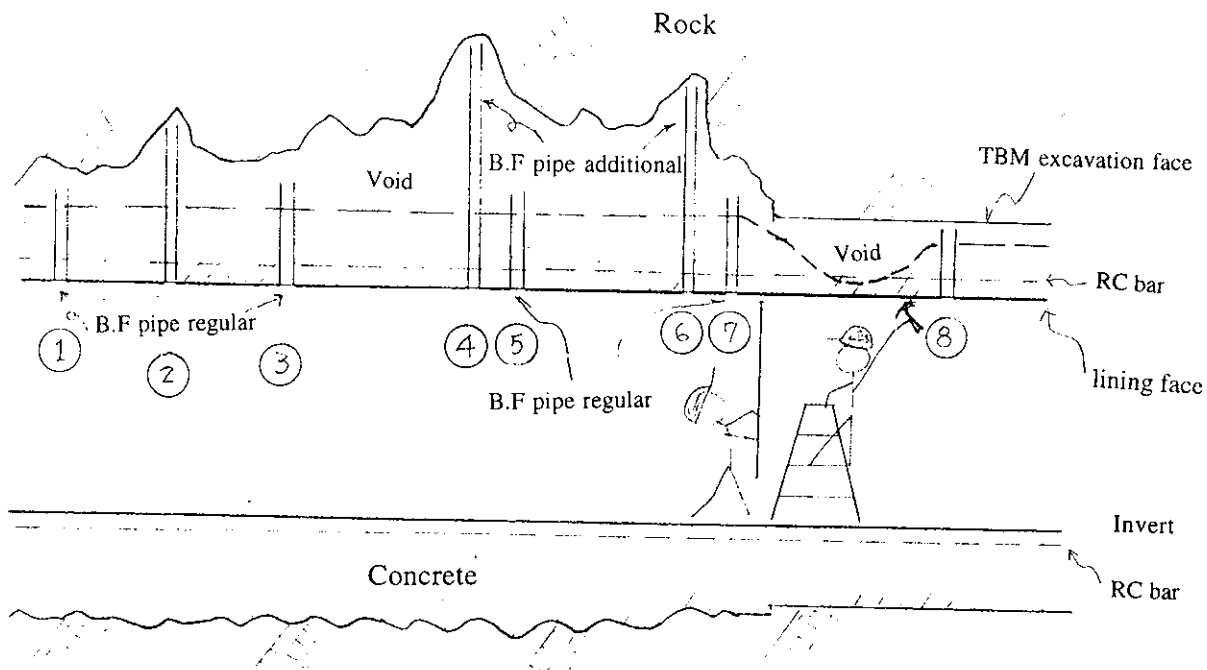


**PART - B**  
**GROUTING WORKS**

1. Back fill grout (referred to work flow chart)

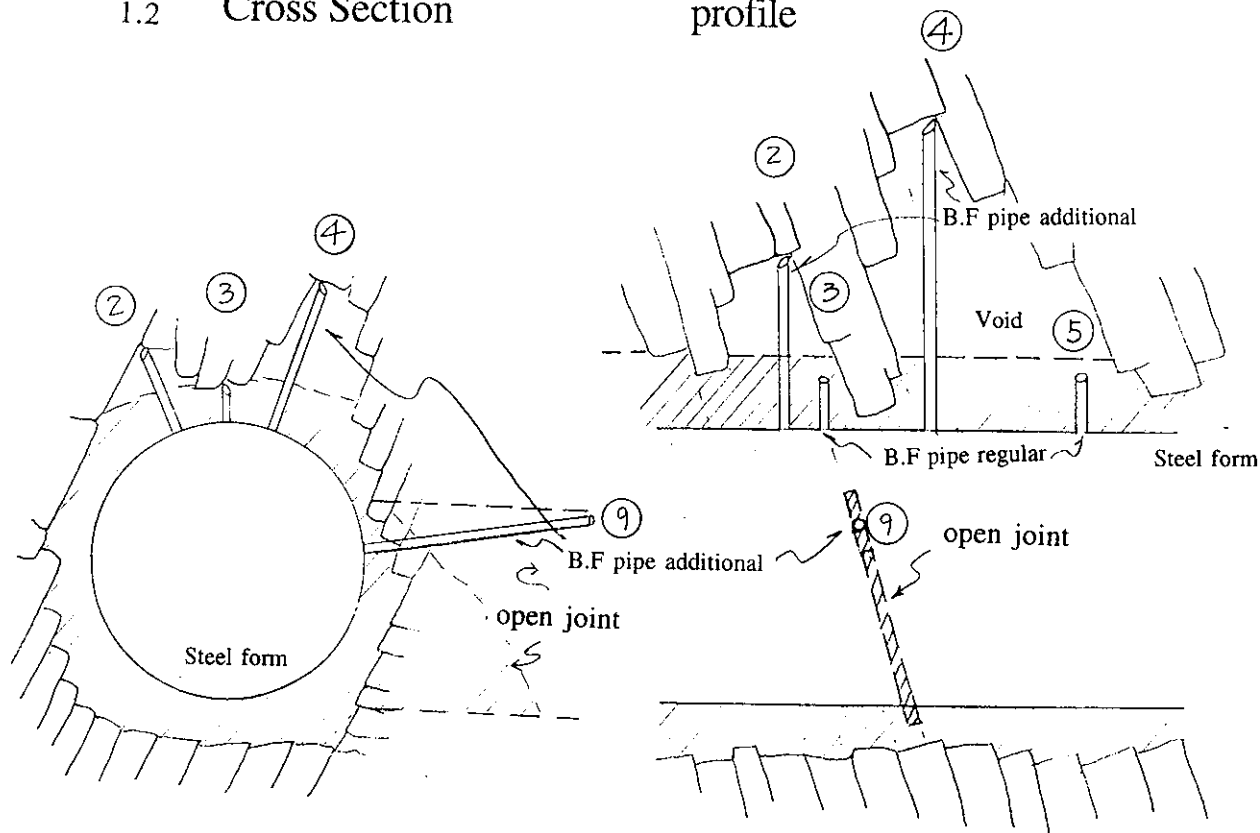
1.1 Purpose

Back fill grouting in the tunnel is the work to be performed for the purpose of uniting for the void above lining concrete.



