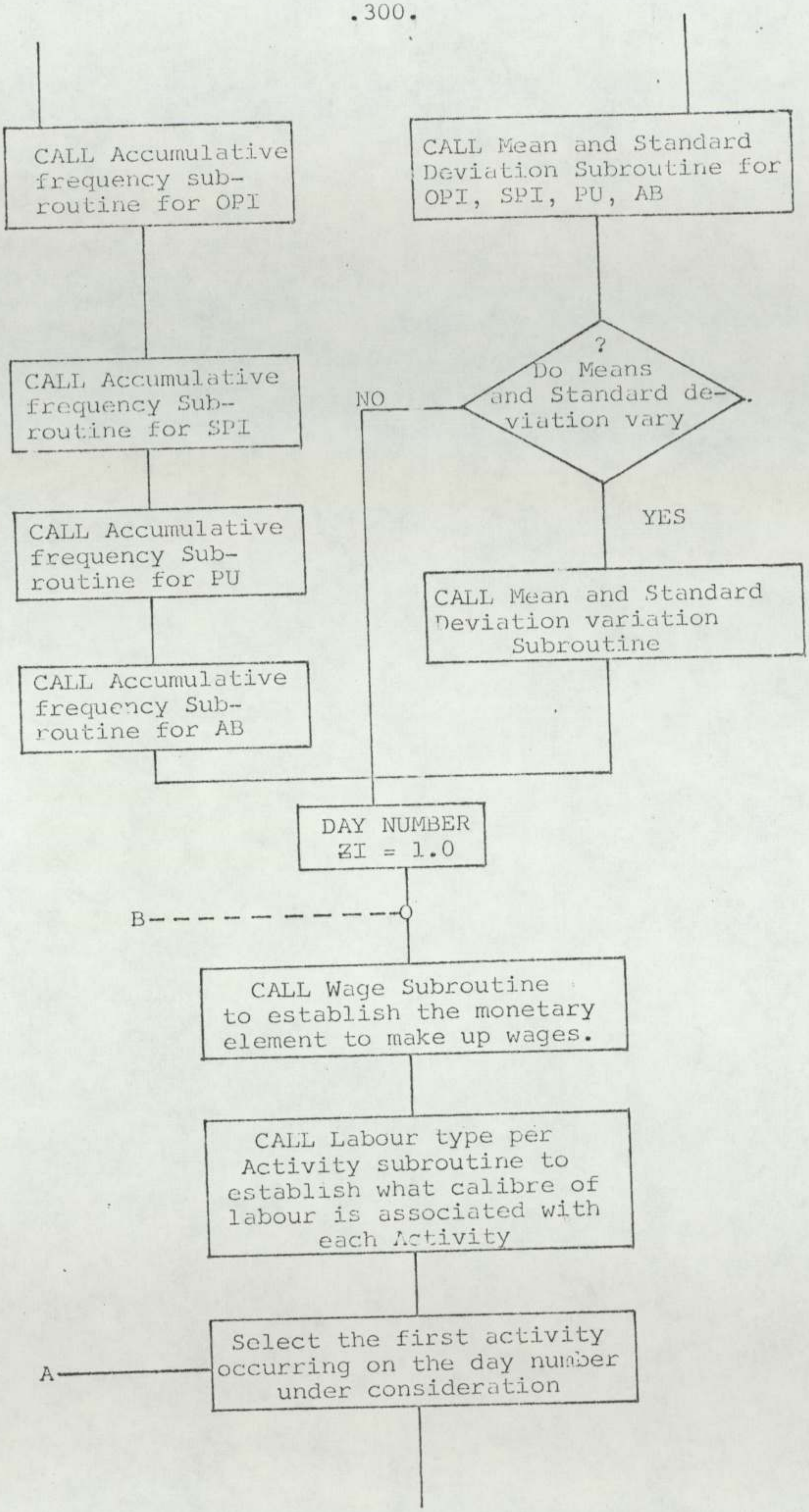
Project sequencing is used twice during the simulation. Firstly, to provide a framework of the project at standard performance. Secondly, to adjust the project and activity duration according to preselected levels of performance.

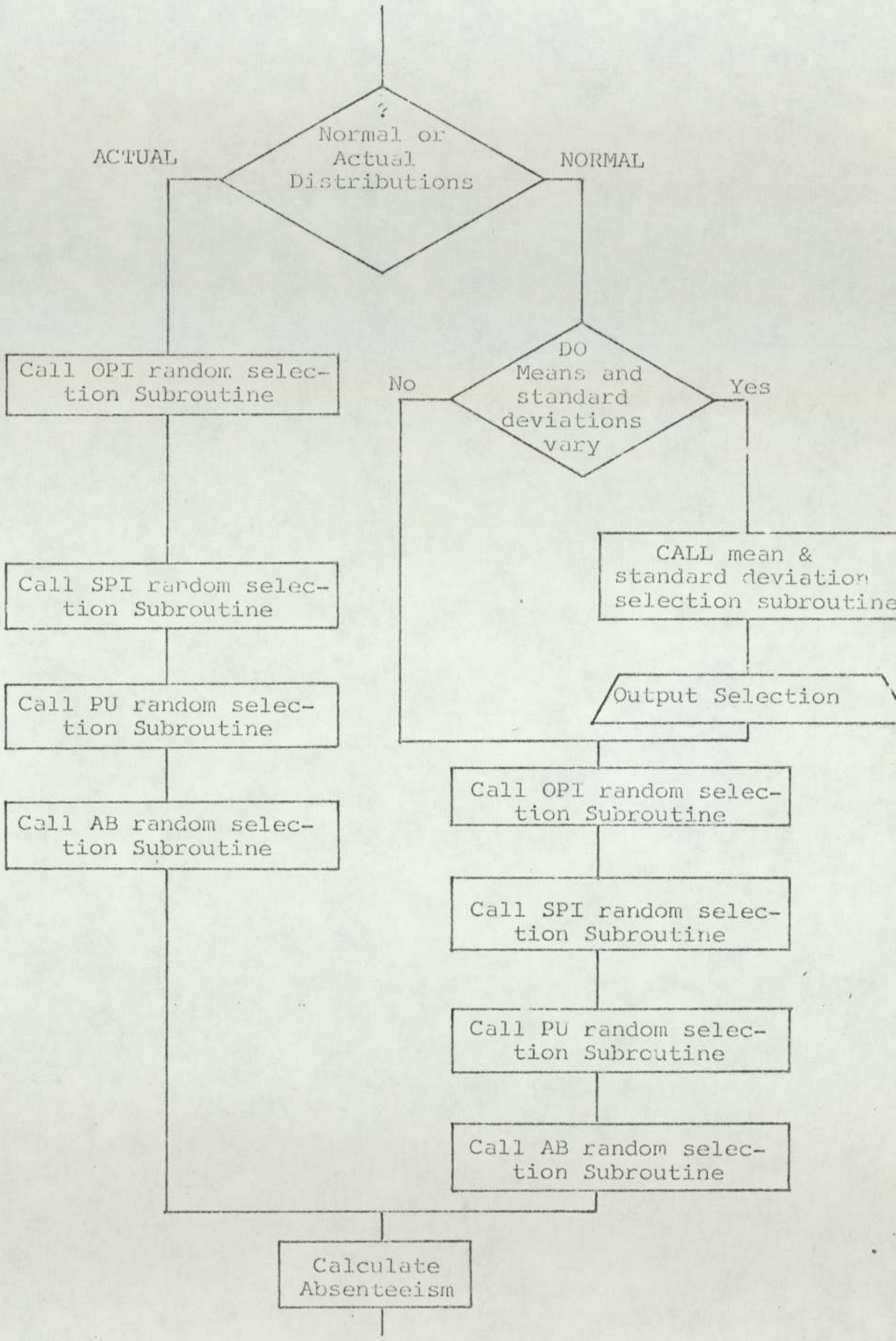
The precedence network is input in matrix form (figure .4.) in which each activity is positioned by the number and description of its immediate predecessors.

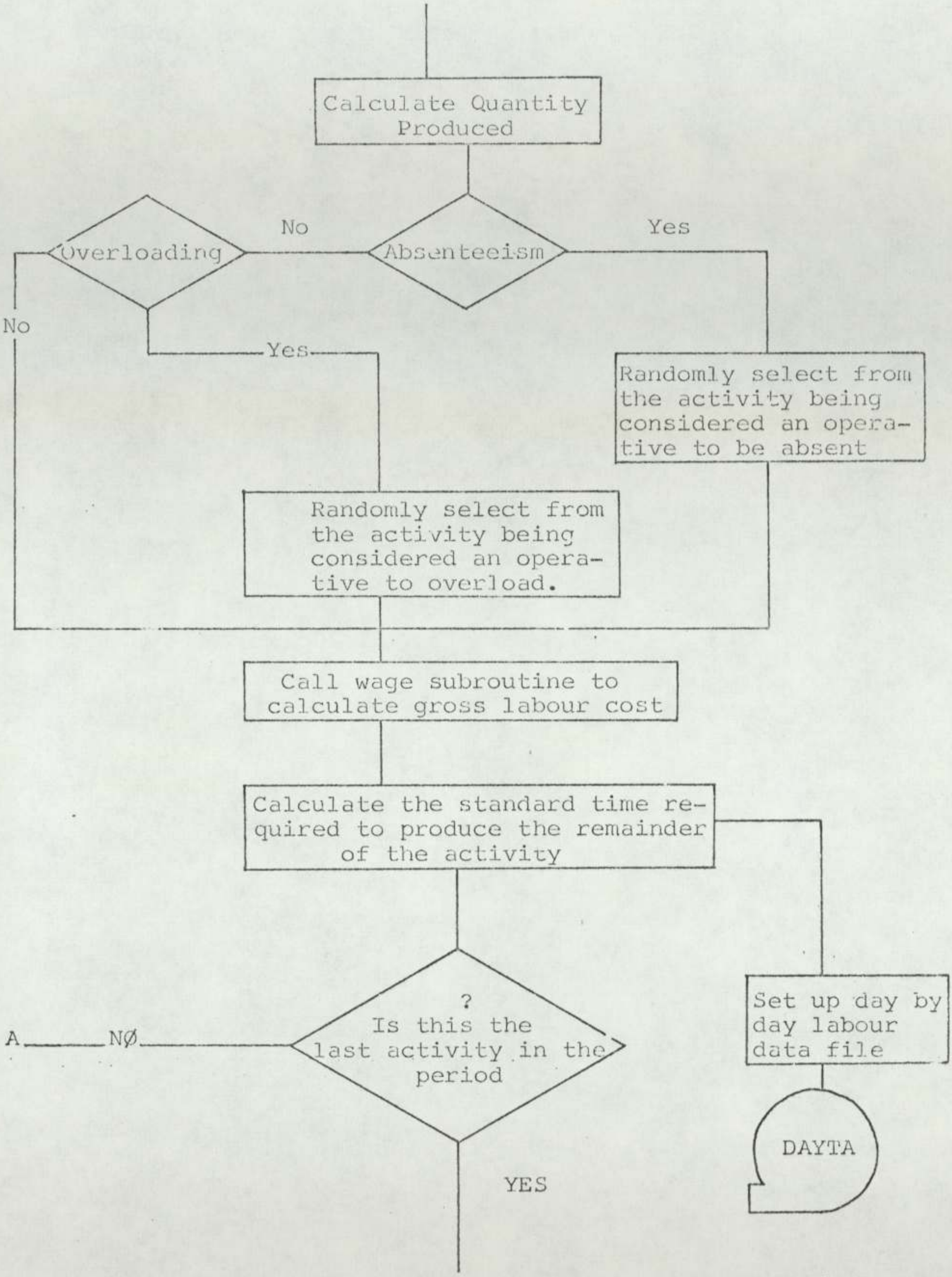
(SIMCØMP)

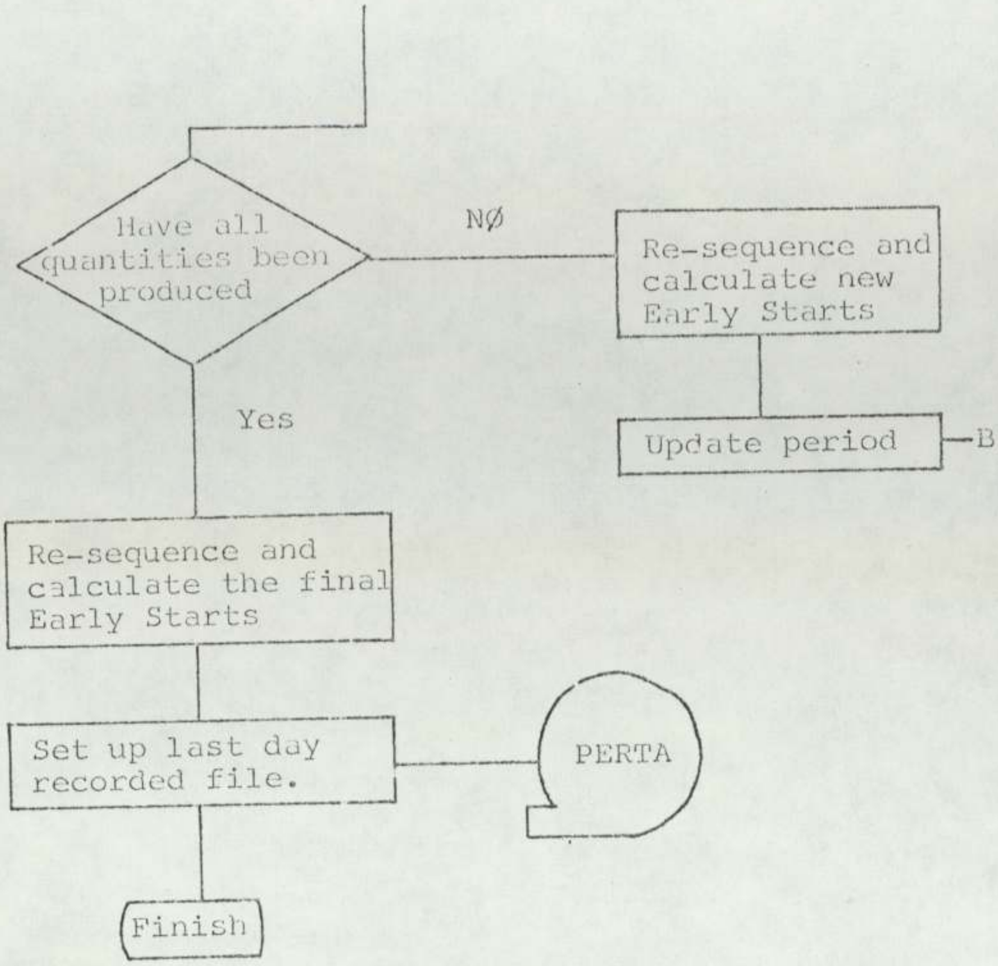
Figure. 2 .




CALL Accumulative frequency sub-routine for OPI
CALL Accumulative frequency Sub-routine for SPI
CALL Accumulative frequency Sub-routine for PU
CALL Accumulative frequency Sub-routine for AB
CALL Mean and Standard Deviation Subroutine for OPI, SPI, PU, AB
? Do Means and Standard de-viation vary
NO
YES
CALL Mean and Standard Deviation variation Subroutine
DAY NUMBER ZI = 1.0
B
CALL Wage Subroutine to establish the monetary element to make up wages.
CALL Labour type per Activity subroutine to establish what calibre of labour is associated with each Activity
A
Select the first activity occurring on the day number under consideration


Normal or Actual Distributions
ACTUAL
NORMAL
Call OPI random selection Subroutine
Call SPI random selection Subroutine
Call PU random selection Subroutine
Call AB random selection Subroutine
DO Means and standard deviations vary
No
Yes
CALL mean & standard deviation selection subroutine
Output Selection
Call OPI random selection Subroutine
Call SPI random selection Subroutine
Call PU random selection Subroutine
Call AB random selection Subroutine
Calculate Absenteeism


Calculate Quantity Produced
Overloading
No
Absenteeism
Yes
No
Yes
Randomly select from the activity being considered an operative to be absent
Randomly select from the activity being considered an operative to overload.
Call wage subroutine to calculate gross labour cost
Calculate the standard time required to produce the remainder of the activity
? Is this the last activity in the period
A
NØ
YES
Set up day by day labour data file
DAYTA


Have all quantities been produced
NØ
Re-sequence and calculate new Early Starts
Update period
B
Yes
Re-sequence and calculate the final Early Starts
Set up last day recorded file.
PERTA
Finish

General Simulation Configuration

Figure. 3 .

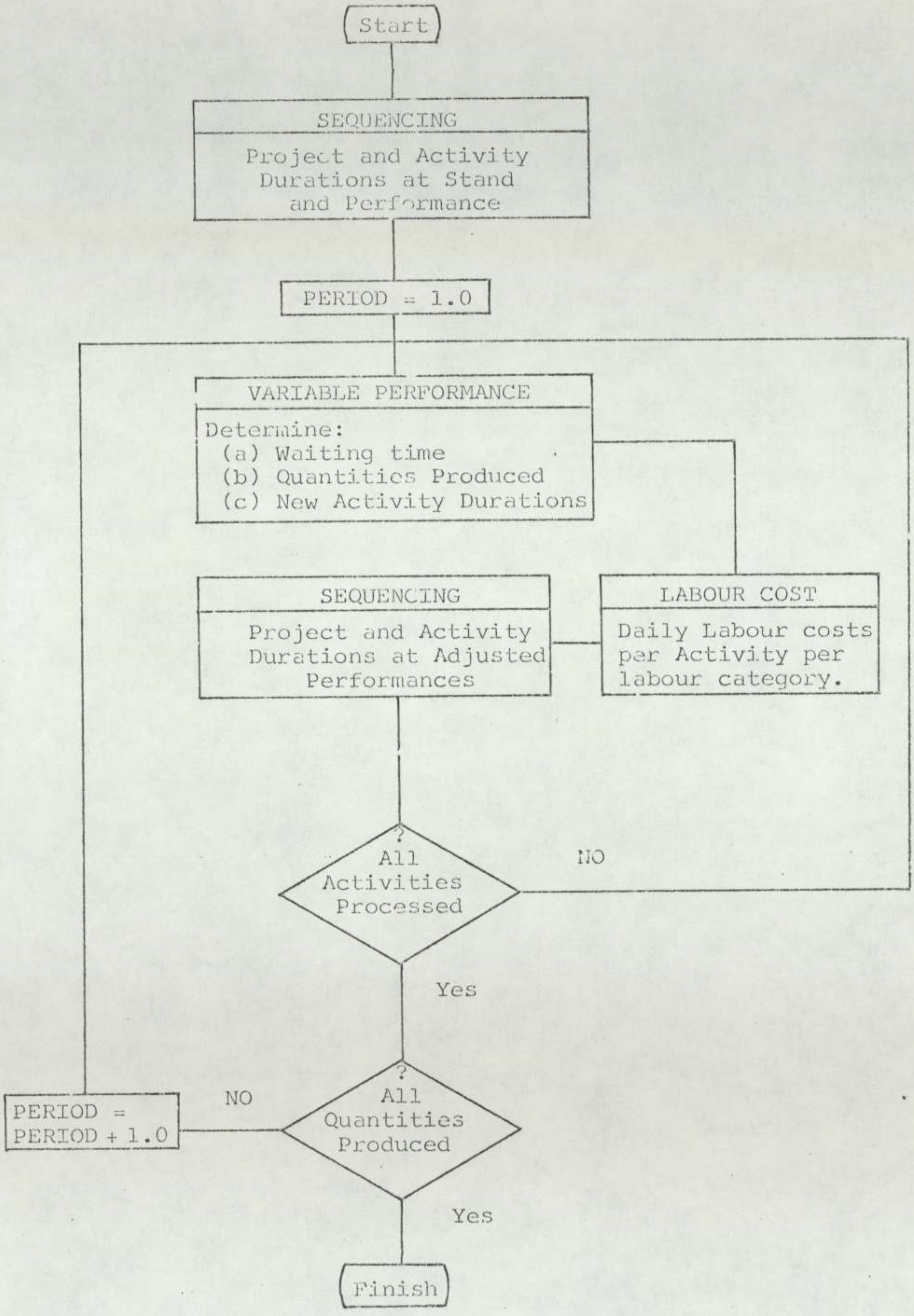
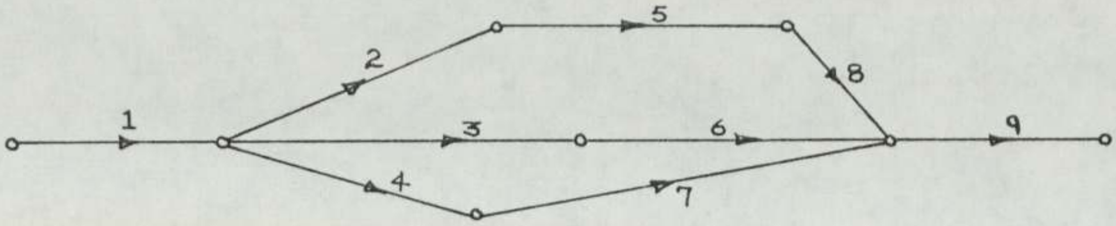


Figure.4.

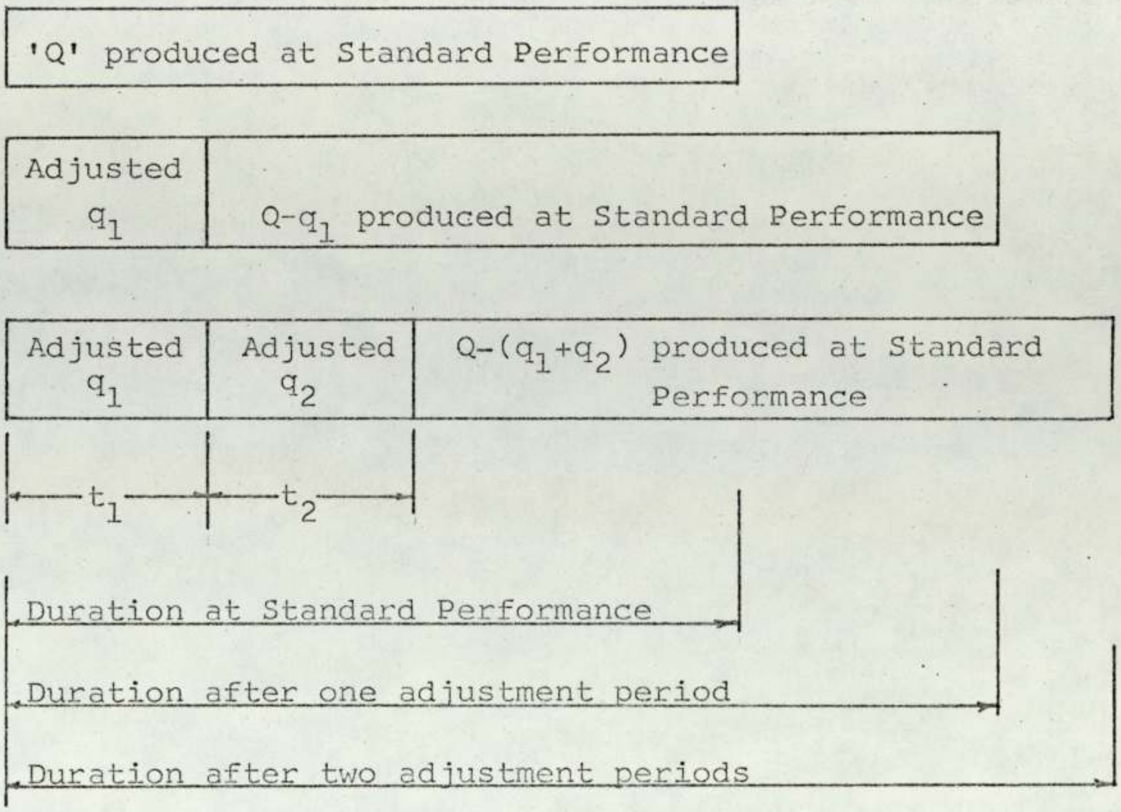
Precedence Network Matrix



Activity Number	Immediate Predecessors			Total Number
1	0			1
2	1			1
3	1			1
4	1			1
5	2			1
6	3			1
7	4			1
8	5			1
9	6	7	8	3

Initially the 'Early Starts' for each project activity are calculated at standard performance. At this stage, no production losses due to varying performance levels are considered.

The simulation start 'PERIOD' (figure 3) is set to unity and all activities occurring within it are processed in turn, the adjusted activity duration being determined in the following way:-



Hence the construction duration time 'Tm' for a single project activity after 'm' periods of simulated adjustment is given by:-

$$Tm = \sum_{i=1}^{i=m} t_i + \frac{Su}{n} . (Qm) \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

As the period increments are integer steps only, the totally adjusted construction duration 'Tc' occurs when the quantity left to produce becomes zero. This may not (in fact hardly ever) occur on an integer step and hence requires adjusting for 'overrun'. (Quantity left becoming zero after 'm' integer steps and before 'm+1' integer steps). Hence:-

$$Tc = Tm \text{ if } \frac{Su}{n} . (Qm) = 0.0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

or $Tc = Tm + e \text{ if } \frac{Su}{n}.(Qm) < 0.0$ ....(3)

where $$\frac{Su}{n}.(Qm) = \frac{Su}{n}\left(Q - \sum_{i=1}^{i=m} qi\right)$$ ....(4)

and $$e = \frac{t}{\left\{\frac{Qm-1}{Qm} + 1\right\}}$$ ....(5)

Equations to inclusive primarily depend on the project activity quantity produced, which in turn is determined by the production, various waiting times incurred and the degree of absenteeism or overloading of labour resources.

4.1.2 Variable Performance Selection and Manipulation Subprogramme

Performance data required for adjusting the standard production rate is selected psuedo-randomly for either normal or actual (Chapter 3) accumulative frequency distributions using the Inverse Transformation Method[1] which assumes that the probability of a variate according to 'F(x)' as its density function is less than, or equal to, 'x' in the form:-

$$P\left\{F^{-1}(r) \leqslant x\right\} = P\left\{r \leq F(x)\right\} = F(x)$$ ....(6)

where

r = Psuedo Random Fraction

x = The Dependent Variate

Psuedo-random numbers 'R' being generated using the Multiplicative Congraential Method[1] [2], which takes the form:-

$R = a.\ R_{i-1}\ (\text{Mod } M)$ ....(7)

where Ro = Positive Integer

a = Positive Integer

$|M|$ = Large Positive Integer

Psuedo-random fractions $^{(r)}$ are, therefore, created by forming the sequence $\{Ri/M\}$.

After selecting the relevant performance data for the activity being considered, the quantity produced (q) is calculated and subtracted from the total quantity (Q). All activities occurring are processed in turn in a similar way. The quantity produced and total waiting time incurred are dependent upon the performance levels anticipated.

Quantity Produced and Total Forced Waiting Time

Performance data psuedo-randomly selected either from Normal or Actual Distributions is used to determine the quantity produced in any one period in the following way:-

Let ϕ = Operative Performance Index

S = Site Performance Index

Z = Work day per man (hrs.)

pu = Productive Unmeasured time (hrs.)

n = Ideal Gang Size

na = Actual Gang Size

Su = Standard Man-hours allowed per unit.

q = Quantity of work produced

Ap = Actual Productive Man-hours

fw = Performance force waiting time

by definition

$$S = \frac{100.Su.q}{Ap + Tfw} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

$$\emptyset = \frac{100.Su.q}{Ap} \quad \ldots\ldots\ldots\ldots\ldots (9)$$

The Total Attendance Man-hours is given by:-

$$Z.na = Ap + Tfw + na.pu \quad \ldots\ldots\ldots\ldots\ldots (10)$$

Now from equations (8) and (9):-

$$Tfw = 100.Su.q. \left\{ \frac{1}{S} - \frac{1}{\emptyset} \right\}$$

Hence $$Tfw = \frac{100.Su.q}{S} . (1 - S/\emptyset) \quad \ldots\ldots\ldots\ldots (11)$$

and $$q = \frac{S.\ Tfw}{100.Su.(1-S/\emptyset)} \quad \ldots\ldots\ldots\ldots (12)$$

The total force waiting time 'Tfw' is assumed to have two prime components:-

(a) $\emptyset fw$ or ufw, one or the other depending on whether the gang is overloaded or underloaded respectively.

(b) fw natural forced waiting derived from the differences in performance between '$\emptyset$' and 'S'.

When there is no absenteeism or overloading, the total forced waiting time 'Tfw' is dependent upon the performance differences only.

$$Tfw = fw = na . (Z - pu) . (1 - S/\emptyset) \quad \ldots\ldots\ldots (13)$$

However, if the gang becomes overloaded 'Tfw' is modified depending upon the degree of overloading.

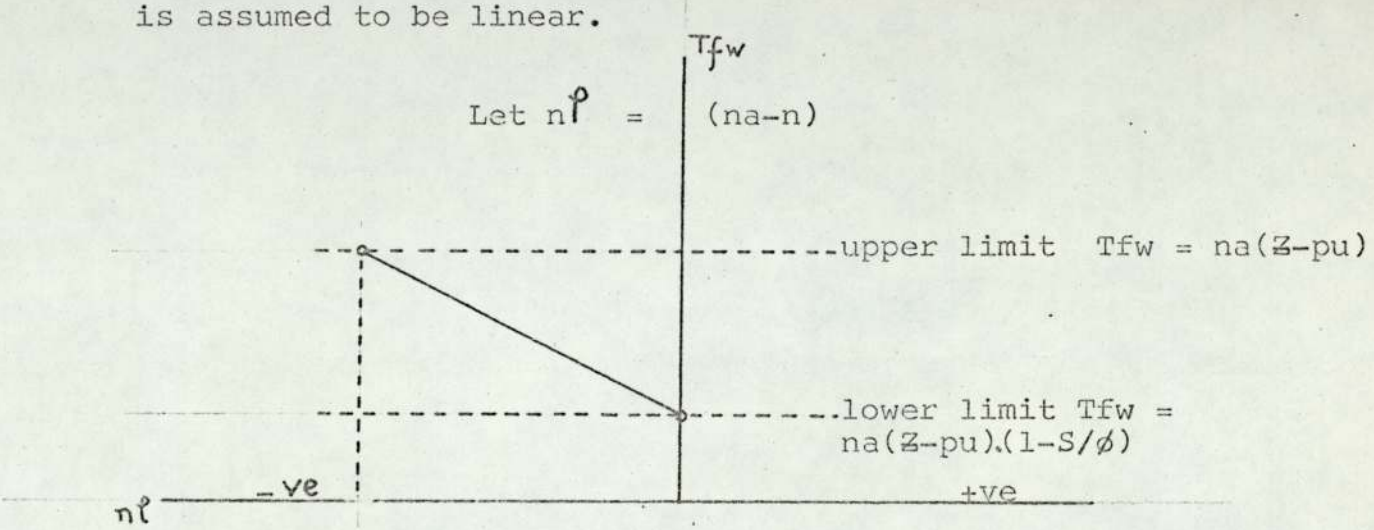
$$Tfw = fw + \emptyset fw$$

$$\therefore \quad Tfw = na.(Z - pu).(1-S/\emptyset) + (na - n).(Z - pu)$$

$$\underline{Tfw = (Z - pu).\left\{na\,(1-S/\emptyset) + (na-n)\right\}} \quad ....(14)$$

If there is absenteeism, the total forced waiting time is again increased, but only to a certain critical point at which production must cease. This level is denoted by 'α' and the relationship between the forced waiting time 'fw' is assumed to be linear.

Let $n\ell$ = (na-n)



production ceases $n\ell_c = \alpha n$

Hence $Tfw = -m'.n\ell + C'$

where $C' = na.(Z-pu).(1-S/\emptyset)$

$$m' = \frac{na\,(Z-pu) - na(Z-pu)\,(1-S/\emptyset)}{\alpha n}$$

$$m' = \frac{na(Z-pu)}{\alpha n}\,(1 - (1-S/\emptyset))$$

$$m' = \frac{na\,(Z-pu)\,S}{\alpha.n.\emptyset}$$

$$Tfw = na(Z-pu)(1-S/\phi) - \frac{na(Z-pu).S.(na-n)}{\alpha.n.\phi}$$

$$Tfw = na(Z-pu) \left\{ (1-S/\phi) - \frac{S(na-n)}{\alpha.n.\phi} \right\}$$

$$Tfw = na\ (Z-pu) \left\{ 1 - S/\phi - \frac{S(na-n)}{\alpha.n.\phi} \right\} \qquad \text{.........(15)}$$

An average value of = - 0.5950 was established which implies that production ceases when:-

$na = 0.4050.n$ (or 59.5% absenteeism)

4.1.3 Labour Cost Subprogramme

The programme (SIMCOMP) accepts five labour types, all of which are commonly used during estimating. They are:-

(1) Working Foreman

(2) Gangers

(3) Tradesmen

(4) Skilled Labourers

(5) Labourer

All direct labour in the above categories is included in a 100% incentive scheme operated by the Company's Production Department.

Let b	=	Basic Rate	(p/hr.)
p	=	Plus Rate	(p/hr.)
g	=	Guaranteed Bonus	(p/hr.)
c	=	Cost of Living Allowance	(£/week)
f	=	Fall Back Bonus	(p/hr.)
w	=	Work Overtime	(hrs./week)
s	=	Subsistance Allowance	(£/week)

t	=	Travelling Allowance	(£/week)
t^1	=	Tool Money Allowance	(£/week)
n'	=	National Insurance Allowance	(T/week)
h	=	H.W.P. Allowance	(£/week)
p'	=	P.H.W.P. Allowance	(£/week)
w^1	=	Wet Time Addition	(%)
c^1	=	Adjustments	
c^{11}	=	Operatives Class Increase	(%)
pb	=	Total Productive Bonus	
fb	=	Total Fall Back Bonus	
gb	=	Total Guaranteed Bonus	
z	=	Maximum attendance possible	(hrs.)
z^1	=	Actual Attendance	(hrs.)

from equation (10)

$$z^1 = Ap + Tfw + pu$$

For 100% incentive scheme

$$pb = b.c^{11}.Ap\left\{\frac{\emptyset}{75.0} - 1.0\right\} \quad \ldots\ldots\ldots\ldots\ldots(16)$$

and $$fb = f\,.\,(Tfw + pu) \quad \ldots\ldots\ldots\ldots\ldots(17)$$

and $$gb = \frac{g.z^1}{z} \quad \ldots\ldots\ldots\ldots\ldots(18)$$

Therefore, the total Bonus paid 'Tb' is given by the greater of

$$Tb = \frac{pb + fb}{(z^1 - w)} \quad \text{or} \quad \frac{gb + fb}{(z^1 - w)} \text{ ----p/hr. } \ldots.(19)$$

The total wage is made up broadly of five segments:-

(1) Overtime

(2) Bonus and Basic

(3) Allowances

(4) Wet Time Addition

(5) Adjustment

Hence, the total labour cost T_c is given by:-

$$Tc = \left[\frac{1.5\ w\ b}{100.0}\right] + \left[\frac{(b + p + Tb)\ (Z^1 - w)}{100.0}\right] + \left[c + s + t + tm + n' + h + p'\right] + \left[\frac{wt}{100.0}\left\{\frac{1.5.wb}{100} + \frac{(b + p + Tb)\ (Z^1 - w)}{100}\right\}\right] + \left[c^1\right] \quad ..(20)$$

Hence the total labour cost (L) for a given period containing '<u>n</u>' activities and '<u>m</u>' categories of labour

$$L = \sum_{j=1}^{j=n} \left\{ \left\{ \sum_{i=1}^{i=m} Cij.Tci \right\} - (nj - naj)\ \bar{\bar{C}}ij.T\bar{c}i \right\} \quad ..(21)$$

where '$\bar{i}$' in the latter part of equation 21 is chosen at random from the gang and '$\bar{\bar{C}}_i$' takes the value of zero if there are no operatives of type 'i' present and unity if there are.

4.2 <u>Weekly Summaries (WEEKSUM), (WEEKADD)</u>

These programmes perform two ancillary functions. Firstly WEEKSUM (figure 5) sorts the daily performance, production and labour cost data into weekly and activity categories. Secondly, WEEKADD (figure.6.) calculates and outputs to the lineprinter the anticipated production information which is summarised in period totals, accumulative period totals, activity totals and accumulative period totals (a typical output produced by WEEKADD is given subsequently.

4.3 Plant Cost Addition (PLANT1)

A maximum of ten types of plant are analysed by this programme (figure.7.), the cost of each being calculated in the following way:-

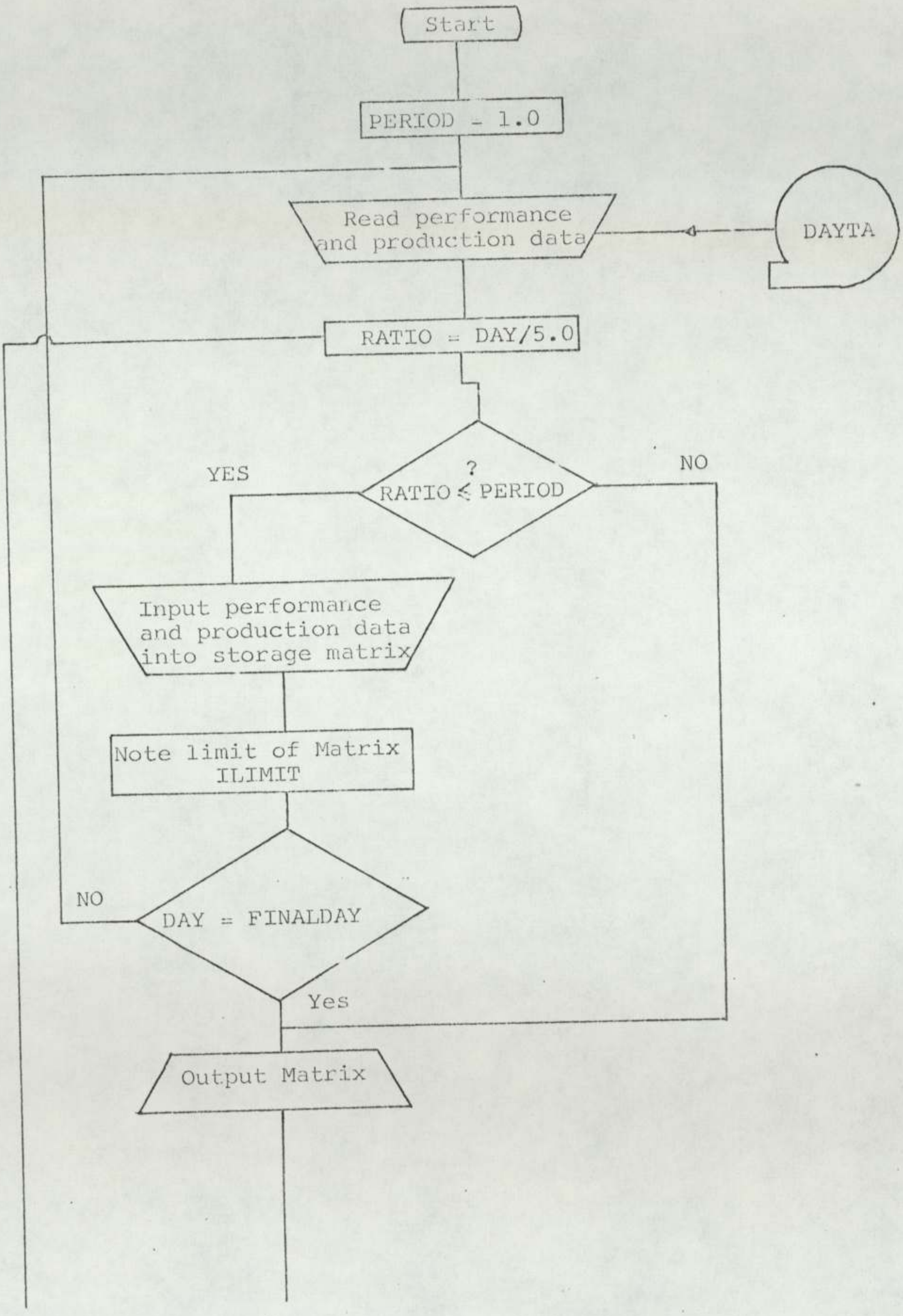
$$Cpj = \sum_{i=1}^{i=10} (cpi + bpi).Npij \quad \ldots\ldots\ldots\ldots\ldots\ldots (22)$$

where

Cpj = Total plant cost for a single weekly period
cpi = Unit cost of plant type 'i'
bpi = Unit bonus for plant type 'i'
Npij = Number of plant type 'i' in activity 'j'.