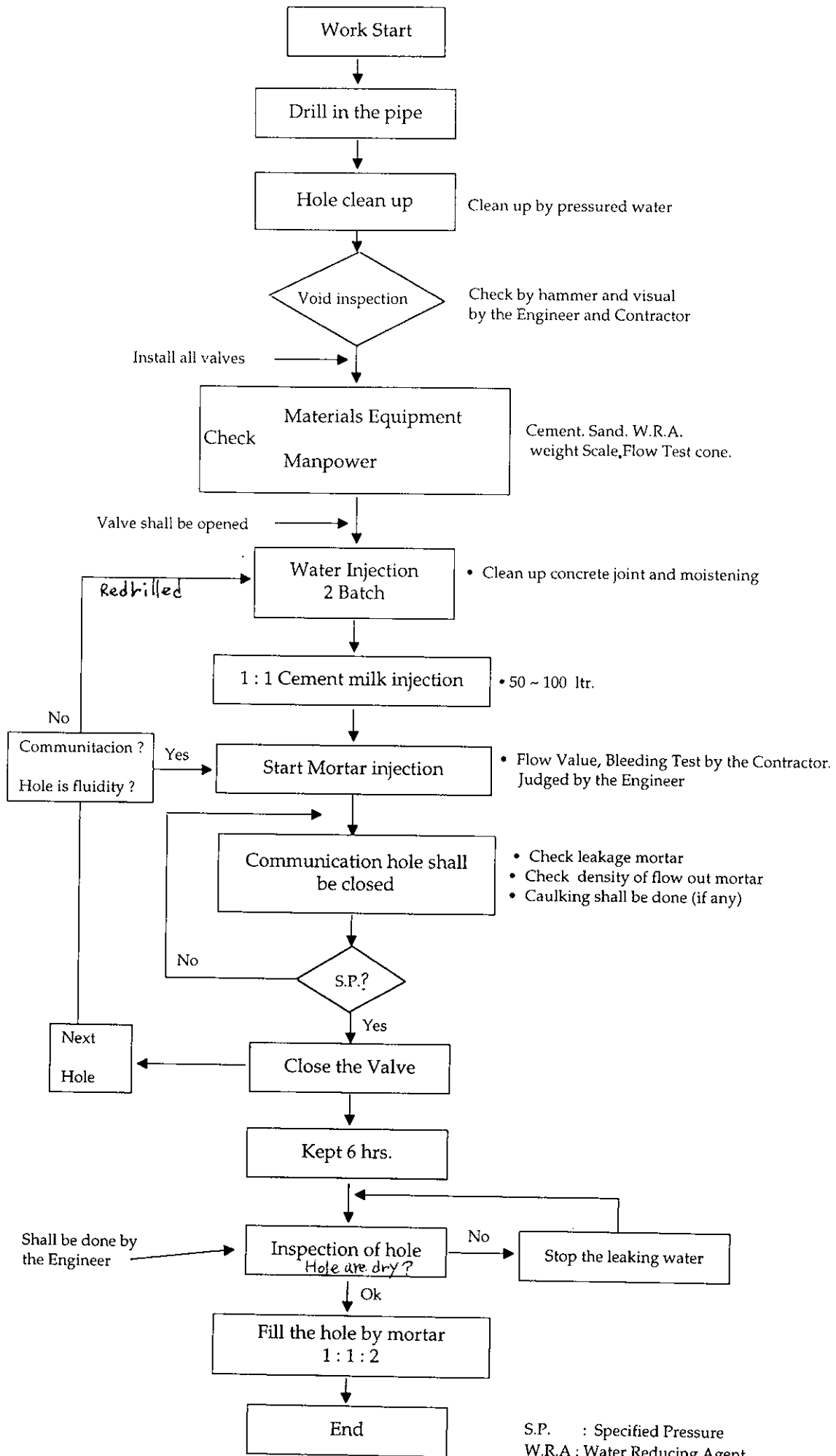
1.2 Cross Section

profile



• Don't forget back fill grouting for open joints.

## Flow Chart for Back Fill Grouting



S.P. : Specified Pressure  
W.R.A : Water Reducing Agent

# **CONSOLIDATION GROUTING**

## 2. GENERAL

### 2.1 Purpose

Consolidation grouting in the headrace tunnel is the work to be performed for the purpose of uniting and strengthening rock surrounding the tunnel by means of injection cement grout under pressure into openings in it such as fissures, joints and cracks.

Consolidation grouting contributes as well (1) to fill up small openings which might be remained even after backfill grouting, (2) to solidify rocks which have been released during excavation, (3) to improve mechanical properties of fractured rocks in a fault zone, and (4) to ensure water tightness of rock surrounding the tunnel particularly near the appurtenant structures and/or adjacent tunnel caverns, such as the working adits, drain tunnel and surge tank.

### 2.2 Working Flow

Working flow of consolidation grouting shown in Page 22 and 23.

Consolidation grouting holes shall be drilled three (3) meters into rock after penetrated through lining concrete and backfilled mortar. Additional holes will be decided progressively considering grouting results, tunnel geology, adjacent structures, etc.

### 2.3 DRILLING FOR GROUTING

#### Depth and Diameter

Consolidation grouting holes shall be drilled three (3) meters from "B" line unless otherwise directed by the Engineer, into rock after penetrated through lining concrete and backfilled mortar.

### 2.4 Washing of hole

Grouting holes shall be drilled using a sufficient circulation of water in order to remove all sediments. Immediately prior to each grouting operation boreholes shall be adequately flushed clean. Washing shall be done with water and air under pressure, a pipe shall be inserted to the full depth and washing shall be continued until the reappearing water is absolutely clear and clear.

## 2.5 Drilling [pattern and sequence]

The drilling order of holes shall generally be planned in such a pattern that the primary holes shall be drilled alternately so that their effectiveness can be checked and assured by the secondary holes which will be drilled between them. Additional holes may be ordered between the secondary holes.

## 2.6 Prohibition of drilling

Grouted boreholes and their adjacent holes shall not be drilled and/or drilled before the grout has set to prevent washing out.

<u>Prohibiting area and period</u>		
<u>Grout Take (GT, lit)</u>	<u>Area</u>	<u>Period</u>
GT < 20	Grouted hole	6 hours
$20 \leq GT \leq 500$	within 6 m	6 hours
$500 < GT$	within 9 m	8 hours

## 2.7 WATER PRESSURE TESTING (Lugion Test)

### 2.7.1 Measurement of Ground Water and Pressure

Ground water head (pressure) shall be measured prior to the starting of consolidation grouting of a certain area at a representative location, since it might take rather long time to restore the ground water head which have been decreased due to the discharge through a drilled hole. Ground water pressure ( $P_w$ ), however, might be varied according to the progress of the consolidation grouting and/or seasonal fluctuation, so that the Contractor shall have a care about such fluctuation of ground water pressure in order to assure that adequate and effective grouting and shall report immediately to the Engineer, if find high  $P_w$ , variation of  $P_w$  and/or any obstruction due to ground water discharge.