Activity and week number information is used from files LCOSTA and COUNT to produce a new file LPCOSTA. Plant hire rates per week or per hour are accepted by the programme. The labour cost file LCOSTA is retained so that amendments can be made to the plant data without having to re-run the whole of the simulation programme.

WEEKSUM


Start
PERIOD = 1.0
Read performance and production data
DAYTA
RATIO = DAY/5.0
YES
NO
RATIO ≤ PERIOD ?
Input performance and production data into storage matrix
Note limit of Matrix ILIMIT
NO
DAY = FINALDAY
Yes
Output Matrix

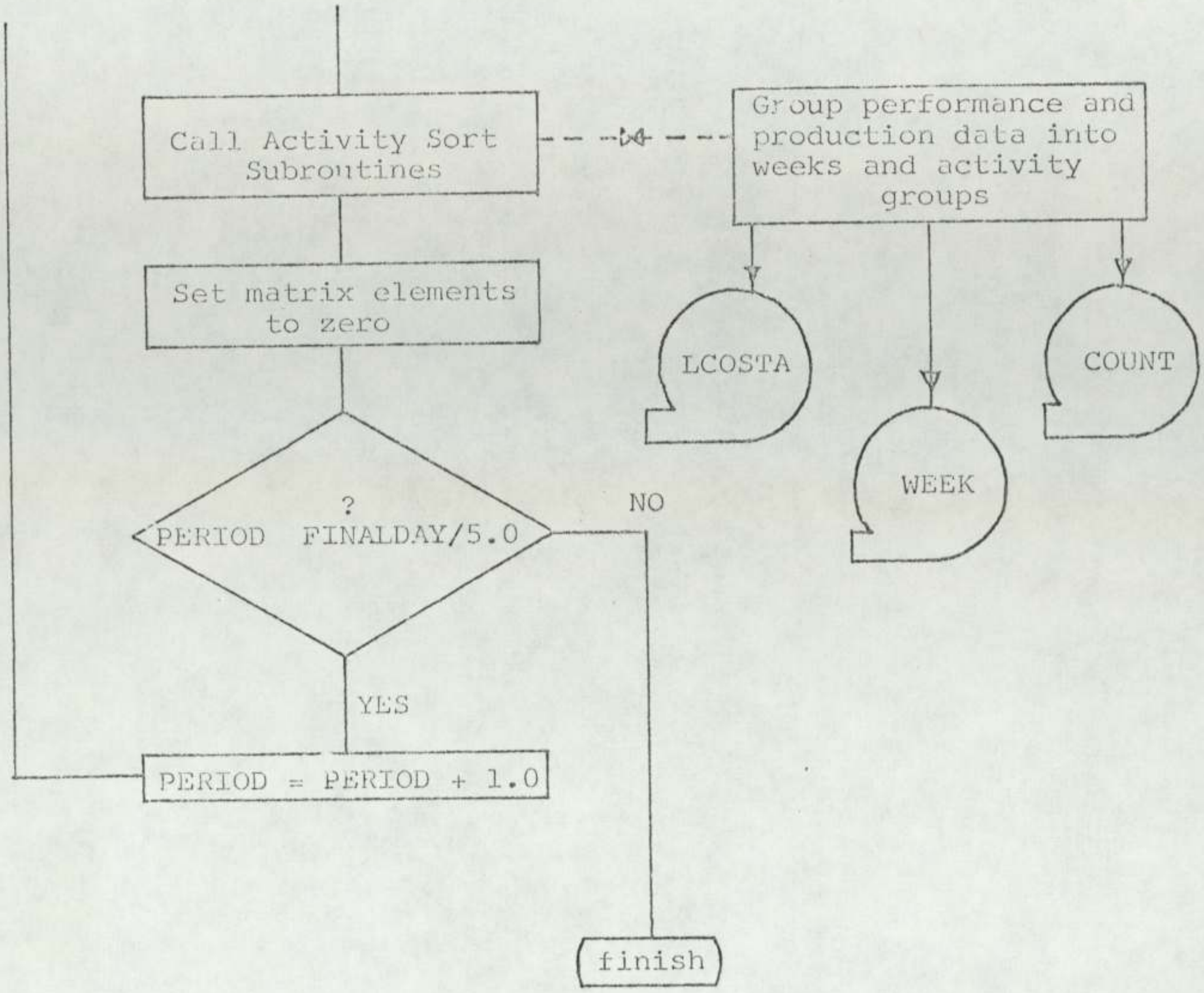

Call Activity Sort Subroutines
Group performance and production data into weeks and activity groups
Set matrix elements to zero
LCOSTA
WEEK
COUNT
?
PERIOD FINALDAY/5.0
NO
YES
PERIOD = PERIOD + 1.0
finish

Figure. 5 .

WEEKADD

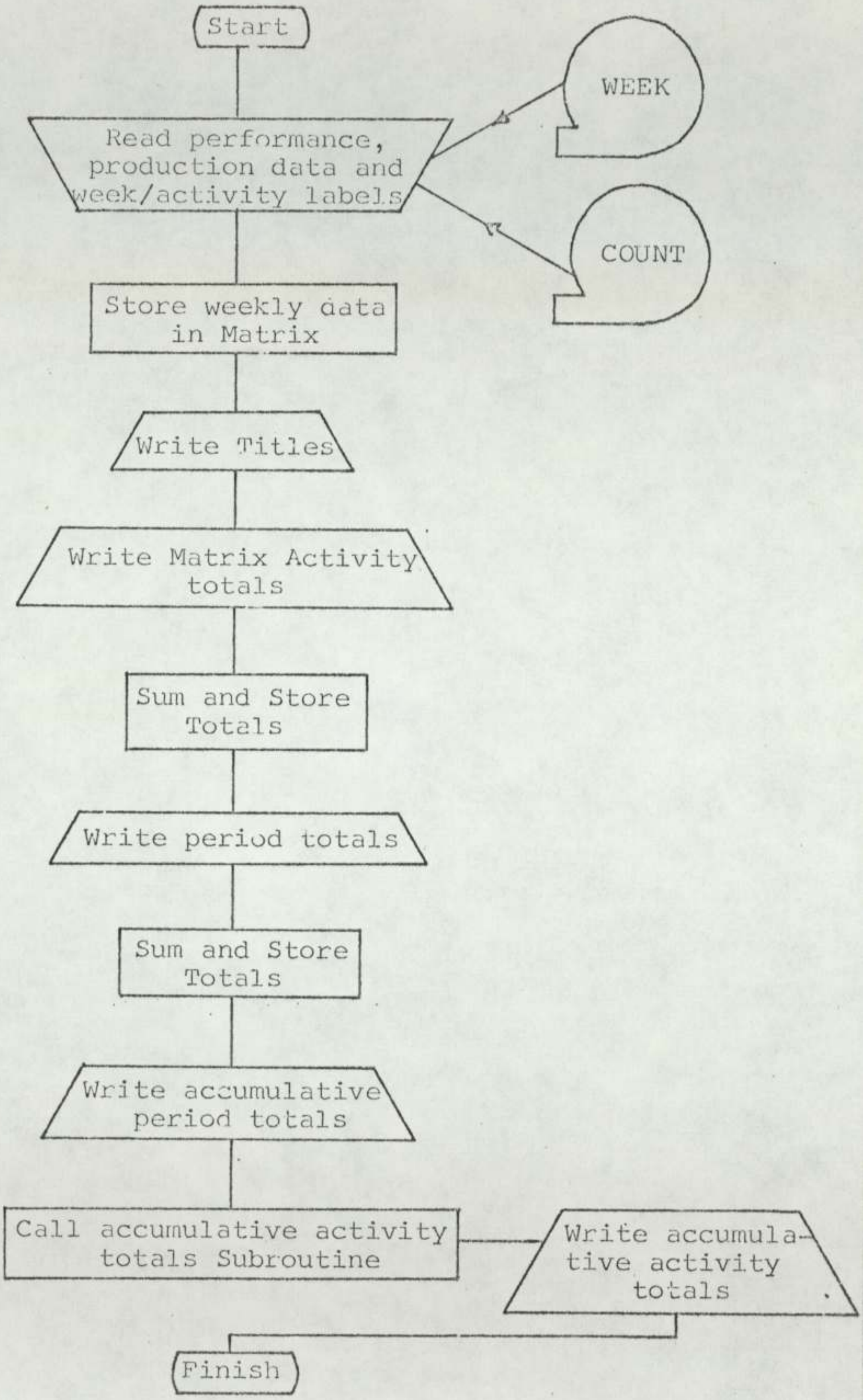


Figure. 6 .

PLANT 1

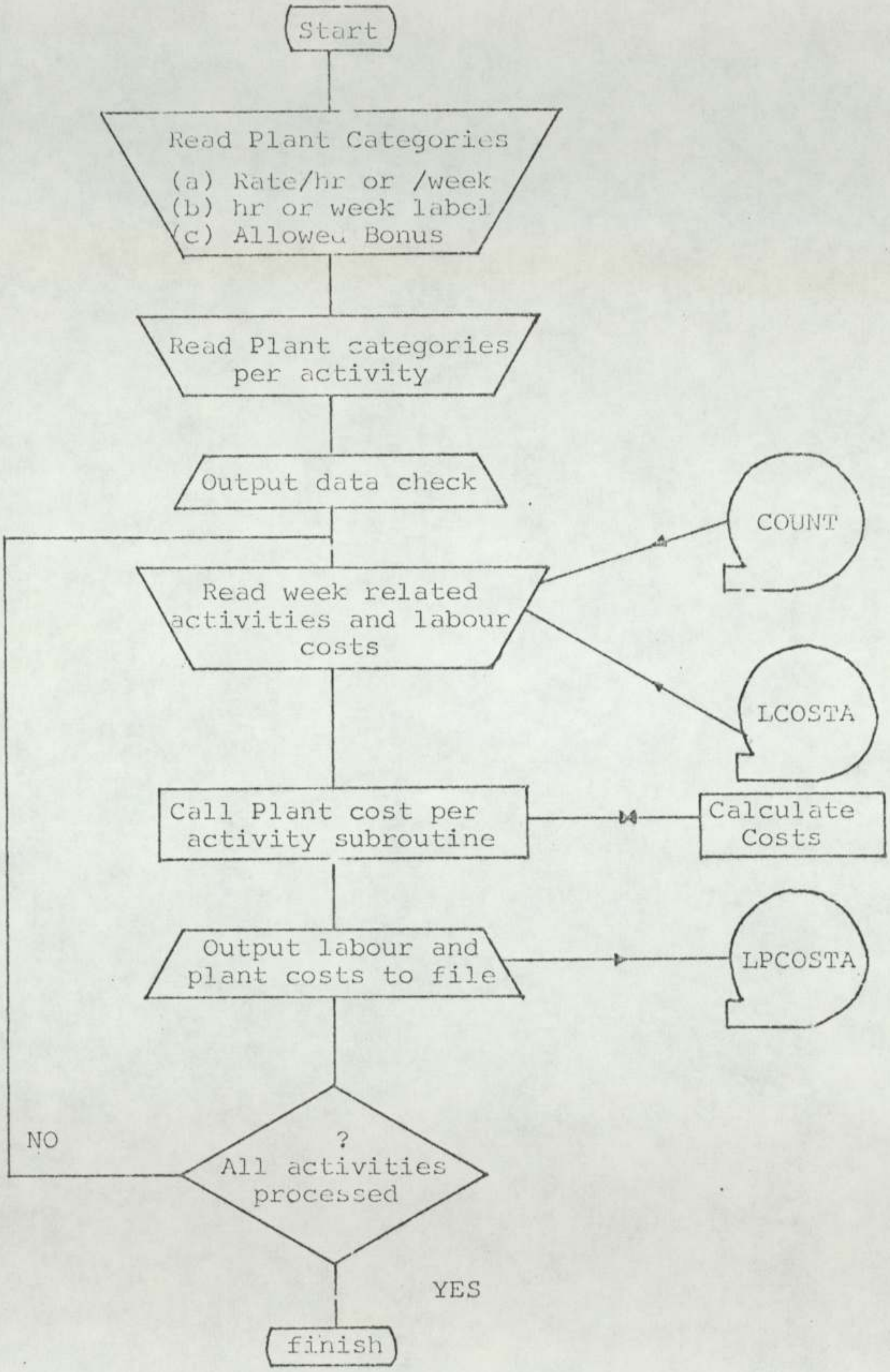


Figure. 7 .

4.4 Material Cost Addition (MATERIAL)

This programme (figure.8.) calculates and adds the anticipated material costs to the previously created LPCOSTA file, to create LMPCOSTA.

Material and transport costs per specified quantity are required by the programme. The material cost for 'm' types of material per activity being calculated in the following way:-

$$Cmj = \frac{q}{Q} . \sum_{i=1}^{i=m} xij \ (cmi + Tmi) \quad \ldots\ldots\ldots\ldots\ldots (23)$$

where

xij = Quantity of material type 'i' in the activity being considered

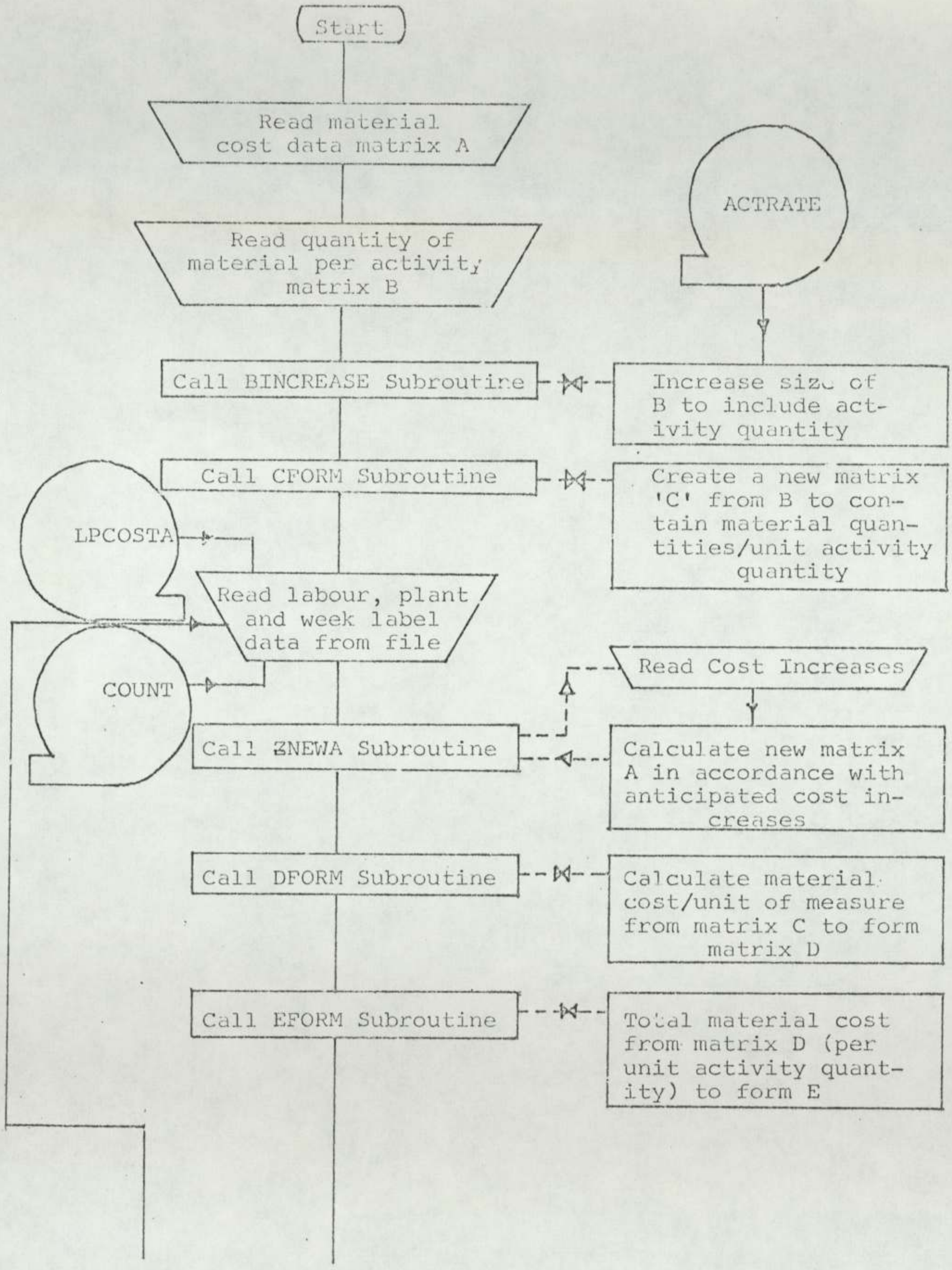
cmi = Unit cost of material type 'i'

Tmi = Unit cost of transport for material type 'i'

Cmj = Total material cost for a single weekly period for activity 'j'.

If required, the programme calculates material cost increases from anticipated percentage increases. The increases may be applied to all or some of the material types in any pre-determined period range, a linear increase being assumed between the period range limits. If the period in which the material used is underestimated, then the material is assumed to increase in cost at a rate given by the previous cost increase period used by the programme.

MATERIAL/SUBCONTRACTORS



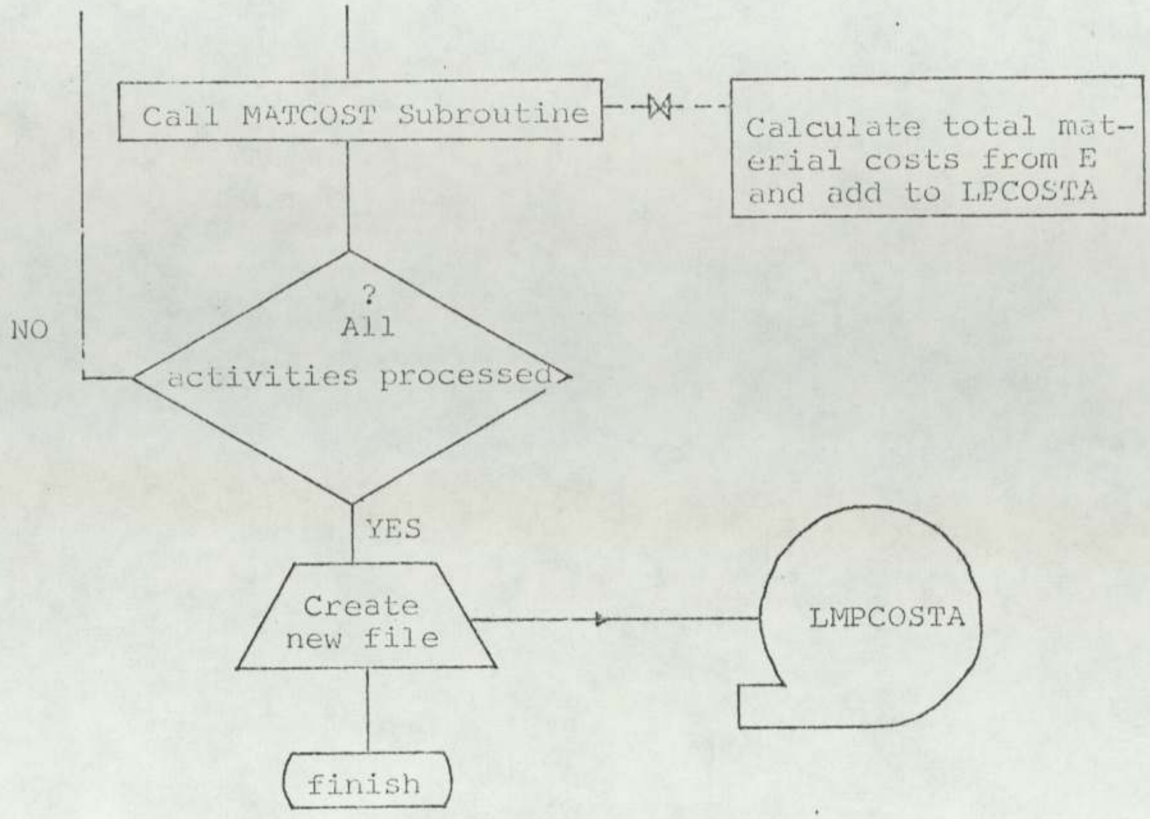

Call MATCOST Subroutine
Calculate total material costs from E and add to LPCOSTA
?
All
activities processed
NO
YES
Create new file
LMPCOSTA
finish

Figure. 8 .

4.5 Subcontractor Cost Addition (SUBCONTRACTORS)

Subcontractor costs are calculated using a similar programme structure to that used for material cost addition. However, increased subcontractor costs are not included at this stage.

The programme reads from files LMPCOSTA and COUNT to form LMPSCOSTA, LMPCOSTA being retained for possible future use.

Refer to figure .8. and section 4.4 for the programme's flow diagram and theory.

4.6 Preliminaries Cost Addition (PRELIMS)

Preliminaries costs, which are time bases costs (Supervision, Multi-purpose Plant etc.) are calculated and stored on file LMPSPCOSTA.

The programme (figure.9.) apportions preliminaries costs over specified activities and period ranges. An unlimited number of preliminaries may be processed. On completion of the simulation, this programme can be used to re-arrange the amount of money applied to any activity at any time period.

4.7 SUMMARY Programme

This programme (figure.10.) uses the information stored on file LMPSPCOSTA. The information is stored and anticipated labour, plant, sub-contractor and preliminaries cost increases are applied and the results re-stored and output to the lineprinter. The summary produced contains activity totals, accumulative activity totals, period totals and accumulative period totals. Subsequently, two tables are produced which give the total net cost and net cost rate for each activity. A typical output summary is given subsequently.

PRELIMINARIES

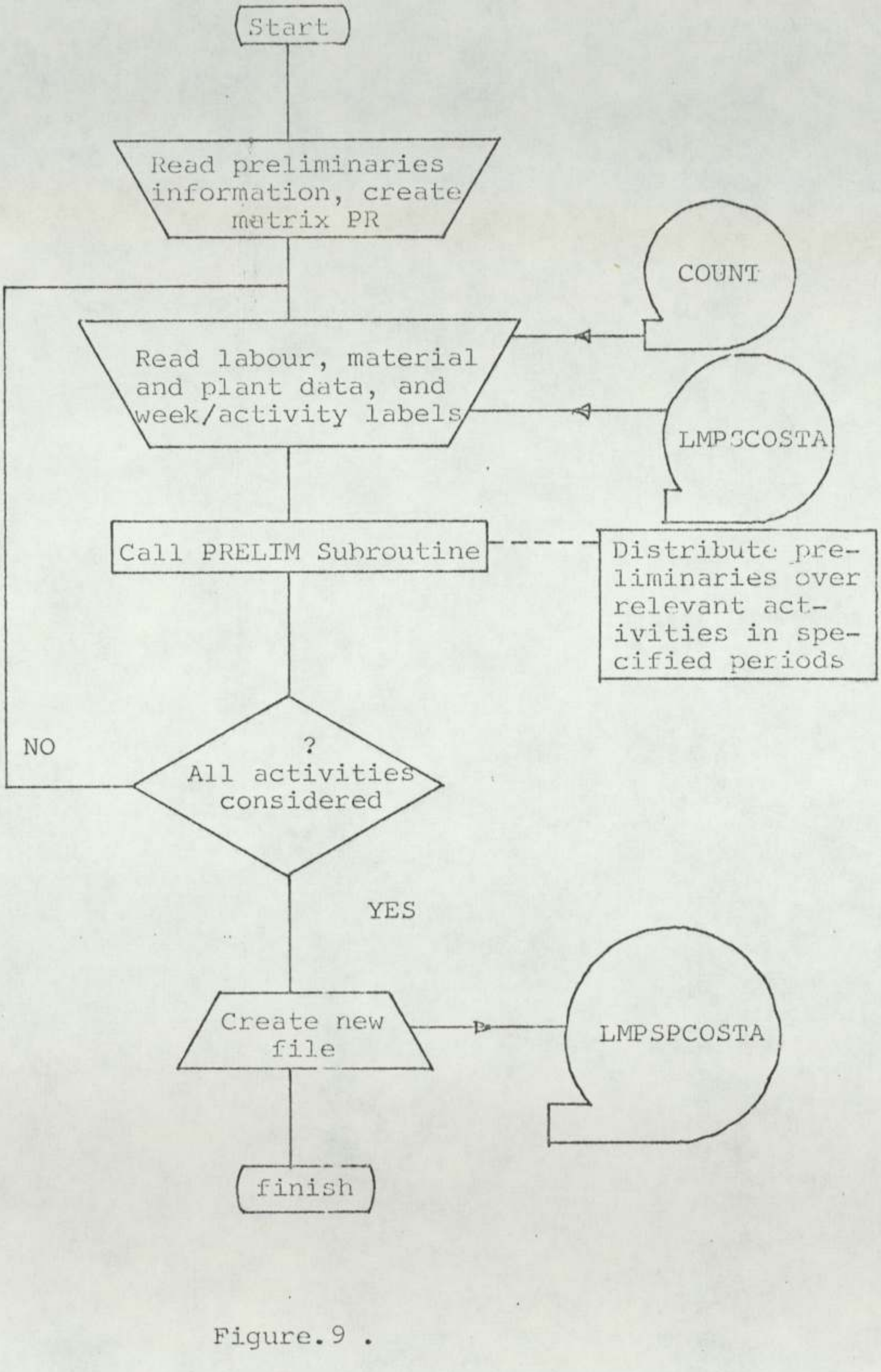
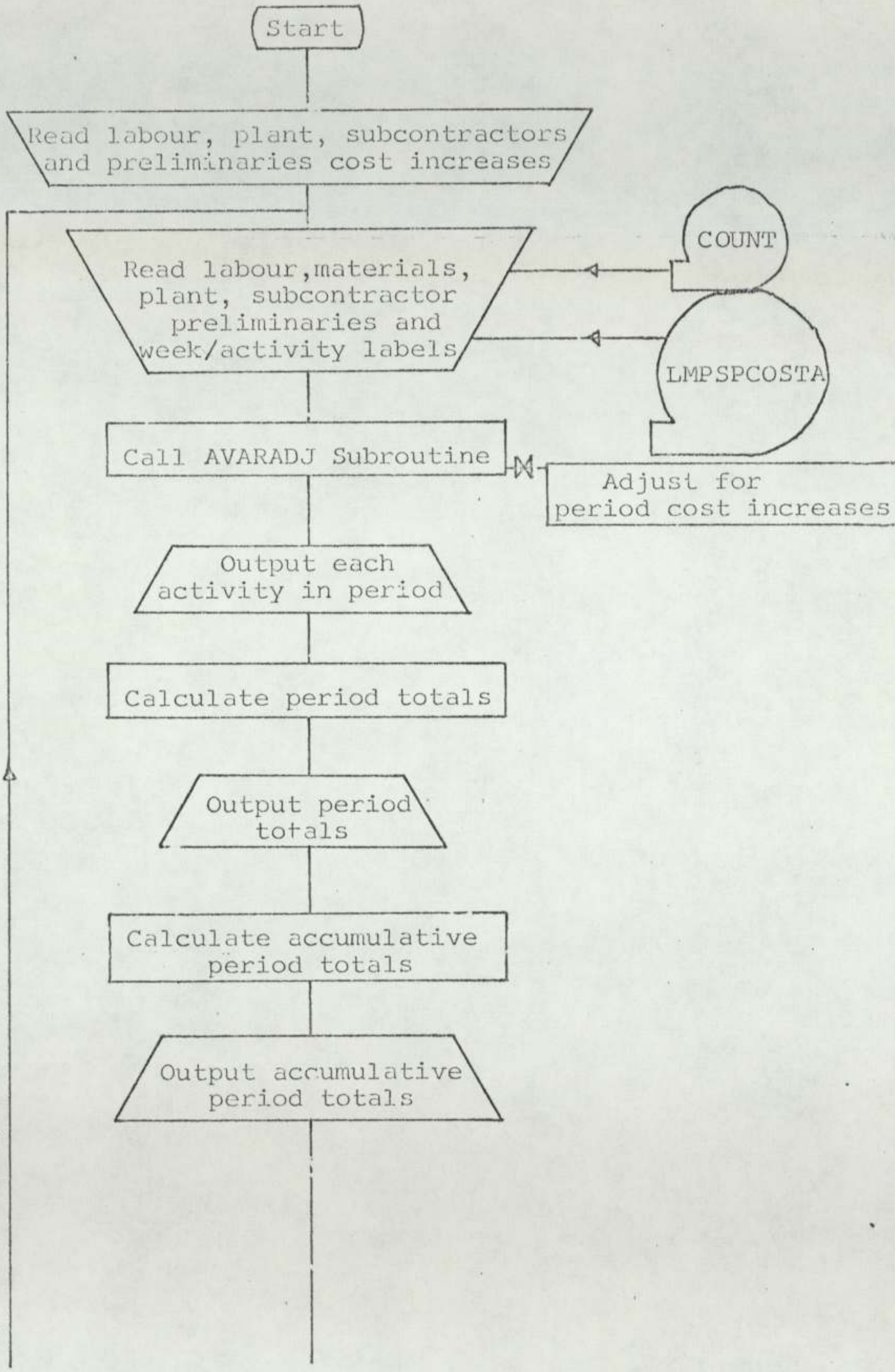


Figure. 9 .

SUMMARY


Start
Read labour, plant, subcontractors and preliminaries cost increases
Read labour, materials, plant, subcontractor preliminaries and week/activity labels
COUNT
LMPSPCOSTA
Call AVARADJ Subroutine
Adjust for period cost increases
Output each activity in period
Calculate period totals
Output period totals
Calculate accumulative period totals
Output accumulative period totals

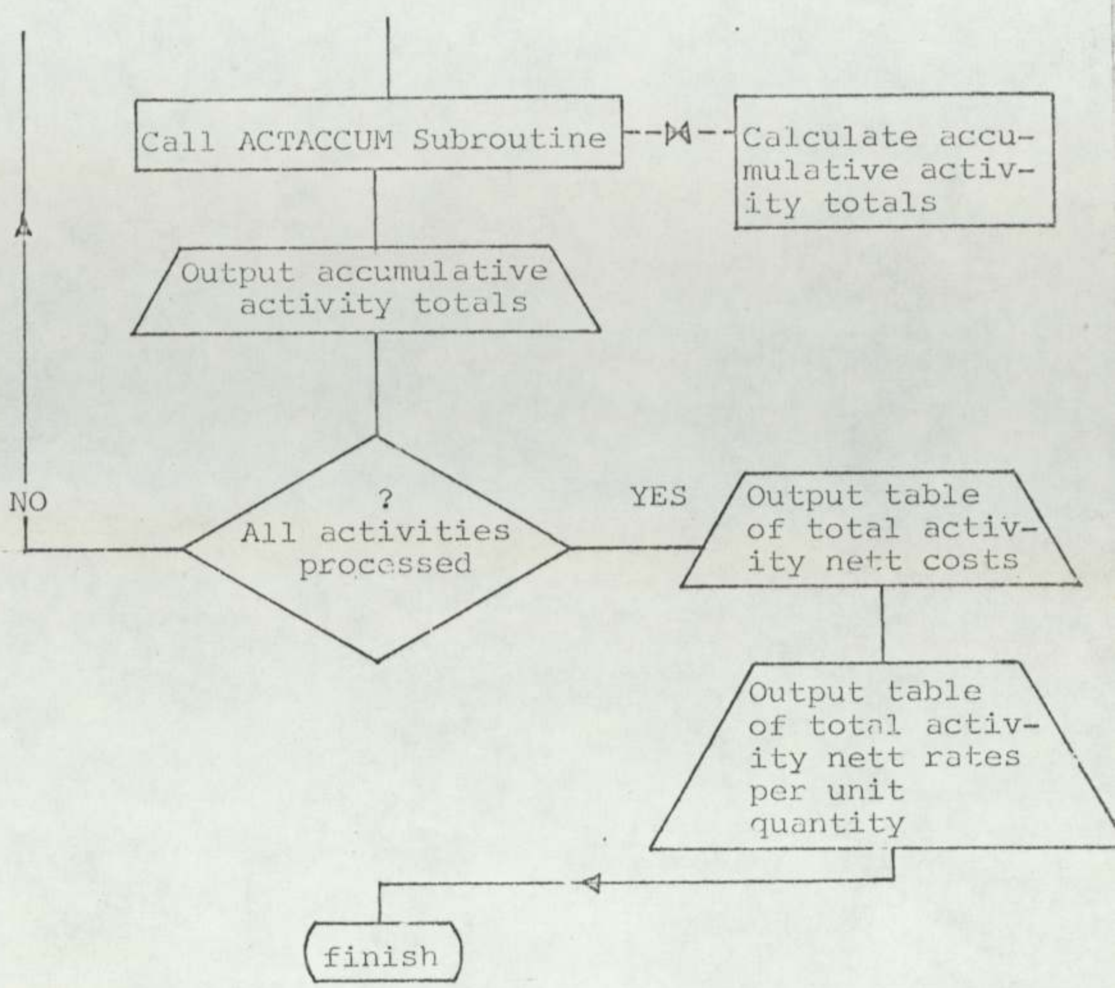

Call ACTACCUM Subroutine
Calculate accumulative activity totals
Output accumulative activity totals
NO
?
All activities processed
YES
Output table of total activity nett costs
Output table of total activity nett rates per unit quantity
finish

Figure.10.

SECTION 5

COMPUTER SIMULATION

USER MANUAL

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5.1 Restrictions

(a) All dimensions should be metric.

(b) The data should be 'right bias'.

5.2 Simulation Programme (SIMCOMP)

This programme sets up the following 'card punch files':-

(1)	ACTRATE	)
		)
(2)	PERTA	) Refer to table .1 .
		)
(3)	DATA	)

5.2.1 Network and Resource Input

Card Number	Field	Input Description
1	1 to 5	Total number of activities in network.
	6 to 10	Maximum number of predecessors.
	11 to 15	Number of hours in a working day.
2	1 to 4	Maximum number of predecessors plus 2.
3	1 to 5	Activity number.
	6 to 15	Standard man-hours per unit of activity production.
	16 to 25	Total activity quantity.
	26 to 30	Recommended gang size (labour only).
	31 to 35	1 if the activity is completed by subcontract labour only. Otherwise leave blank.

There must be as many card 3's as there are activities.

Card Number	Field	Input Description
4	1 to 5	Activity number.
	6 to 10)	
	11 to 15)	Entry activity numbers.
	16 to 20)	
	etc)	
	x to x+5	Total number of entry activities.

There must be as many card 4's as there are activities.

5.2.2. Performance Input

1	*)	
	*)	
	*)	5 prime starters
	*)	
	*)	
2	*	1 if standard normal distributions are to be used. 0 if natural distributions are to be input.

If 0 was entered, proceed with section 5.2.2.1 if 1 was entered, start section 5.2.2.2

5.2.2.1 Natural Distribution Input

Card Number	Field	Input Description
1	1 to 3	Number of rows of distribution data.

Card Number	Field	Input Description
2	1 to 5	Operative performance index.
	6 to 10	Frequency of occurrence.
3	1 to 3	Number of rows of distribution data.
4	1 to 5	Site performance index.
	6 to 10	Frequency of occurrence.
5	1 to 3	Number of rows of distribution data.
6	1 to 5	Productive unmeasured data (%).
	6 to 10	Frequency of occurrence.
7	1 to 3	Number of rows of distribution data.
8	1 to 5	Absenteeism and overloading data (%).
	6 to 10	Frequency of occurrence.

There must be as many card 2's, 4's, 6's and 8's as there are rows of distribution data.

Proceed with Section 5.2.3

5.2.2.2 Standard Normal Distribution Input

Card Number	Field	Input Description
1	*	Mean operative performance index.
	*	O.P.I. standard deviation.
2	*	Mean site performance index.
	*	S.P.I. standard deviation.

Card Number	Field	Input Description
3	*	Mean productive unmeasured time.
	*	P.U. standard deviation.
4	*	Mean Absenteeism and overloading. (A/O)
	*	A/O standard deviation.
5	*	1 if the performance data is to vary through the contract duration. 0 if it is not.

If 0 was entered, proceed with section 2.3.

6	*	Number of rows of data.
7	1 to 5	Activity number.
	6 to 10	Variation start day number.
	11 to 15	Variation finish day number.
	16 to 21	New mean O.P.I.
	22 to 27	New O.P.I. standard deviation.
	28 to 33	New mean S.P.I.
	34 to 39	New S.P.I. standard deviation.
	40 to 45	New mean Pu (%)
	46 to 51	New 'Pu' standard deviation.
	52 to 57	New mean A/O (%).
	58 to 63	New A/O standard deviation.

If 0 is entered for the new performance, the originals input on cards 1 to 4 inclusive will be assumed.

5.2.3 Labour Cost Input

Complete Table.2 . and enter each row onto separate cards in the following way:-

Card Number	Field	Input Description
To be entered from Table.1.		
1 to 15	*	Working foreman wage data.
	*	Ganger wage data.
	*	Craftsmen wage data.
	*	Skilled labourer wage data.
	*	Labourer wage data.
16	1 to 5	Activity Number.
	6 to 10	Number of working foremen.
	11 to 15	Number of Gangers.
	16 to 20	Number of craftsmen.
	21 to 25	Number of skilled labourers.
	26 to 30	Number of labourers.

There must be as many card 16's as there are activities.

5.3 Plant Cost Addition Programme (PLANT1)

This programme reads from, and creates, the following files:

(1) LCOSTA)
) Input Data
(2) COUNT)

(3) LPCOSTA (creates)

Table.2.

Wage Composition

Element Description		Unit	Working Foreman	Gangers	Craftsmen	Skilled Labourers	Labourers
1	Basic Rate	p/hr					
2	Plus Rate	p/hr					
3	Guaranteed Bonus	p/week					
4	Cost of Living Allowance	£/week					
5	Fall Back Rate	p/hr					
6	Worked Overtime	hr/week					
7	Subsistence Allowance	£/week					
8	Travelling Allowance	£/week					
9	Tool Money Allowance	£/week					
10	Graduated Pension & National Insurance	£/week					
11	H.W.P.	£/week					
12	P.H.W.P.	£/week					
13	Wet Time Allowance	%					
14	Adjustments	x					
15	Operatives class Adjustment	x					

Where variables are not included, input 0.0

5.3.1 Plant Cost Input

Card Number	Field	Input Description
1	1 to 10	Total number of activities.
	11 to 20	Number of hours in a working week.

Complete table.3. and enter each row on separate cards in the following way:-

Card Number	Field	Input Description
2	1 to 7	Hire Rates. (£)
	8 to 14	
	15 to 21	
	22 to 28	
	29 to 35	
	36 to 42	
	43 to 49	
	50 to 56	
	57 to 63	
	64 to 70	
3	1 to 17	1 if hire rate/hr. 0 if hire rate/week.
	8 to 14	
	15 to 21	
	22 to 28	
	29 to 35	
	36 to 42	
	43 to 49	
	50 to 56	
	57 to 63	
	64 to 70	

Table.3.

PLANT RATES

	PLANT TYPE									
	1	2	3	4	5	6	7	8	9	10
Hire Rate £										
Hire rate/hr enter 1, hire rate/week, enter 0.										
£ Bonus or fuel addition per week.										

Table. 4.

MATERIAL RATES

	MATERIAL TYPE													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cost/Unit £														
Additional Cost/Unit £														
Unit														

Card Number	Field	Input Description
4	1 to 7	Bonus or fuel addition per week. (£)
	8 to 14	
	15 to 21	
	22 to 28	
	29 to 35	
	36 to 42	
	43 to 49	
	50 to 56	
	57 to 63	
	64 to 70	
5	1 to 5	Activity Number.
	6 to 12	Number of plant type 1.
	13 to 19	Number of plant type 2
	20 to 26	Number of plant type 3.
	27 to 33	Number of plant type 4.
	34 to 40	Number of plant type 5.
	41 to 47	Number of plant type 6.
	48 to 54	Number of plant type 7.
	55 to 61	Number of plant type 8.
	62 to 68	Number of plant type 9.
	69 to 75	Number of plant type 10.