2.7.2 Water Pressure Test

- a. Water injection shall be continued for at least 10 minutes after the water take has become stable and under the specified pressure (clause 3.8 of Technical Specifications).
- b. Testing pressure shall be add value of ground water pressure to 5 kgf/cm
- c. In case that the above testing pressure could not be obtained even under the maximum pumping rate, the maximum pressure obtained shall be recorded.
- d. Water leakage from other holes and/or cracks shall be recorded in detail, if any during testing.
- e. Lugeon value is determined with the following equation :

$$Lu = \frac{10 \cdot Q}{P \cdot L} \longrightarrow Lu = \frac{10 \cdot Q}{(P - P_w) \cdot L}$$

shall be subtract ground water pressure value

1.5ノオン  
 一定圧力(標準10kg/cm<sup>2</sup>)の  
 モニタリング開始後、  
 水を注入し、そのホーリング後、  
 時間を計り、注入量により表現  
 Lu (lit/min/m)  
 under 10kg/cm<sup>2</sup>

- where,
- Lu = Lugeon value
  - P = applied pressure (kgf/cm<sup>2</sup>)
  - Q = Constant rate of flow (lit/min)
  - L = Length of test section (m)
  - Pw = Ground water pressure

= 15 × 10<sup>-5</sup> m/sec

\* Ground water measures payment will not be separate (In clause 3.12.1 Technical Specifications)

2.8 Mixing Ratio

The following ratios will be used for the consolidation grouting.

The starting mix proportion and changing criteria are mentioned in the flow chart.

Mixing Ratio

Specific gravity of cement 3.15

Mix. Proportion C : W = 1 : n	Required Cement weight (kg)	Cement volume (ltr)	Water volume (ltr)	Total grout volume (ltr)	Conversion Rate of Cement Weight/kg/ltr
1 : 6	31.17	10.1	189.6	200 ltr.	0.16
1 : 4	46.3	14.7	185.3	200 ltr.	0.23
1 : 2	86.3	27.4	172.6	200 ltr.	0.43
1 : 1	151.8	48.2	151.8	200 ltr.	0.76
1 : 0.65	206.6	65.6	134.4	200 ltr.	1.00

$$WC = \frac{3.15}{3.15n + 1} V$$

$$WW = \frac{3.15n}{3.15n + 1} V$$

Note :

1 : n : (C : W) Mix proportion

WC : Weight of cement

WW : Weight of water

V : Total mixing volume

## 2.9 Grouting pressures

As for Renun Project, the maximum grouting pressure shall be 7 kgf/cm<sup>2</sup> for the upstream headrace tunnel and 9 kgf/cm<sup>2</sup> for the Downstream headrace tunnel and branch tunnel in case of the grout water pressure being less than 1 kgf/cm<sup>2</sup>. If the ground water pressure is higher than 1 kgf/cm<sup>2</sup>, the maximum grouting pressure varies according to the following criteria.

### A. Upstream Headrace Tunnel

Low Pressure Consolidation Grouting,

- a. when  $P_w \leq 1 \text{ kgf/cm}^2$  ..... PG = primary 5 kgf/cm<sup>2</sup>  
 secondary 6 kgf/cm<sup>2</sup>  
 tertiary 7 kgf/cm<sup>2</sup>



- b. when  $1 \leq p_w < 12 \text{ kg/cm}^2$  ..... PG = primary  $5 \text{ kgf/cm}^2 + P_w$   
secondary  $6 \text{ kgf/cm}^2 + P_w$   
tertiary  $7 \text{ kgf/cm}^2 + P_w$

B. Downstream Headrace Tunnel and Brach Tunnel

- a. when  $P_w \leq 1 \text{ kg/cm}^2$  ..... PG = primary  $6 \text{ kgf/cm}^2$   
secondary  $7 \text{ kgf/cm}^2$   
tertiary  $9 \text{ kgf/cm}^2$
- b. when  $1 \leq p_w \leq 12 \text{ kg/cm}^2$  ..... PG = primary  $6 \text{ kgf/cm}^2 + 1/2 P_w$   
secondary  $7 \text{ kgf/cm}^2 + 2/3 P_w$   
tertiary  $9 \text{ kgf/cm}^2 + 2/3 P_w$

where, PG = maximum grouting pressure  
Pw = ground water pressure

In equations, count fractions of 0.5 and over as units and out away the rest, so that PG must be an integer.

If ground water pressure is not less than  $12 \text{ kgf/cm}^2$ , the observed ground water pressure shall be reported to the engineer immediately.

2.10 Injection Rate and Increasing Rate of Pressure

Sudden injection of large volume shall not be allowed. Injection rate shall be less than  $20 \text{ lit/min}$ . Increasing rate of grouting pressure shall be less than  $2 \text{ kgf/cm}^2$  per minute.

2.11 Refusal, Blocking, Finishing and Cleaning

- (1) Grouting shall be continued 30 minutes ("blocking") after the hole takes grout a rate of less than  $2 \text{ lit. per } 10 \text{ min. per linear meter}$  of the hole (grouting hole "refusal" of grout take).
- (2) In case that injection rate could not decrease below the hole refusal even after  $1,000 \text{ lit.}$  having been injected in the mixing proportion of  $C : W = 1 : 1$  the grouting shall be stopped and be reported to the engineer immediately.

- (3) A grouting packer shall not be released until 4 hours for dry hole. 6 hours if the pressure of underground water is less than 1 kgf/cm<sup>2</sup>, and until 10 hours, if the pressure of underground water is not less than 1 kgf/cm<sup>2</sup>, after the completion of "Blocking".
- (4) Upon completion of the grouting works all supply connections embedded in the concrete shall be removed. All drilled holes shall be redrilled to the depth of 10 cm and filled with dry mortar flush to the concrete surface.
- (5) During the duration of the grouting works, all wasted grout shall be adequately disposed and washed. After the completion of the grouting works the interior surface of the tunnel shall be cleaned and restored to its original condition.

#### 2.12 Leakage and Hole-to-hole Communication

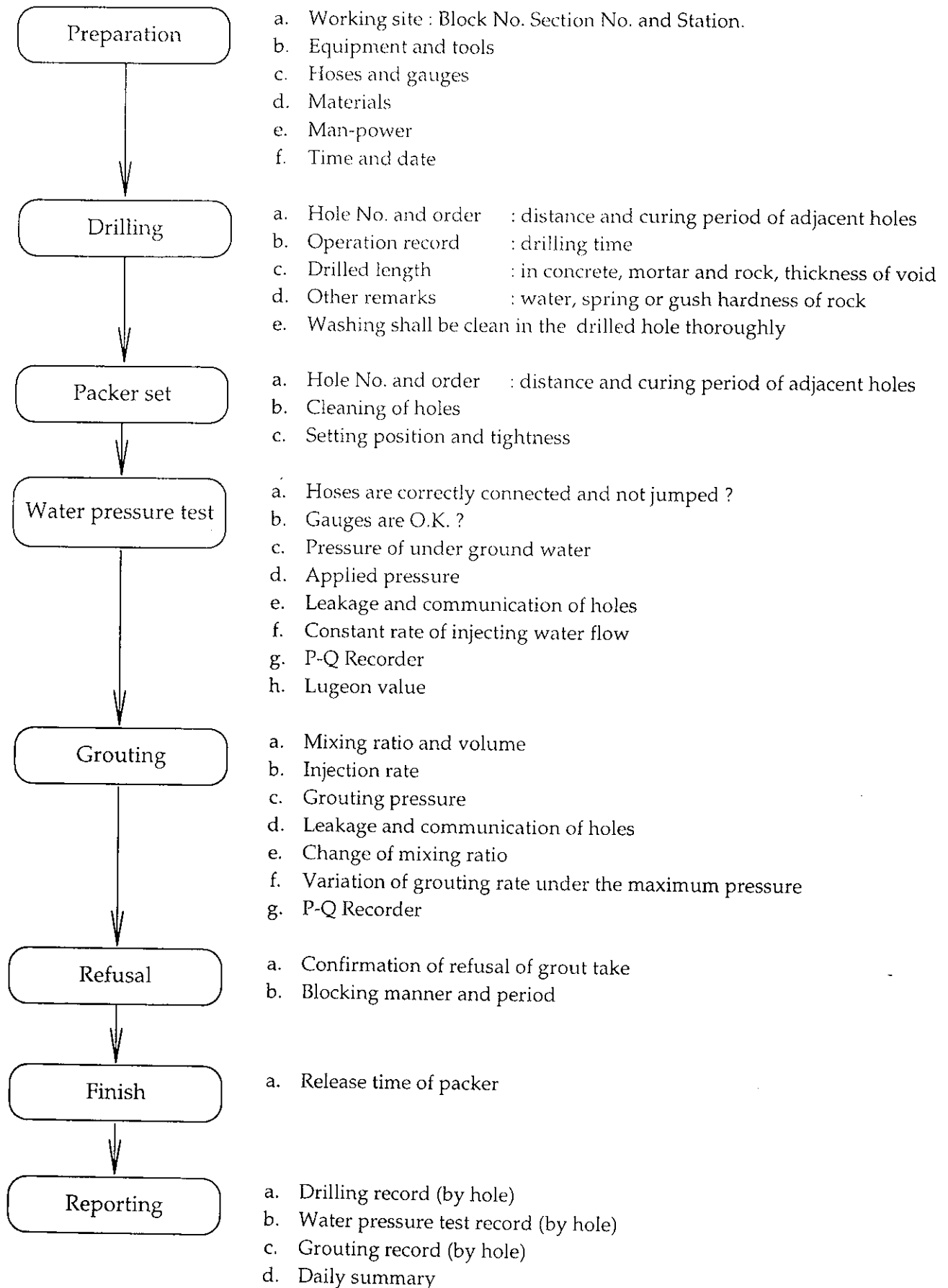
- (1) Leakage of grout from cracks and joints, if any, shall be calked adequately and persistently in order to stop after the leakage materials having been confirmed as the same with the injected cement water grout. Calking materials, such as wedges, wasted clothes, lead thread, etc. therefore, shall be provided at the site prior to the start of grouting.
- (2) If gout is communicated to the adjacent holes, a rubber packer with a pressure gauge and a stop valve shall be set in the lining concrete of the communicated holes and the stop valve shall be closed after the leaked materials having been confirmed as the same with the injected cement-water grout. Then the pressure gauge shall be read.