There must be as many card 5's as there are activities.

5.4 Material Cost Addition Programme (MATERIAL)

This programme uses and creates the following files:-

(1)	LPCOSTA	Input Data
(2)	COUNT	Input Data
(3)	ACTRATE	Input Data
(4)	LMPCOSTA	created

5.4.1 Material Cost Input

Complete table.4. and enter each row on separate cards in the following way:-

Card Number	Field	Input Description
1	1 to 5	Cost/Unit in £. (Table.4.)
	6 to 10	
	11 to 15	
	16 to 20	
	21 to 25	
	26 to 30	
	31 to 35	
	36 to 40	
	41 to 45	
	46 to 50	
	51 to 55	
	56 to 60	
	61 to 65	
	66 to 70	

Card Number	Field	Input Description
2	1 to 5	Additional Cost/Unit (Table.4.)
	6 to 10	
	11 to 15	
	16 to 20	
	21 to 25	
	26 to 30	
	31 to 35	
	36 to 40	
	41 to 45	
	46 to 50	
	51 to 55	
	56 to 60	
	61 to 65	
	66 to 70	
3	1 to 5	Unit (Table.4.)
	6 to 10	
	11 to 15	
	16 to 20	
	21 to 25	
	26 to 30	
	31 to 35	
	36 to 40	
	41 to 45	
	46 to 50	
	51 to 55	
	56 to 60	
	61 to 65	
	66 to 70	

Card Number	Field	Input Description
4	1 to 5	Activity Number
	6 to 10	Quantity of material type 1.
	11 to 15	Quantity of material type 2.
	16 to 20	Quantity of material type 3.
	21 to 25	Quantity of material type 4.
	26 to 30	Quantity of material type 5.
	31 to 35	Quantity of material type 6.
	36 to 40	Quantity of material type 7.
	41 to 45	Quantity of material type 8.
	46 to 50	Quantity of material type 9.
	51 to 55	Quantity of material type 10.
	56 to 60	Quantity of material type 11.
	61 to 65	Quantity of material type 12.
	66 to 70	Quantity of material type 13.
	71 to 75	Quantity of material type 14.

5.4.2 Material Cost Increases Input

Card Number	Field	Input Description
1	*	Number of data rows.

If 0 was entered, proceed with section 5.0.

2	1 to 5	Increased cost start week number.
	6 to 10	Increased cost finish week number.
	11 to 15	% rise for material type 1.
	16 to 20	% rise for material type 2.

Card Number	Field	Input Description
	21 to 25	% rise for material type 3.
	26 to 30	% rise for material type 4.
	31 to 35	% rise for material type 5.
	36 to 40	% rise for material type 6.
	41 to 45	% rise for material type 7.
	46 to 50	% rise for material type 8.
	41 to 55	% rise for material type 9.
	56 to 60	% rise for material type 10.
	61 to 65	% rise for material type 11.
	66 to 70	% rise for material type 12.
	71 to 75	% rise for material type 13.
	76 to 80	% rise for material type 14.

There must be as many card 2's as there are rows, specified by card.1.

5.5 Subcontractors Cost Addition Programme (SUBCNTR)

This programme reads from the following files:-

(1) ACTRATE)
)
(2) LMPCOSTA)
) Refer to table.1 .
(3) COUNT)
)
and creates)
)
(4) LMPSCOSTA)

5.5.1 Subcontractors Cost Input

Complete table.5. and enter each row, on separate cards, in the following way:-

Card Number	Field	Input Description
1	1 to 5	Cost/Unit (£) (Table.5.)
	6 to 10	
	11 to 15	
	16 to 20	
	21 to 25	
	26 to 30	
	31 to 35	
	36 to 40	
	41 to 45	
	46 to 50	
	51 to 55	
	56 to 60	
	61 to 65	
	66 to 70	
2	1 to 5	Additional cost/unit (£) (Table.5.)
	6 to 10	
	11 to 15	
	16 to 20	
	21 to 25	
	26 to 30	
	31 to 35	
	36 to 40	
	41 to 45	
	46 to 50	
	51 to 55	
	56 to 60	
	61 to 65	
	66 to 70	

Table. 5.

SUBCONTRACTOR COSTS

	SUBCONTRACTOR TYPE													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cost/Unit £														
Additional Cost/Unit £														
Unit														

Card Number	Field	Input Description
3	1 to 5	Unit (Table.5.)
	6 to 10	
	11 to 15	
	16 to 20	
	21 to 25	
	26 to 30	
	31 to 35	
	36 to 40	
	41 to 45	
	46 to 50	
	51 to 55	
	56 to 60	
	61 to 65	
	66 to 70	
4	1 to 5	Activity Number.
	6 to 10	Quantity to be allotted to s/c 1
	11 to 15	Quantity to be allotted to s/c 2
	16 to 20	Quantity to be allotted to s/c 3
	21 to 25	Quantity to be allotted to s/c 4
	26 to 30	Quantity to be allotted to s/c 5
	31 to 35	Quantity to be allotted to s/c 6
	36 to 40	Quantity to be allotted to s/c 7
	41 to 45	Quantity to be allotted to s/c 8
	46 to 50	Quantity to be allotted to s/c 9
	51 to 55	Quantity to be allotted to s/c 10
	56 to 60	Quantity to be allotted to s/c 11

Card Number	Field	Input Description
	61 to 65	Quantity to be allotted to s/c 12
	66 to 70	Quantity to be allotted to s/c 13
	71 to 75	Quantity to be allotted to s/c 14

5.6 Preliminaries Cost Addition Programme (PRELIMS)

The programme uses one, creates the following 'card punch' files:-

(1) LMPSCOSTA)
)
(2) COUNT) Input Data

(3) LMPSPCOSTA - created

5.6.1 Preliminaries Cost Input

Card Number	Field	Input Description
1	*	Number of preliminaries.
2	31 to 35	Activity number over which the preliminaries are to be spread. Enter O if all activities are to be included.
	36 to 40	Start week number. Enter O if the spread is to start as soon as the activity occurs.
	41 to 45	Finish week number. Enter O if the spread is to stop when the relevant activity stops.

Card Number	Field	Input Description
	46 to 55	Preliminaries cost/period (£).
	56 to 60	Period.

5.7 Summary Programme (SUMMARY)

This programme reads from the following 'card punch' files:

(1) LMPSCOSTA

(2) COUNT

5.7.1 Increased Cost Input

Card Number	Field	Input Description
1	*	Number of lines of increased costs.

If 0 was entered, omit the remainder of this section.

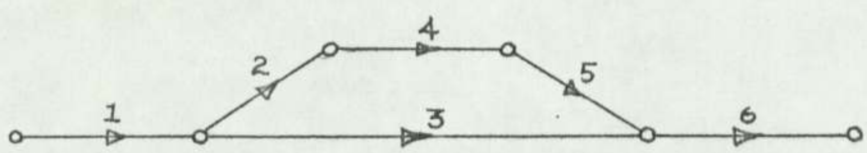
2	*	Start week number for increased costs. Enter 0 if the increase is to start at the beginning of the contract period.
	*	Finish week number for increased costs. Enter a large integer figure if duration is unknown.

Card Number	Field	Input Description
	*	% increase in labour cost in period.
	*	% increase in plant cost in period.
	*	% increase in cost of sub-contractors in period.
	*	% increase in cost of preliminaries.

There must be as many card 2's as specified in card 1.

5.8 Example Input and Output

The following six activity networks will be analysed to illustrate the method of data input and the output produced.



Refer to the following tables of data and the data input sheets.

NETWORK AND RESOURCE INPUT

```
    6    2 9.25
   4
    1     1.000   100.000    2    0
    2     0.750   150.000    2    0
    3     1.500   200.000    4    0
    4     0.500    50.000    3    0
    5     0.300    60.000    3    0
    6     0.975   120.000    2    1
    1    0    0    0
    2    1    0    1
    3    1    0    1
    4    2    0    1
    5    4    0    1
    6    3    5    2
```

PERFORMANCE DATA INPUT

```
   11.0 23.0  7.0  191.0  103.0
    1
100.0    20.0
 75.0    15.0
 10.0     3.0
  1.0     3.0
    0
```

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PAPER TAPE OR CARD DATA LAYOUT SHEET

LABOUR COST INPUT

72.5	72.5	72.5	61.5	61.5
5.0	5.0	0.0	5.0	0.0
300.0	300.0	300.0	260.0	260.0
0.0	0.0	0.0	0.0	0.0
15.0	12.5	10.0	8.0	6.5
6.25	6.25	6.25	6.25	6.25
12.25	12.25	12.25	0.0	0.0
0.0	0.0	0.0	5.6	5.6
0.0	0.0	0.2	0.0	0.0
3.05	3.06	2.89	2.75	2.61
1.80	1.80	1.80	1.80	1.80
0.61	0.61	0.56	0.52	0.49
5.0	5.0	5.0	5.0	5.0
0.0	0.0	1.2	0.0	0.80
1.4	1.25	1.1	1.0	1.0

5	11	15	20	25	30
1		1	1		
2		1		1	
3			1	2	1
4		1	2		
5		1		2	
6	1	1			

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PAPER TAPE OR CARD DATA LAYOUT SHEET

CC/D

```
         6     46.25
   3.00    10.00  10.50   2.00
   1.0      0.00   0.00   1.00
   5.0      1.00   1.00   5.00
    1       1
    2              1
    3       1               1
    4                       1
    5                       1      1
    6       1                      1

25.00  6.50  1.50  7.00
 2.00  1.00  0.25  1.00
1000.     1.  10.     1.
    12000.     2.
    2          6.    5.   1.
    31000.     1.
    4                4.   1.
    5          9.    5.   1.
    6 576.     .5    7.   1.
0
```

PLANT COST INPUT

MATERIAL COST INPUT

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```
         5    10   15   20   25   30   35   40   45   50   55   60   65   70   75   80
30.0065.00
 5.00 5.00
10.0040.00
    1
    2
    3
    4
    5       100
    6   40

1                                 0    0    0  7000.500   52
0
```

SUBCONTRACTORS COST INPUT (rows 1–10)

PRELIMINARIES COST AND SUMMARY INPUT. (rows 11–12)

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PAPER TAPE OR CARD DATA LAYOUT SHEET

WEEK	ACT	IDEAL GANG	ACTUAL GANG	PROD HRS	OPI	OFW HRS	FW HRS	TFW HRS	PU HRS	SPI	X	QLEFT	LABOUR COST
5.0	3.0	4.0	3.9	19.8	102.7	0.0	12.0	13.4	2.5	61.3	13.5	0.0	34.0
5.0	4.0	3.0	3.0	22.9	109.0	0.0	19.2	26.1	5.5	51.0	50.0	0.0	60.9
5.0	5.0	3.0	3.0	19.4	92.5	0.0	21.5	32.0	3.5	35.0	60.0	0.0	50.3
5.0	6.0	2.0	2.0	31.2	99.3	0.8	19.0	19.7	4.7	60.8	31.8	88.2	0.0
PERIOD TOTALS													
5.0				93.4		0.8	71.7	91.2	16.2				145.2
ACCUM' PERIOD TOTALS													
5.0				578.0		8.0	311.4	346.6	104.3				995.5
ACCUM' ACTIVITY TOTALS													
5.0	3.0			285.7		3.3	137.4	142.1	50.8				482.9
5.0	4.0			22.9		0.0	19.2	26.1	5.5				60.9
5.0	5.0			19.4		0.0	21.5	32.0	3.5				50.3
5.0	6.0			31.2		0.8	19.0	19.7	4.7				0.0

WEEK NO	ACT NO	QUANTITY PRODUCED	LABOUR COST	MATERIAL COST	PLANT COST	TOTAL	SUBCTRS COST	TOTAL	PRELIM COST	TOTAL
5.	3.	13.53	33.96	2.33	155.25		0.00		33.66	
5.	4.	50.00	60.92	8.70	11.50		0.00		33.66	
5.	5.	60.00	50.27	76.37	109.00		175.00		33.66	
5.	6.	31.80	0.00	7.56	241.25		37.10		33.66	
PERIOD TOTALS										
5.			145.15	94.96	517.00		212.10		134.64	
						757.11		969.21		1103.85
ACCUM' PERIOD TOTALS										
5.			995.54	250.00	1303.25		212.10		673.12	
						2548.79		2760.89		3434.01
ACCUM' ACTIVITY TOTALS										
5.	3.	200.01	482.87	34.50	621.00		0.00		213.15	
						1138.37		1138.37		1351.52
5.	4.	50.00	60.92	8.70	11.50		0.00		33.66	
						81.12		81.12		114.78
5.	5.	60.00	50.27	76.37	109.00		175.00		33.66	
						235.64		410.64		444.30
5.	6.	31.80	0.00	7.56	241.25		37.10		33.66	
						248.81		285.91		319.57

ACTIVITY NETT COST SUMMARY
****

COMPLETION WEEK	ACTIVITY CODE	QUANTITY PRODUCED	LABOUR COST	MATERIAL COST	PLANT COST	SUBCTRS COST	PRELIM COST
2.00	1.00	99.99	199.67	68.99	287.50	0.00	179.50
4.00	2.00	150.00	201.81	53.88	33.00	0.00	179.49
5.00	3.00	200.01	482.87	34.50	621.00	0.00	213.15
5.00	4.00	50.00	60.92	8.70	11.50	0.00	33.66
5.00	5.00	60.00	50.27	76.37	109.00	175.00	33.66
7.00	6.00	120.00	0.00	28.53	723.75	140.01	302.92

ACTIVITY NETT RATE SUMMARY
****

COMPLETION WEEK	ACTIVITY CODE	QUANTITY PRODUCED	LABOUR COST	MATERIAL COST	PLANT COST	SUBCTRS COST	PRELIM COST
2.	1.	99.990	1.997	0.690	2.875	0.000	1.795
4.	2.	150.000	1.345	0.359	0.220	0.000	1.197
5.	3.	200.010	2.414	0.172	3.105	0.000	1.066
5.	4.	50.000	1.218	0.174	0.230	0.000	0.673
5.	5.	60.000	0.838	1.273	1.817	2.917	0.561
7.	6.	120.000	0.000	0.238	6.031	1.167	2.524

SECTION 6

SIMULATION PROGRAMME

LISTING

```
      LIST (LP)
      LIST (LP)
      PROGRAM (FXXX)
      INPUT  1 = CRO
      OUTPUT 2 = LPO
      OUTPUT 4 =CPO
      OUTPUT 6 =CP1
      OUTPUT 8 = CP2
      COMPRESS INTEGER AND LOGICAL
      EXTENDED
      TRACE 2
      END


      MASTER
      DIMENSION A(100,2),A1(100,5),B(100,100),C(100,7),
     1FMT(4)
      DATA FMT(1)/'   ('/,FMT(3)/'F5.O'/,FMT(4)/')   '/
      READ(1,50) N,IW,Z
   50 FORMAT( 2I5,F5.2 )
C     FMT(2)=IW+2
      READ(1,577) FMT(2)
  577 FORMAT(A4)
      WRITE(2,109) N,IW,Z
  109 FORMAT(1H ,10X,I5,10X,I5,10X,F5.2)
C     WHERE N=NUMBER OF ACTIVITIES
C           IW=MAXIMUM NO OF ENTRIES
      WRITE(8,110) N
  110 FORMAT(I5)
      DO 100 I=1,N
      READ(1,52) A1(I,1),A1(I,2),A1(I,4),A1(I,4),A1(I,5)
   52 FORMAT( F5.O,2F10.3,F5.O,F5.0
      WRITE(8,111) A1(I,1),A1(I,2),A1(I,3)
  111 FORMAT(F5.O,2F10.3)
      C(I,5)=A1(I,3)
      C(I,7)+A1(I,5)
      A(I,1)=A1(I,1)
      A(I,2)=A1(I,2)*A1(I,3)
      A(I,2)+A(I,2)/(A1(I,4)*Z)
      WRITE(2,101) I,A(I,1),A(I,3),C(I,5)
  101 FORMAT(1H ,10X,I5,10X,F5.0,10X,F10.3,10X,F10.3)
  100 CONTINUE
      IW=IW+2
      READ(1,FMT) ((B(I,J),J=1,IW),I=1,N)
      WRITE(2,FMT)((B(I,J),J=1,IW),I=1,N)
   51 CONTINUE
      DO 199 I=1,N
      C(I,1)=O.O
      C(I,2)=O.O
      C(I,3)=O.O
  199 CONTINUE
      CALL SEQ2(A,B,C,N,IW)
      DO 555 I=1,N
      C(I,4)=A(I,2)
      C(I,7)=C(I,7)
      C(I,5)=C(I,5)
      C(I,6)=A1(I,4)
```

```
      WRITE(2,557) C(I,1),C(I,3),C(I,3),C(I,4),C(I,5),C(I,6)
     1,C(I,7)
  557 FORMAT(1H ,F5.0,5X,F10.3,5X,F10.3,5X,F10.3,5X,F10.3,5
     1X,F5.0,5X,F5.0)
  555 CONTINUE
      CALL (VPS(A,C,N,Z,B,IW)
      STOP
      END


      SUBROUTINE SEQ2(A,B,C,N,IW)
      DIMENSION A(100,2),B9100,100),C(100,7)
      I=O
   54 I=I+1
      IF(B(I,IW).EQ.1.O) GO TO 55
      IF(B(I,IW).EQ.O.O) GO TO 56
      K=2
      ZLIM=B(I,IW)
      ESTART=O.O
   92 ACT=B(I,K)
      CALL SEARCH(C,N,ACT,EFINISH)
      IF(EFINISH.GE.ESTART) GO TO 57
      C(I,1)=C(I,1)
      C(I,2)=C(I,2)
      C(I,3)=C(I,3)
      ESTART=C(I,2)
   91 ZLIM=ZLIM-1.0
      IF(ZLIM.GF.1.O) GO TO 58
   90 CONTINUE
      IF(I.LT.N) GO TO 54
      GO TO 80
   55 ACT=B(I,2)
      CALL SEARCH(C,N,ACT,EFINISH)
      C(I,1)=B(I,1)
      C(I,2)=EFINISH
      C(I,3)=C(I,2)+A(I,2)
      GO TO 90
   56 C(I,1)=B(I,1)
      C(I,3)=O.O
      C(I,3)=C(I,3)+A(I,2)
      GO TO 90
   57 C(I,1)=B(I,1)
      C(I,2)=EFINISH
      C(I,3)=C(I,2)+A(I,2)
      ESTART=C(I,2)
      GO TO 91
   58 K=K+1
      GO TO 92
   80 CONTINUE
      RETURN
      END


      SUBROUTINE SEARCH(C,N,ACT,EFINISH)
      DIMENSION C(100,7)
      M=O
   93 M=M+1
```

```
      IF(C(M,1).EQ.ACT) GO TO 94
      IF(M.LT.N)GO TO 93
      WRITE(2,96)
   96 FORMAT(1H ,10X,19HERROR IN SUBROUTINE)
      GO TO 95
   94 EFINISH=C(M,3)
   95 CONTINUE
      RETURN
      END


      SUBROUTINE VPS(A,C,N,Z,B,IW)
      DIMENSION R(27,2),H(200,4),F(200,4)C(100,7),A(100,2),
     1E(200,4)B(100,100),ZP(100,1),W(15,5),W1(100,6),SF(100
     2,11),ST(1,11),QA(200,4)
      UM1=2.0**16
      CALL INPRIME(R20,R21,R22,R23,R24)
      DO 34 I=1,27
      READ(1,35) R(I,1),R(I,2)
   35 FORMAT( F5.3,F6.3)
   34 CONTINUE
      CALL RDA(NORM)
      IF(NORM.EQ.1) GO TO 127
      CALL FREQOPI(NROWS,F)
      CALL FREQSPI(IROWS,F)
      CALL FREQPU(JROWS,H)
      CALL FREQAB(KROWS,QA)
      GO TO 1271
  127 CALL RDB(OMEAN,OSTDEV,SMEAN,SSTDEV,PMEAN,PSTDEV,ZMEAN,
     1STDEV)
      READ(1,1277) IVAR
 1277 FORMAT(I0)
      IF(IVAR.EQ.0) GO TO 1271
      CALL PERA(SF,NA,OMEAN,OSTDEV,SMEAN,SSTDEV,PMEAN,PSTDE
     1V,ZMEAN,STDEV,ST)
 1271 ZI=1.0
      CALL WAGRID(W)
      CALL ACTRID(N,W1)
      DO 777 I=1,N
      ZP(I,1)=0.0
  777 CONTINUE
   23 I=0
    2 I=I+1
      DS1=C(I,3)-C(I,2)
   21 DS=DS1
      IF(ZI.LT.C(I,2)) GO TO 5
      IF(C(I,5).GT.0.0) GO TO 6
      GO TO 5
    6 Q=C(I,5)
      IF(NORM.EQ.1) GO TO 128
      CALL RANDOPI(OP,NROWS,E,UM1,R20)
 1103 CALL RANDSPI(SP,IROWS,F,R21,UM1)
      IF(SP.LE.OP) GO TO 1102
      GOTO 1103
 1102 CALL RANDPU(PU,JROWS,H,R22,UM1)
      CALL RANDAB(S,KROWS,QA,R24,UM1)
      GO TO 129
  128 CONTINUE
```

```
      CI1=C(I,1)
      IF(IVAR.EQ.0) GO TO 1280
      CALL VARSEL(SF,CI1,ZI,OMEAN,OSTDEV,SMEAN,SSTDEV,PMEAN,
     1PSTDEV,ZMEAN,STDEV,NA,ST)
      WRITE(2,71)ZI,CI1,OMEAN,OSTDEV,SMEAN,SSTDEV,PMEAN,PST
     1DEV,ZMEAN,STDEV
   71 FORMAT(1H ,2F5.0,2X,8F6.2)
 1280 CALL NORMOPI(R20,UM1,OP,R,OMEAN,OSTDEV)
  130 CALL NORMSPI(R21,UM1,SP,R,SMEAN,SSTDEV)
      IF(SP.LE.OP) GO TO 131
      GO TO 130
  131 CALL NORMPU(R22,UM1,PU,R,PMEAN,PSTDEV)
      CALL RANDMAN(R23,UM1,S,R,ZMEAN,STDEV)
  129 CONTINUE
      PU=Z*PU/100.0
      SO=Q/DS
      BACK1=S*C(I,6)/100.0
      ZNA=C(I,6)-BACK1
      ZNL=ZNA-C(I,6)
      ZN=C(I,6)
      TEST=-2.0*C(I,6)/3.0
      IF(ZNL.LT.TEST) GO TO 1001
      IF(ZNL.LE.0.0) GO TO 1002
      OFW=Z-PU
      OFW=ZNL*OFW
      DIF=Z-PU
      RAT=1.0-(SP/OP)
      FW=ZNA*DIF*RAT
      GO TO 1003
 1001 OFW=0.0
      FW=ZNA*(Z-PU)
      GO TO 1003
 1002 OFW=0.0
      BACK2=SP/OP
      SMID=3.0*SP*SNL/(2.0*OP*C(I,6))
      BKT=1.0-ZMID-BACK2
      DIF=Z-PU
      FW=ZNA*DIF*BKT
 1003 TFW=FW+OFW
      DIF=Z-PU
      FRT=ZNA*DIF
      APMH=FRT-TFW
C     TO CALCULATE QUANTITY PRODUCED
      ZINS=ZNA*(Z-PU)
      BTM1=C(I,4)*100.0
      TP2=ZINS-TFW
      X=OP*TP2/BTM1
      IF(Q.GE.X) GO TO 24
      Q2=0.0
      DS1=Q/X
      X=Q
      APMH=C(I,4)*X*100.0/OP
      TFW=ZINS-APMH
      A(I,2)=DS1+ZP(I,1)
      C(I,5)=0.0
      GO TO 25
   24 Q1=Q-X
```

```
      Q2=Q1
      DS1=C(I,4)*Q2/C(I,6)
      DS1=DS1/Z
      A(I,2)=DS1+ZP(I,1)+1.0
      C(I,5)=Q2
   25 CONTINUE
      IF(C(I,7).EQ.1.0) GO TO 9908
      IF(ZNA.GT.ZN) GO TO 900
      IF(ZNA.EQ.ZN) GO TO 901
      IF(ZNA.EQ.0.0) GO TO 9001
      ZRATIO=ZN/ZNA
      GO TO 9002
 9001 ZRATIO=1000000.0
 9002 ZAPMH=ZRATIO*APMH
      ZTFW=ZRATIO*TFW
      ZPU=ZRATIO*PU*ZNA
      ZMULT=-1.0
      ZDIF=ZN-ZNA
      RATIO=ZDIF/ZN
      WHOLE=ZN
      OAPMH=RATIO*ZAPMH
      OTFW=RATIO*ZTFW
      OPU=RATIO*ZPU
      GO TO 904
  901 SUM=0.0
      RAPMH=APMH/ZN
      RTFW=TFW/ZN
      RPU=PU
      WHOLE=ZN
      GO TO 905
  900 ZDIF=ZNA-ZN
      RATIO=ZDIF/ZNA
      WHOLE=ZN
      OAPMH=RATIO*APMH
      OTFW=RATIO*TFW
      OPU=RATIO*PU*ZNA
      SMULT=1.0
  904 CONTINUE
      SUM=0.0
      CALL ABSELECT(R24,UM1,CI1,W1,J,IE)
      J=J
      CALL WAGE(OP,W(1,J),W(2,J),W(3,J),W(4,J),W(6,J),W(7,
     1J),W(8,J),W(9,J),W(10,J),W(11,j),W(12,J),W(13,J),W(
     214,J),OPU,W(5,J),OAPMH,OTFW,Z,SP,TWW,TOTIME ,W(15,J))
      SUM=TWW*ZMULT
      IF(ZMULT.LT.0.0) GO TO 903
      RAPMH=(APMH-OAPMH)/WHOLE
      RTFW=(TFW-OTFW)/WHOLE
      RPU=(PU*ZNA-OPU)/WHOLE
      GO TO 905
  903 RAPMH=ZAPMH/WHOLE
      RTFW=ZTFW/WHOLE
      RPU=ZPU/WHOLE
  905 COUNT=0.0
      J=0
  906 J=J+1
      IF COUNT.GE.WHOLE) GO TO 908
```

```
      IF(W1(IE,J+1).LT.1.) GO TO 907
      COUNT=COUNT+W1(IE,J+1)
      IF(COUNT.GT.WHOLE) GO TO 918
      CALL WAGE(OP,W(1,J),W(2,J),W(3,J),W(4,J),W(6,J),W(7,
     1J),W(8,J),W(9,J),W(10,J),W11,J),W(12,J),W(13,J),W(14
     2,J),RPU,W(5,J),RAPMH,RTFW,Z,SP,TWW,TOTIME ,W(15,J))
      TWW=TWW*W1(IE,J+1)
      SUM=SUM+TWW
      IF(J.LT.6) GO TO 906
      GO TO 908
  907 IF(J.LT.6) GO TO 906
      GO TO 908
  918 WDEB=COUNT-WHOLE
      CALL WAGE(OP,W(1,J),W(2,J),W(3,J),W(4,J),W(6,J),W(7
     1,J),W(8,J),W(9,J),W(10,J),W(11,J),W(12,J),W(13,J),W(
     214,J),RPU,W(5,J),RAPMH,RTFW,Z,SP,TWW,TOTIME ,W(15,J)
      TWW=TWW*WDED
      SUM=SUM+TWW
      GO TO 908
 9908 SUM=0.0
  908 CONTINUE
      CALL WEEK(CI1,C(I,6),ZNA,APMH,OP,OFW,FW,TFW,PU,SP,X,C
     1(I,5),A(I,2),SUM,ZI)
      ZP(I,1)=ZP(I,1)+1.0
    5 IF(I.LT.N) GO TO 2
      IF(I.EQ.N) GO TO 8
      GO TO 9
    8 II=0
  121 II=II+1
      IF(C(II,5).GT.0.0) GO TO 51
      IF(II.LT.N) GO TO 121
      GO TO 9
   51 CONTINUE
      CALL SEQ2(A,B,C,N,IW)
  122 ZI=ZI+1.0
      GO TO 23
    9 CALL SEQ2(A,B,C,N,IW)
      CALL FINALZ1(ZI)
      DO 10 I=1,N
      WRITE(2,11) C(I,1),C(I,2),C(I,3),C(I,4),C(I,5),C(I,6)
     1,C(I,7)
   11 FORMAT(1H ,F5.0,5X,F10.3,5X,F10.3,5X,F10.3,5X,F10.3,5
     1X,F10.3,5X,F5.0,5X,F5.0)
   10 CONTINUE
      RETURN
      END


      SUBROUTINE INPRIME(R20,R21,R22,R23,R24)
      READ(1,1) R20,R21,R22,R23,R24
    1 FORMAT(5F0.0)
      RETURN
      END


      SUBROUTINE FREQOPI(NROWS,E)
      DIMENSION D(200,2),E(200,4)
```

```
      READ(1,20) NROWS
   20 FORMAT( 13 )
      DO 21 I=1,NROWS
      READ(1,22) D(I,1),D(I,2)
   22 FORMAT( F5.0,F5.0 )
   21 CONTINUE
      SUM=0.0
      I=0
   23 I=I+1
      E(I,1)=D(I,1)
      E(I,2)=D(I,2)
      SUM=SUM+E(I,2)
      IF(I.LT.NROWS) GO TO 23
      TOTAL=SUM
      SUM1=0.0
      I=0
   24 I=I+1
      E(I,3)=E(I,2)/TOTAL
      SUM1=SUM1+E(I,3)
      E(I,4)=SUM1
      IF(I.LT.NROWS) GO TO 24
      RETURN
      END


      SUBROUTINE FREQSPI(IROWS,F)
      DIMENSION F(200,4)
      DIMENSION G(200,2)
      READ(1,20) IROWS
   20 FORMAT( I3 )
      DO 21 I=1,IROWS
      READ(1,22) G(I,1),G(I,2)
   22 FORMAT(F5.0,F5.0)
   21 CONTINUE
      SUM=0.0
      I=0
   23 I=I+1
      F(I,1)=G(I,1)
      F(I,2)=G(I,2)
      SUM=SUM+F(I,2)
      IF(I.LT.IROWS) GO TO 23
      TOTAL=SUM
      SUM1=0.0
      I=0
   24 I=I+1
      F(I,3)=F(I,2)/TOTAL
      SUM1=SUM1+F(I,3)
      F(I,4)=SUM1
      IF(I.LT.IROWS) GO TO 24
      RETURN
      END


      SUBROUTINE    RDA(NORM)
      READ(1,126) NORM
  126 FORMAT(I0)
      RETURN
      END
```

```
      SUBROUTINE RDB(OMEAN,OSTDEV,SMEAN,SSTDEV,PMEAN,PSTDEV,
     1ZMEAN,STDEV)
      READ(1,140) OMEAN,OSTDEV
      READ(1,140) PMEAN,PSTDEV
      READ(1,140) ZMEAN,STDEV
  140 FORMAT(2FO.O)
      SMEAN=1.34*OMEAN-47.82
      SSTDEV=OSTDEV-1.40
      RETURN
      END

      SUBROUTINE PERA(SF,NA,A,B,C,D,E,F,G,H,ST)
      DIMENSION SF(100,11),ST(1,11)
      READ(1,1) NA
    1 FORMAT(IO)
      READ(1,2) ((SF(I,J),J=1,11),I=1,NA)
    2 FORMAT(3F5.0,8F6.2)
      ST(1,1)=O.O
      ST(1,2)=O.O
      ST(1,3)=O.O
      ST(1,4)=A
      ST(1,5)=B
      ST(1,6)=C
      ST(1,7)=D
      ST91,8)=E
      ST(1,9)=F
      ST(1,10)=G
      ST(1,11)=H
      I=O
    3 I=I+1
      DO 5 J=4,11
      IF(SF(I,J).EQ.O.O) GO TO 6
      GO TO 5
    6 SF(I,J)=ST(1,J)
    5 CONTINUE
      IF(I.LT.NA) GO TO 3
      WRITE(2,8) ((SF(I,J),J=1,11),I=1,NA)
    8 FORMAT(1H ,3F5.0,8F6.2)
      RETURN
      END

      SUBROUTINE FREQPU(JROWS,H)
      DIMENSION H(200,4)
      DIMENSION P(200,2)
      READ(1,20) JROWS
   20 FORMAT(I3)
      DO 21 I=1,JROWS
      READ(1,22) P(I,1),P(I,2)
   22 FORMAT( F5.0,F5.0)
   21 CONTINUE
      SUM=O.O
      I=O
   23 I=I+1
      H(I,1)=P(I,1)
      H(I,2)=P(I,2)
```

```
      SUM=SUM+H(I,2)
      IF(I.LT.JROWS) GOTO23
      TOTAL=SUM
      SUM1=0.0
      I=O
   24 I=I+1
      H(I,3)=H(I,2)/TOTAL
      SUM1=SUM1+H(I,3)
      H(I,4)=SUM1
      IF(I.LT.JROWS) GO TO 24
      RETURN
      END


      SUBROUTINE FREQAB(KROWS,Q)
      DIMENSION P(200,2),Q(200,4)
      READ(1,20) KROWS
   20 FORMAT(I3)
      DO 21 I=1,KROWS
      READ(1,22) P(I,1),P(I,2)
   22 FORMAT(2F5.O)
   21 CONTINUE
      SUM=O.O
      I=O
   23 I=I+1
      Q(I,1)=P(I,1)
      Q(I,2)=P(I,2)
      SUM=SUM+Q(I,2)
      IF(I.LT.KROWS) GO TO 23
      TOTAL=SUM
      SUM1=O.O
      I=O
   24 I=I+1
      Q(I,3)=Q(I,2)/TOTAL
      SUM1=SUM1+Q(I,3)
      Q(I,4)=SUM1
      IF(I.LT.KROWS) GO TO 24
      RETURN
      END


      SUBROUTINE RANDOPI(IO,NROWS,E,UM1,R20)
      DIMENSION E(200,4)
      R10=R20
      PRODCT=259.0*R10
      FACTOR=INT(PRODCT/UM1)
      R20=PRODCT-FACTOR*UM1
      Y=R20/UM1
      Y=Y+O.OOOO1
      I=O
   34 I=I+1
      IF(Y.LE.E(I,4)) GO TO 35
      GO TO 34
   35 FIRST=Y-E((I-1),4)
      SECOND=E(I,1)-E((I-1),1)
      BOTTOM=E(I,4)-E((I-1),4)
      OP=FIRST*SECOND/BOTTOM
```

```
      OP=E((I-1),1)+OP
      RETURN
      END

      SUBROUTINE RANDSPI(SP,IROWS,F,R21,UM1)
      DIMENSION F(200,4)
      R11=R21
      PRODCT=259.0*R11
      FACTOR=INT(PRODCT/UM1
      R21=PRODCT-FACTOR*UM1
      Y=R21/UM1
      Y=Y+0.00001
      I=0
   34 I=I+1
      IF(Y.LE.F(I,4)) GO TO 35
      GO TO 34
   35 FIRST=Y-F((I-1),4)
      SECOND=F(I,1)-F((I-1),1)
      BOTTOM=F(I,4)-F((I-1),4)
      SP=FIRST*SECOND/BOTTOM
      SP=F((I-1),1)+SP
      RETURN
      END

      SUBROUTINE RANDPU(PU,JROWS,H,R22,UM1)
      DIMENSION H(200,4)
      R12=R22
      PRODCT=259.0*R12
      FACTOR=INT(PRODCT/UM1)
      R22=PRODCT-FACTOR*Um1
      Y=R22/UM1
      Y=Y+0.00001
      I=0
   34 I=I+1
      IF(Y.LE.H(I,4)) GO TO 35
      GO TO 34
   35 FIRST=Y-H((I-1),4)
      SECOND=H(I,1)-H((I-1),1)
      BOTTOM=H(I,4)-H((I-1),4)
      PU=FIRST*SECOND/BOTTOM
      PU=H((I-1),1)+PU
      RETURN
      END

      SUBROUTINE RANDAB(S,KROWS,Q,R23,UM1)
      DIMENSION Q(200,4)
      R13=R23
      PRODCT=259.0*R13
      FACTOR=INT(PRODCT/UM1)
      R23=PRODCT-FACTOR*UM1
      Y=R23/UM1
      Y=Y+0.00001
      I=0
   34 I=I+1
```

```
      IF(Y.LE.Q(I,4)) GO TO 35
      GO TO 34
   35 FIRST=Y-Q((I-1),4)
      SECOND=Q(I,1)-Q((I-1),1)
      BOTTOM=Q(I,4)-Q((I-1),4)
      S=FIRST*SECOND/BOTTOM
      S=Q((I-1),1)+S
      RETURN
      END


      SUBROUTINE VARSEL(SF,CI1,ZI,A,B,C,D,E,F,G,H,NA,ST)
      DIMENSION SF(100,11),ST(1,11)
      I=O
    1 I-I+1
      J=2
      IF(ZI.GE.SF(I.J)) GO TO 2
      GO TO 3
    2 IF(ZI.LE.SF(I.J+1)) GO TO 4
      GO TO 3
    4 IF(SF(I,1).EQ.O.O) GO TO 5
      IF(SF(I,1).EQ.CI1) GO TO 5
    3 IF(I.LT.NA) GO TO 1
      A=ST(1,4)
      B=ST(1,5)
      C=ST(1,6)
      D=ST(1,7)
      E=ST(1,8)
      F=ST(1,9)
      G=ST(1,10)
      H=ST(1,11)
      GO TO 6
    5 A=SF(I,4)
      B=SF(I,5)
      C=SF(I,6)
      D=SF(I,7)
      E=SF(I,8)
      F=SF(I,9)
      G=SF(I,10)
      H=SF(I,11)
    6 RETURN
      END


      SUBROUTINE NORMOPI(R20,UM1,OP,R,OMEAN,OSTDEV)
      DIMENSION R(27,2)
      R10=R20
      PRODCT=259.O*R10
      FACTOR=INT(PRODCT/UM1)
      R20=PRODCT-FACTOR*UM1
      Y=R20/UM1
      Y=Y+O.OOOO1
      I=O
   34 I=I+1
      IF(Y.LE,R(I,1)) GO TO 35
      GO TO 34
   35 FIRST=Y-R((I-1),1)
```

```
      SECOND=R(I,2)-R((I-1),2)
      BOTTOM=R(I,1)-R((I-1),1)
      Z1=FIRST*SECOND/BOTTOM
      Z1=R((I-1),2)+Z1
      OP=OMEAN+Z1*OSTDEV
      RETURN
      END


      SUBROUTINE NORMSPI(R21,UM1,SP,R,SMEAN,SSTDEV)
      DIMENSION R(27.2)
      R11=R21
      PRODCT=259.0*R11
      FACTOR=INT(PRODCT/UM1)
      R21=PRODCT-FACTOR*UM1
      Y=R21/UM1
      Y=Y+0.00001
      I=0
   34 I=I+1
      IF(Y.LE.R(I,1)) GO TO 35
      GO TO 34
   35 FIRST=Y-R((I-1),1)
      SECOND=R(I,2)=R((I-1),2)
      BOTTOM=R(I,1)-R((I-1),1)
      Z1=FIRST*SECOND/BOTTOM
      Z1=R((I-1),2)+Z1
      SP=SMEAN+Z1*SSTDEV
      RETURN
      END


      SUBROUTINE NORMPU(R22,UM1,PU,R,PMEAN,PSTDEV)
      DIMENSION R(27.2)
      R12-R22
      PRODCT=259.0*R12
      FACTOR=INT(PRODCT/UM1
      R22=PRODCT-FACTOR*UM1
      Y=R22/UM1
      Y=Y+0.00001
      I=0
   34 I=I+1
      IF(Y.LE.R(I,1)) GO TO 35
      GO TO 34
   35 FIRST=Y-R((I-1),1)
      SECOND=R(I,2)-R((I-1),2)
      BOTTOM=R(I,1)-R((I-1),1)
      Z1=FIRST*SECOND/BOTTOM
      Z1=R((I-1),2)+Z1
      PU=PMEAN+Z1*PSTDEV
      RETURN
      END


      SUBROUTINE RANDMAN(R23,UM1,S,R,ZMEAN,STDEV)
      DIMENSION R(27,2)
C     START OF RANDOM SELECTION
      R13=R23
      PRODCT=259.0*R13
```