In case that the pressure at the collar of a communicated hole is the same with specified maximum grouting pressure, the communicated holes will be considered as completed simultaneously with the injected hole. If the pressure is less than the specified maximum grouting pressure, the communicated hole shall be redrilled and grouted.

- (3) If leakage of considerably large volume which seems to be hardly crack is seen during the water pressure testing, grouting shall be suspended until such large cracks and/or joints having been repaired and/or sealed.

# WORK FLOW OF CONSOLIDATION GROUTING

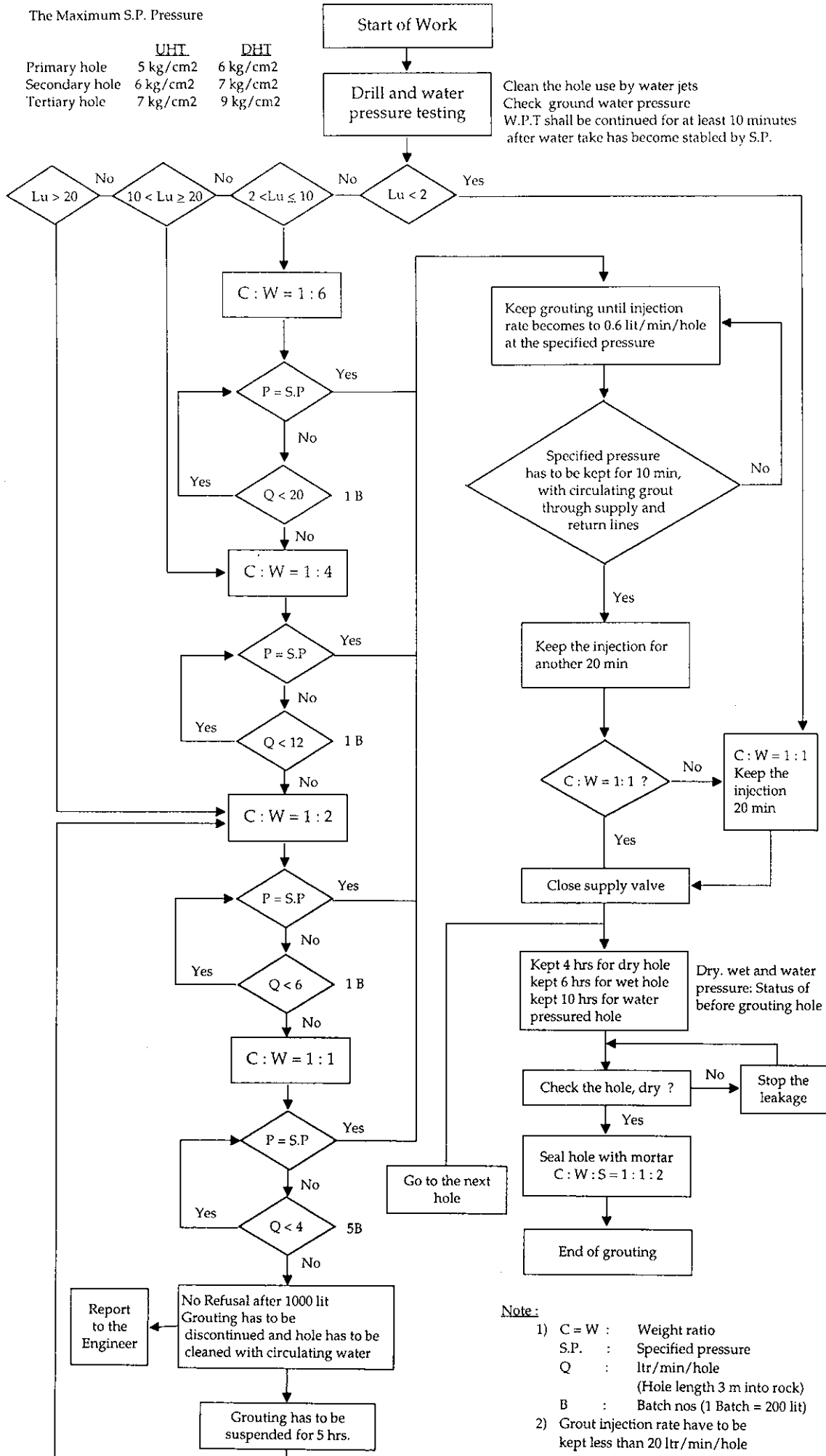
## Check Items



# Flow Chart of Consolidation Grouting for Tunnel

The Maximum S.P. Pressure

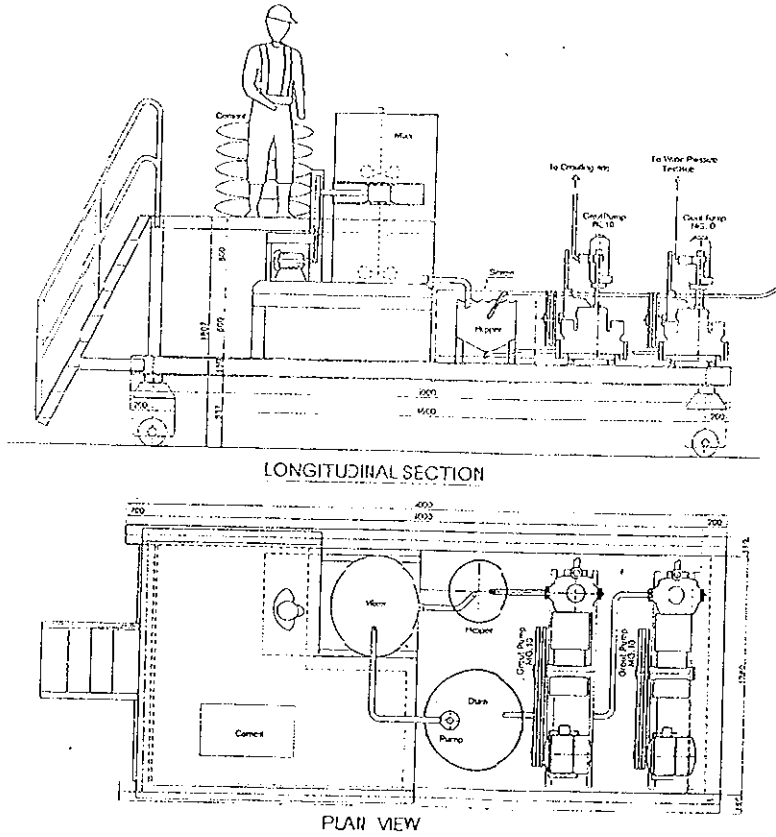
	UHL	DHI
Primary hole	5 kg/cm <sup>2</sup>	6 kg/cm <sup>2</sup>
Secondary hole	6 kg/cm <sup>2</sup>	7 kg/cm <sup>2</sup>
Tertiary hole	7 kg/cm <sup>2</sup>	9 kg/cm <sup>2</sup>