```
      FACTOR=INT(PRODCT/UM1)
      R23=PRODCT-FACTOR*UM1
      Y=R23/UM1
      Y=Y+0.00001
      I=0
   34 I=I+1
      IF(Y.LE.R(I,1)) GO TO 35
      GO TO 34
   35 FIRST=Y-R((I-1),1)
      SECOND=R(I,2)-R((I-1),2)
      BOTTOM=R(I,1)-R((I-1),1)
      Z1=FIRST*SECOND/BOTTOM
      Z1=R((I-1),2)+Z1
      S=ZMEAN+Z1*STDEV
      RETURN
      END


      SUBROUTINE WAGRID(W)
      DIMENSION W(15,5)
      DO 1 I=1,15
      READ(1,2) W(I,1),W(I,2),W(I,3),W(I,4),W(I,5)
    2 FORMAT(5F0.0)
      WRITE(2,3) W(I,1),W(I,2),W(I,3),W(I,4),W(I,5)
    3 FORMAT(1H ,10X,5F10.2)
    1 CONTINUE
      RETURN
      END


      SUBROUTINE ACTRID(N,W1)
      DIMENSION W1(100,6)
      READ(1,2) ((W1(I,J),J=1,6),I=1,N)
    2 FORMAT(6F5.0)
      WRITE(2,3) ((W1(I,J),J=1,6),I=1,N)
    3 FORMAT(1H ,10X,6F10.2)
      RETURN
      END


      SUBROUTINE ABSELECT(R24,UM1,ACT,W1,J,I)
      DIMENSION W1(100,6)
    1 R14=R24
      PRODCT=259.00*R14
      FACTOR=INT(PRODCT/UM1)
      R24=PRODCT-FACTOR*UM1
      Y=R24/UM1
      IF(Y.LE.0.2) GO TO 2
      IF(Y.LE.0.4) GO TO 3
      IF(Y.LE.0.6) GO TO 4
      IF(Y.LE.0.8) GO TO 5
      J=5
      GO TO 6
    2 J=1
      GO TO 6
    3 J=2
      GO TO 6
```

```
 4 J=3
   GO TO 6
 5 J=4
   GO TO 6
 6 CONTINUE
   I=0
 7 I=I+1
   IF(W1(I,1).EQ.ACT) GO TO 8
   GO TO 7
 8 IF(W1(I,J+1).GE.1.0) GO TO 9
   GO TO 1
 9 RETURN
   END

      SUBROUTINE WAGE(OP,BRPH,PRPH,GBA,CLA,WOT,SUBS,TRAV,TM
     1,ZNI,AHWP,PHWP,WTL,ADJ,PU,FBB,BNSTME,WAIT,Z,SP,TWW,T
     2OTIME,OAJ)
      GBA=GBA/5.0
      CLA=CLA/5.0
      WOT=WOT/5.0
      SUBS=SUBS/5.0
      TRAV=TRAV/5.0
      TM=TM/5.0
      ZNI=ZNI/5.0
      AHWP=AHWP/5.0
      PHWP=PHWP/5.0
      TOTIME=BNSTME=WAIT+PU
      IF(TOTIME.LE.0.0)  GO TO 5
      ZPERF=OP/75.0
      PBONUS=BRPH*(ZPERF-1.0)*OAJ
      TPB=BNSTME*PBONUS
      TFB=(WAIT+PU)*FBB
      FGB=GBA*TOTIME/Z
      IF(TPB.GE.FGB) GO TO 1
      GO TO 2
    1 TBPW=TPB+TFB
      GO TO 3
    2 TBPW=FGB+TFB
    3 CONTINUE
      WOT=WOT*TOTIME/Z
      TOTBPH=TBPW/(TOTIME-WOT)
      WAGE1=BRPH+PRPH*TOTBPH
      WAGE2=(WOT*1.5)*BRPH
      WAGE3=WAGE2+WAGE1*(TOTIME-WOT)
      WAGE3=WAGE3/100.0
      WAGE4=SUB+TRAV+TM
      OGW=WAGE3+WAGE4+CLA
      GP=0.0475*WAGE3
      REDSK=0.015*WAGE3
      WAGE5=GP+ZNI+AHWP+PHWP+REDSK
      TOTWTL=WTL*WAGE3/100.0
      TWW=OGW+WAGE5+TOTWTL+ADJ
      THW=TWW/TOTIME
      WRITE(2,4) BRPH,TOTIME,BNSTME,TWW,THW
    4 FORMAT(1H ,20X,5F10.2)
      GO TO 6
```

```
5 THW=0.0
  TWW=0.0
6 RETURN
  END


  SUBROUTINE WEEK(YI,CC,ZNA,APMH,OP,OFW,FW,TFW,PU,SP,X,
 1CI,AA,SUM,ZI)
  WRITE(2,1) ZI,YI,CC,ZNA,APMH,OP,OFW,FW,TFW,PU,SP,X,CI
 1,AA,SUM
1 FORMAT(1H ,2F5.0,2F6.1,5F6.0,F4.0,F6.0,F8.2,F9.2,F7.2
 1,F10.2)
  WRITE(4,2) ZI,YI,CC,ZNA,APMH,OP,OFW,FW,TFW,PU,SP,X,CI
 1,SUM
2 FORMAT(    F6.0,F5.0,F4.0,F5.2,F7.2,F6.2,4F7.2,F6.2/3
 1F10.2)
  RETURN
  END


  SUBROUTINE FINALZ1(ZI)
  WRITE(6,1) ZI
1 FORMAT(F10.0)
  RETURN
  END

  FINISH
```

```
LIST (LP)
PROGRAM (FXXX)
INPUT 1=CRO
INPUT  3 =CRL
INPUT  5 =CR2
INPUT 7 = CR3
OUTPUT2=LPO
OUTPUT 4 = CPO
OUTPUT 6 = CP1
OUTPUT 8=CP2
COMPRESS INTEGER AND LOGICAL
EXTENDED
TRACE 2
END


      MASTER
      DIMENSION (C2(100,14),D2(100,2)
      READ(7,19) N1
   19 FORMAT(I5)
      DO 110 I=1,N1
      READ(7,111)  ACTD,STDT
  111 FORMAT(F5.0,F10.3)
      D2(I,1)=ACTD
      D2(I,2)=STDT
  110 CONTINUE
      PERIOD=1.0
      READ(5,2) FINALZI
    2 FORMAT(F10.0)
    7 I=0
    6 READ(3,1) ZI,YI,CC,ZNA,APMH,OPI,OFW,FW,TFW,PU,SPI,X,
     1QLEFT,ZMONEY
    1 FORMAT(F6.0,F5.0,F4.0,F5.2,F7.2,4F7.2,F6.2/3F10.2)
   99 RATIOZI=ZI/5.0
      IF(RATIOZI.LE.PERIOD) GO TO 3
    9 CONTINUE
      WRITE(2,999) ((C2(I,J),J=1,14),I=1,ILIMIT)
  999 FORMAT(1H ,14F8.2)
      CALL SORTCOL(C2,ILIMIT,PERIOD,D2
      DO 900 I=1,ILIMIT
      DO 900 J=1,14
      C2(I,J)=0.0
  900 CONTINUE
      IF(PERIOD.LT.FINALZI/5.0) GO TO 4
      GO TO 5
    3 I=I+1
      C2(I,1)=ZI
      C2(I,2)=YI
      C2(I,3)=CC
      C2(I,4)=ZNA
      C2(I,5)=APMH
      C2(I,6)=OPI
      C2(I,7)=OFW
      C2(I,8)=FW
      C2(I,9)=TFW
      C2(I,10)=PU
      C2(I,11)=SPI
```

```
      C2(I,12)=X
      C2(I,13)=QLEFT
      C2(I,14)=ZMONEY
      ILIMIT=I
      IF(RATIOZI.EQ.PERIOD) GO TO 61
   61 IF(ZI.EQ.FINALZI) GO TO 9
      GO TO 6
    4 PERIOD=PERIOD+1.0
      I=O
      GO TO 99
    5 CONTINUE
      ICOUNT=50000
      WRITE(4,12) ICOUNT
   12 FORMAT(I10)
      STOP
      END


      SUBROUTINE SORTCOL(C2,ILIMIT,PERIOD,D2)
      DIMENSION C2(100,14),D2(100,2)
      I=1
    1 TAG=C2(I,2)
      IF(I.EQ.ILIMIT-1) GO TO 2
      K=I+1
    3 CONTINUE
      IF(C2(K,2).FQ.TAG) GO TO 4
      IF(K.LT.ILIMIT) GO TO 5
      GO TO 2
    5 K=K+1
      GO TO 3
    4 ZM1=C2(I+1,1)
      ZM2=C2(I+1,2)
      ZM3=C2(I+1,3)
      ZM4=C2(I+1,4)
      ZM5=C2(I+1,5)
      ZM6=C2(I+1,6)
      ZM7=C2(I+1,7)
      ZM8=C2(I+1,8)
      ZM9=C2(I+1,9)
      ZM10=C2(I+1,10)
      ZM11=C2(I+1,11)
      ZM12=C2(I+1,12)
      ZM13=C2(I+1,13)
      ZM14=C2(I+1,14)
      C2(I+1,1)=C1(K,1)
      C2(I+1,2)=C2(K,2)
      C2(I+1,3)=C2(K,3)
      C2(I+1,4)=C2(K,4)
      C2(I+1,5)=C2(K,5)
      C2(I+1,6)=C2(K,6)
      C2(I+1,7)=C2(K,7)
      C2(I+1,8)=C2(K,8)
      C2(I+1,9)=C2(K,9)
      C2(I+1,10)=C2(K,10)
      C2(I+1,11)=C2(K,11)
      C2(I+1,12)=C2(K,12)
      C2(I+1,13)=C2(K,13)
```

```
      C2(I+1,14)=C2(K,14)
      C2(K,1)=ZM1
      C2(K,2)=ZM2
      C2(K,3)=ZM3
      C2(K,4)=ZM4
      C2(K,5)=ZM5
      C2(K,6)+ZM6
      C2(K,7)=ZM7
      C2(K,8)=ZM8
      C2(K,9)=ZM9
      C2(K,10)=ZM10
      C2(K,11)=ZM11
      C1(K,12)=ZM12
      C2(K,13)=ZM13
      C2(K,14)=ZM14
    2 CONTINUE
      IF(K.LT.ILIMIT) GO TO 6
      WRITE(2,999) ((C2(I,J),J=1,14),I=1,ILIMIT)
  999 FORMAT(1H ,14F8.2)
      CALL SUMRY(C2,ILIMIT,PERIOD,D2)
      GO TO 7
    6 I=I+1
      GO TO 1
    7 RETURN
      END


      SUBROUTINE SUMRY(C2,ILIMIT,PERIOD,D2)
      DIMENSION C2(100,14),D2(100,2)
      ICOUNT=0
      M=0
      I=0
    1 I=I+1
      IF(I.GE.ILIMIT) GO TO 2
      IF(C2(I,2).EQ.C2(I+1,2)) GO TO 1
    2 IMARK=I
      SUMA=0.0
      SUMB=0.0
      SUMC=0.0
      SUMD=0.0
      SUME=0.0
      SUMF=0.0
      SUMG=0.0
      SUMH=0.0
      SUMI=0.0
      SUMJ=0.0
      SMARK=1.0
    3 M=M+1
      WKN=PERIOD
      ACTN=C2(M,2)
      IP=IFIX(ACTN)
      ZMN=C2(M,3)
      SUMA=SUMA+C2(M,4)
      SUMB=SUMB+C2(M,5)
      SUMC=SUMC+C2(M,6)
      SUMD=SUMD+C2(M,7)
      SUME=SUME+C2(M,8)
```

```
      SUMF=SUMF+C2(M,9)
      SUMG=SUMG+C2(M,10)
      SUMH=SUMH+C2(M,11)
      SUMI=SUMI+C2(M,12)
      QLEFT=C2(M,13)
      SUMJ=SUMJ+C2(M,14)
      IF(M.LT.IMARK) GO TO 4
      SUMA=SUMA/ZMARK
      SUMG=SUMA*SUMG
      SUMC=D2(IP,2)*SUMI/SUMB
      SUMH=D2(IP,2)*SUMI/(SUMB+SUMF)
      SUMC=SUMC*100.0
      SUMH=SUMH*100.0
      WRITE(6,7) WKN,ACTN,ZMN,SUMA,SUMB,SUMC,SUMD,SUME,SUMF
     1,SUNG,SUMH,SUMI,QLEFT,SUMJ
    7 FORMAT( 8F10.2/6F10.2)
      WRITE(8,9) WKN,ACTN,SUMI,SUMJ
    9 FORMAT(4F10.2)
      ICOUNT=ICOUNT+1
      IF(IMARK.LT.ILIMIT) GO TO 1
      GO TO 6
    4 ZMARK=ZMARK+1.0
      GO TO 3
    6 WRITE(4,8) ICOUNT
    8 FORMAT(I10)
      RETURN
      END

      FINISH
```

```
LIST (LP)
PROGRAM (FXXX)
INPUT  1=CRO
INPUT 3 =CRL
INPUT 5 = CR2
OUTPUT 2=LPO
COMPRESS INTEGER AND LOGICAL
EXTENDED
TRACE 2
END


 MASTER
 DIMENSION A(100,14),B(100,8)
 TOT1=0.0
 TOTA=0.0
 TOTB=0.0
 TOTC=0.0
 TOTD=0.0
 TOTE=0.0
 TOTF=0.0
 DO 1 I=1,100
 DO 1 J=1,8
 B(I,J)=0.0
1 CONTINUE
 READ(3,2) I1
2 FORMAT(I10)
 IF(I1.EQ.50000) GO TO 3
 SUMA=0.0
 SUMB=0.0
 SUMC=0.0
 SUMD=0.0
 SUME=0.0
 SUMF=0.0
 N=0
4 N=N+1
 READ(5,5) WKN,ACTN,ZMN,ZNA,APMH,OPI,OFW,FW,TFW,PU,SP
 1I,X,QLEFT,ZMONEY
5 FORMAT( 8F10.2/6F10.2)
 A(N,1)=WKN
 A(N,2)=ACTN
 A(N,3)=ZMN
 A(N,4)=ZNA
 A(N,5)=APMH
 A(N,6)=OPI
 A(N,7)=OFW
 A(N,8)=FW
 A(N,9)=TFW
 A(N,10)=PU
 A(N,11)=SPI
 A(N,12)=X
 A(N,13)=QLEFT
 A(N,14)=ZMONEY
 IF(N.LT.I1) GO TO 4
 WRITE(2,6)
6 FORMAT(1H1,2X,98H WEEK ACT IDEAL ACTUAL PROD POI OFW
 1  FW     TFW     PU     SPI X     QLEFT LABOUR)
```

```
      WRITE(2,61)
   61 FORMAT(1H ,2X,98H                GANG  GANG    HRS     HRS
     1 HRS    HRS    HRS                          COST )
      DO 15 K=1,I1
      WRITE(2,7) A(K,1),A(K,2),A(K,3),A(K,4),A(K,5),A(K,6),
     1A(K,7),A(K,8),A(K,9),A(K,10),A(K,11),A(K,12),A(K,13),
     2A(K,14)
    7 FORMAT(1H ,14F7.1)
      WKN=A(K,1)
      SUMA=A(K,5)+SUMA
      SUMB=A(K,7)+SUMB
      SUMC=A(K,8)+SUMC
      SUMD=A(K,9)+SUMD
      SUME=A(K,10)+SUME
   15 SUMF=A(K,14)+SUMF
      WRITE(2,8)
    8 FORMAT(1H ,20H        PERIOD TOTALS)
      WRITE(2,9) WKN   ,SUMA,SUMB,SUMC,SUMD,SUME,SUMF
    9 FORMAT(1H ,F7.1,21X,F7.1,7X,4F7.1,21X,F7.1)
      TOT1=WKN
      TOTA=SUMA+TOTA
      TOTB=SUMB+TOTB
      TOTC=SUMC+TOTC
      TOTD=SUMD+TOTD
      TOTE=SUME+TOTE
      TOTF=SUMF+TOTF
      WRITE(2,10)
   10 FORMAT(1H ,27H        ACCUM' PERIOD TOTALS)
      WRITE(2,11) TOT1,TOTA,TOTB,TOTC,TOTD,TOTE,TOTE
   11 FORMAT(1H ,F7.1,21X,F7.1,7X,4F7.1,21X,F7.1)
      CALL ACTACCUM(A,B,I1)
      GO TO 1
    3 CONTINUE
      STOP
      END


      SUBROUTINE ACTACCUM(A,B,I1)
      DIMENSION A(100,14),B(100,8)
      N=0
    1 N=N+1
      R1=A(N,2)
      I2=IFIX(R1)
      ZMARK=A(N,1)
      B(I2,1)=A(N,1)
      B(I2,2)=A(N,2)
      B(I2,3)=A(N,5)+B(I2,3)
      B(I2,4)=A(N,7)+B(I2,4)
      B(I2,5)=A(N,8)+B(I2,5)
      B(I2,6)=A(N,9)+B(I2,6)
      B(I2,7)=A(N,10)+B(I2,7)
      B(I2,8)=A(N,14)+B(I2,8)
      IF(N.LT.I1) GO TO 1
      WRITE(2,2)
    2 FORMAT(1H ,29H        ACCUM' ACTIVITY TOTALS)
      DO 3 M=1,100
      IF(B(M,1).EQ.0.0) GO TO 3
```

```
      IF(B(M,1).NE.ZMARK) GO TO 3
      WRITE(2,4) B(M,1),B(M,2),B(M,3),B(M,4),B(M,5),B(M,6),
     1B(M,7),B(M,8)
    4 FORMAT(1H ,2F7.1,14X,F7.1,7X,4F7.1,21X,F7.1)
    3 CONTINUE
      RETURN
      END

      FINISH
```

```
LIST (LP)
PROGRAM (FXXX)
INPUT 1 = CRO
INPUT 3 = CR1
INPUT 5 = CR2
OUTPUT 2= LPO
OUTPUT 4=CPO
COMPRESS INTEGER AND LOGICAL
EXTENDED
TRACE 2
END
```

```
      MASTER
      DIMENSION A(100,5)          ,HIRATE(3,10),PLACT(100,11)
      READ(1,100) N,Z
  100 FORMAT(I10,F10,2)
      DO 101 I=1,3
      READ(1,102) HIRATE(I,1),HIRATE(I,2),HIRATE(I,3),HIRA
     1TE(I,4),HIRATE(I,5),HIRATE(I,6),HIRATE(I,7),HIRATE(I
     2,8),HIRATE(I,9),HIRATE(I,10)
  102 FORMAT( 10F7.2)
  101 CONTINUE
      DO 103 I=1,N
      READ(1,104) PLACT(I,1),PLACT(I,2),PLACT(I,3),PLACT(I
     1,4),PLACT(I,5),PLACT(I,6),PLACT(I,7),PLACT(I,8),PLAC
     2T(I,9),PLACT(I,10),PLACT(I,11)
  104 FORMAT( F5.0,10F7.0)
  103 CONTINUE
      WRITE(2,900) ((HIRATE(I,J),J=10),I=1,3)
  900 FORMAT(1H ,10X,10F7.2)
      WRITE(2,903) ((PLACT(I,J),J=1,11),I=1,N)
  903 FORMAT(1H ,10X,10F7.0)
    1 CONTINUE
      READ(3,2) I1
    2 FORMAT(I10)
      IF(I1.EQ.50000) GO TO 3
      N=0
    4 N=N+1
      READ(5,5) WKN,ACTN,X,ZMONEY
    5 FORMAT(4F10.2)
      A(N,1)=WKN
      A(N,2)=ACTN
      A(N,3)=X
      A(N,4)=ZMONEY
      CALL PCOST(ACTN,Z,SUMZ,PLACT,HIRATE)
      A(N,5)=SUMZ
      IF(N.LT.I1) GO TO 4
      DO 15 K=1,I1
      WRITE(4,711) A(K,1),A(K,2),A(K,3),A(K,4),A(K,5)
  711 FORMAT(5F10.2)
   15 CONTINUE
      GO TO 1
    3 CONTINUE
      STOP
      END
```

```
      SUBROUTINE PCOST(ACTN,Z,SUMZ,PLACT,HIRATE)
      DIMENSION HIRATE(3,10),PLACT(100,11)
      I=0
    1 I=I+1
      IF(PLACT(I,1).EQ.ACTN) GO TO 2
      GO TO 1
    2 SUMZ=0.0
      J=0
    3 J=J+1
      IF(J.LE.10) GO TO 4
      GO TO 5
    4 SUM=PLACT(I,J+1)*HIRATE(1,J)
      IF(HIRATE(2,J).EQ.1.0) GO TO 6
      SUM=SUM
      GO TO 7
    6 SUM=SUM*Z
    7 CONTINUE
      IF(PLACT(I,J+1).GE.1.0) GO TO 8
      SUM=SUM
      GO TO 9
    8 SUM=SUM+HIRATE(3,J)
    9 SUMZ=SUMZ+SUM
      GO TO 3
    5 RETURN
      END

      FINISH
```

```
      LIST (LP)
      PROGRAM (FXXX)
      INPUT 1=CRO
      INPUT 3=CR1
      INPUT 5=CR2
      INPUT 7=CR3
      OUTPUT2=LPO
      OUTPUT 4=CPO
      COMPRESS INTEGER AND LOGICAL
      EXTENDED
      TRACE2
      END


      MASTER
      DIMENSION A(3,14),B(100,16),C(100,15),D(100,15),E(100,
     12),F(100,6),P(100,16),UPA(3,14)
      READ(7,1) N
    1 FORMAT(I5)
      READ(1,2) ((A(I,J),J=1,14),I=1,3,2)
    2 FORMAT(14F5.2)
      READ(1,3) ((A(I,J),J=1,14),I=2,2)
    3 FORMAT(14F5.O)
      WRITE(2,21) ((A(I,J),J=1.14),I=1,3)
   21 FORMAT(1H ,14F8.2)
      READ(1,4) ((B(I,J),J=1,15),I=1,N)
    4 FORMAT(15F5.O)
      CALL BINCREASE(B,N)
      WRITE(2,22) ((B(I,J),J=1,16),I=1,N)
   22 FORMAT(1H ,16F7.2)
      CALL CFORM(C,B,N)
      L=N
      READ(1,1001) N1
 1001 FORMAT(IO)
      IF(N1.EQ.O) GO TO 5
      READ(1,1002) ((P(I,J),J=1,16),I=1,N1)
 1002 FORMAT(16F5.O)
      WRITE(2,1003) ((P(I,J),J=1,16),I=1,N1)
 1003 FORMAT(1H ,16F5.O)
    5 CONTINUE
      READ(3,6) I1
    6 FORMAT(I10)
      IF(I1.EQ.50000) GO TO 99
      N=O
    7 N=N+1
      READ(5,8) WKN,ACTN,X,ZLAB,ZPLANT
    8 FORMAT(5F10.2)
      F(N,1)=WKN
      F(N,2)=ACTN
      F(N,3)=X
      F(N,4)=ZLAB
      F(N,6)=7PLANT
      IF(N1.EQ.O) GO TO 1007
      CALL ZNEWA(WKN,A,UPA,N1,P)
      CALL DFORM(UPA,C,D,L)
      GO TO 1005
 1007 CALL DFORM(A,C,D,L)
```

```
1005 CALL EFORD(D,E,L)
     CALL ZMATCOST(ACTN,SUMZ,X,E)
     F(N,5)=SUMZ
     IF(N.LT.I1) GO TO 7
     DO 11 K=1,I1
     WRITE(4,12) F(K,1),F(K,3),F(K,3),F(K,4),F(K,5),F(K,6)
  12 FORMAT(6F10.2)
  11 CONTINUE
     GO TO 5
  99 CONTINUE
     STOP
     END

     SUBROUTINE BINCREASE(B,N)
     DIMENSION B(100,16),B1(100,3)
     DO 2 I=1,N
     READ(7,1) B1(I,1),B1(I,2),  B1(I,3)
   1 FORMAT(F5.0,2F10.3)
   2 CONTINUE
     I=0
   3 I=I+1
     IF(B(I,1).EQ.B1(I,1)) GO TO 4
   6 K=I
   5 K=K+1
     IF(K.GT.N) GO TO 7
     IF(B(I,1).EQ.B1(K,1)) GO TO 8
     GO TO 5
   7 K=0
     GO TO 6
   8 B(I,16)=B1(K,3)
     IF(I.LT.N) GO TO 3
     GO TO 9
   4 B(I,16)=B1(I,3)
     IF(I.LT.N) GO TO 3
   9 CONTINUE
     RETURN
     END

     SUBROUTINE CFORM(C,B,N)
     DIMENSION C(100,15),B(100,16)
     DO 1 I=1,N
     DO 1 J=2,15
     C(I,J)=B(I,J)/B(I,16)
   1 CONTINUE
     DO 2 I=1,N
     C(I,1)=B(I,1)
   2 CONTINUE
     RETURN
     END

     SUBROUTINE DFORM(A,C,D,N)
     DIMENSION A(3,14),C(100,15),D(100,15),UPA(3,14)
     DO 1 I=1,N
     DO 1 J=2,15
```

```
      IF(A(2,J-1).EQ.O.O) GO TO 3
      D(I,J)=C(I,J)*A(1,J-1)/A(2,J-1)
      D(I,J)=D(I,J)+C(I,J)*A(3,J-1)/A(2,J-1)
      GO TO 1
    3 D(I,J)=O.O
    1 CONTINUE
      DO 2 I=1 ,N
      D(I,1)=C(I,1)
    2 CONTINUE
      RETURN
      END


      SUBROUTINE   EFORM(D,E,N)
      DIMENSION D(100,15),E(100,2
      DO 1 I=1,N
      SUM=O.O
      DO 1 J=2,15
      SUM=SUM+D(I,J)
      E(I,2)=SUM
    1 CONTINUE
      DO 2 I=1,N
      E(I,1)=D(I,1)
    2 CONTINUE
      RETURN
      END


      SUBROUTINE ZMATCOST(ACTN,SUMZ,X,E)
      DIMENSION E(100,2)
      I=O
    1 I=I+1
      IF(E(I,1).EQ.ACTN) GO TO 2
      GO TO 1
    2 CONTINUE
      SUM=X*E(I,2)
      SUMZ=SUM
      RETURN
      END


      SUBROUTINE ZNEWA(W,A,UPA,N2,P)
      DIMENSION A(3,14),P(100,16),UPA(3,14)
      I=O
    1 I=I+1
      IF(W.GE.P(I.1)) GO TO 2
      GO TO 1
    2 CONTINUE
      IF(W.LE.P(I,3)) GO TO 3
      IF(I.LT.N2) GO TO 1
      I=N2
    3 CONTINUE
      J=O
    5 J=J+1
      IF(I.EQ.1) GO TO 6
      RATIO=(P(I,J+2)-P(I-1,J+2))/(P(I,2)-P(I,1))
      Y2=RATIO*(W-P(I,1))
```

```
      Y2=Y2+P(I-1,J+2)
      GO TO 7
    6 CONTINUE
      Y2=P(I,J+2)*(W-P(I,1))
      Y2=Y2/(P(I,2)-P(I,1))
    7 UPA(1,J)=A(1,J)+Y2*A(1,J)/100.0
      UPA(2,J)=A(2,J)
      UPA(3,J)=A(3,J)+Y2*A(3,J)/100.0
      IF(J.LT.14.0) GO TO 5
      RETURN
      END

      FINISH
```

```
      LIST (LP)
      PROGRAM (FXXX)
      INPUT 1=CRO
      INPUT 3=CR1
      INPUT 5=CR2
      INPUT 7=CR3
      OUTPUT2=LPO
      OUTPUT 4=CPO
      COMPRESS INTEGER AND LOGICAL
      EXTENDED
      TRACE2
      END


      MASTER
      DIMENSION A(3,14),B(100,16),C(100,15),D(100,15),E(10
     1O,2),F(100,7)
      READ(7,1) N
    1 FORMAT(I5)
      READ(1,2) ((A(I,J),J=1,14),I=1,3,2)
    2 FORMAT(14F5.2)
      READ(1,3) ((A(I,J),J=1,14),I=2,2)
    3 FORMAT(14F5.O)
      READ(1,4) ((B(I,J),J=1,15),I=1,N)
    4 FORMAT(15F5.0)
      CALL BINCREASE(B,N)
      WRITE(2,900) ((A(I,J),J=1,14),I=1,3)
  900 FORMAT(1H ,14F8.2)
      WRITE(2,901) ((B(I,J),J=1,16),I=1,N)
  901 FORMAT(1H ,16F7.2)
      CALL CFORM(C,B,N)
      CALL DFORM(A,C,D,N)
      CALL EFORM(D,E,N)
    5 CONTINUE
      READ(3,6) I1
    6 FORMAT(I1O)
      IF(I1.EQ.50000) GO TO 99
      N=O
    7 N=N+1
      READ(5,8) WKN,ACTN,X,ZLAB,ZMAT,ZPLANT
    8 FORMAT(6F10.2)
      F(N,1)=WKN
      F(N,2)=ACTN
      F(N,3)=X
      F(N,4)=ZLAB
      F(N,5)=ZMAT
      F(N,6)=ZPLANT
      CALL ZSUBCOST(ACTN,SUMZ,X,E)
      F(N,7)=SUMZ
      IF(N.LT.I1) GO TO 7
      DO 11 K=1.I1
      WRITE(4,12) F(K,1),F(K,3),F(K,3),F(K,4),F(K,5),F(K,6)
     1,F(K,7)
   12 FORMAT(7F10.2)
   11 CONTINUE
      GO TO 5
   99 CONTINUE
```

```
      STOP
      END

      SUBROUTINE BINCREASE(B,N)
      DIMENSION B(100,16),B1(100,3)
      DO 2 I=1,N
      READ(7,1) B1(I,1),B1(I,2),  B1(I,3)
    1 FORMAT(F5.0,2F10.3)
    2 CONTINUE
      I=0
    3 I=I+1
      IF(B(I,1).EQ.B1(I,1)) GO TO 4
    6 K=I
    5 K=K+1
      IF(K.GT.N) GO TO 7
      IF(B(I,1).EQ.B1(K,1)) GO TO 8
      GO TO 5
    7 K=0
      GO TO 6
    8 B(I,16)=B1(K,3)
      IF(I.LT.N) GO TO 3
      GO TO 9
    4 B(I,16)=B1(I,3)
      IF(I.LT.N) GO TO 3
    9 CONTINUE
      RETURN
      END

      SUBROUTINE CFORM(C,B,N)
      DIMENSION C(100,15),B(100,16)
      DO 1 I=1,N
      DO 1 J=2,I5
      C(I,J)=B(I,J)/B(I,16)
    1 CONTINUE
      DO 2 I=1,N
      C(I,1)=B(I,1)
    2 CONTINUE
      RETURN
      END

      SUBROUTINE DFORM(A,C,D,N)
      DIMENSION A(3,14),C(100,15),D(100,15)
      DO 1 I=1,N
      DO 1 J=2,15
      IF(A(2,J-1).EQ.0.0) GO TO 3
      D(I,J)=C(I,J)*A(1,J-1)/A(2,J-1)
      D(I,J)=D(I,J)+C(I,J)*A(3,J-1)/A(2,J-1)
      GO TO 1
    3 D(I,J)=0.0
    1 CONTINUE
      DO 2 I=1 ,N
      D(I,1)=C(I,1)
    2 CONTINUE
```

```
      RETURN
      END


      SUBROUTINE   EFORM(D,E,N)
      DIMENSION D(100,15),E(100,2)
      DO 1 I=1,N
      SUM=0.0
      DO 1 J=2,15
      SUM=SUM+D(I,J)
      E(I,2)=SUM
    1 CONTINUE
      DO 2 I=1,N
      E(I,1)=D(I,1)
    2 CONTINUE
      RETURN
      END


      SUBROUTINE ZSUBCOST(ACTN,SUMZ,X,E)
      DIMENSION E(100,2)
      I=0
    1 I=I+1
      IF(E(I,1).EQ.ACTN) GO TO 2
      GO TO 1
    2 CONTINUE
      SUM=X*E(I,2)
      SUMZ=SUM
      RETURN
      END


      FINISH
```

```
      LIST(LP)
      PROGRAM (FXXX)
      INPUT 1=CRO
      INPUT 3=CR1
      INPUT 5=CR2
      OUTPUT2=LPO
      OUTPUT4=CPO
      COMPRESS INTEGER AND LOGICAL
      EXTENDED
      TRACE 2
      END


      MASTER
      DIMENSION PR(100,6)
      READ(1,1) M
    1 FORMAT(IO)
      READ(1,2) ((PR(I,J),J=1,5),I=1,M)
    2 FORMAT(30X,3F5.0,F10.3,F5.0)
      CALL PRINCR(PR,M )
      WRITE(2,900 ((PR(I,J),J=1,  6),I=1,M)
  900 FORMAT(1H ,6F10.3)
    3 READ(3,4) I1
    4 FORMAT(I10)
      IF(I1,EQ.50000) GO TO 5
      MM=O
      ZI1=FLOAT(I1)
    6 READ(5,7) WKN,ACTN,X,ZLAB,ZMAT,ZPLANT,ZSC
    7 FORMAT(7F10.2)
      MM=MM+1
      CALL PRELIM(WKN,ZI1,ACTN,PR,M,SUM)
      WRITE(4,8) WKN,ACTN,X,ZLAB,ZMAT,ZPLANT,ZSC,SUM
    8 FORMAT(8F10.2)
      IF(MM.LT.I1) GO TO 6
      GO TO 3
    5 CONTINUE
      STOP
      END


      SUBROUTINE PRINCR(PR,M)
      DIMENSION PR(100,6)
      DO 1 I=1,M
      PR(I,6)=PR(I,4)/PR(I,5)
    1 CONTINUE
      RETURN
      END


      SUBROUTINE PRELIM(WKN,ZI1,ACT,P,N,SUM)
      DIMENSION P(100.6)
      SUM=O.O
      I=O
  990 I=I+1
      IF(P(I,1).EQ.O.O) GO TO 1
      IF(P(I,1).EQ.ACT) GO TO 2
      GO TO 99
```

```
    2 IF(P(I,2).EQ.O.O) GO TO 3
      IF(WKN.GE.P)I,2)) GO TO 4
      GO TO 99
    3 (F(P(I,3).EQ.O.O) GO TO 5
      IF(WKN.LE.P(I,3)) GO TO 5
      GO TO 99
    4 IF(P(I,3).EQ.O.O) GO TO 5
      IF(WKN.LE.P(I,3)) GO TO 5
      GO TO 99
    5 SUM=SUM+P(I,6)
      GO TO 99
C INDEPENDENT OF ACTIVITY NOTATION
    1 DIV=P(I,6)/ZI1
      IF(P(I,2).EQ.O.O) GO TO 6
      IF(WKN.GE.P(I,2)) GO TO 7
      GO TO 99
    6 IF(P(I,3).EQ.O.O) GO TO 8
      IF(WKN.LE.P(I,3)) GO TO 8
      GO TO 99
    7 IF(P(I,3).EQ.O.O) GO TO 8
      IF(WKN.LE.P(I,3)) GO TO 8
      GO TO 99
    8 SUM=SUM+DIV
   99 IF(I.LT.N) GO TO 990
      RETURN
      END

      FINISH
```

```
      LIST (LP)
      PROGRAM (FXXX)
      INPUT 1= CRO
      INPUT 3= CR1
      INPUT 5= CR2
      OUTPUT2= LPO
      COMPRESS INTEGER AND LOGICAL
      EXTENDED
      TRACE 2
      END

      MASTER
      DIMENSION A(100,8),B(100,8),PINC(100,7),BR(100,8)
      TOT1=0.0
      TOTA=0.0
      TOTB=0.0
      TOTC=0.0
      TOTD=0.0
      TOTE=0.0
      DO 111 I=1,100
      DO 111 J=1,8
      B(I,J)=0.0
  111 CONTINUE
      READ(1,150) N1
  150 FORMAT(I0)
      IF(N1.EQ.0) GO TO 114
      DO 21 I=1,N1
      READ(1,22)PINC(I,1),PINC(I,2),PINC(I,3),PINC(I,5),PI
     1NC(I,6),PINC(I,7)
   22 FORMAT(6F0.0)
   21 PINC(I,4)=0.0
      WRITE(2,31) ((PINC(I,J),J=1,7),I=1,N1)
   31 FORMAT(1H ,7F5.0)
  114 CONTINUE
  101 READ(3,1) I1
    1 FORMAT(I10)
      IF(I1.EQ.50000) GO TO 3
      SUMA=0.0
      SUMB=0.0
      SUMC=0.0
      SUMD=0.0
      SUME=0.0
      N=0
    2 N=N+1
      READ(5,4) WKN,ACTN,X,ZLAB,ZMAT,ZPLANT,ZSC,ZPRE
    4 FORMAT(8F10.2)
      A(N,1)=WKN
      A(N,2)=ACTN
      A(N,3)=X
      A(N,4)=ZLAB
      A(N,5)=ZMAT
      A(N,6)=ZPLANT
      A(N,7)+ZSC
      A(N,8)=ZPRE
      IF(N.LT.I1) GO TO 2
      WRITE(2,5)
```

```
    5 FORMAT(1H1,4HWEEK,2X,4H ACT,2X,10H QUANTITY ,2X,10H
     1LABOUR   ,2X,10H MATERIAL ,2X,10H  PLANT    ,2X,10H
     2TOTAL    ,2X,10H SUBCTRS  ,2X,10H  TOTAL    ,2X,10H
     3PRELIM   ,2X,10H  TOTAL   )
      WRITE(2,6)
    6 FORMAT(1H ,4H NO ,2X,4H NO ,2X,10H PRODUCED ,2X,10H
     1COST     ,2X,10H   COST   ,2X,10H   COST    ,2X,10H
     2,2X,10H    COST     ,2X,10H              ,2X,10H    COST
     3,2X,10H             ,//)
      IF(N1.EQ.0) GO TO 112
      CALL AVARADJ(I1.A.PINC,N1)
  112 CONTINUE
      DO 15 K=1,I1
      WRITE(2,7) A(K,1),A(K,2),A(K,3),A(K,4),A(K,5),A(K,6),
     1A(K,7),A(K,8)
    7 FORMAT(1H ,F4.0,2X,F4.0,2X,F10.2,2X,F10.2,2X,F10.2,2X
     1,F10.2,2X, 10X ,2X,F10.2,2X, 10X ,2X,F10.2,2X, 10X )
      WKN=A(K,1)
      SUMA=A(K,4)+SUMA
      SUMB=A(K,5)+SUMB
      SUMC=A(K,6)+SUMC
      SUMD=A(K,7)+SUMD
   15 SUME=A(K,8)+SUME
      WRITE(2,151)
  151 FORMAT(1H ,//)
      WRITE(2,8)
    8 FORMAT(1H ,20H     PERIOD TOTALS   )
      WRITE(2,9) WKN,SUMA,SUMB,SUMC,SUMD,SUME
    9 FORMAT(1H ,F4.0,2X,4X,2X,10X,2X,F10.1,2X,F10.2,2X,F10
     1.2,2X,F10.2,2X,10X,2X,F10.2,2X,10X,2X,F10.2)
      TOTAL1=SUMA+SUMB+SUMC
      TOTAL2=TOTAL1+SUMD
      TOTAL3=TOTAL2+SUME
      WRITE(2,10) TOTAL1,TOTAL2,TOTAL3
   10 FORMAT(1H ,60X,F10.2,2X,10X,2X,F10.1,2X,10X,2X,F10.2
     1,//)
      TOT1=WKN
      TOTA=SUMA+TOTA
      TOTB=SUMB+TOTB
      TOTC=SUMC+TOTC
      TOTD=SUMD+TOTD
      TOTE=SUME+TOTE
      WRITE(2,11)
   11 FORMAT(1H ,26H     ACCUM' PERIOD TOTALS )
      WRITE(2,12) TOT1,TOTA,TOTB,TOTC,TOTD,TOTE
   12 FORMAT(1H ,F4.0,2X,4X,2X,10X,2X,F10.2,2X,F10.2,2X,F10
     1.2,2X,10X,2X,F10.2,2X,10X,2X,F10.2)
      TOTAL1=TOTA+TOTB+TOTC
      TOTAL2=TOTAL1=TOTD
      TOTAL3=TOTAL2+TOTE
      WRITE(2,13) TOTAL1,TOTAL2,TOTAL3
   13 FORMAT(1H ,60X,F10.2,2X,10X,2X,F10.2,2X,10X,2X,F10.2,
     1//)
      CALL ACTACCUM(A,B,I1)
      GO TO 101
    3 CONTINUE
      WRITE(2,199)
  199 FORMAT(1H1)
```

```
      WRITE(2,1990)
 1990 FORMAT(1H ,23X,'ACTIVITY NETT COST SUMMARY')
      WRITE(2,1991)
 1991 FORMAT(1H ,23X,'*****************************')
      WRITE(2,206)
      WRITE(2,207)
      WRITE(2,208)
      NOTE=0
      DO 200 I=1,100
      IF(b(I,2).EQ.0.0) GO TO 200
      WRITE(2,202) (B(I,J),J=1,8)
      NOTE=NOTE+1
  202 FORMAT(1H ,8F10.2)
      BR(I,1)=B(I,1)
      BR(I,2)=B(I,2)
      BR(I,3)=B(I,3)
      BR(I,4)=B(I,4)/B(I,3)
      BR(I,5)=B(I,5)/B(I,3)
      BR(I,6)=B(I,6)/B(I,3)
      BR(I,7)=B(I,7)/B(I,3)
      BR(I,8)=B(I,8)/B(I,3)
  200 CONTINUE
      WRITE(2,203)
  203 FORMAT(1H1)
      WRITE(2,204)
  204 FORMAT(1H ,23X,'ACTIVITY NETT RATE SUMMARY')
      WRITE(2,205)
  205 FORMAT(1H ,23X,'*****************************')
      WRITE(2,206)
  206 FORMAT(1H ,///)
      WRITE(2,207)
  207 FORMAT(1H ,'COMPLETION  ACTTVITY  QUANTITY     LABOUR
     1MATERIAL PLANT    SUBCTRS     PRELIM')
      WRITE(2,208)
  208 FORMAT(1H ,'      WEEK       CODE  PRODUCED         COST
     1COST  COST  COST       COST',//)
      WRITE(2,209) ((BR(I,J),J=1,8),I=1,NOTE)
  209 FORMAT(1H ,2F10.0,6F10.3)
      STOP
      END


      SUBROUTINE ACTACCUM(A,B,I1)
      DIMENSION A(100,8),B(100,8)
      N=0
    1 N=N+1
      R1=A(N,2)
      I2=IFIX(R1)
      ZMARK=A(N,1)
      B(I2,1)=A(N,1)
      B(I2,2)=A(N,2)
      B(I2,3)=A(N,3)+B(I2,3)
      B(I2,4)=A(N,4)+B(I2,4)
      B(I2,5)=A(N,5)+B(I2,5)
      B(I2,6)=A(N,6)+B(I2,6)
      B(I2,7)=A(N,7)+B(I2,7)
      B(I2,8)=A(N,8)B(I2,8)
      IF(N.LT.I1) GO TO 1
```

```
      IF(N.LT.I1) GO TO 1
      WRITE(2,2)
    2 FORMAT(1H ,29H      ACCUM' ACTIVITY TOTALS   )
      DO 3 M=1,100
      IF(B(M,1).EQ.O.O) GO TO 3
      IF(B(M,1).NE.ZMARK) GO TO 3
      WRITE(2,4) B(M,1),B(M,2),B(M,3),B(M,4),B(M,5),B(M,6),
     1B(M,7),B(M,8)
    4 FORMAT(1H ,F4.0,2X,F4.0,2X,F10.2,2X,F10.2,2X,F10.2,2
     1X,F10.2,2X, 10X ,2X,F10.2,2X, 10X ,2X,F10.2,2X, 10X )
      TOTAL1=B(M,4)+B(M,5)+B(M,6)
      TOTAL2=TOTAL1+B(M,7)
      TOTAL3=TOTAL2+B(M,8)
      WRITE(2,5) TOTAL1,TOTAL2,TOTAL3
    5 FORMAT(1H ,60X,F10.2,2X,10X,2X,F10.2,2X,10X,2X,F10.2,//)
    3 CONTINUE
      RETURN
      END


      SUBROUTINE AVARADJ(I1,A,PINC,N1)
      DIMENSION A(100,8),PINC(100,7)
      K=O
    7 K=K+1
      I=O
    1 I=I+1
      IF(A(K,1).GE.PINC(I,1)) GO TO 2
      GO TO 1
    2 IF(A(K,1).LE.PINC(I,2)) GO TO 3
      IF(I.LT.N1) GO TO 1
      I=N1
    3 J=2
    6 J=J+1
      IF(I.EQ.1) GO TO 4
      TOP=PINC(I,J)-PINC(I-1,J)
      BOT=PINC(I,2)-PINC(I,1)
      SLOPE=TOP/BOT
      Y2=A(K,1)-PINC(I,1)
      Y2=(Y2*SLOPE)+PINC(I-1,J)
      A(K,J+1)=A(K,J+1)+Y2*A(K,J+1)/100.0
      GO TO 5
    4 CONTINUE
      TOP-PINC(I,J)
      BOT=PINC(I,2)
      SLOPE=TOP/BOT
      Y2=A(I,1)*SLOPE
      A(K,J+1)-A(K,J+1)+Y2*A(K,J+1)/100.0
    5 CONTINUE
      IF(J.LT.7) GO TO 6
      IF(K.LT.I1) GO TO 7
      RETURN
      END


      FINISH
```

REFERENCES

.1. TAUSSKY, O., and TODD, J., "Generation and Testing of Pseudo Random Numbers".

.2. HULL, T. E., and DOBELL, A. R., "Random Number Generators".

APPENDIX .5.

MAIN DRAINAGE PLANNING MANUAL

DRAINAGE ELEMENTS

PLANNING MANUAL

Civil Engineering Division,
C. Bryant & Son Limited.

D. M. Bramwell
1972-1973

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SUMMARY

Construction Sequences

There are five main elements of drainage construction which can be classified separately. In construction sequence they are:-

Excavation

The trench which will receive the pipes is excavated, usually by mechanical equipment. The machine is assisted by a small gang of men who trim the base of the trench after excavation, and ensure that it is excavated to the required line and level.

Trench Support

If necessary, after excavation, the trench is supported. The excavation machine often assists the gang in this operation (lowering the structural members into the trench).

Pipe Laying

The pipes are lowered into the trench manually or mechanically. Flexibly jointed concrete or clayware pipes are frequently used, but pipes manufactured from asbestos or plastic are becoming more popular with designers. Small diameter pipes (below 375 mm) are connected manually by simply pushing two pipes together. However, large diameter pipes are connected, using hydraulic or mechanical jacks. The pipes are usually placed on blocks or saddles which are placed on the bottom of the trench prior to pipe laying. The blocks

help the pipe layer to adjust the pipes to the correct line and level and ensures that the bedding material fully surrounds the pipes.

Bedding

After laying, the pipes are then surrounded by a bedding material. Concrete or granular materials are commonly used. More designers are now taking advantage of the high strength pipes which are available in order to reduce the need for bedding structure to protect the pipes.

Backfill

The trench support system is removed, and the remainder of trench is filled with acceptable material. The originally excavated material is often used, but where pipelines are constructed through unsuitable strata (tips, etc.,) fill material is imported.

Structure of Manual

The Manual is presented in eight sections. Each section is designed to provide the user with standard times, sizes and composition of gangs necessary for carrying out the drainage construction.

Section 1 Machine Selection and Excavation Rate

Section one deals with mechanical excavation only. A method is provided which will help the user to select the best excavation machine to use under certain pre-determined site conditions. A method is then provided for calculating the excavation rate which may be expected from the pre-selected machine. The variables used in the formulae are presented graphically for ease of reference.

Section 2
Trench Support Structure

This section deals with the design of the trench support structure and the determination of the gang size and standard time required to construct it.

Various formulae are provided for calculating the earth pressure exerted on the structure and the magnitude of the members required to withstand it. However, to simplify the calculations necessary, one type of trench sheet* and only steel waters* are considered. The trench struts* are also assumed to be square section grade two timber[4].

* For definition see Section 2, page

Section 3
Pipe Laying

This section gives details of the pipe laying operation. A table is presented which recommends the gang size, gang composition and the standard time necessary to lay the pipes.

Section 4
Pipe Bedding

Eight different types of bedding structure are provided for in this section. Standard dimensions are then used[5] to calculate the volumes of the bedding material. The volumes are presented in tabular form together with the relevant dimensions of the bedding structure.

Concrete (type A) and Granular (type B) bedding materials are considered, but selected back fill (type C) is not, owing to the lack of detailed information.

Three tables are given at the rear of this section which list the standard time, gang size and composition for forming the bedding structure.

Section 5
Backfill

This section provides various graphical relationships which may be used to determine the standard time required to backfill the trench, together with various gang sizes and compositions.

Section 6
Manholes

Precast concrete and brick manholes are considered in this section. Standard time data and gang information is presented in several tables, each dealing with a separate element of manhole construction.

A small appendix is presented at the rear of this section which gives standard time data for such items as manhole covers, step irons and other manhole fittings.

Section 7
Miscellaneous

There are many drainage items which are an integral part of drainage construction, but do not warrant a separate section, (Road Gullies, Yard Gullies, Breaking out of Concrete and Brickwork etc.). The miscellaneous section brings together, in alphabetical order as many of these as possible, giving standard time and gang size information for each.

Limitations

Pipe and Pipeline testing is not covered in this manual, mainly due to the lack of current work study data. However, supplements will be distributed when the information does become available.

NOTATION

		UNIT
Rs	Mean Standard Rate of Excavation	M^3/hr
Bc	Theoretical Bucket Capacity	M^3
bc	Proportion of the theoretical bucket capacity utilised.	
D	Depth of the Excavation	M
W	Width of the Excavation	M
N	Depth to Width Ratio	
E_t	Excavation Time	mins
U_T	Unloading Time	mins
R	Working Radius	M
Qe	The quantity of material excavated by a single digging stroke	M^3
S	Strata Grading	
Ap	Apparent Earth Pressure	KN/M^2
$\emptyset$	Internal Angle of Friction	degs
c	Cohesion	kg/M^2
γ	Density	kg/M^3
K_A	Coefficient of Active Earth Pressure	
L	Maximum permissible waler spacing	M
L_D	Required waler spacing	M
Zr	Required section modulus	cm^3
B	Width/Depth of timber struts	mm
Wgt	Weight of Waler	kg/m
Ls	Length of Trench Sheets	M
T_{SH}	Standard duration per trench sheet	mins
T_{st}	Standard duration per trench strut	mins
Tw	Standard duration per waler	mins

INTRODUCTION

An ever increasing proportion of the Civil Engineering construction taking place today involves working in Urban areas. This creates several immediate problems for the contractor.

The construction work must be phased so that the inconvenience caused to pedestrians and traffic is minimised. Existing buildings and roads are often situated near the construction site, thus restricting the size of the working area. The continuity of construction is affected by the presence of services, (water, gas, post office and electricity pipes and cables).

Existing planning and estimating techniques tend to involve the application of a gross rate to an item of construction. This method is satisfactory if the construction is unaffected by the type of external restrictions mentioned above. However, as the required construction procedure becomes more complex, so the validity of the gross rate becomes suspect, primarily for three reasons:-

(a) Established gross rates, although originally based on accurate elemental data tend to become distorted,due to alterations which are made to the gross rate as a whole and not to the elemental data on which it is based.

(b) The gross rate tends to be accepted at face value, irrespective of inherent complications which may be caused by working in difficult conditions, i.e. Urban Areas.

(c) The gross rate is not flexible. It cannot be altered to produce more than one solution to the complex phasing and work output problems inherent in Urban Area construction.

The aim of this manual is not to completely replace the gross rate (as it is still extremely effective in many situations), but to provide the existing gross rates with an elemental data base and to help the planner and estimator create new rates for unique construction methods.

SECTION 1

MACHINE SELECTION
AND
EXCAVATION RATE

1.1 Definitions

Mean Standard Rate of Excavation (Rs)

This is the mean output which can be expected from a Hydraulic Excavator working at standard performance under pre-determined site conditions.

Theoretical Bucket Capacity (Solid) for the Machine considered (Bc)

The bucket capacity published by the machine manufacturers. It is dependent upon the type of machine and the width of its buckets. A graph showing these relationships is given in figure.1 .

Proportion of the Theoretical Bucket Capacity Utilised (bc)

The quotient of the observed volume utilised and the theoretical volume available. It is primarily dependent upon the strata being excavated. See figure.2 .

Trench Shape Factor (N)

The ratio of the depth of the excavation (D) and the width of the excavation (W)

$$N = \frac{D}{W}$$

Excavation Time (E_t) for Strata Grading 10

The time required to excavate per machine cycle. It is assumed to be affected by the physical characteristics of the trench and the strata being excavated only.

Unloading Time (U_T) for Strata Grading 10

The time required to unload the excavated spoil, per machine cycle. It is assumed to be dependent upon the working radius (R).

1.2 Machine Selection

The required machine should be selected using the information given in Tables.1. and .2.

TABLE.1.

Machine Type	Minimum Bucket width (MM) (b)	Theoretical Bucket Capacity (M^3) (Bc)	Maximum Bucket Width (MM) (b)	Theoretical Bucket Capacity (M^3) (Bc)
*JCB3	225	0.08	675	0.25
*JCB3C	225	0.13	675	0.29
*JCB3D	225	0.13	675	0.29
JCB5C	450	0.32	1200	0.56
JCB6C	450	0.32	1300	0.49
JCB6D	450	0.32	1300	0.49
JCB7B	450	0.32	1200	0.67
JCB7C	600	0.50	1300	1.06
Hy-Mac580	400	0.29	1350	0.57
RH6	600	0.50	1300	1.06

* Centre Post Skewing Action

Machine Type	Digging Depth (mm)			Horizontal Reach (mm)			Loading Height (mm)		
	Normal	Short Arm	Long Arm	Normal	Short Arm	Long Arm	Normal	Short Arm	Long Arm
JCB 3	3700			5410			3450		
JCB 3C	4190			5570			3380		
JCB 3D	4190			5570			3290		
JCB 5C		5760			9020			6270	
JCB 6C		5610	6350		8740	9200		5330	6050
JCB 6D		5610	6350		8740	9200		5330	6050
JCB 7B		6100			9300			5540	
JCB 7C		5660	6730		8690	9730		5640	6100
Hy-Mac 580		2819	6425		7469	9093		5358	3073
RH 6		4500	6700		8400	10500		3000	3000

TABLE .2.

1.3 Excavation Rate

The mean standard rate of excavation may be determined in either of the following ways:-

(a) Graphically using figure. 6 .

(b) Analytically using the following formulae:-

$$Rs = \frac{Qe}{n} \sum_{i=1}^{i=n} \frac{1}{U_T + E_{Ti}}$$

The calculation of 'Rs' using the formulae is repetitive. Therefore, for simplicity, use table.3.

Step by Step Solution

1. Having selected the machine, determine the Theoretical Bucket Capacity (Bc) from figure. 1 .

2. Select the strata grading from table.4., using figure. 2 . Determine the proportion of the Theoretical Bucket Capacity utilised (bc).

3. Determine 'Qe' from

$$\underline{Qe = Bc \times bc}$$

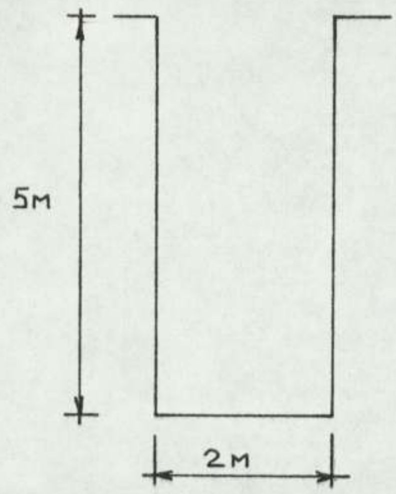
4. Knowing the required working radius (R), determine the unloading time (U_T) from either figure. 3 . or figure. 4 . Refer to table.1. to

determine whether the machine selected exhibits a 'Centre Post' or 'Radial' skewing action.

5. Determine the Obstruction Grading from table.5.

6. Divide the depth of the trench into 10. Calculate N for each depth increment. Using figure.5 . determine the respective Excavation Time (E_t). Enter the results in table.3.

Example



Working radius (R) = 4M

Strata Grading = 8

Obstruction Grading = 3

Use a Hy-Mac 580, bucket width (b) 1350MM, theoretical bucket capacity (Bc) $0.57m^3$.

1. Bc = $0.57M^3$
2. bc = 0.45
3. Qe = 0.57x0.45 = $\underline{0.256\ M^3}$
4. U_t = 0.195 mins.
5. Obstruction Grading = 3
6. See table.3.

TABLE.3.

Qe	D_i	w	Ni	E_{ti}	U_T	$E_{Ti} + T$
	0.5	2.0	0.25	0.04	0.195	0.235
	1.0	2.0	0.50	0.08		0.275
	1.5	2.0	0.75	0.10		0.295
	2.0	2.0	1.0	0.16		0.355
	2.5	2.0	1.25	0.18		0.375
	3.0	2.0	1.50	0.21		0.405
	3.5	2.0	1.75	0.24		0.435
	4.0	2.0	2.0	0.25		0.445
	4.5	2.0	2.25	0.26		0.455
	5.0	2.0	2.50	0.28		0.475
0.256	M^3				Total	3.70
					÷ 10	0.37 minutes

$$\text{mean Rs} = \frac{60.0 \times 0.256}{0.370}$$

$$\underline{\underline{\text{mean Rs} = 41.51\ M^3/hr}}$$

TABLE. 4 .

STRATA GRADING

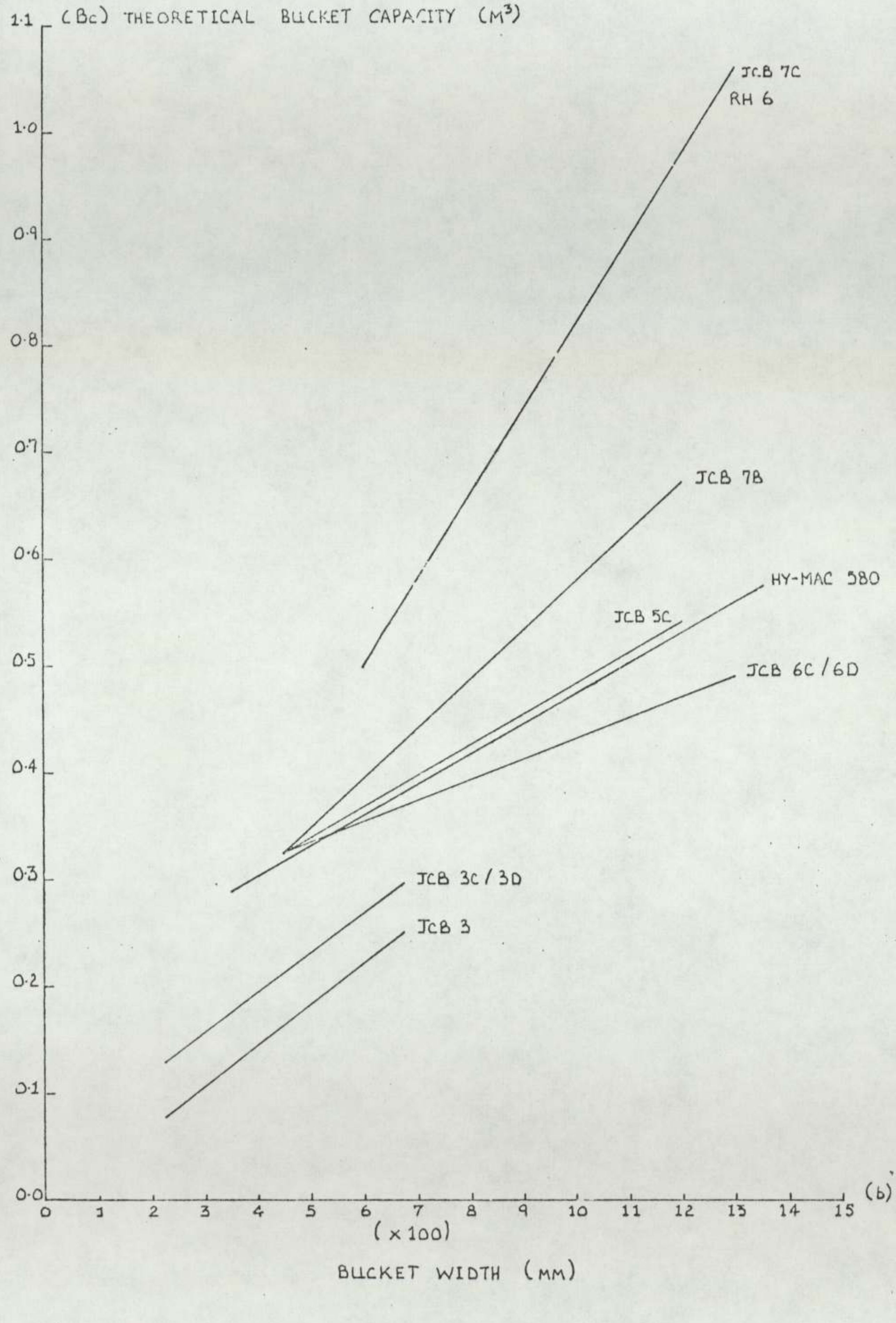
DESCRIPTION	GRADING
'ROCK' shall mean those geological strata and individual boulders exceeding 6 cubic feet (0.17m) in size or other masses of hard material outside those strata which necessitate the use of blasting or approved pneumatic tools for their removal.*	1
'MEDIUM ROCK' As 'A' above but not exceed-ind 6 cubic feet (0.17m) but exceeding 1 cubic foot (0.028m).	2
'SOFT ROCK' As 'B' but not exceeding 1 cubic foot (0.028m) and possessing bedding plains to allow breakage.	3
'SOFT LAMINATED ROCK' As 'C' but with excess laminations or bedding plains (slate, soft sandstone, shale).	4
'COHESIVE SOIL' (stiff) includes clays and marls with up to 20 per cent of gravel having a moisture content not less than the value of the plastic limit (BS 1377) minus 4; also chalk having a saturation moisture content of 20 per cent or greater.*	5-6
'SOFT COHESIVE SOIL' (medium) As '5-6' but excluding marls and including all clays and approximately 10 per cent sand or below.	7
Well-graded granular and dry cohesive soils, include clays or marls containing more than 20 per cent gravel.*	8
Well-graded sand and gravels with uniform-ity coefficient exceeding 10, also clinker and spent domestic refuse.	9
Uniformity graded material includes sands and gravels with uniformity coefficient of 10 or less, all silts and pulverised fuel ashes.*	10

* "Specification for Road and Bridge Works". 1969. Clause 601, 1.(iv), 2.(i), 2.(ii), 2.(iii).

TABLE. 5 .

OBSTRUCTION GRADING

DESCRIPTION	GRADING
Excavation involving the breaking out of metalled road surfaces or other such obstructions situated on top of frequently occurring services.	1
Excavating in ground possessing frequently occurring major services and house connection.	2
(a) Excavating in ground possessing infrequent major services but frequently occurring house services. (b) Excavating in ground possessing infrequent major services and infrequent minor services. (c) Excavating in ground possessing infrequent minor services and for tree roots etc.	3
Excavating in ground possessing minor obstructions only, i.e. tree roots, small quantities of hard core, etc.	4
Excavating in ground possessing no obstructions other than those which are an integral part of the strata.	5



(Bc) THEORETICAL BUCKET CAPACITY (M³)
1·1
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0·0
JCB 7C
RH 6
JCB 7B
HY-MAC 580
JCB 5C
JCB 6C / 6D
JCB 3C / 3D
JCB 3
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
(x 100)
BUCKET WIDTH (MM)
(b)

Figure .1 .

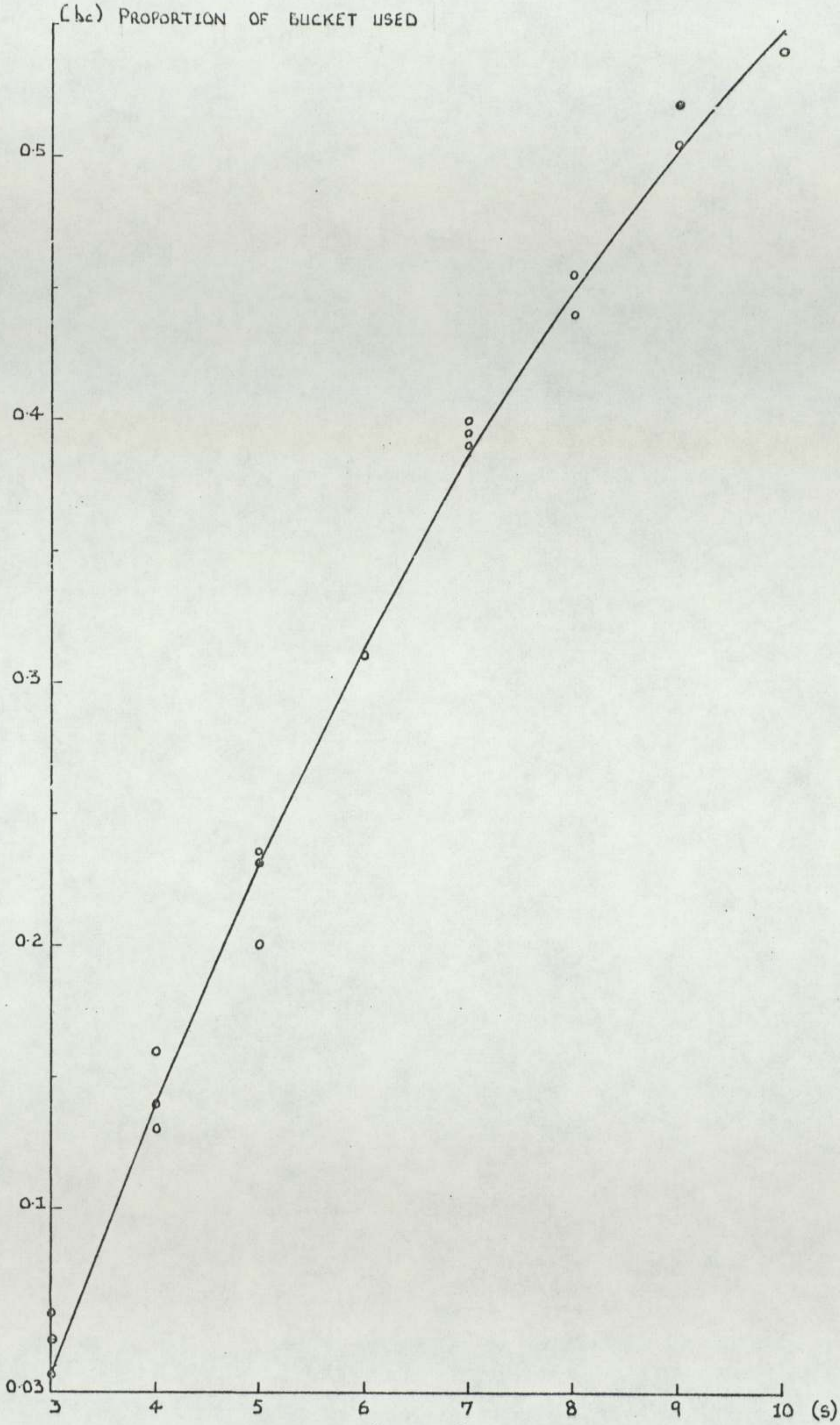

(bc) PROPORTION OF BUCKET USED
0.5
0.4
0.3
0.2
0.1
0.03
3
4
5
6
7
8
9
10
(s)
STRATA GRADING

Figure . 2.

RADIAL EXCAVATORS

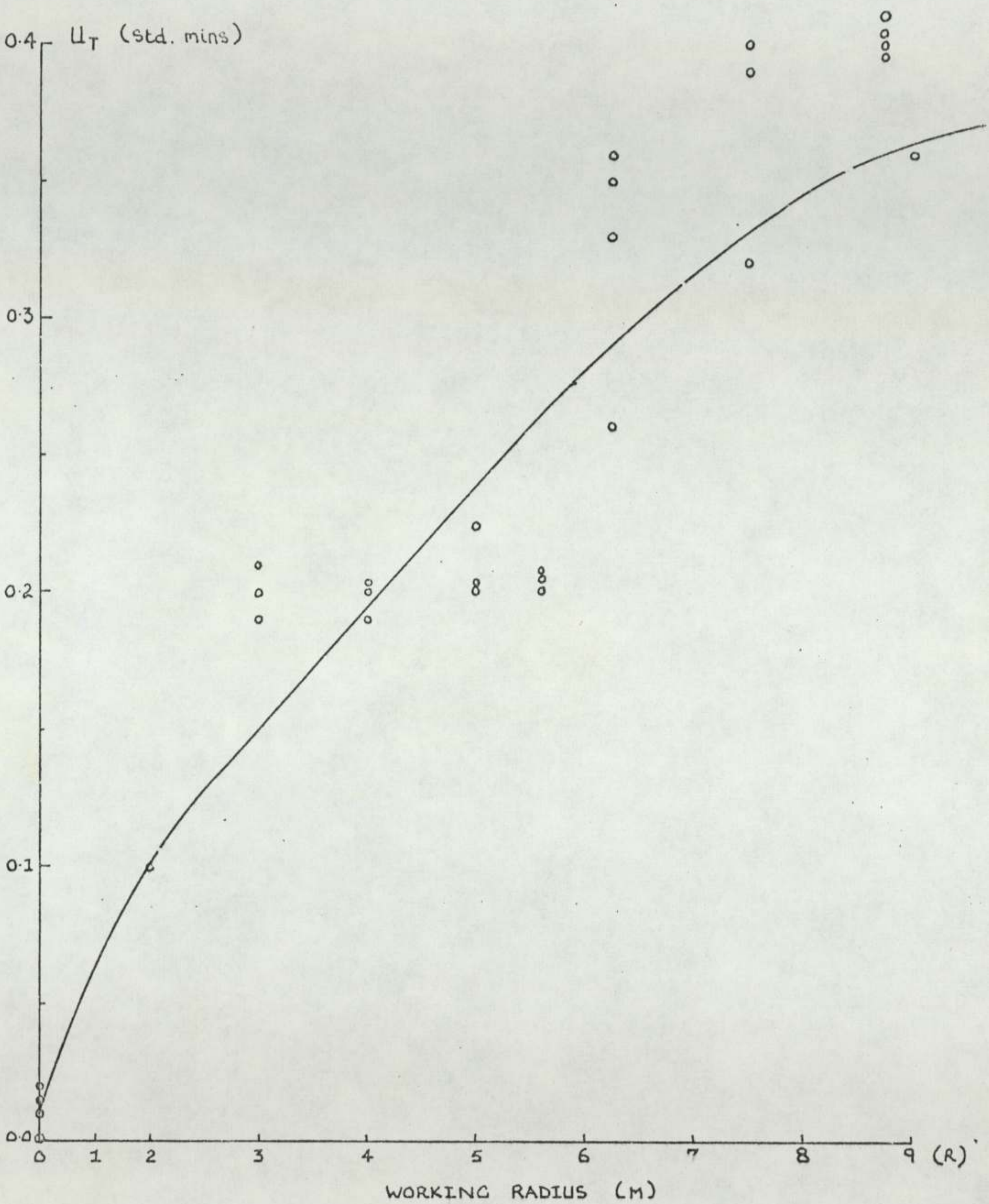


Figure . 3.

CENTRE POST EXCAVATORS

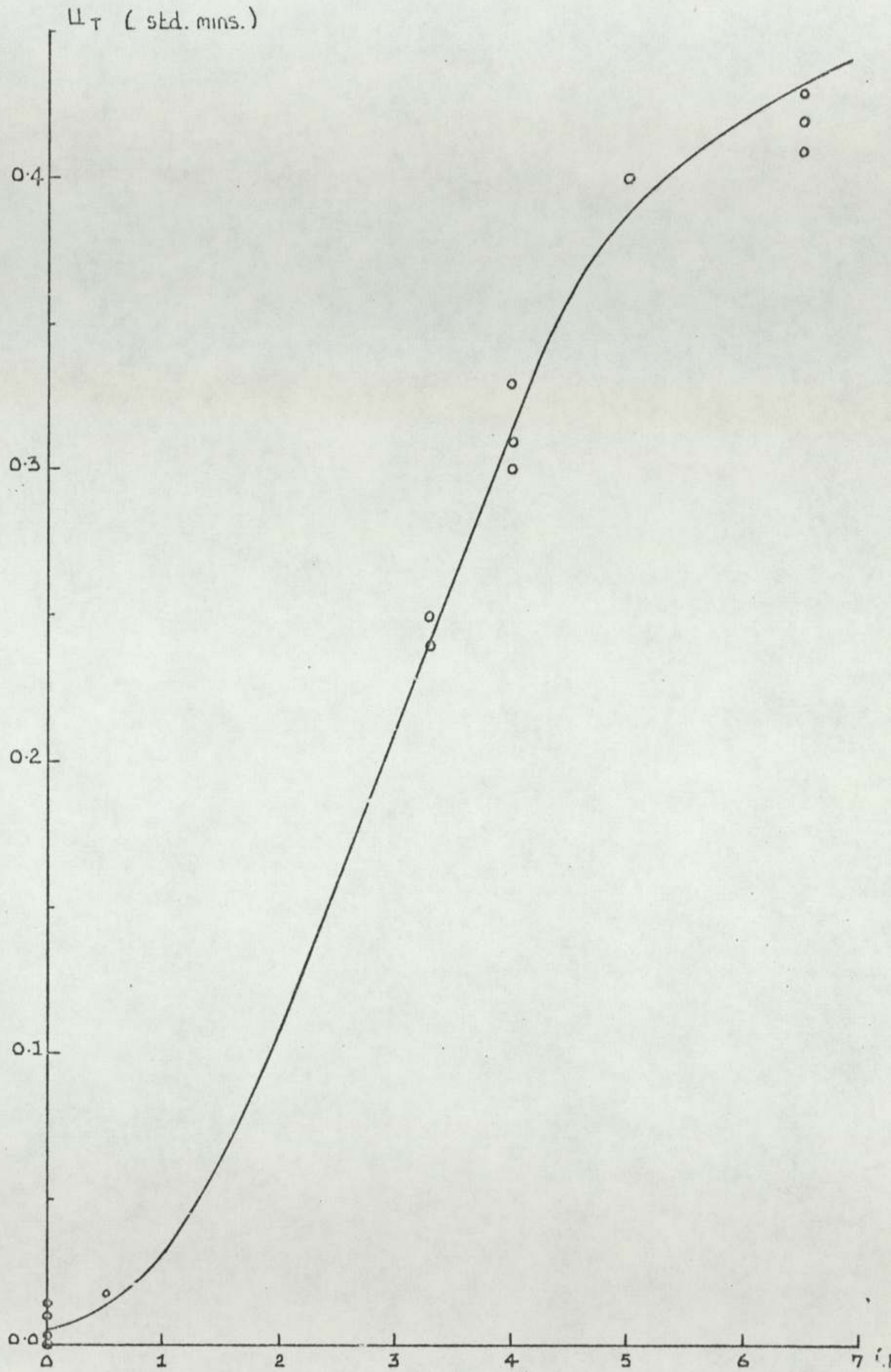


Figure . 4 .

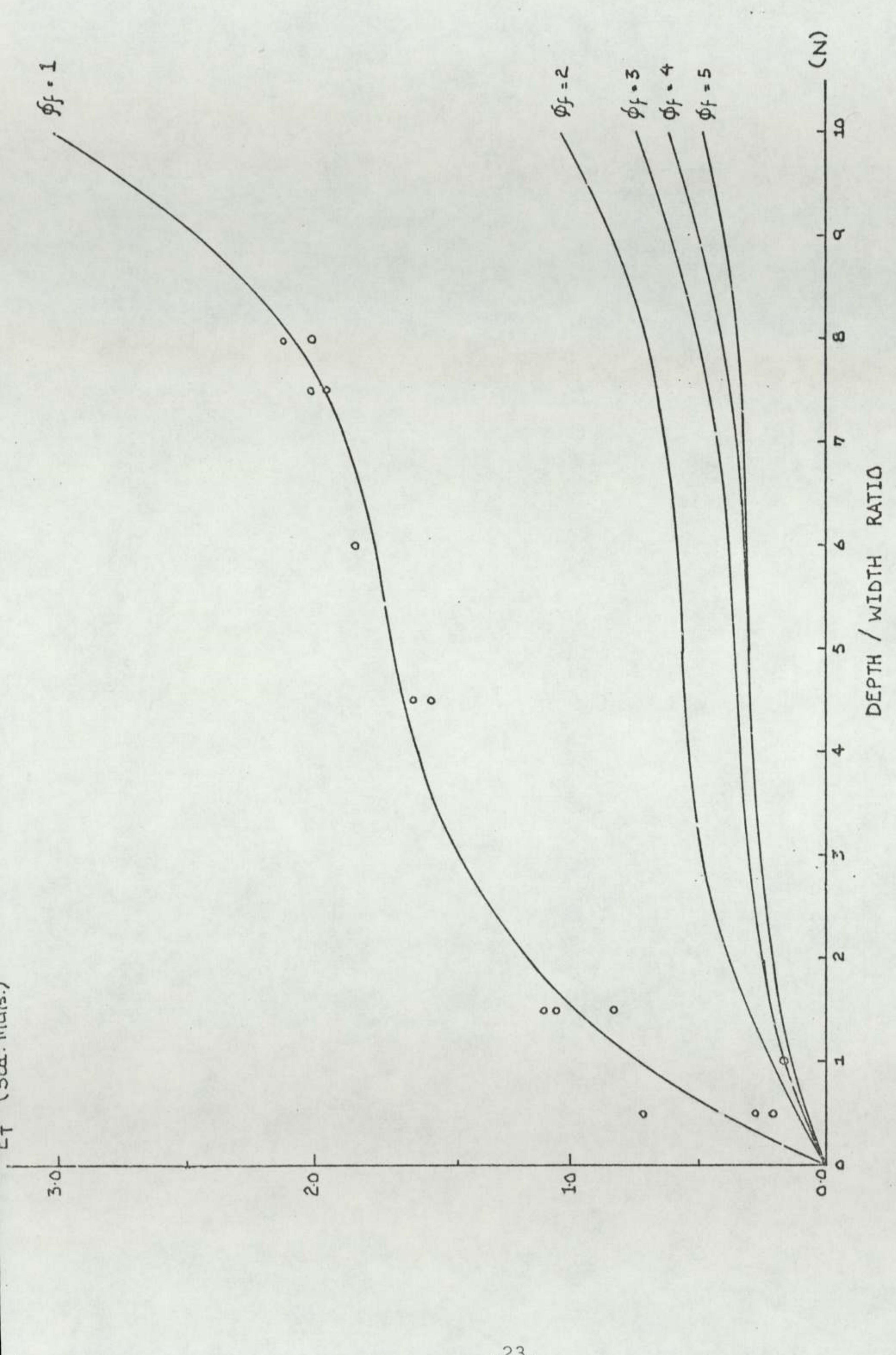
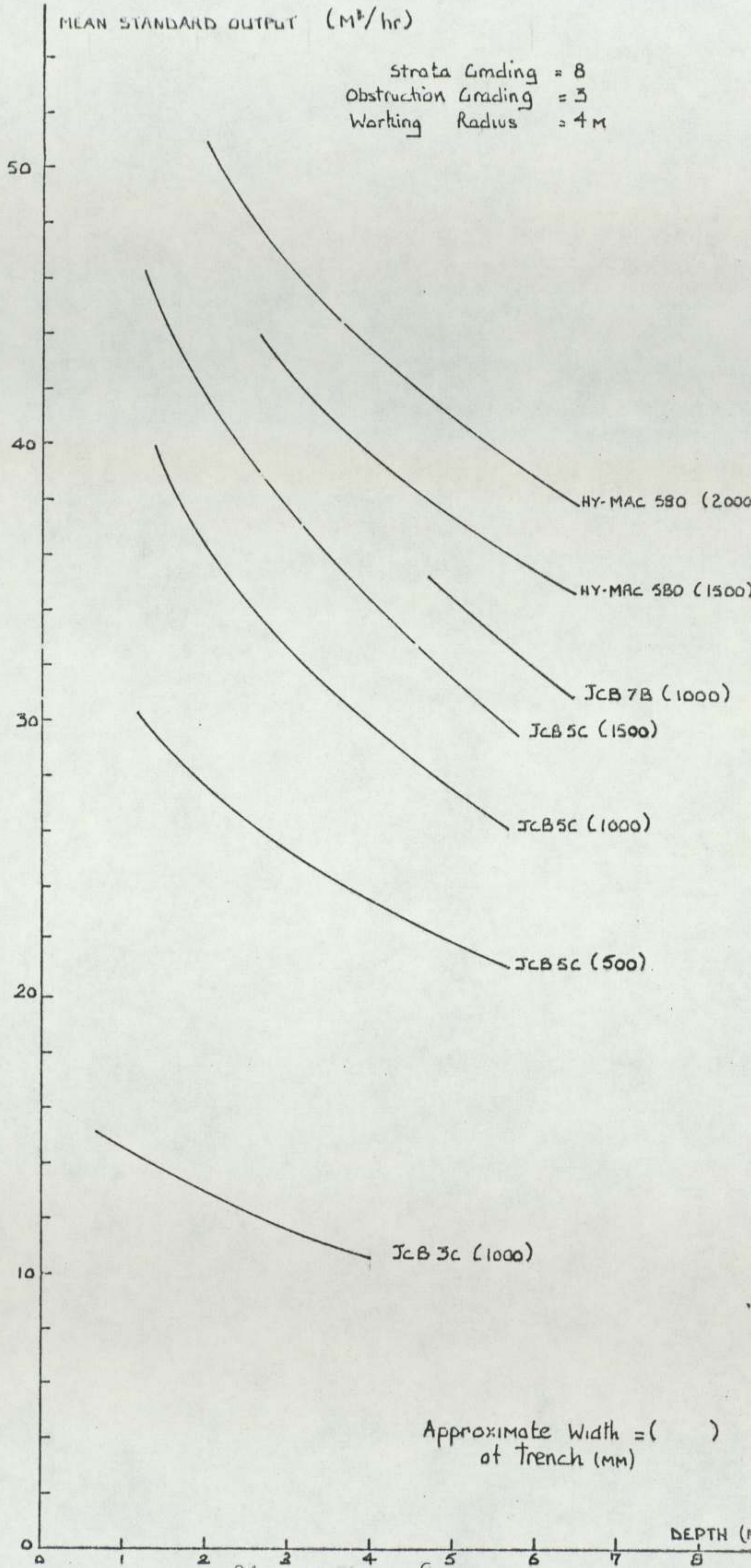

3·0
2·0
1·0
0·0
0
1
2
3
4
5
6
7
8
9
10
(N)
DEPTH / WIDTH RATIO
$\phi_f = 1$
$\phi_f = 2$
$\phi_f = 3$
$\phi_f = 4$
$\phi_f = 5$

Figure .5.


MEAN STANDARD OUTPUT (M³/hr)
Strata Grading = 8
Obstruction Grading = 3
Working Radius = 4 M
HY-MAC 580 (2000
HY-MAC 580 (1500)
JCB 7B (1000)
JCB 5C (1500)
JCB 5C (1000)
JCB 5C (500)
JCB 3C (1000)
Approximate Width = ( )
of Trench (MM)
DEPTH
0
10
20
30
40
50
1
2
3
4
5
6
7
8

SECTION 2

THE TRENCH SUPPORT STRUCTURE

2.1 Definitions
Soil
Properties

Apparent Earth Pressure (Ap)

For design purposes, the real distribution of earth pressure is assumed to be rectangular, trapezoidal or a combination of both. Various other assumptions dealing with cohesion (C) and the angle of internal friction (Ø) are also made to simplify the calculations. For these reasons the pressure calculated is designated the apparent earth pressure (Ap)[2].

Cohesion (C) and the Angle of Internal Friction (Ø)

All soils possess shearing resistance. It has two main components

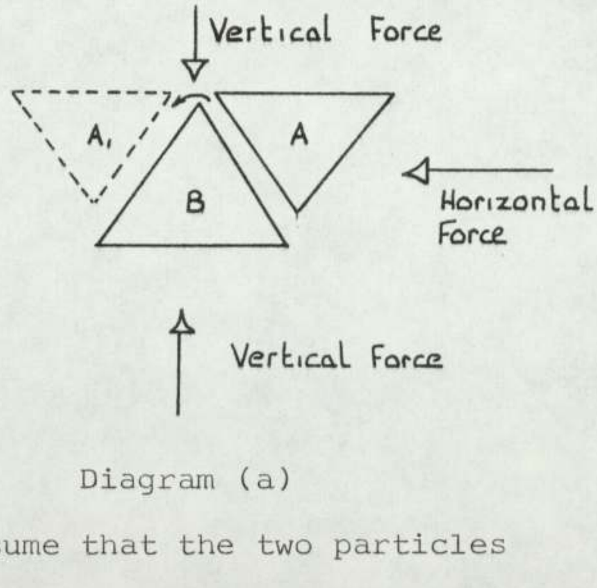
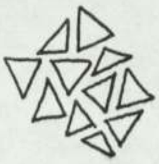


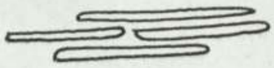
Diagram (a)

1. Assume that the two particles (Diagram (a)) of soil 'A' and 'B' are subjected to vertical forces which tend to push the particles together, and a horizontal force which is attempting to push 'A' over 'B' into the new position 'A_1' (shown dotted). The movement of 'A' is physically resisted by particle 'B'. The angle of internal friction (Ø)

is a measurement of this physical resistance, (the larger the resistance, the larger the value of Ø). Sands which possess angular particles exhibit a high degree of physical resistance to movement.

2. The particles of all soils are covered with a minute film of water. The water possess an electrostatic change and its overall magnitude is affected by the physical and chemical properties of the soil particles, i.e.





Sand Diagram (b)	Clay Diagram (c)
Small area of contact. The Electrostatic force of attraction is neutralised by the chemical composition of the particles, hence a minute overall attractive force is exhibited.	Large area of contact. The Electrostatic force of attraction is not neutralised by the chemical compositio of the particles, hence a large overall attractive force is exhibited

Cohesion (c) is a measurement of the electrostatic attraction between soil particles. (The larger the attraction, the larger the value of 'c').

In conclusion:-

Shearing Resistance =

Electrostatic Attraction + Physical Resistance to Movement

Sands (Diagram 'b') possess angular particles, hence they exhibit a minute electrostatic attraction (c) but a large physical resistance to movement (Ø).

Clays (Diagram 'c') possess flat particles, hence they exhibit a large electrostatic attraction (c) but a minute physical resistance to movement (Ø).

Coefficient of Active Earth Pressure (K_A)

This is a measurement of the component of vertical pressure which is transmitted in a horizontal direction.

It is dependant upon the Angle of Internal Friction (Ø) in cohesionless soils, and is given by

$$K_A = \frac{(1 - \sin \emptyset)}{(1 + \sin \emptyset)}$$

In cohesive soils it is dependant upon the soil density (γ), the value of the cohesion (c) and the depth of excavation (D) in the form

$$K_A = 1 - \frac{4C}{\gamma D}$$

Structural Members

Walers

They are steel members, placed horizontally parralled to the vertical centre line of the trench. It supports the trench sheets which in turn support the strata. The walers are supported by trench struts. (See Figure .10.)

Struts

They are timber members, placed horizontally and at right angles to the vertical centre line of the trench. The struts are subjected to compressive stresses induced by the transmition of load from the strata through the waters. (See Figure.10.)

Trench Sheets

They are corrugated steel members, approximately 0.33 m wide. The trench sheets are placed vertically in direct contact with the fact of the strata being supported. (See Figure.10.)

2.2 The Apparent Earth Pressure

Three types of strata are considered in this section. Formulae are presented which will permit the user to calculate the magnitude of the Apparent Earth Pressure (Ap) imposed on the trench support structure.

2.2.1 Excavation in Sand

The value of the Apparent Earth Pressure (Ap) can be shown[2] to approximate to

$$Ap = \frac{6.3743.K_A.\gamma.D}{1000} \quad K_N/M^2$$

where:-

K_A = Coefficient of Active Earth Pressure

$K_A = (1-\sin\emptyset)/(1+\sin\emptyset)$

γ = Unit weight of the strata in Kg/M^3.

D = Depth of Excavation in M

$\emptyset$ = Angle of Internal Friction in Degrees.

2.2.2 Excavation in Soft to Medium Clay

It can be shown(2) that

$$Ap = \frac{9.8066.K_A.\gamma.D}{1000} \quad K_N/M^2$$

where:-

$$K_A = 1 - \frac{4C}{D}$$

$$C = \text{Cohesion in } kg/M^2$$

2.2.3 Excavation in Stiff Fissured Clay

It can be shown(2) that

$$Ap = \frac{3.922.\gamma.D}{1000} \quad KN/M^2$$

The distribution of earth pressure varies both with the depth of excavation and the type of strata. For design purposes, the distribution is generally assumed to be rectangular, trapezoidal or a combination of both. All assumptions use the maximum Apparent Earth Pressure (Ap) as their prime ordinate. Thus the assumed distributions yield conservative results.

To simplify the calculations necessary later in this section, two initial assumptions are made.

(a) The Apparent Earth Pressure distributions for the three types of strata mentioned (in 2.21, 2.22 and 2.23) are similar in form.

(b) The pressure distributions are rectangular.

The relationship between the Coefficient of Active Earth Pressure (K_A) and the Angle of Internal Friction (Ø) given in 2.21, is shown graphically in Figure .7.

These graphs are presented in Figures .8. and .9. which should be used if detailed information about the strata is unknown. All three curves were derived assuming that the unit weight of the strata (γ) was constant at 2082.6 kg/ (130 lb/ft^3). A value which is high but commonly used.

If none of the variables (γ,Ø,C) are known.

Assume

γ = 2082.6 kg/M^3

Ø = 25^o

C = 1400 kg/M^2

and use Figures .8. or .9. to find the Apparent Earth Pressure (Ap). The result obtained will be an over estimate.

Some stratas will not fall into any of the categories mentioned earlier (in 2.21, 2.22 and 2.23). If this occurs, take the largest value of Apparent Earth Pressure (Ap), obtained from the two categories considered to be most representative of strata being studied.

If the strata falls into the 'Fissured Clay' category (2.23), use the curve marked 'A' in Figure .9. to determine the value of the Apparent Earth Pressure (Ap).

'Step by Step' Solution for the Apparent Earth Pressure (Ap)

Step 1

Establish the type of strata. If it does not fall into any of the three categories mentioned in 2.21, 2.22 and 2.23, select two categories which may apply.

Step 2

If the values of 'γ', 'ϕ' and 'C' are known, use the relevant formulae to calculate 'Ap'. Take the largest value if two formulae are used.

Step 3

If any of the values are unknown, assume

γ = 2082.6 kg/M^3

ϕ = 25^o

C = 1400 kg/M^2

and use Figures .8. and/or .9. to determine the value of 'Ap'.

Example (1)

A trench is to be excavated in sand with an Internal Angle of Friction ϕ = 10^o. If the trench is to be 4.0 m deep, determine the value of the Apparent Earth Pressure 'Ap'.

Eg (1) Steps 1 to 3

From Figure .8. knowing ϕ = 10^o and D = 4.0 m

Ap = 27.50 K_N/M^2

NOTE: The unit weight γ must be assumed to be 2082.6 kg/M^3 as it is not given in the question.

Example (2) Two trenches are to be excavated in strata which has a Cohesion C = 1400 kg/M^2. The trenches are 3.0 m wide and 6.0 m deep respectively. What is the value of the Apparent Earth Pressure 'Ap'?

Eq (2) Steps 1 to 3

NOTE: The unit weight is unknown, therefore,it is assumed to be 2082.6 kg/M^3.

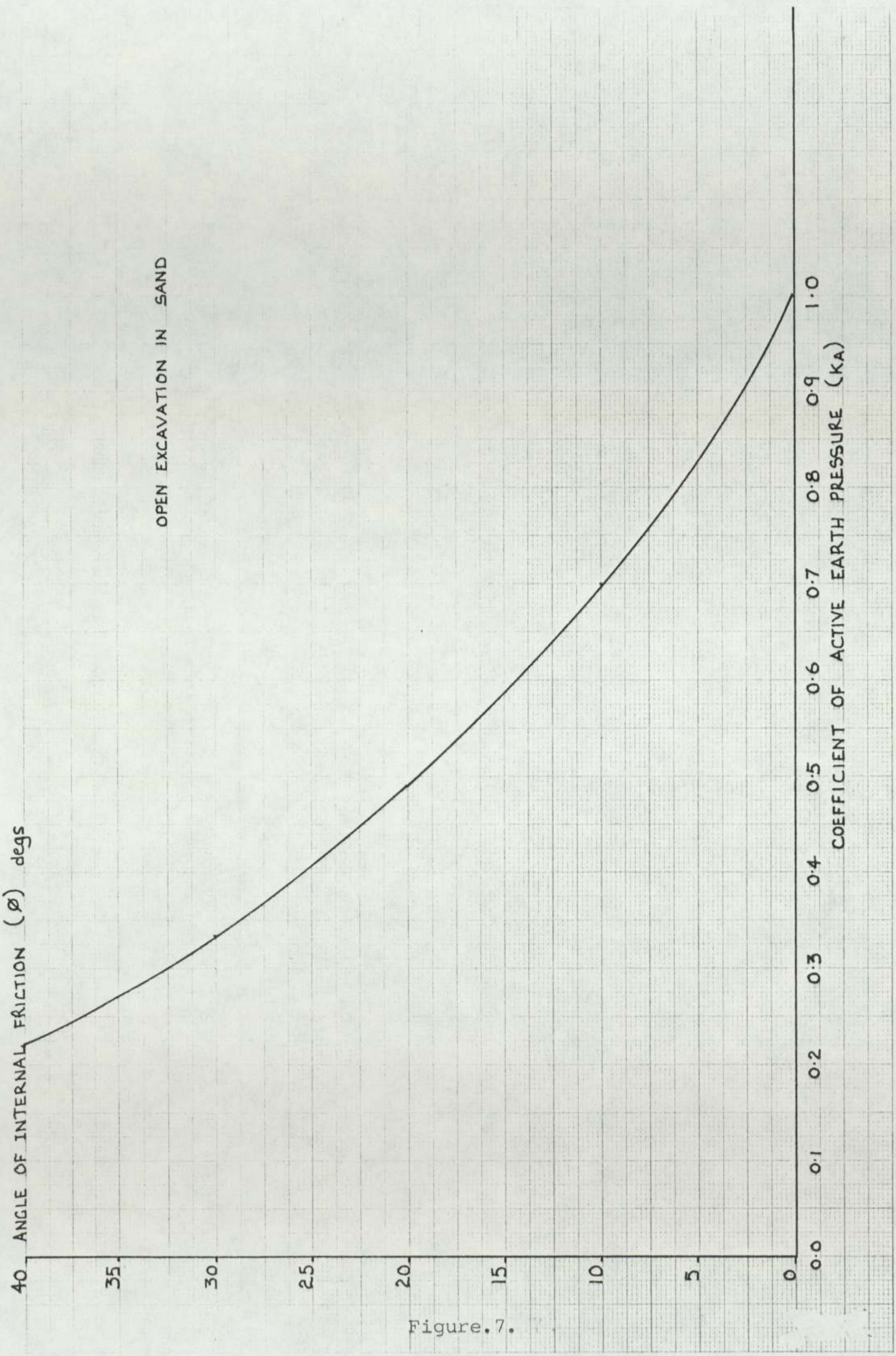
From Figure .9. knowing C = 1400 kg/M^2

Tranch (a) 3.0 m deep

Ap = 25 K_N/M^2

(b) 6.0 m deep

Ap = 67.5 K_N/M^2



ANGLE OF INTERNAL FRICTION (ø) degs
OPEN EXCAVATION IN SAND
COEFFICIENT OF ACTIVE EARTH PRESSURE (KA)
40
35
30
25
20
15
10
5
0
0·0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0

Figure.7.

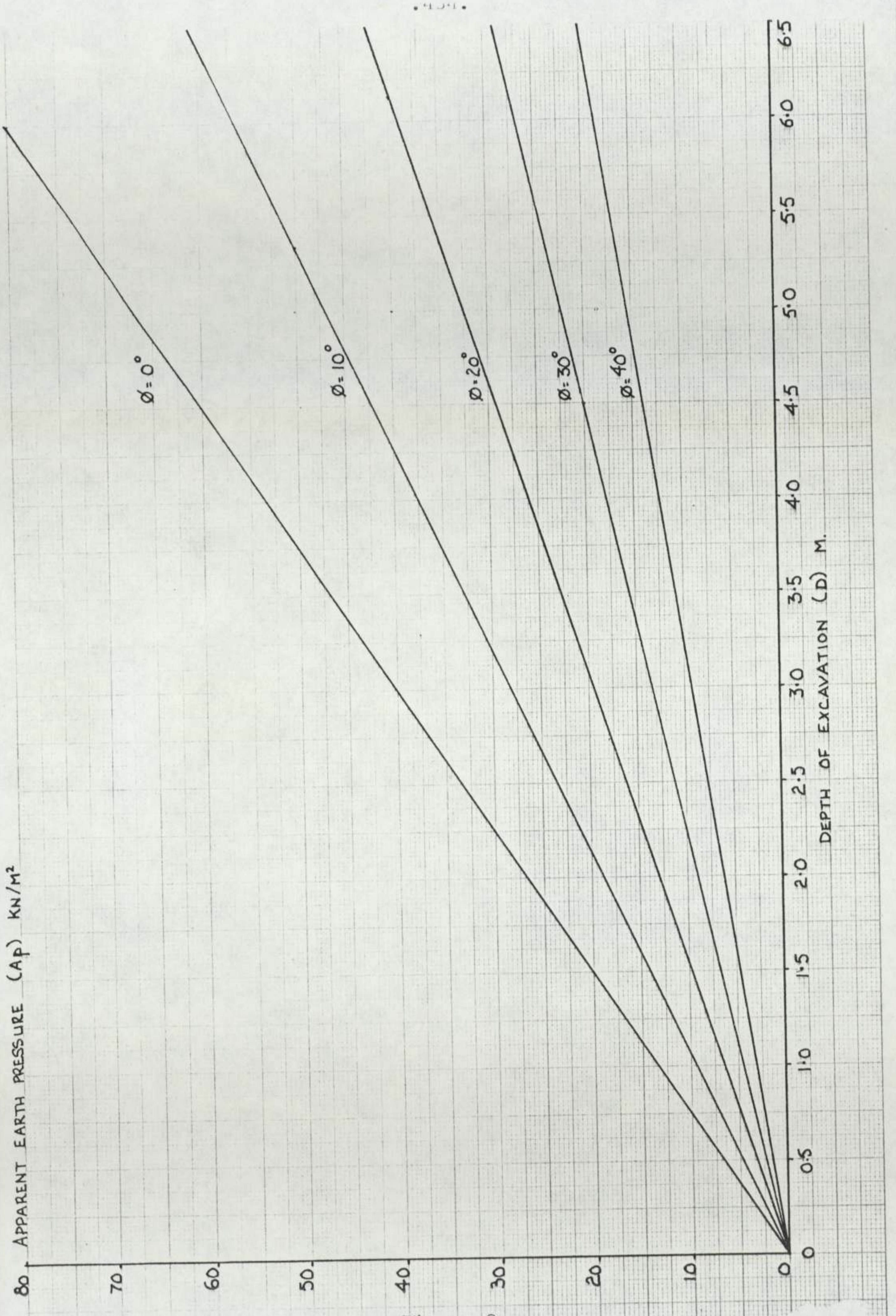

APPARENT EARTH PRESSURE (Ap) KN/M²
DEPTH OF EXCAVATION (D) M.
Ø=0°
Ø=10°
Ø=20°
Ø=30°
Ø=40°
80
70
60
50
40
30
20
10
0
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5

Figure.8.

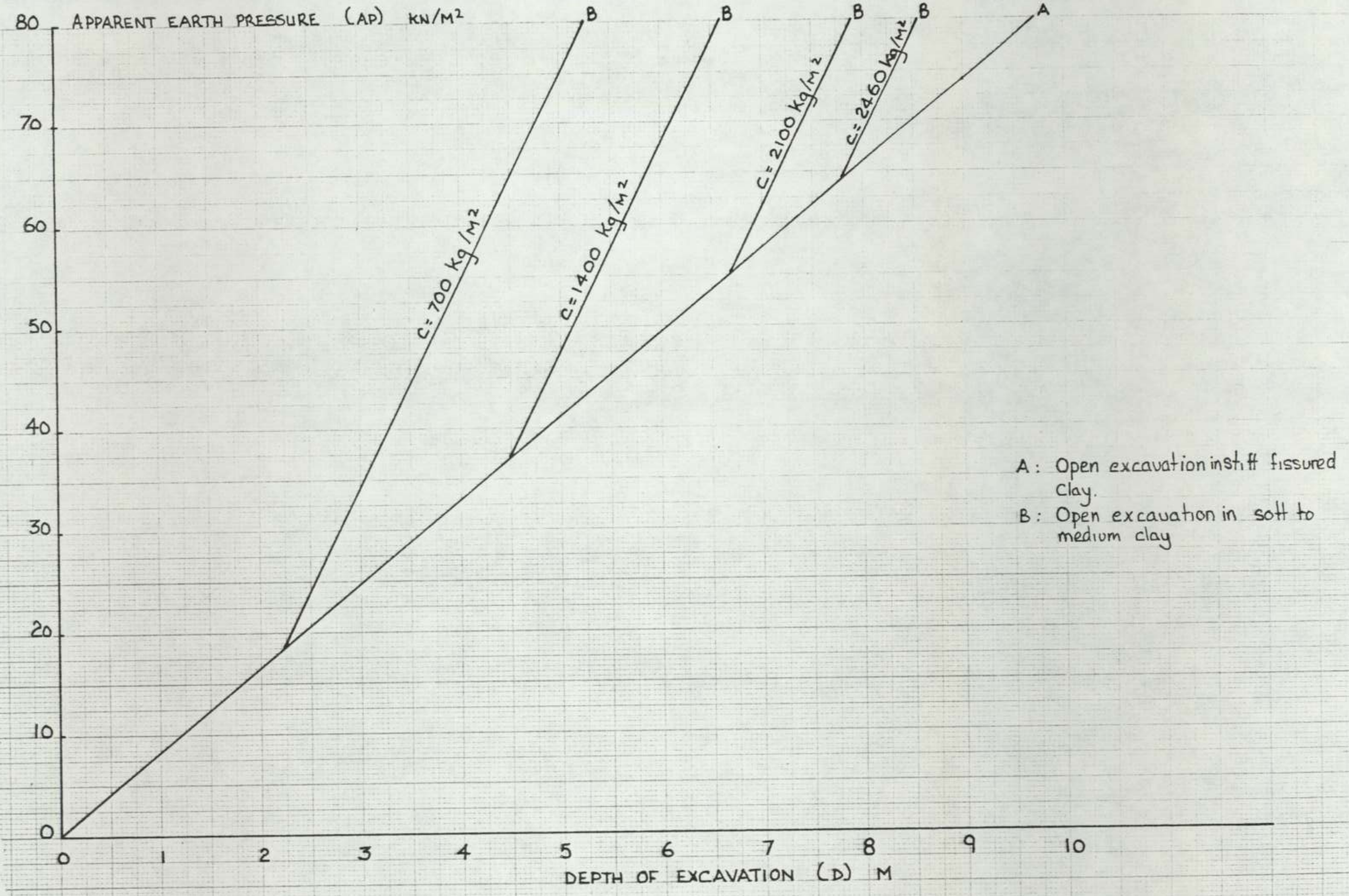

APPARENT EARTH PRESSURE (AP) KN/M2
80
70
60
50
40
30
20
10
0
DEPTH OF EXCAVATION (D) M
0
1
2
3
4
5
6
7
8
9
10
C= 700 Kg/M2
C=1400 Kg/M2
C= 2100 Kg/M2
C= 2460 Kg/M2
B
B
B
B
A
A : Open excavation instiff fissured clay.
B : Open excavation in soft to medium clay

Figure.9.

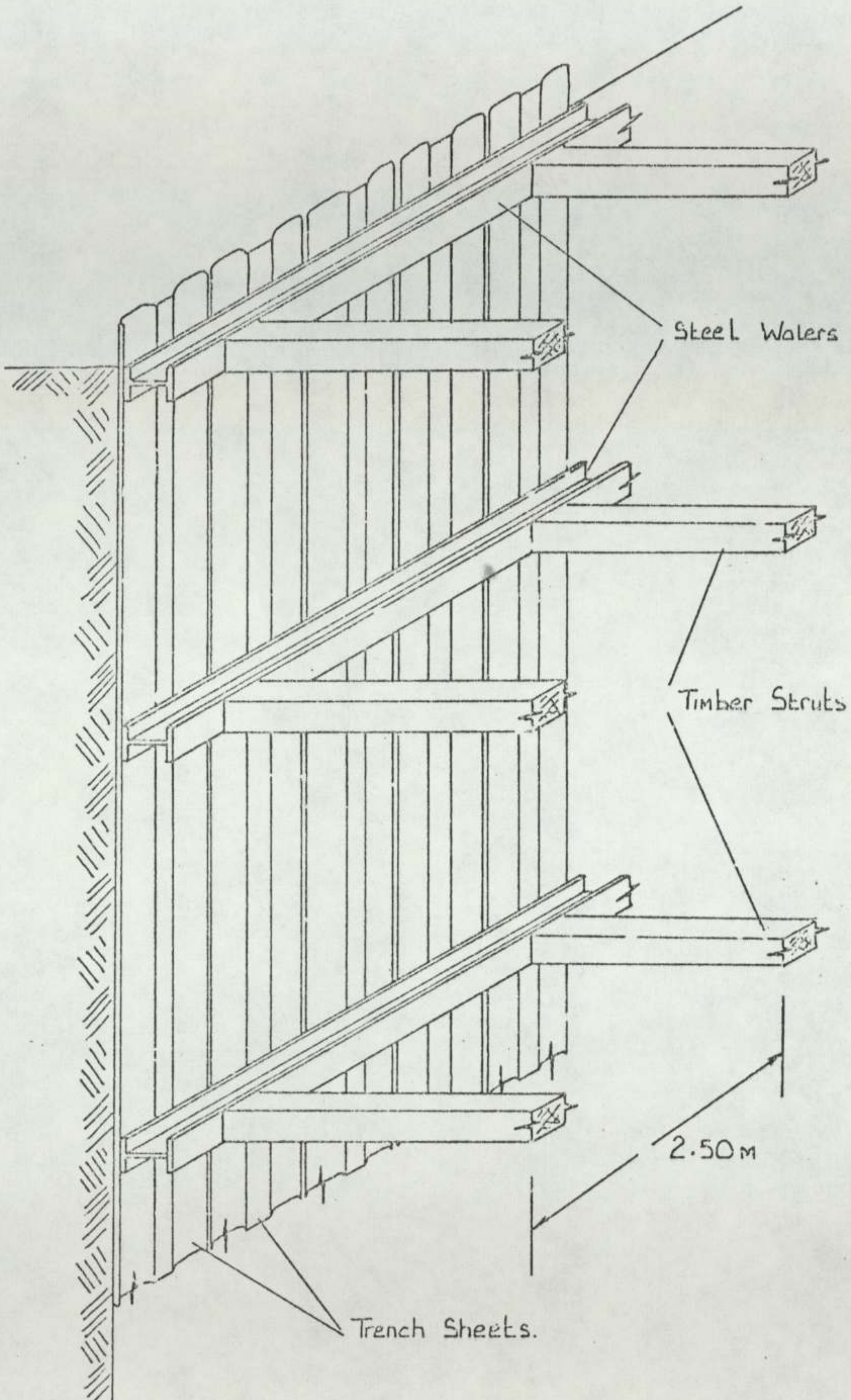


Figure.10.

2.3 Design of the Support Structure

The structural design of the support structure given in this section is for estimating and planning purposes only. The following equations have been developed to simplify the procedure:-

$$L = \frac{15.43}{\sqrt{Ap}} \quad (M)$$

$$LD \leq L \quad (M)$$

$$Zr \geq 4.734xApxLD \quad (CM^3)$$

$$B \geq 22.9833x\sqrt{Ap.LD} \geq 38.49.w \quad (MM)$$

Step by Step Solution

1. Determine the Apparent Earth Pressure 'Ap'.
2. Calculate the maximum permissible vertical waler spacing 'L' from

$$L = \frac{15.43}{\sqrt{Ap}}$$

3. Select a vertical waler spacing 'L_D'. It must be less than or equal to 'L'.
4. Calculate the required waler section modulus 'Zr' from

$$Zr = 4.734 \times Ap \times L_D \quad (CM^3)$$

5. Select the standard waler to be used from table. 6.

6. Calculate the breadth/width of the timber struts from

$$B = 22.9833 \times \sqrt{Ap \times L_D}$$

and

$$B = 38.49 \times W$$

the largest value of B must be used.

Example

1. Assume $Ap = \underline{27.5\ KN/M^2}$

<u>Depth = 4.0M</u> and <u>Width = 1.0M</u>

2. $L = \frac{15.43}{27.5} = \frac{15.43}{5.25}$

$\underline{L = 2.94\ M}$

3. $\underline{L_D = 2.0\ M}$

4. $Zr = 4.734 \times 27.5 \times 2.0$

$Zr = 260.37\ cm^3$

5. Selection Section <u>number 6</u>

Weight = 30.0 kg/m

6.

B = 22.9833 27.5 x 2.0

B = 22.9833 x 7.416 = <u>170.44M</u>

B = 38.49 x 1.0 = <u>38.49</u>

<u>Use 170.44 mm square timber struts</u>

2.3.1 Gang Size

(1) Trench Depth less than or equal to 3.0 m.
- 1 Banksman/Ganger
- 3 Labourers

(2) Trench Depth greater than 3.0 m.
- 1 Banksman
- 3 Labourers
- 1 Machine to assist

TABLE.6.

PERMISSIBLE STEEL WALER SECTIONS

SECTION NOTATION	SECTION SHAPE	SECTION WEIGHT kg/M	D (mm)	B (mm)	T (mm)	ELASTIC MODULUS (cm^3)
1	I	13.38	127	76	7.6	75.12
2	I	17.10	152	89	8.3	115.90
3	[	20.82	178	76	10.3	150.4
4	[	23.80	203	76	11.2	192.00
5	I	25.00	203	133	7.8	231.00
6	I	30.00	207	134	9.6	279.00
7	I	31.00	251	146	8.6	352.00
8	I	43.00	260	147	12.7	504.00
9	I	31.00	307	166	11.8	646.00

2.4 Erection Duration 'Step by Step' Procedure to find the Standard Construction Time

Step 1 Knowing the trench and strata date, design the trench support structure. Thus calculating

(a) Dimensions of struts 'b'

(b) Weight of waler per metre 'Wgt'

Select the length of the trench sheets 'Ls' in metres and calculate the total number of trench sheets, walers and timber struts per 2.5 m bay.

Step 2 Knowing the length of the trench sheets, use Figure .11. to determine 'T_{SH}' (the standard duration/trench sheet),multiply this by the number of trench sheets to be used.

Step 3 Knowing the dimensions of struts to be used, use Figure.12. to determine 'T_{st}' (the standard duration/strut), multiply this by the total number of struts.

Step 4 Knowing the weight of the walers to be used, use Figure .13.to determine 'Tw' (the standard duration/waler), multiply this by the total number of walers.

Step 5 Add the times obtained from Steps 2, 3 and 4 to obtain the total standard duration per 2.5 m bay (in minutes)

Step 6 Select the gang size to be employed from 2.3.1.

Example 1 A structure has been designed to support a trench 4.0 m deep and 1.5 m wide.

Use the following information to determine the standard duration and standard man hours per metre of a 2.5 m bay.

Weight of Waler (Wgt) = 20.82 kg/M

vertical strut/waler

Spacing = 2.0 m

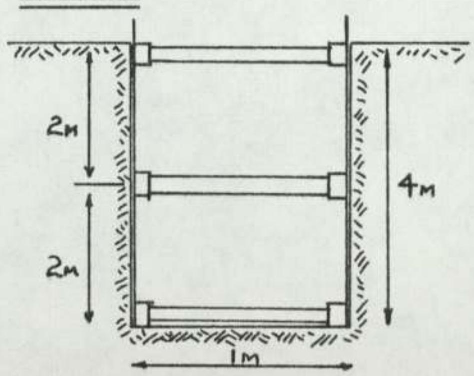
Width/Depth of timber

Struts (B) = 114 mm

Width of B.S.P. Type 5 trench sheets

= 0.33 m

Eg (1) Step 1 Let the length of the trench sheets 'Ls' = 4.33 m



Total number of trench sheets:-

$$\frac{2.5 \times 2.0}{0.33} = 14.7$$

Say 14

Total number of trench struts = 6

Total number of walers = 6

Eg (1) Step 2

From Figure .11. knowing Ls = 4.33 m

T_{SH} = 3.475 mins/sheet

Total duration = 3.475 x 14 = 48.65 mins

Eg (1) Step 3

From Figure .12. knowing W = 1.5 m and B = 114 mm

T_{st} = 4.25 mins/Strut

Total duration = 4.28 x 6 = 25.68 mins.

Eg (1) Step 4

From Figure .13. knowing Wgt = 20.82

Tw = 0.625 mins/Waler

Total duration = 0.625 x 6 = 3.75 mins.

Eg (1) Step 5

Total standard duration per 2.5 m bay = 48.65 + 25.68 + 3.75 = 78.08 min

Standard duration per metre =

$$78.08 = \frac{31.16}{2.50} \text{ mins}$$

= <u>0.5190 Standard Hours</u>

Eg (1) Step 6

From 2.3.1 the required gang size is:-

1 Banksman/Ganger

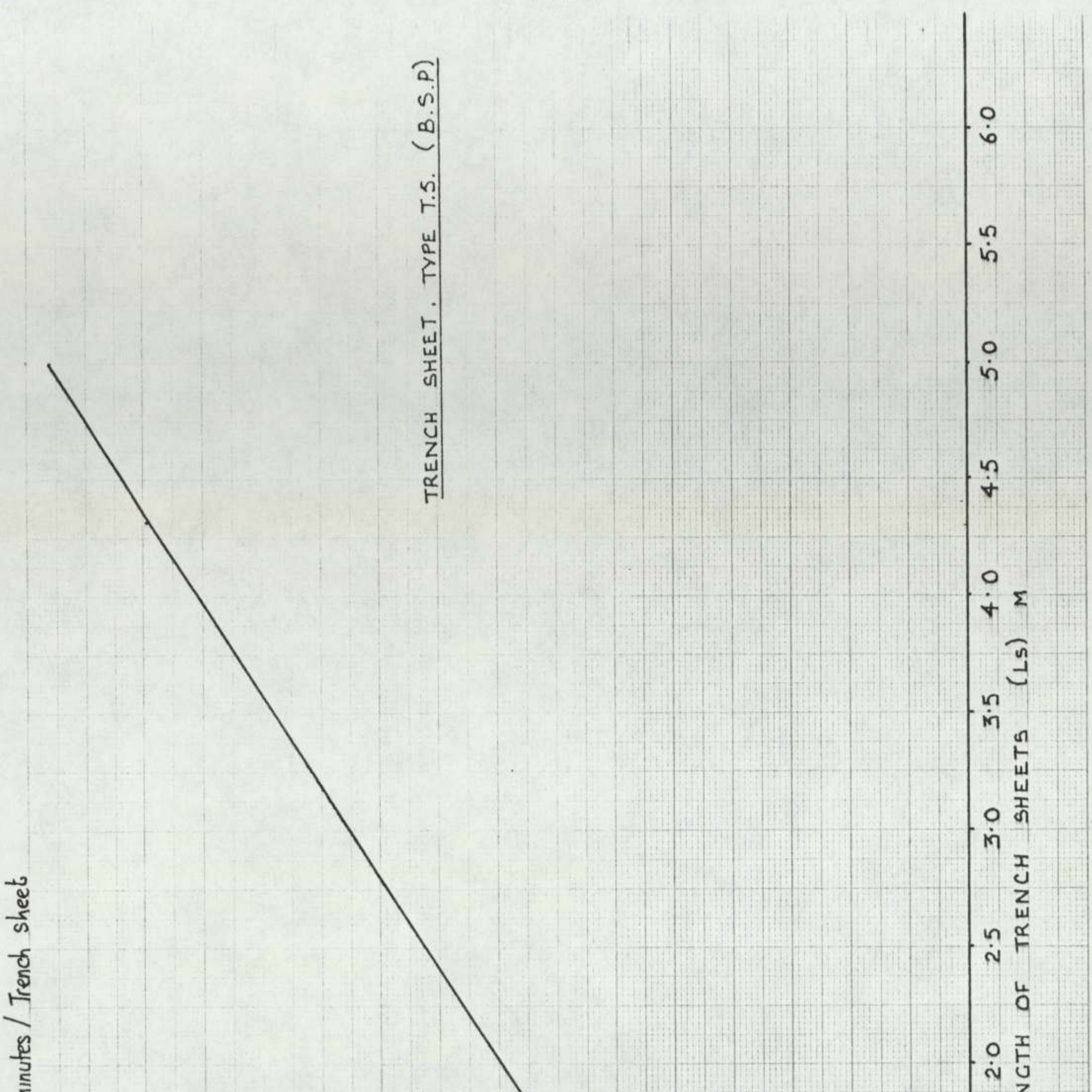
3 Labourers

1 Machine (on tracks) to assist plus driver

Total 5 men

Total standard man hours per metre

= <u>0.5190 x 5 = 2.5950 man hours</u>



TRENCH SHEET. TYPE T.S. (B.S.P)
STANDARD DURATION (TSH) minutes / Trench sheet
LENGTH OF TRENCH SHEETS (Ls) M
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0

Figure.11.

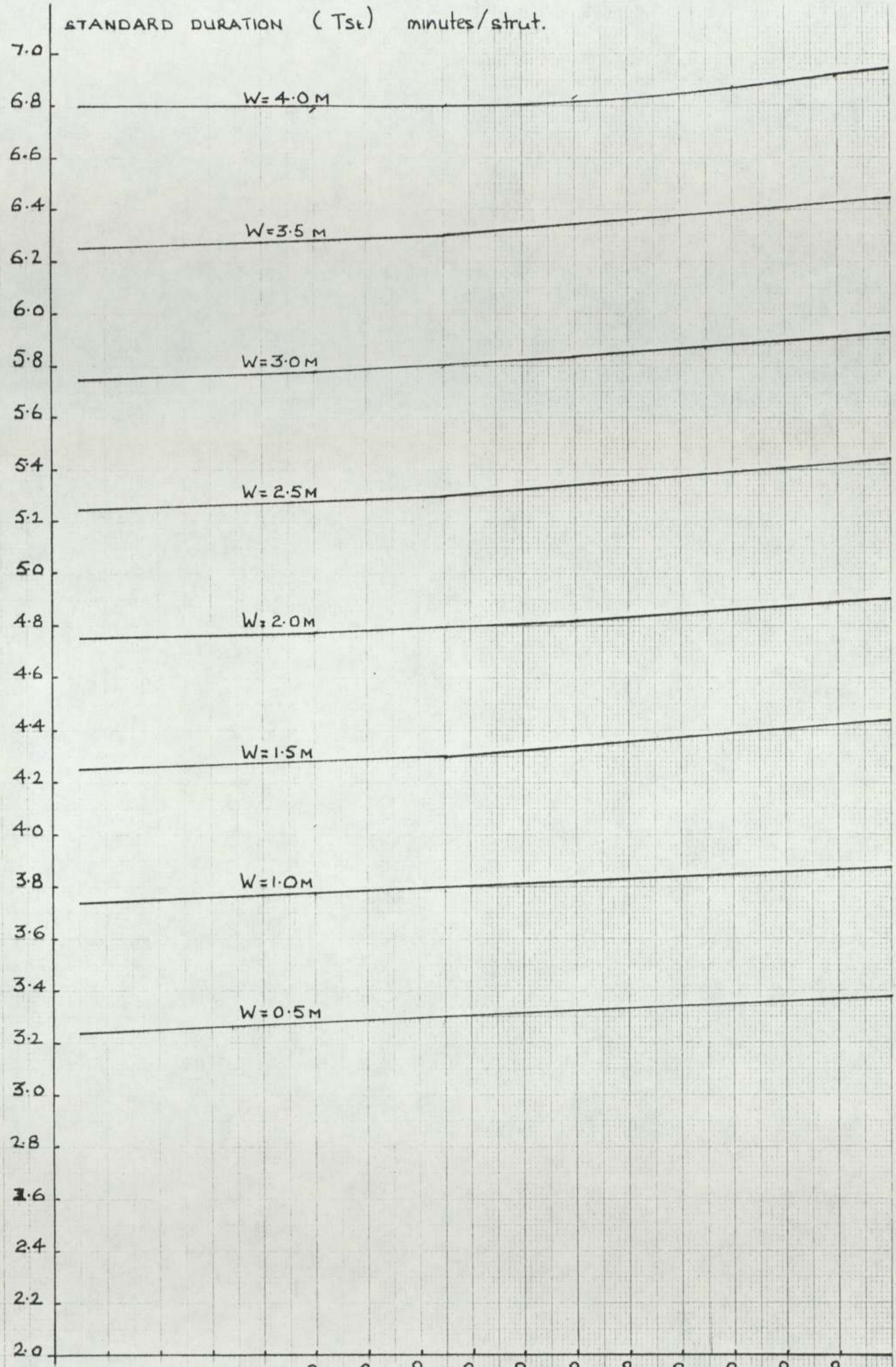

STANDARD DURATION (Tst) minutes/strut.
7.0
6.8
6.6
6.4
6.2
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
W=4.0M
W=3.5M
W=3.0M
W=2.5M
W=2.0M
W=1.5M
W=1.0M
W=0.5M
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
BREADTH/DEPTH OF TIMBER STRUTS (B) mm

Figure.12.

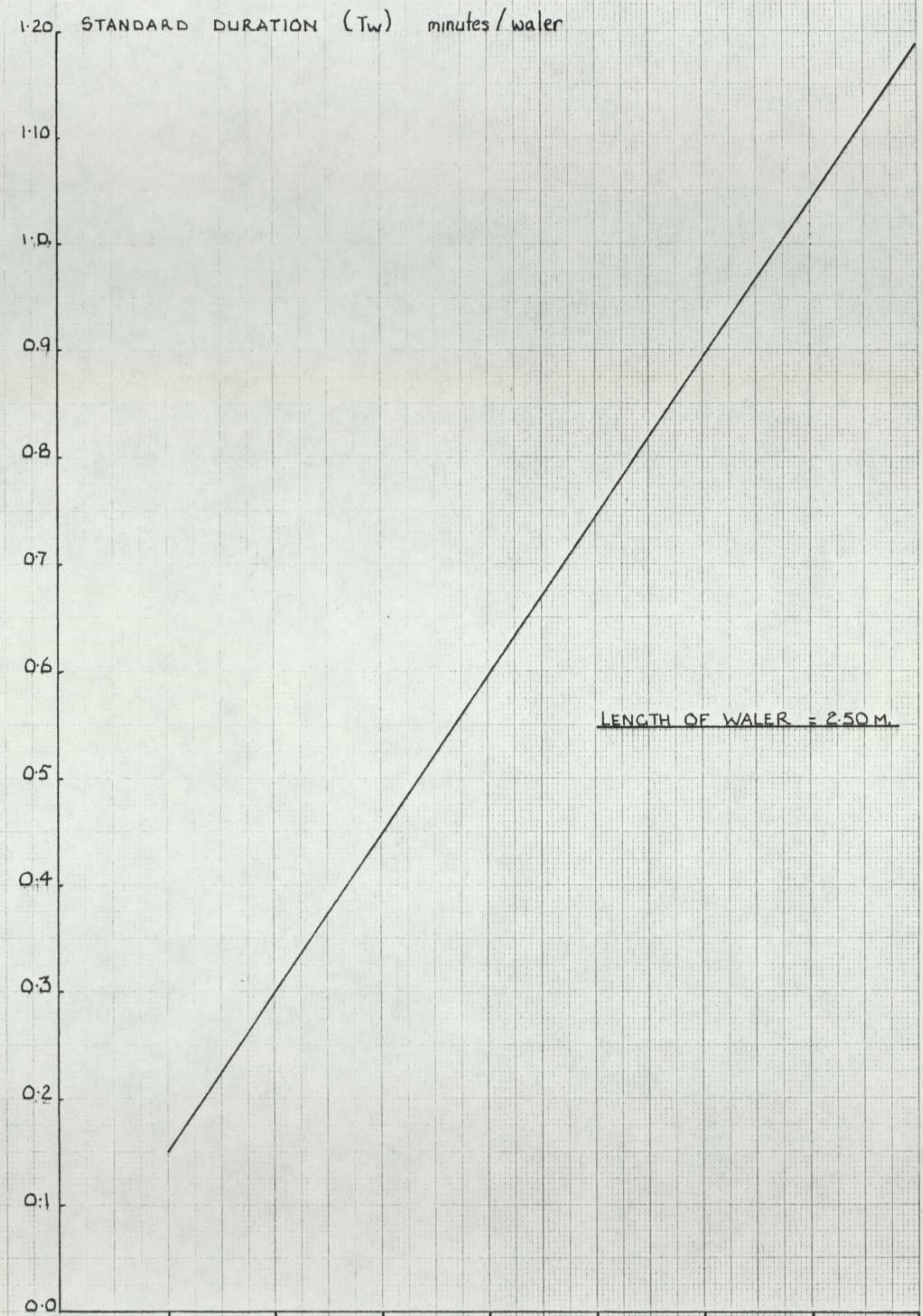

1·20
STANDARD DURATION (Tw) minutes / waler
1·10
1·0
0.9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0·0
LENGTH OF WALER = 2·50 M.
0
5
10
15
20
25
30
35
40
WIECHT PER UNIT LENGTH OF WALER (Wgt) Kg/m

Figure.13.

SECTION 3

PIPE LAYING

3.1 Operatives

The pipe laying operation comprises of 16 individual tasks, several of which require two or more operatives to work at the same time. The standard time and gang size for the pipe laying operation is given in Table 7. In some circumstances, the user may find it necessary to adjust the gang size and consequently the standard time allowed.

However, when considering gang size, use the following rules as a general base from which to start.

(a) If the pipe diameter is 300 mm or less, and the trench is less than or equal to 2.5 m in depth, the gang should contain:-

1 Surface Ganger

1 Pipe Layer

1 Labourer

(b) If the pipe diameter is 450 mm or less and the trench is less than or equal to 5.0 m in depth, the gang should contain:-

1 Surface Ganger

1 Pipelayer

1 Labourer

1 Excavator (on tracks) to assist

(c) If the pipe diameter is less than or equal to 2100 mm in diameter and the trench is less than or equal to 7.5 m in depth, the gang should contain:-

1 Surface Ganger

1 Pipe Layer

1 Labourer

1 Crane (on tracks) to assist

(See Figure 14 at the rear of this section).

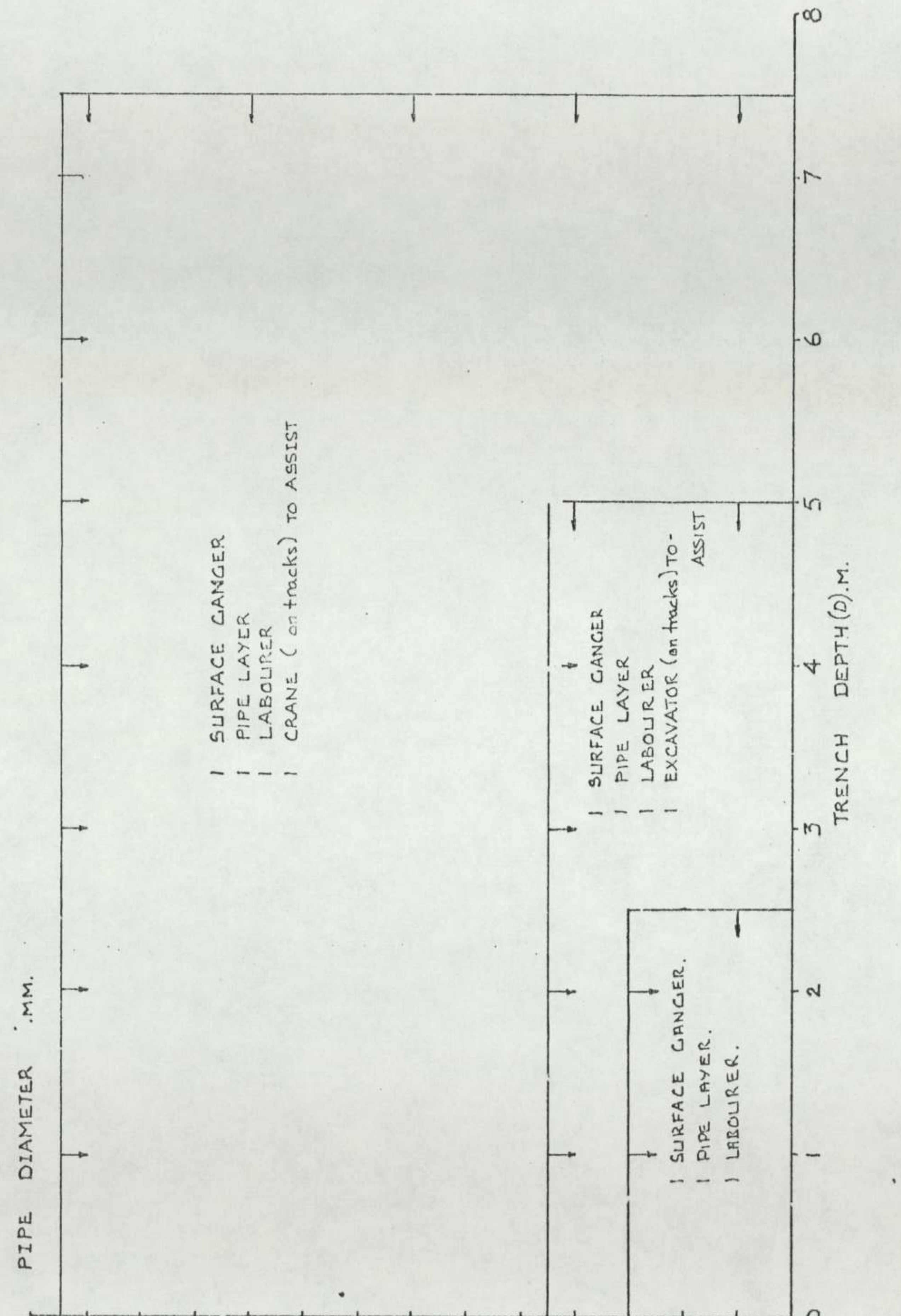

PIPE DIAMETER .MM.
2200
2000
1800
1600
1400
1200
1000
800
600
500
400
300
200
100
0
1 SURFACE GANGER
1 PIPE LAYER
1 LABOURER
1 CRANE (on tracks) TO ASSIST
1 SURFACE GANGER
1 PIPE LAYER
1 LABOURER
1 EXCAVATOR (on tracks) TO-ASSIST
1 SURFACE GANGER.
1 PIPE LAYER.
1 LABOURER.
0
1
2
3
4
5
6
7
8
TRENCH DEPTH (D).M.

Figure.14.

3.2 Pipe Laying Duration

Basic minute data was compiled from studies made on site(1). The data was then adjusted by applying Relaxation and Contingency Allowances of 18% and 3% respectively.

Table.7.(overleaf) shows the final standard time data. It must be used in conjunction with the gangs and pipe details given.

TABLE .7.

STANDARD TIME DATA FOR PIPE LAYING ONLY

Diameter (mm)	Length (m)	Depth 0 -3m Ex	Cr	Lbr	Depth 3 - 5 m Ex	Cr	Lbr	Depth Above 5m Ex	Cr	Lbr	Std.Duration (min) per pipe	per metre		
100	1.83			3	1		3		1	3	9.2		5.0	
150	1.83			3	1		3		1	3	12.3		6.7	
225	1.83			3	1		3		1	3	15.0		8.2	
300	1.83			3	1		3		1	3	20.5		11.2	
375	1.83	1		3	1		3		1	3	24.0		13.1	
450	1.83 2.44	1		3	1		3		1	3	27.4		15.0	11.2
525	1.83 2.44	1		3		1	3		1	3	30.3		16.6	12.4
600	1.83 2.44		1	3		1	3		1	3	33.0		18.0	13.5
675	1.83 2.44		1	3		1	3		1	3	35.4		19.3	14.5
750	1.83 2.44		1	3		1	3		1	3	27.4		20.4	15.3
825	1.83 2.44		1	3		1	3		1	3	40.0		21.9	16.4
900	1.83 2.44		1	3		1	3		1	3	42.7		23.3	17.5
975	1.83 2.44		1	3		1	3		1	3	45.4		24.8	18.6
1050	1.83 2.44		1	3		1	3		1	3	48.1		26.3	19.7
1125	1.83 2.44		1	3		1	3		1	3	50.7		27.7	20.8
1200	1.83 2.44		1	3		1	3		1	3	53.0		29.0	21.7
1275	1.83 2.44		1	3		1	3		1	3	55.5		30.3	22.7
1350	1.83 2.44		1	3		1	3		1	3	58.0		31.7	23.8
1425	1.83 2.44		1	3		1	3		1	3	60.5		33.1	24.8
1500	1.83 2.44		1	3		1	3		1	3	63.0		34.4	25.8
1575	1.83 2.44		1	3		1	3		1	3	65.6		35.8	26.9
1650	1.83 2.44		1	3		1	3		1	3	68.0		37.2	27.9
1725	1.83 2.44		1	3		1	3		1	3	70.3		38.4	28.8
1800	1.22 1.83 2.44		1	3		1	3		1	3	72.5	59.4	39.6	29.7
1875	1.22 1.83 2.44		1	3		1	3		1	3	74.5	61.1	40.7	30.5
1950	1.22 1.83 2.44		1	3		1	3		1	3	76.5	62.7	41.8	31.4
2025	1.22 1.83 2.44		1	3		1	3		1	3	78.2	64.1	42.7	32.1
2100	1.22 1.83 2.44		1	3		1	3		1	3	80.0	65.6	43.7	32.8

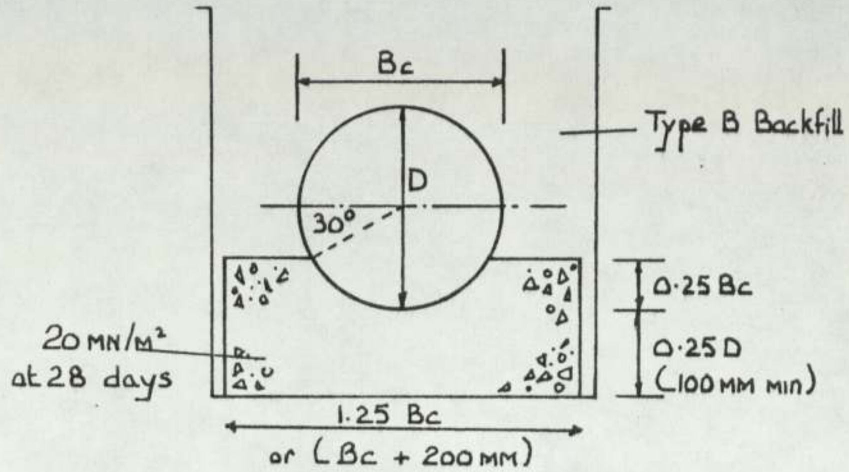
SECTION 4

THE PIPE BEDDING STRUCTURE

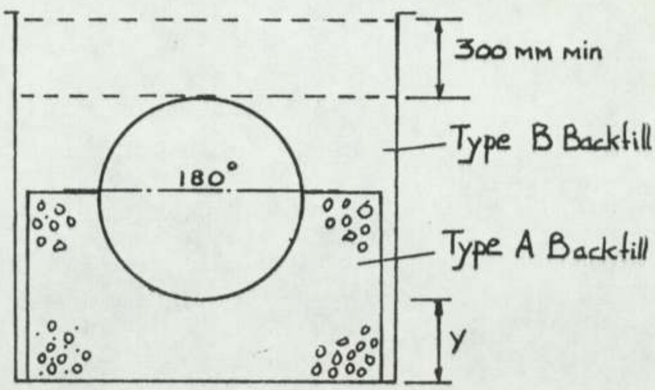
4.1 Standard Bedding Structures

Three main bedding conditions are recommended and commonly used by engineers as a basis for their designs. They are:-

Type A (Concrete Structure)

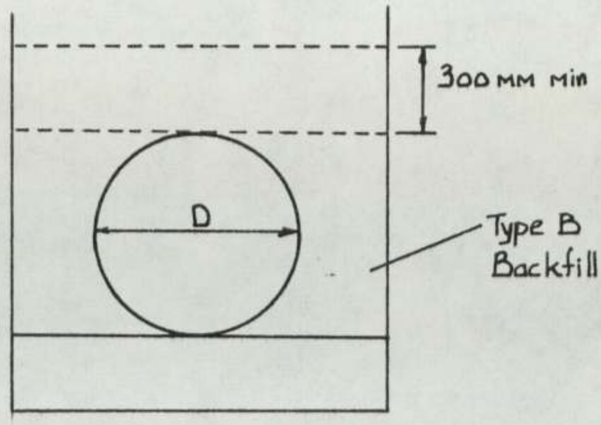


Type B (Granular Structure)



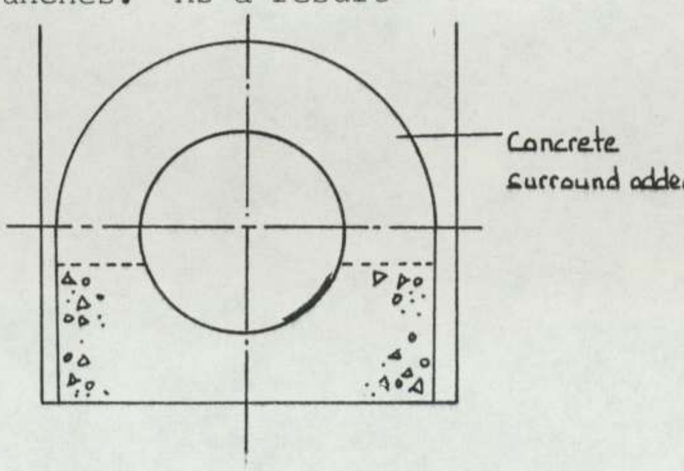
Where 'y' in average conditions is not to be less than 100 mm with not less than 50 mm under the sockets. In very soft and wet conditions where the trench bottom is very irregular and where there are areas of rock, it should be at lease 200 mm under the barrels and sockets.

Type C (Selected Backfill Structure)



Where Type A backfill is broken stone or gravel, 10 mm nominal size as specified in Table 1 BS 882, 1201: 1965. Type B backfill is to be selected fill free from large stones, tree roots, vegetable matter and large lumps of clay (over 75mm). It should be compacted in 100 mm layers.

The three main bedding structures indicate the general form of the structures and give minimum dimensions. Many engineers extend the recommended bedding structure to include surrounds and haunches. As a result



of this, the overall bedding structures' dimensions differ from design to design.

A contractor receives work from many different designers, consequently constant recalculation of the bedding structure volumes is necessary.

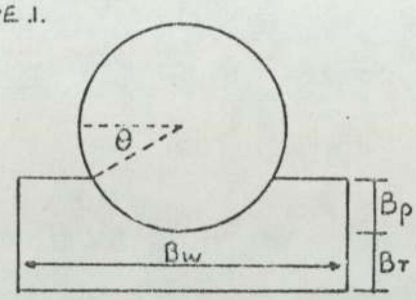
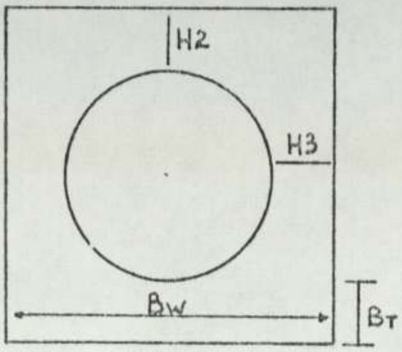
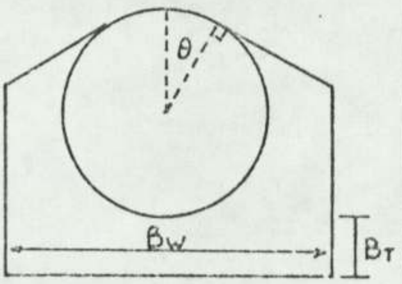
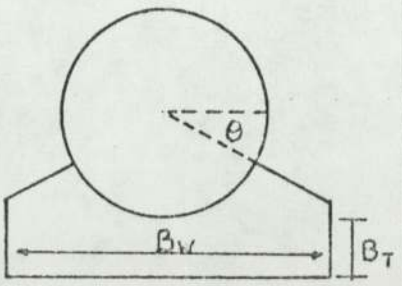
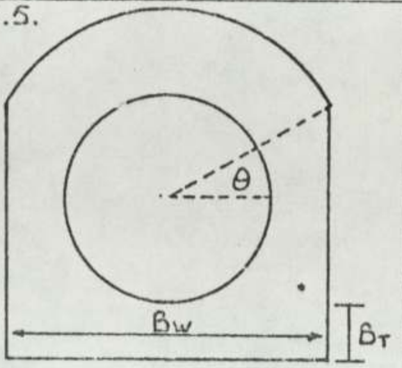
Eight different bedding structures are presented in Table .8. It was compiled using the most commonly occurring dimensions used by various designers.

Tables.9. to.16. use the dimensions shown in Table .8. to give the volume of bedding material per linear metre of pipe[1].

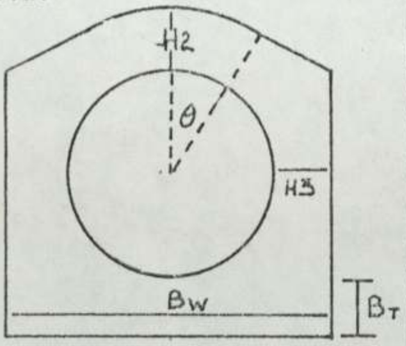
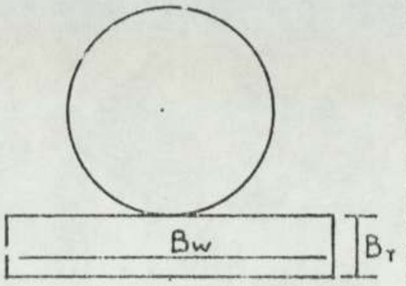
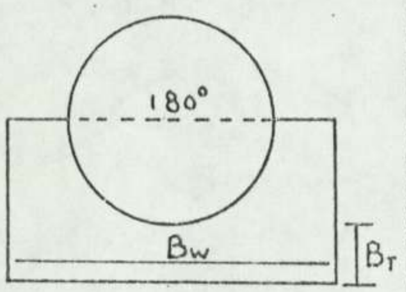
The pipe wall thicknesses shown in Tables.9. to.16. are mean values derived from several sets of manufacturers' data. A separate summary of these is shown in Table .17.

TABLE. 8.

STANDARD BEDDING STRUCTURES

TYPE	STANDARD DIMENSIONS
	D = Internal diameter of pipe Bc = External diameter of pipe
TYPE .1. 	Bp = 0.25 Bc BT = 0.25 D (100 MM min) BW = 1.25 Bc or Bc + 200 MM (whichever is greater) $\theta = 30°$
TYPE. 2. 	H3 = (BW - Bc)/2.0 H2 = H3 BT = 0.25 D (100 MM min) BW = 1.25 Bc or Bc + 200 MM
TYPE .3. 	BT = 0.25 D (100 MM min) BW = 1.25 Bc or Bc + 200 MM $\theta = 30°$
TYPE. 4. 	BT = 0.25 D (100 MM min) BW = 1.25 Bc or Bc + 200 MM $\theta = 30°$
TYPE .5. 	BT = 0.25 D (100 mm min) BW = 1.25 Bc or Bc + 200 MM $\theta = 30°$

continued overleaf.

TYPE .6. 	$H3 = (Bw - Bc)/2.0$ $H2 = H3$ $B_T = 0.25D$ (100MM MIN) $B_W = 1.25\ Bc$ or $Bc + 200$ mm $\theta = 30°$
TYPE .7. 	$B_T = 0.25D$ (100 mm min) $B_W = 1.25\ Bc$ or $Bc + 200$ mm
TYPE .8. 	$B_T = 0.25D$ (100 mm min) $B_W = 1.25\ Bc$ or $Bc + 200$ mm.

D INTERNAL DIAMETER (MM)	T WALL THICKNESS (MM)	BW BED WIDTH (MM)	BT BED THICKNESS (MM)	HI (MM)	H2 (MM)	H3 (MM)	THETA (DEG)	VOLUME OF BEDDING MATERIAL FOR CONSTRUCTION TYPE.1. (M3/M LIN)
100.	26.	352.	100.	138.	0.	100.	30.	0.0450
150.	26.	402.	100.	150.	0.	100.	30.	0.0542
225.	30.	485.	100.	171.	0.	100.	30.	0.0706
300.	34.	568.	100.	192.	0.	100.	30.	0.0883
375.	38.	651.	100.	213.	0.	100.	30.	0.1073
450.	41.	732.	112.	245.	0.	100.	30.	0.1362
525.	48.	821.	131.	287.	0.	100.	30.	0.1760
600.	52.	904.	150.	326.	0.	100.	30.	0.2186
675.	56.	987.	169.	365.	0.	100.	30.	0.2656
750.	60.	1087.	188.	405.	0.	109.	30.	0.3242
825.	64.	1191.	206.	445.	0.	119.	30.	0.3900
900.	67.	1292.	225.	484.	0.	129.	30.	0.4607
975.	71.	1396.	244.	523.	0.	140.	30.	0.5386
1050.	78.	1507.	263.	564.	0.	151.	30.	0.6269
1125.	82.	1611.	281.	603.	0.	161.	30.	0.7172
1200.	86.	1715.	300.	643.	0.	171.	30.	0.8136
1275.	86.	1809.	319.	681.	0.	181.	30.	0.9093
1350.	93.	1920.	337.	722.	0.	192.	30.	1.0229
1425.	97.	2024.	356.	761.	0.	202.	30.	1.1375
1500.	101.	2127.	375.	801.	0.	213.	30.	1.2582
1575.	114.	2254.	394.	845.	0.	225.	30.	1.4040
1650.	115.	2350.	412.	883.	0.	235.	30.	1.5311
1725.	115.	2444.	431.	920.	0.	244.	30.	1.6613
1800.	116.	2540.	450.	958.	0.	254.	30.	1.7992
1875.	123.	2651.	469.	999.	0.	265.	30.	1.9577
1950.	130.	2762.	487.	1040.	0.	276.	30.	2.1229
2025.	137.	2874.	506.	1081.	0.	287.	30.	2.2948
2100.	144.	2985.	525.	1122.	0.	299.	30.	2.4734
2175.	151.	3096.	544.	1163.	0.	310.	30.	2.6586

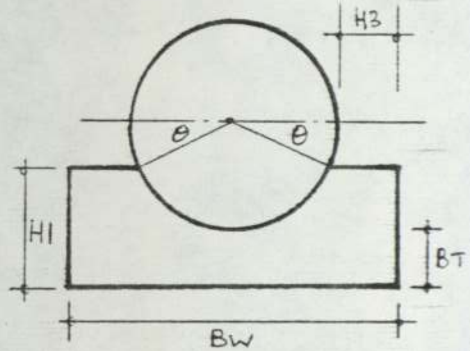


Table.9.

D INTERNAL DIAMETER (MM)	T WALL THICKNESS (MM)	BW BED WIDTH (MM)	BT BED THICKNESS (MM)	H1 (MM)	H2 (MM)	H3 (MM)	THETA (DEG)	* VOLUME OF BEDDING MATERIAL FOR CONSTRUCTION TYPE.2. (M3/M LIN)
100.	26.	352.	100.	100.	100.	100.	0.	* 0.1058
150.	26.	402.	100.	100.	100.	100.	0.	* 0.1296
225.	30.	485.	100.	100.	100.	100.	0.	* 0.1714
300.	34.	568.	100.	100.	100.	100.	0.	* 0.2162
375.	38.	651.	100.	100.	100.	100.	0.	* 0.2640
450.	41.	732.	112.	112.	100.	100.	0.	* 0.3227
525.	48.	821.	131.	131.	100.	100.	0.	* 0.3968
600.	52.	904.	150.	150.	100.	100.	0.	* 0.4731
675.	56.	987.	169.	169.	100.	100.	0.	* 0.5555
750.	60.	1087.	188.	188.	109.	109.	0.	* 0.6738
825.	64.	1191.	206.	206.	119.	119.	0.	* 0.8095
900.	67.	1292.	225.	225.	129.	129.	0.	* 0.9545
975.	71.	1396.	244.	244.	140.	140.	0.	* 1.1148
1050.	78.	1507.	263.	263.	151.	151.	0.	* 1.2986
1125.	82.	1611.	281.	281.	161.	161.	0.	* 1.4846
1200.	86.	1715.	300.	300.	171.	171.	0.	* 1.6830
1275.	86.	1809.	319.	319.	181.	181.	0.	* 1.8763
1350.	93.	1920.	337.	337.	192.	192.	0.	* 2.1125
1425.	97.	2024.	356.	356.	202.	202.	0.	* 2.3480
1500.	101.	2127.	375.	375.	213.	213.	0.	* 2.5960
1575.	114.	2254.	394.	394.	225.	225.	0.	* 2.9054
1650.	115.	2350.	412.	412.	235.	235.	0.	* 3.1634
1725.	115.	2444.	431.	431.	244.	244.	0.	* 3.4264
1800.	116.	2540.	450.	450.	254.	254.	0.	* 3.7061
1875.	123.	2651.	469.	469.	265.	265.	0.	* 4.0353
1950.	130.	2762.	487.	487.	276.	276.	0.	* 4.3785
2025.	137.	2874.	506.	506.	287.	287.	0.	* 4.7357
2100.	144.	2985.	525.	525.	299.	299.	0.	* 5.1070
2175.	151.	3096.	544.	544.	310.	310.	0.	* 5.4922

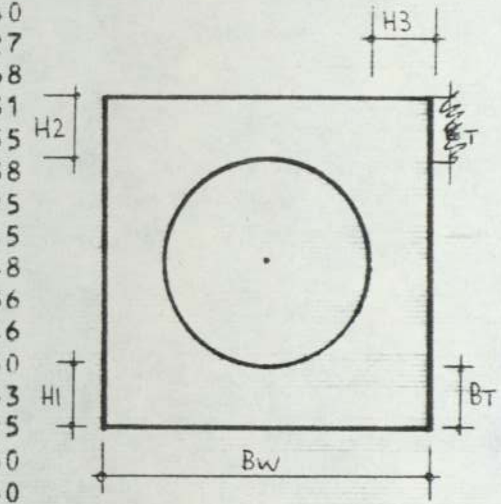


Table.10.

D INTERNAL DIAMETER (MM)	T WALL THICKNESS (MM)	BW BED WIDTH (MM)	BT BED THICKNESS (MM)	H1 (MM)	H2 (MM)	H3 (MM)	THETA (DEG)	*	VOLUME OF BEDDING MATERIAL FOR CONSTRUCTION TYPE.3. (M3/M LIN)
100.	26.	352.	100.	100.	0.	100.	30.	*	0.0565
150.	26.	402.	100.	100.	0.	100.	30.	*	0.0718
225.	30.	485.	100.	100.	0.	100.	30.	*	0.0986
300.	34.	568.	100.	100.	0.	100.	30.	*	0.1272
375.	38.	651.	100.	100.	0.	100.	30.	*	0.1577
450.	41.	732.	112.	112.	0.	100.	30.	*	0.1984
525.	48.	821.	131.	131.	0.	100.	30.	*	0.2516
600.	52.	904.	150.	150.	0.	100.	30.	*	0.3073
675.	56.	987.	169.	169.	0.	100.	30.	*	0.3680
750.	60.	1087.	188.	188.	0.	109.	30.	*	0.4478
825.	64.	1191.	206.	206.	0.	119.	30.	*	0.5384
900.	67.	1292.	225.	225.	0.	129.	30.	*	0.6353
975.	71.	1396.	244.	244.	0.	140.	30.	*	0.7424
1050.	78.	1507.	263.	263.	0.	151.	30.	*	0.8644
1125.	82.	1611.	281.	281.	0.	161.	30.	*	0.9886
1200.	86.	1715.	300.	300.	0.	171.	30.	*	1.1211
1275.	86.	1809.	319.	319.	0.	181.	30.	*	1.2512
1350.	93.	1920.	337.	337.	0.	192.	30.	*	1.4083
1425.	97.	2024.	356.	356.	0.	202.	30.	*	1.5656
1500.	101.	2127.	375.	375.	0.	213.	30.	*	1.7313
1575.	114.	2254.	394.	394.	0.	225.	30.	*	1.9350
1650.	115.	2350.	412.	412.	0.	235.	30.	*	2.1083
1725.	115.	2444.	431.	431.	0.	244.	30.	*	2.2855
1800.	116.	2540.	450.	450.	0.	254.	30.	*	2.4735
1875.	123.	2651.	469.	469.	0.	265.	30.	*	2.6924
1950.	130.	2762.	487.	487.	0.	276.	30.	*	2.9206
2025.	137.	2874.	506.	506.	0.	287.	30.	*	3.1580
2100.	144.	2985.	525.	525.	0.	299.	30.	*	3.4047
2175.	151.	3096.	544.	544.	0.	310.	30.	*	3.6607

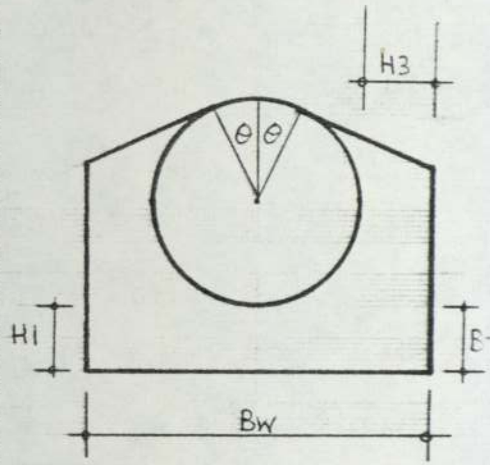


Table.11.

D	T	BW	BT					
INTERNAL DIAMETER (MM)	WALL THICKNESS (MM)	BED WIDTH (MM)	BED THICKNESS (MM)	H1 (MM)	H2 (MM)	H3 (MM)	THETA (DEG)	VOLUME OF BEDDING MATERIAL FOR CONSTRUCTION TYPE.4. (M3/M LIN)
100.	26.	352.	100.	100.	0.	100.	30.	0.0380
150.	26.	402.	100.	100.	0.	100.	30.	0.0468
225.	30.	485.	100.	100.	0.	100.	30.	0.0624
300.	34.	568.	100.	100.	0.	100.	30.	0.0793
375.	38.	651.	100.	100.	0.	100.	30.	0.0975
450.	41.	732.	112.	112.	0.	100.	30.	0.1256
525.	48.	821.	131.	131.	0.	100.	30.	0.1644
600.	52.	904.	150.	150.	0.	100.	30.	0.2061
675.	56.	987.	169.	169.	0.	100.	30.	0.2522
750.	60.	1087.	188.	188.	0.	109.	30.	0.3081
825.	64.	1191.	206.	206.	0.	119.	30.	0.3707
900.	67.	1292.	225.	225.	0.	129.	30.	0.4380
975.	71.	1396.	244.	244.	0.	140.	30.	0.5121
1050.	78.	1507.	263.	263.	0.	151.	30.	0.5959
1125.	82.	1611.	281.	281.	0.	161.	30.	0.6819
1200.	86.	1715.	300.	300.	0.	171.	30.	0.7736
1275.	86.	1809.	319.	319.	0.	181.	30.	0.8647
1350.	93.	1920.	337.	337.	0.	192.	30.	0.9727
1425.	97.	2024.	356.	356.	0.	202.	30.	1.0817
1500.	101.	2127.	375.	375.	0.	213.	30.	1.1965
1575.	114.	2254.	394.	394.	0.	225.	30.	1.3349
1650.	115.	2350.	412.	412.	0.	235.	30.	1.4558
1725.	115.	2444.	431.	431.	0.	244.	30.	1.5799
1800.	116.	2540.	450.	450.	0.	254.	30.	1.7113
1875.	123.	2651.	469.	469.	0.	265.	30.	1.8620
1950.	130.	2762.	487.	487.	0.	276.	30.	2.0190
2025.	137.	2874.	506.	506.	0.	287.	30.	2.1823
2100.	144.	2985.	525.	525.	0.	299.	30.	2.3520
2175.	151.	3096.	544.	544.	0.	310.	30.	2.5281

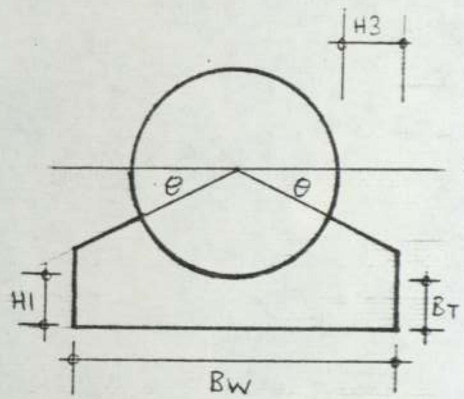


Table.12.

D	T	BW	BT					
INTERNAL DIAMETER (MM)	WALL THICKNESS (MM)	BED WIDTH (MM)	BED THICKNESS (MM)	H1 (MM)	H2 (MM)	H3 (MM)	THETA (DEG)	VOLUME OF BEDDING MATERIAL FOR CONSTRUCTION TYPE.5. (M3/M LIN)
100.	26.	352.	100.	100.	127.	100.	30.	0.1049
150.	26.	402.	100.	100.	131.	100.	30.	0.1285
225.	30.	485.	100.	100.	138.	100.	30.	0.1699
300.	34.	568.	100.	100.	144.	100.	30.	0.2141
375.	38.	651.	100.	100.	150.	100.	30.	0.2613
450.	41.	732.	112.	112.	157.	100.	30.	0.3191
525.	48.	821.	131.	131.	164.	100.	30.	0.3924
600.	52.	904.	150.	150.	170.	100.	30.	0.4678
675.	56.	987.	169.	169.	176.	100.	30.	0.5491
750.	60.	1087.	188.	188.	193.	109.	30.	0.6660
825.	64.	1191.	206.	206.	211.	119.	30.	0.8002
900.	67.	1292.	225.	225.	229.	129.	30.	0.9435
975.	71.	1396.	244.	244.	248.	140.	30.	1.1021
1050.	78.	1507.	263.	263.	267.	151.	30.	1.2837
1125.	82.	1611.	281.	281.	286.	161.	30.	1.4675
1200.	86.	1715.	300.	300.	304.	171.	30.	1.6637
1275.	86.	1809.	319.	319.	321.	181.	30.	1.8548
1350.	93.	1920.	337.	337.	341.	192.	30.	2.0884
1425.	97.	2024.	356.	356.	359.	202.	30.	2.3212
1500.	101.	2127.	375.	375.	377.	213.	30.	2.5664
1575.	114.	2254.	394.	394.	400.	225.	30.	2.8721
1650.	115.	2350.	412.	412.	417.	235.	30.	3.1272
1725.	115.	2444.	431.	431.	433.	244.	30.	3.3873
1800.	116.	2540.	450.	450.	450.	254.	30.	3.6638
1875.	125.	2651.	469.	469.	470.	265.	30.	3.9893
1950.	130.	2762.	487.	487.	490.	276.	30.	4.3285
2025.	137.	2874.	506.	506.	510.	287.	30.	4.6816
2100.	144.	2985.	525.	525.	529.	299.	30.	5.0486
2175.	151.	3096.	544.	544.	549.	310.	30.	5.4294

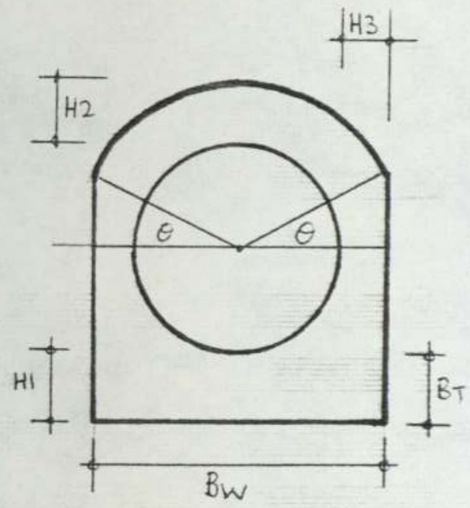


Table.13.

D	T	BW	BT					*	
INTERNAL DIAMETER (MM)	WALL THICKNESS (MM)	BED WIDTH (MM)	BED THICKNESS (MM)	H1 (MM)	H2 (MM)	H3 (MM)	THETA (DEG)	*	VOLUME OF BEDDING MATERIAL FOR CONSTRUCTION TYPE.6. (M3/M LIN)
100.	26.	352.	100.	100.	100.	100.	30.	*	0.0958
150.	26.	402.	100.	100.	100.	100.	30.	*	0.1166
225.	30.	485.	100.	100.	100.	100.	30.	*	0.1525
300.	34.	568.	100.	100.	100.	100.	30.	*	0.1903
375.	38.	651.	100.	100.	100.	100.	30.	*	0.2300
450.	41.	732.	112.	112.	100.	100.	30.	*	0.2796
525.	48.	821.	131.	131.	100.	100.	30.	*	0.3426
600.	52.	904.	150.	150.	100.	100.	30.	*	0.4074
675.	56.	987.	169.	169.	100.	100.	30.	*	0.4772
750.	60.	1087.	188.	188.	109.	109.	30.	*	0.5787
825.	64.	1191.	206.	206.	119.	119.	30.	*	0.6954
900.	67.	1292.	225.	225.	129.	129.	30.	*	0.8202
975.	71.	1396.	244.	244.	140.	140.	30.	*	0.9581
1050.	78.	1507.	263.	263.	151.	151.	30.	*	1.1158
1125.	82.	1611.	281.	281.	161.	161.	30.	*	1.2758
1200.	86.	1715.	300.	300.	171.	171.	30.	*	1.4465
1275.	86.	1809.	319.	319.	181.	181.	30.	*	1.6132
1350.	93.	1920.	337.	337.	192.	192.	30.	*	1.8161
1425.	97.	2024.	356.	356.	202.	202.	30.	*	2.0187
1500.	101.	2127.	375.	375.	213.	213.	30.	*	2.2321
1575.	114.	2254.	394.	394.	225.	225.	30.	*	2.4969
1650.	115.	2350.	412.	412.	235.	235.	30.	*	2.7193
1725.	115.	2444.	431.	431.	244.	244.	30.	*	2.9462
1800.	116.	2540.	450.	450.	254.	254.	30.	*	3.1873
1875.	123.	2651.	469.	469.	265.	265.	30.	*	3.4701
1950.	130.	2762.	487.	487.	276.	276.	30.	*	3.7649
2025.	137.	2874.	506.	506.	287.	287.	30.	*	4.0717
2100.	144.	2985.	525.	525.	299.	299.	30.	*	4.3905
2175.	151.	3096.	544.	544.	310.	310.	30.	*	4.7214

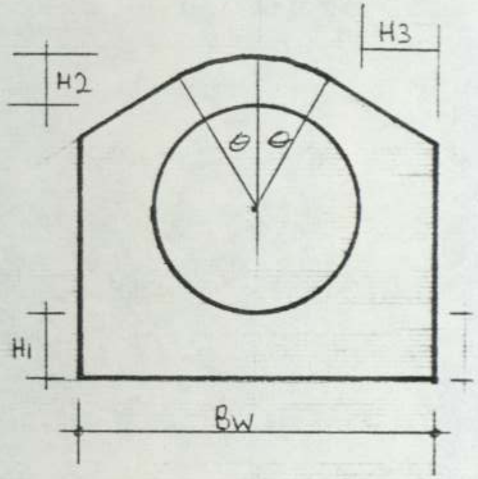


Table.14.

D INTERNAL DIAMETER (MM)	T WALL THICKNESS (MM)	BW BED WIDTH (MM)	BT BED THICKNESS (MM)	H1 (MM)	H2 (MM)	H3 (MM)	THETA (DEG)	*	VOLUME OF BEDDING MATERIAL FOR CONSTRUCTION TYPE.7. (M3/M LIN)
100.	26.	352.	100.	100.	0.	100.	0.	*	0.0352
150.	26.	402.	100.	100.	0.	100.	0.	*	0.0402
225.	30.	485.	100.	100.	0.	100.	0.	*	0.0485
300.	34.	568.	100.	100.	0.	100.	0.	*	0.0568
375.	38.	651.	100.	100.	0.	100.	0.	*	0.0651
450.	41.	732.	112.	112.	0.	100.	0.	*	0.0823
525.	48.	821.	131.	131.	0.	100.	0.	*	0.1078
600.	52.	904.	150.	150.	0.	100.	0.	*	0.1356
675.	56.	987.	169.	169.	0.	100.	0.	*	0.1666
750.	60.	1087.	188.	188.	0.	109.	0.	*	0.2039
825.	64.	1191.	206.	206.	0.	119.	0.	*	0.2457
900.	67.	1292.	225.	225.	0.	129.	0.	*	0.2908
975.	71.	1396.	244.	244.	0.	140.	0.	*	0.3403
1050.	78.	1507.	263.	263.	0.	151.	0.	*	0.3957
1125.	82.	1611.	281.	281.	0.	161.	0.	*	0.4532
1200.	86.	1715.	300.	300.	0.	171.	0.	*	0.5145
1275.	86.	1809.	319.	319.	0.	181.	0.	*	0.5765
1350.	93.	1920.	337.	337.	0.	192.	0.	*	0.6480
1425.	97.	2024.	356.	356.	0.	202.	0.	*	0.7210
1500.	101.	2127.	375.	375.	0.	213.	0.	*	0.7978
1575.	114.	2254.	394.	394.	0.	225.	0.	*	0.8874
1650.	115.	2350.	412.	412.	0.	235.	0.	*	0.9694
1725.	115.	2444.	431.	431.	0.	244.	0.	*	1.0539
1800.	116.	2540.	450.	450.	0.	254.	0.	*	1.1430
1875.	123.	2651.	469.	469.	0.	265.	0.	*	1.2428
1950.	130.	2762.	487.	487.	0.	276.	0.	*	1.3467
2025.	137.	2874.	506.	506.	0.	287.	0.	*	1.4548
2100.	144.	2985.	525.	525.	0.	299.	0.	*	1.5671
2175.	151.	3096.	544.	544.	0.	310.	0.	*	1.6836

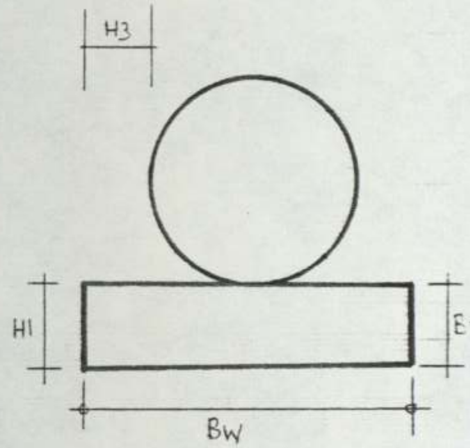


Table.15.

D	T	BW	BT					
INTERNAL DIAMETER (MM)	WALL THICKNESS (MM)	BED WIDTH (MM)	BED THICKNESS (MM)	H1 (MM)	H2 (MM)	H3 (MM)	THETA (DEG)	VOLUME OF BEDDING MATERIAL FOR CONSTRUCTION TYPE.8. (M3/M LIN)
100.	26.	352.	100.	100.	0.	100.	0.	0.0529
150.	26.	402.	100.	100.	0.	100.	0.	0.0648
225.	30.	485.	100.	100.	0.	100.	0.	0.0857
300.	34.	566.	100.	100.	0.	100.	0.	0.1081
375.	38.	651.	100.	100.	0.	100.	0.	0.1320
450.	41.	732.	112.	112.	0.	100.	0.	0.1659
525.	48.	821.	131.	131.	0.	100.	0.	0.2112
600.	52.	904.	150.	150.	0.	100.	0.	0.2592
675.	56.	987.	169.	169.	0.	100.	0.	0.3117
750.	60.	1087.	188.	188.	0.	109.	0.	0.3797
825.	64.	1191.	206.	206.	0.	119.	0.	0.4566
900.	67.	1292.	225.	225.	0.	129.	0.	0.5391
975.	71.	1396.	244.	244.	0.	140.	0.	0.6301
1050.	78.	1507.	263.	263.	0.	151.	0.	0.7335
1125.	82.	1611.	281.	281.	0.	161.	0.	0.8391
1200.	86.	1715.	300.	300.	0.	171.	0.	0.9517
1275.	86.	1809.	319.	319.	0.	181.	0.	1.0628
1350.	93.	1920.	337.	337.	0.	192.	0.	1.1959
1425.	97.	2024.	356.	356.	0.	202.	0.	1.3297
1500.	101.	2127.	375.	375.	0.	213.	0.	1.4706
1575.	114.	2254.	394.	394.	0.	225.	0.	1.6424
1650.	115.	2350.	412.	412.	0.	235.	0.	1.7902
1725.	115.	2444.	431.	431.	0.	244.	0.	1.9415
1800.	116.	2540.	450.	450.	0.	254.	0.	2.1020
1875.	123.	2651.	469.	469.	0.	265.	0.	2.2876
1950.	130.	2762.	487.	487.	0.	276.	0.	2.4811
2025.	137.	2874.	506.	506.	0.	287.	0.	2.6824
2100.	144.	2985.	525.	525.	0.	299.	0.	2.8915
2175.	151.	3096.	544.	544.	0.	310.	0.	3.1086

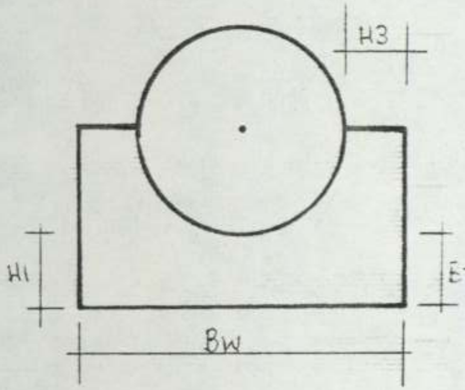


Table.16.

TABLE .17.

OVERALL WALL THICKNESS

Internal Diameter of Pipe (mm)	Overall Wall Thickness (mm)
100	26
150	26
225	30
300	34
375	38
450	41
525	48
600	52
675	56
750	60
825	64
900	67
975	71
1050	78
1125	82
1200	86
1275	86
1350	93
1425	97
1500	101
1575	114
1650	115
1725	115
1800	116
1875	123
1950	130
2025	137
2100	144
2175	151

4.2 Pipe Bedding Duration

Three tables, (.18. .19.and.20.) are given in this part, each recommends standard time data (per cubic metre of bedding material) which should be applied to the relevant volumes determined from Tables.9.to .16.

The tables are compiles assuming that a constant gang size will be used and maintained throughout the bedding operation.

The gang should contain:-

1 Ganger/Banksman

2 Labourers

If Type C Bedding Structure is being considered, use the standard time data given in Section 5 (Backfill).

Unrestricted Discharge for Concrete and Granular Bedding Structures (Types A and B)

TABLE.18.

Item	Standard Man Hours per M^3	Standard Duration per M^3
1. Concrete discharged from wagon, large skip or dumper into large foundations, manhole base or trench base. The time includes finishing, shaping and tamping to the required level.	0.98	0.33
2. Concrete placed by hand from a heap placed at the side of the trench or foundation. The time includes finishing, shaping and tamping to the required level.	1.64	0.55
3. 10 mm diameter gravel discharged from a wagon, large skip or dumper into large foundations or trench base. The time includes finishing and shaping to the required level.	0.69	.23
4. 10 mm diameter gravel placed by hand from a heap placed at the side of the trench or foundation. The time includes finishing and shaping to the required level.	1.16	0.39

Restricted Discharge for Concrete Structures (Type A)

TABLE.19.

Pipe Diameter mm	Standard man hours per M^3	Standard Duration per M^3
150	1.20	0.40
225	1.20	0.40
300	1.20	0.40
375	1.05	0.35
450	1.05	0.35
525	1.05	0.35
600	1.05	0.35
675	1.05	0.35
750	0.99	0.33
825	0.99	0.33
900	0.99	0.33
975	0.99	0.33
1050	0.90	0.30
1125	0.90	0.30
1200	0.90	0.30
1275	0.84	0.28
1350	0.84	0.28
1425	0.84	0.28
1500	0.84	0.28
1575	0.78	0.26
1650	0.78	0.26
1725	0.78	0.26
1800	0.78	0.26
1875	0.78	0.26
1950	0.78	0.26
2025	0.78	0.26
2100	0.78	0.26

Restricted Discharge for Granular Structures

TABLE.20.

Pipe Diameter mm	Standard man hours per M^3	Standard Duration per M^3
150	0.90	0.30
225	0.90	0.30
300	0.90	0.30
375	0.78	0.26
450	0.78	0.26
525	0.78	0.26
600	0.78	0.26
675	0.78	0.26
750	0.72	0.24
825	0.72	0.24
900	0.72	0.24
975	0.72	0.24
1050	0.63	0.21
1125	0.63	0.21
1200	0.63	0.21
1275	0.57	0.19
1350	0.57	0.19
1425	0.57	0.19
1500	0.57	0.19
1575	0.51	0.17
1650	0.51	0.17
1725	0.51	0.17
1800	0.51	0.17
1875	0.51	0.17
1950	0.51	0.17
2025	0.51	0.17
2100	0.51	0.17

SECTION 5

BACKFILL

5.1 Backfill Duration

The data given in this section should be used for backfilling trenches and for bedding condition type C only.

Figure.15.and.16.show the relationship between the standard man hours per cubic metre of backfill and the thickness of compacted material for four different gang sizes. They are:-

(a) 1 Ganger
1 Labourer
1 Pegson Rammer ...... Figure .15.

(b) 1 Ganger
1 Labourer
1 Pegson Rammer
1 Dumper ...... Figure .16.

(c) 1 Ganger
1 Labourer
1 Pegson Rammer
1 JCB 3 with Driver .... Figure .16.

(d) 1 Ganger
1 Labourer
1 Pegson Rammer
1 Drott 175 with Driver. Figure .16.

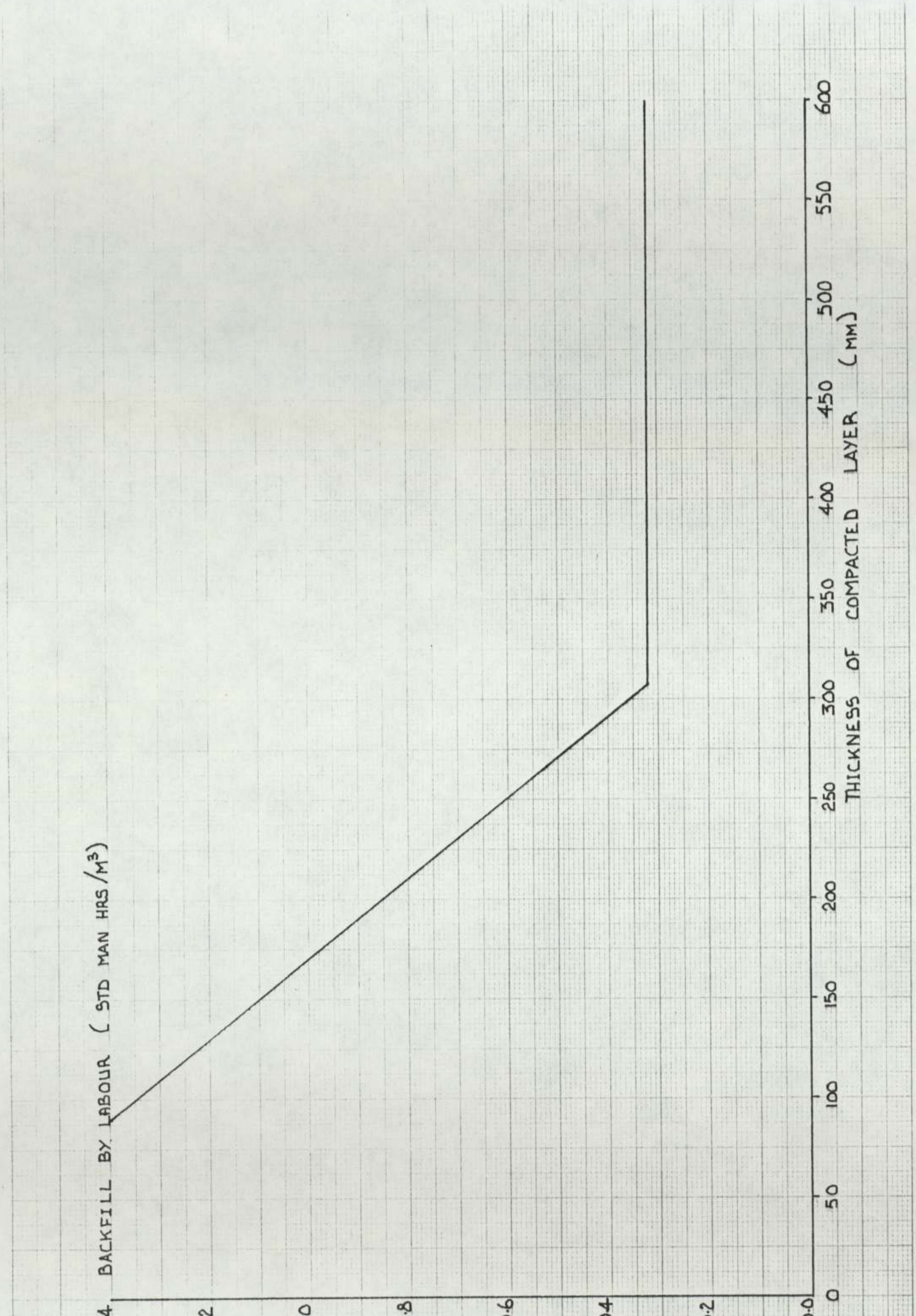

BACKFILL BY LABOUR (STD MAN HRS /M³)
1·4
1·2
1·0
0·8
0·6
0·4
0·2
0·0
0
50
100
150
200
250
300
350
400
450
500
550
600
THICKNESS OF COMPACTED LAYER (MM)

Figure.15.

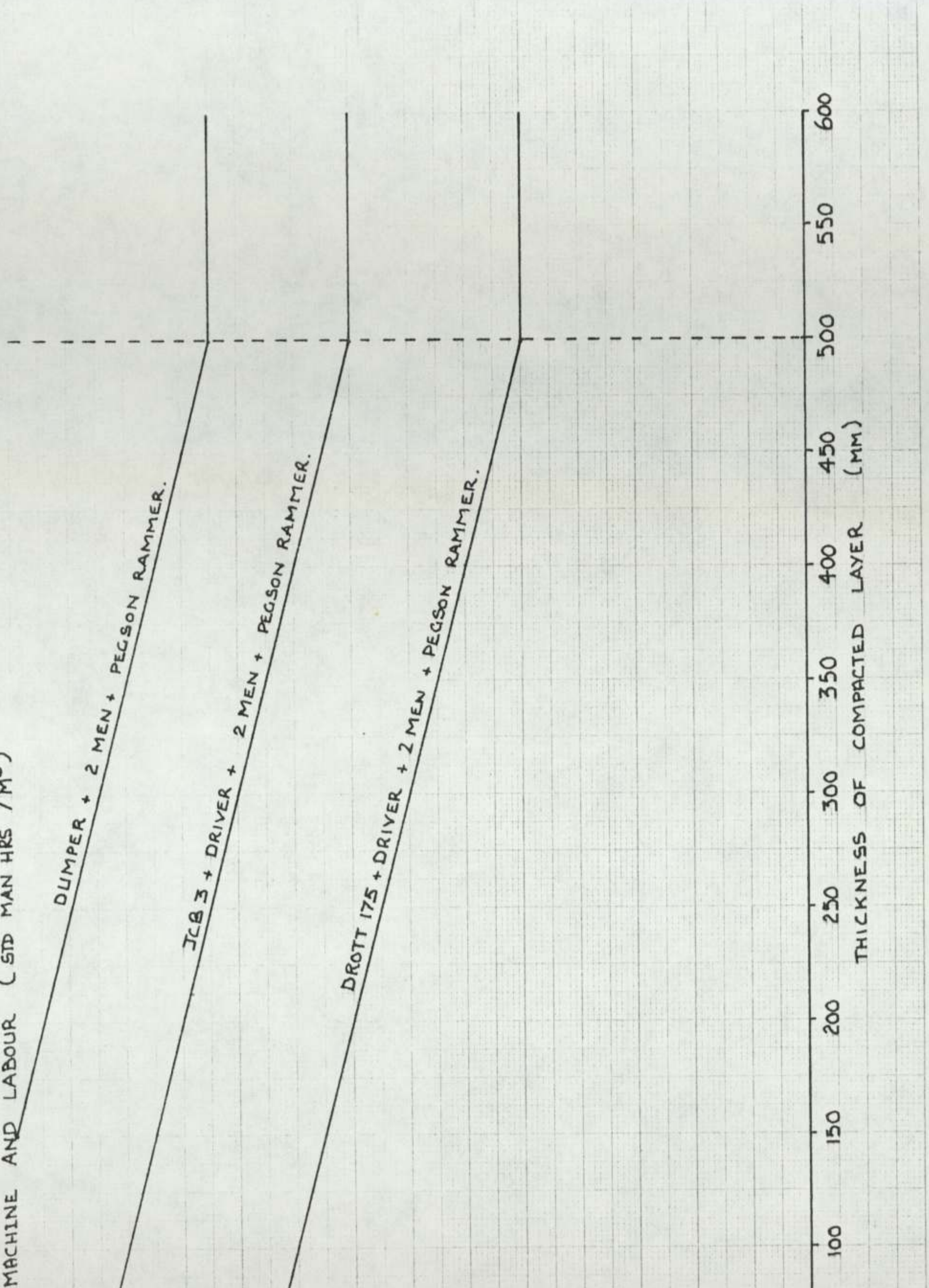

BACKFILL BY MACHINE AND LABOUR (STD MAN HRS /M³)
DUMPER + 2 MEN + PEGSON RAMMER.
JCB 3 + DRIVER + 2 MEN + PEGSON RAMMER.
DROTT 175 + DRIVER + 2 MEN + PEGSON RAMMER.
THICKNESS OF COMPACTED LAYER (MM)
0·14
0·12
0·10
0·08
0·06
0·04
0·02
0·0
0
50
100
150
200
250
300
350
400
450
500
550
600

Figure.16.

SECTION 6

MANHOLES

6.1 Precast Concrete Manholes

This section contains standard time and gang size data for six major components of pre-cast concrete manholes. The data is presented in tabular form under the following listing:-

Table.21. - Chamber Rings

Table.22. - Straight Backed Tapers

Table.23. - Shaft Rings

Table.24. - Cover Slabs (75 mm Thick)

Table.25. - Cover Slabs (150 mm Thick)

Table.26. - Base Units (complete with benching, 600 mm high)

		Assuming a mean ring height of 0.5 m				
Internal Diameter (mm)	Volume of Mortar per Joint M^3	Volume of Mortar per Metre M^3	Standard Duration per ring hrs	Standard Duration per metre hrs	Standard Man-hours per ring hrs	Standard Man-hours per metre hrs
914	0.004	0.008	0.28	0.56	1.12	2.24
1067	0.004	0.008	0.31	0.62	1.24	2.48
1219	0.005	0.010	0.34	0.68	1.36	2.72
1372	0.006	0.012	0.43	0.86	1.72	3.44
1524	0.007	0.014	0.48	0.96	1.96	3.84
1892	0.014	0.028	0.53	1.06	2.12	4.24

Gang Size:-

1 Machine with Driver

1 Labourer

1 Pipelayer

1 Banksman/Ganger

CHAMBER RINGS

TABLE.21.

Height (mm)	Internal Diameters (mm)	Volume of Mortar per Joint M^3	Volume of Mortar per Metre M^3	Standard Duration per ring hrs	Standard Duration per metre hrs	Standard Man-hours per ring hrs	Standard Man-hours per metre hrs
610	686 - 914	0.003		0.34		1.36	
610	686 - 1067	0.004		0.35		1.40	
610	686 - 1219	0.005		0.39		1.56	
914	686 - 1372	0.006		0.48		1.92	
914	686 - 1524	0.007		0.59		2.36	
914	686 - 1829	0.014		C.69		2.76	
914	726 - 1067	0.004		0.39		1.56	

Gang Size:-

1 Machine and Driver

1 Labourer

1 Pipelayer

1 Banksman/ Ganger

STRAIGHT BACKED TAPERS

TABLE.22.

Internal Diameter (mm)	Volume of Mortar per Joint (M^3)	Volume of Mortar per Metre (M^3)	Standard Duration per ring hrs	Standard Duration per metre hrs	Standard Man-hours per ring hrs	Standard Man-hours per metre hrs
686	0.003	0.006	0.24	0.48	0.96	1.92
762	0.003	0.006	0.26	0.52	1.04	2.08

Gang Size:-

1 Machine and Driver

1 Labourer

1 Pipe Layer

1 Banksman/ Ganger

SHAFT RINGS

TABLE.23.

Shaft Diameter (mm)	Volume of Mortar per Joint (M3)	Standard Duration per Slab hrs	Standard Man-hours per Slab hrs
686	0.003	0.23	0.92
762	0.003	0.25	1.00
914	0.004	0.28	1.12
1067	0.004	0.33	1.32
1219	0.005	0.38	1.52
1372	0.006	0.42	1.68
1524	0.007	0.47	1.88
1829	0.014	0.54	2.16

Gang Size:-

1 Machine and Driver

1 Labourer

1 Pipe Layer

1 Ganger/Banksman

COVER SLABS (75mm thick)

TABLE.24.

Shaft Diameter (mm)	Volume of Mortar per Joint (M^3)	Standard Duration per Slab hrs	Standard Man-hours per Slab hrs
686	0.003	0.23	0.92
762	0.003	0.27	1.08
914	0.004	0.30	1.20
1067	0.004	0.34	1.36
1219	0.005	0.40	1.60
1372	0.006	0.45	1.80
1524	0.007	0.55	2.20
1829	0.014	0.64	2.56

Gang Size:-

1 Machine and Driver

1 Labourer

1 Pipelayer

1 Ganger/Banksman

COVER SLABS (150 mm Thick)

TABLE .25.

Internal Diameter (mm)	Volume of Mortar per Joint (M^3)	Standard Duration per base (hrs)	Standard Man-hours per base (hrs)
686	0.005	0.24	0.96
762	0.009	0.31	1.24
914	0.014	0.32	1.28
1067	0.019	0.38	1.52
1219	0.024	0.46	1.84
1372	0.028	0.48	1.92
1524	0.033	0.58	2.32
1829	0.042	0.68	2.72

Gang Size:-

1 Machine and Driver

1 Labourer

1 Pipe Layer

1 Ganger/Banksman

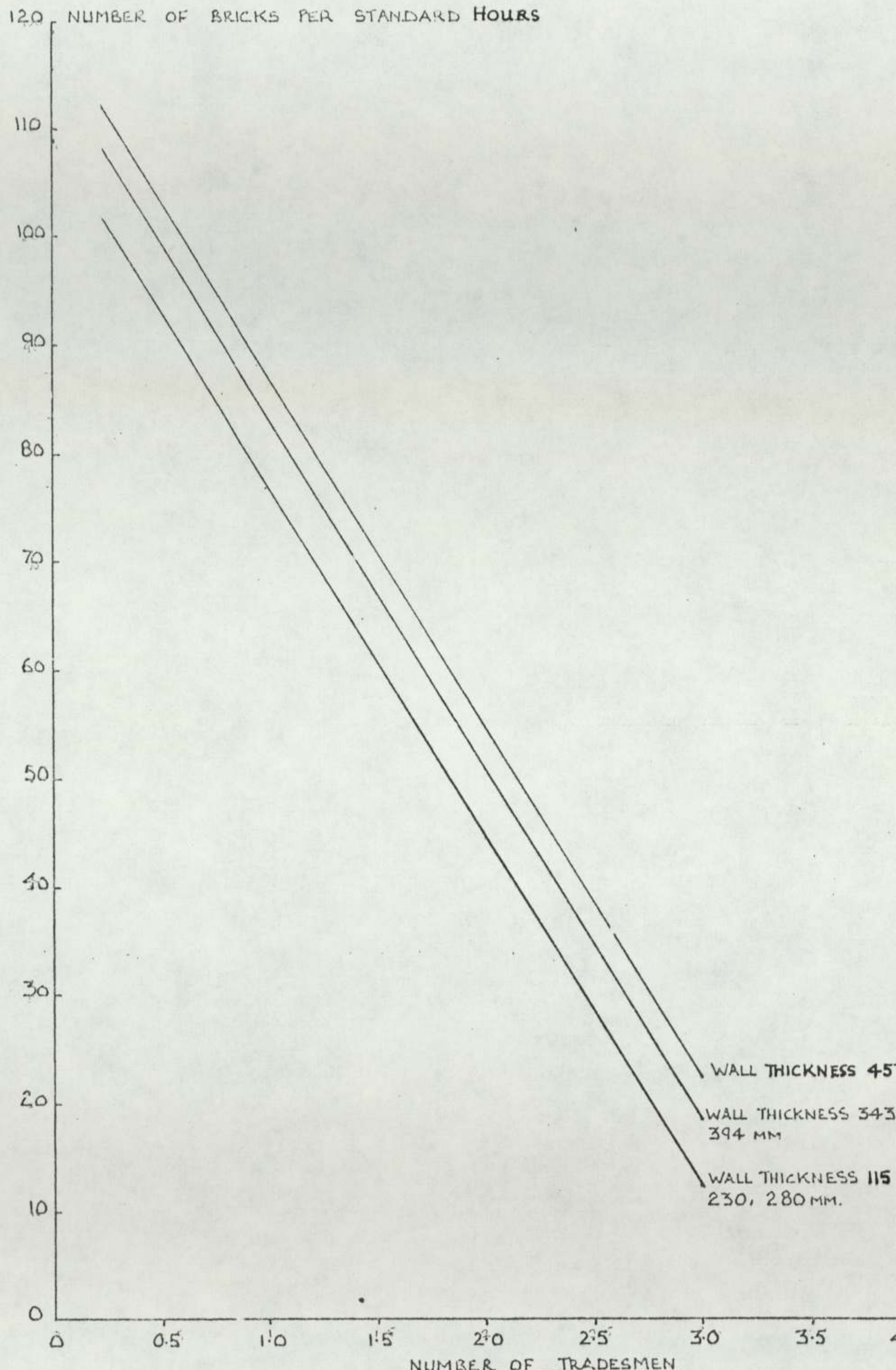
BASE UNITS (Complete with benching, 600 mm high)

TABLE.26.

6.2 Brick Manholes

A graph showing the relationship between wall thickness, the number of bricks per standard man-hour and the tradesman-labourer ratio is given in Figure .17.

The data includes transporting and mixing the cement mortar distances not exceeding 20 m.



120 NUMBER OF BRICKS PER STANDARD HOURS
110
100
90
80
70
60
50
40
30
20
10
0
WALL THICKNESS 45
WALL THICKNESS 343
394 MM
WALL THICKNESS 115
230, 280 MM.
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
NUMBER OF TRADESMEN
NUMBER OF LABOURERS

Figure.17.

6.3 Manhole Fitting
and Miscellaneous
Items

STEP IRONS

No.	Item	Gang	Unit	Standard Man-hours/ Unit
1	Wedge and point step irons into pre-drilled concrete manhole rings.	1	No	0.075
2	Drill holes, wedge and point step irons into pre-cast concrete manhole rings	1	No	0.55
3	Set and point step irons into brick work.	1	No	0.05
4	Drill holes, wedge and point step irons into brick manhole	1	No	0.4

COVER

No.	Item	Gang	Unit	Standard Man-hours/ Unit
1	Place and level manhole cover on mortar bed.	2	No	1.0

FORMWORK

No.	Item	Gang	Unit	Standard Man-hours/ Unit
1	Fix and strike light-weight formwork to circular concrete manholes.		No	1.50
2	Make form work for manhole slabs and sides.		M^2	1.055
3	Fix form work for manhole slabs and sides.		M^2	1.130
4	Strike form work for manhole slabs and sides.		M^2	0.538

STEEL REINFORCEMENT

No.	Item	Gang	Unit	Standard Man Hours/Unit
1	Cutting	See Section (8) Miscellaneous 'Steel'		
2	Bending by Hand			
3	Power Bending			
4	Fixing			

CONCRETE

No.	Item		Gang	Unit	Standard Man Hours/Unit
1	150mm Concrete surround to manholes		2	M^3	1.027
2	In situ concrete base to form channels and branch connections.				
	No. of Channels	No. of Branches			
	1	0	2	M^2	2.691
	1	1	2	M^2	2.906
	1	2	2	M^2	3.122
	1	3	2	M^2	3.337
	1	4	2	M^2	3.552

SECTION 7

MISCELLANEOUS

7.1 Introduction

The information given in this section is presented in tabular form.

Time data is given for each item, expressed in standard man-hours per unit. Recommended gang sizes are also given where possible.

As the items are briefly described and the recommended gang size is not always given, the user should use the data as a basis from which the final standard times can be estimated.

NOTE:

All additional allowances should be clearly specified so that the final outputs used for planning and estimating may be traced back to the manual.

BRICKWORK

Item No	Item Description	Gang	Unit	Standard Man Hrs/Uni
1	Construct two course of 225 mm brick work to take a manhole cover. The item includes for building to line and level and pointing the inner face.	1	Metre Lin	0.30
2	Break out small quantities of manhole brickwork by hand.		M^3	2.25
3	Break out small quantities of manhole brickwork using pneumatic tools.		M^3	1.50

BENDS

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Fix 150mm diameter spigot and socket bend. The item includes setting to line and level and jointing with yarn and mortar.	1	No	0.35
2	Fix 225mm diameter spigot and socket bend. The item includes setting to line and level and jointing with yard and mortar.	1	No	0.56
3	Fix 300mm diameter spigot and socket bend. The item includes setting to line and level and jointing with yarn and mortar.	1	No	0.80

CHANNELS

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Lay 150mm diameter channels on a lean concrete bed. The item includes for positioning to line and level and cutting where necessary.	1	No	0.38
2	Lay 225mm diameter channels on a lean concrete bed. The item includes for positioning to line and level and cutting where necessary.	1	No	0.56
3	Lay 300mm diameter channels on a lean concrete bed. The item includes for positioning to line and level and cutting where necessary	1	No	0.75

CONCRETE

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Break out small quantities of cured mass concrete by hand.		M^3	7.0
2	Break out cured mass concrete using pneumatic equipment.		M^3	4.98
3	Break out cured reinforced concrete using pneumatic equipment.		M^3	4.98
4	Break out cured mass concrete carriageway using an IPH or other heavy mechanised pneumatic equipment.		M^3	1.54

COVERS (IRON)

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Bed and lay iron manhole covers to line and level.			
	Weight			
	0 - 50 kg	2	No	0.60
	50 - 100 kg	2	No	0.94
	100 - 150 kg	2	No	1.31
	above - 150 kg	2	No	1.62
2	Unload and stack iron manhole covers.			
	Weight			
	0 - 50 kg	1 + M/C & driver	No	0.08
	50 - 100 kg	1 + M/C & driver	No	0.15
	100 - 150 kg	1 + M/C & driver	No	0.20
	above - 150 kg	1 + M/C & driver	No	0.25

GULLIES

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unig
1	Yard Gullies, the item includes excavate, position and surround with concrete.		No	0.56
2	Reversible Gullies, the item includes excavate, position and surround with concrete.			
	No. of inlets:-			
	1 only		No	0.75
	2 only		No	0.88
3	Road Gullies, the item includes excavation, positioning and concrete surround.			
	Diameter (mm) / Depth (mm)			
	225 / 600		No	1.13
	225 / 750		No	1.31
	300 / 600		No	1.26
	300 / 750		No	1.50
	300 / 900		No	1.75
	375 / 600		No	1.62
	375 / 750		No	1.88
	375 / 900		No	2.18
	450 / 750		No	2.06
	450 / 900		No	2.42

GULLY CONNECTIONS

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Fix first 2m of 150mm diameter clay pipe for gulley connection.		Gully	0.465
2	Fix straight 150mm x 1220mm long clay pipes.		Metre Lin	0.13

GULLY FRAMES AND GRATINGS

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Assemble to line and level and set on mortar bed Gully Frame and grating. The item includes the brick construction between the base of the frame and the top of the gully.			
	Weight			
	0 - 100 kg		No	1.88
	above 100 kg		No	2.25
2	Unload gully frames and grade from wagon and stock pile.			
	Weight			
	0 - 50 kg	2+M/C	No	0.08
	50 - 100 kg	2+M/C	No	0.15
	100 - 150 kg	2+M/C	No	0.20
	above 150 kg	2+M/C	No	0.25

GULLIES

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Unload Gullies from wagon and stock pile	2+M/C	No	0.15

HARDCORE

Item No.	Item Description	Gang	Unit	Standard Man Hou·s/Unit
1	Spread and level hardcore in 100mm layers and blind with ash.	2+M/C	M^3	2.0
2	Spread and level hardcore in 150mm layers and blind with ash.	2+M/C	M^3	1.88
3	Spreak and level hardcore in 225mm layers and blind with ash.	2+M/C	M^3	1.78

TRAPS

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Excavate, position, joint and surround with concrete 'P' traps.		No	0.375
2	Excavate, position, joint and surround with concrete intercepter traps.		No	1.13

PIPES

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Lay and joint clay ware spigot and socket pipe. The item includes jointing with yarn and mortar, and cutting, where necessary.			
	Diameter (mm)			
	100		Metre lin	0.098
	150		Metre lin	0.113
	225		Metre lin	0.143
	300		Metre lin	0.187
2	Unload and stock pile clay ware pipes individually.			
	Diameter (mm)			
	100	3	10 pipes	0.1
	150	3	10 pipes	0.2
	225	3	10 pipes	0.2
	300	3	10 pipes	0.2

RODDING EYES AND COVERS

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Fix 150 mm diameter spigot and socket Rodding Eye. The item includes setting to line and level and jointing with yarn and mortar.	1	No	0.32

REVERSIBLE GULLIES

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Excavate, position, joint and surround with concrete. Reversible Gullies containing one inlet only.		No	0.75
2	Excavate, position, joint and surround with concrete. Reversible Gullies containing two inlets only.		No	0.88

ROADS (Breakout)

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Break out metalled road surface, using an IPH or other heavy mechanised pneumatic equipment.		M^3	1.15
2	Break out cured mass concrete carriageway using an IPH or other heavy mechanised pneumatic equipment.		M^3	1.54

SLABS

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Unload precast manhole slabs and bases from wagon and stock pile.			
	Diameter			
	0 - 686 mm		No	0.5
	686 - 914 mm		No	0.53
	914 - 1067 mm		No	0.56
	1067 - 1219 mm		No	0.67

SADDLES

Item No.	Item Description	Gang	Unit	Standard Man Hours/ Unit
1	Cut and trim a 225 mm diameter clayware pipe and bed a 225 x 300 mm saddle to concrete line and level.		No	0.58

STEEL

Item No.	Item Description	Gang	Unit	Standard Man Hours/Unit
1	Cut, bend and fix 10 mm diameter steel. The cutting and bending should be performed by powered machines.			
	Power Cut		t	2.25
	Power Bend		t	8.70
	Fix		t	21.80
2	Cut, bend and fix 12 mm diameter stee. The cutting and bending shoula be performed by powered machines.			
	Power Cut		t	1.77
	Power Bend		t	7.18
	Fix		t	17.75
3	Cut, bend and fix 16 mm diameter stee. The cutting and bending should be performed by powered machines.			
	Power Cut		t	1.28
	Power Bend		t	5.13
	Fix		t	12.80

REFERENCES

(1) Drainage Elements Volume 2
D. M. Bramwell, 1973

(2) Soil Mechanics in Engineering Practice
Terzaghi and Peck, 1967

(3) B.S. 449: Part 2, 1969
The Use of Structural Steel in Building
British Standards Institution.

(4) C. P. 112

(5) Building Research Station Digest 130