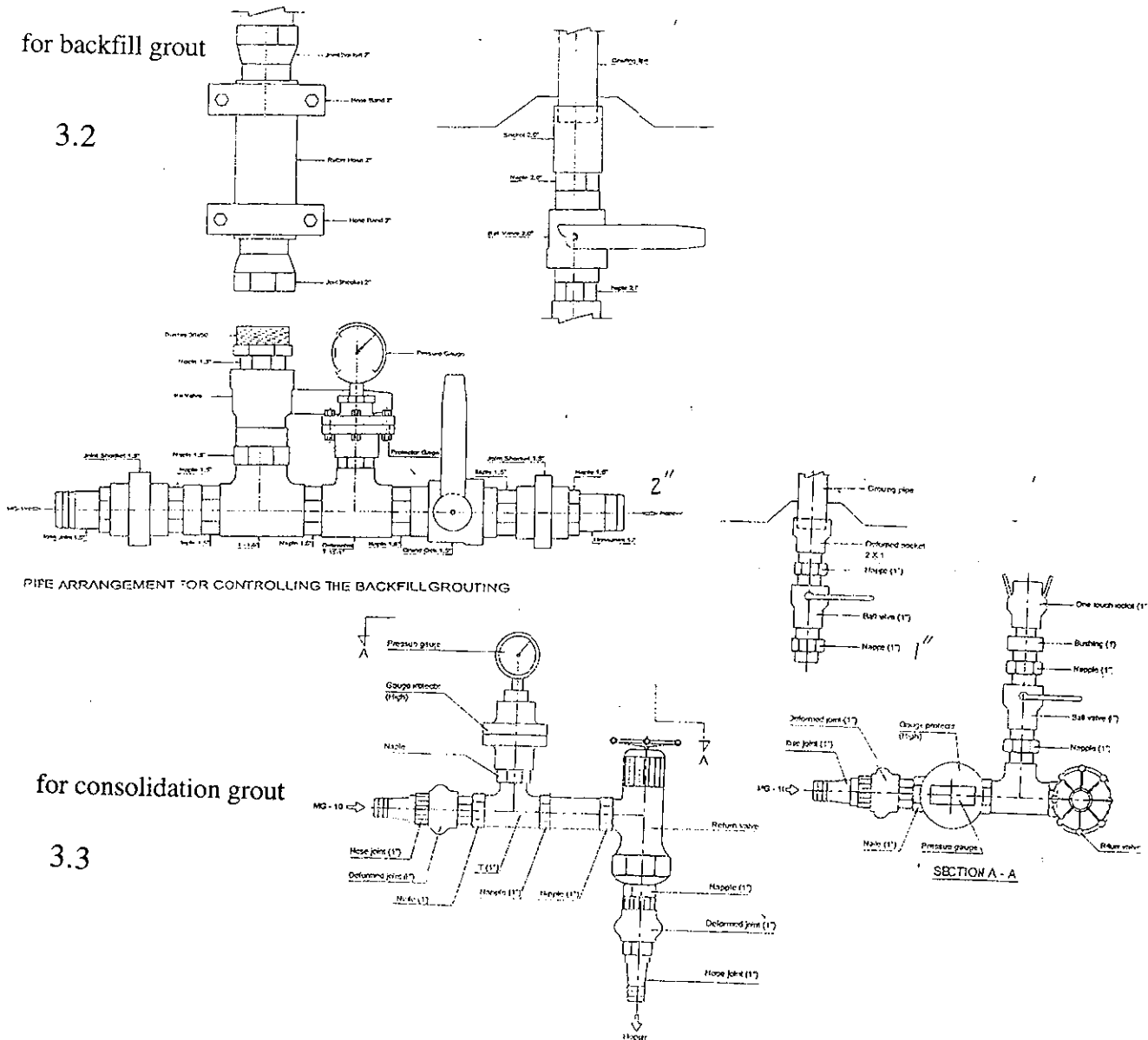
### 3. Typical of work stage and controlling manifold pipes

3.1



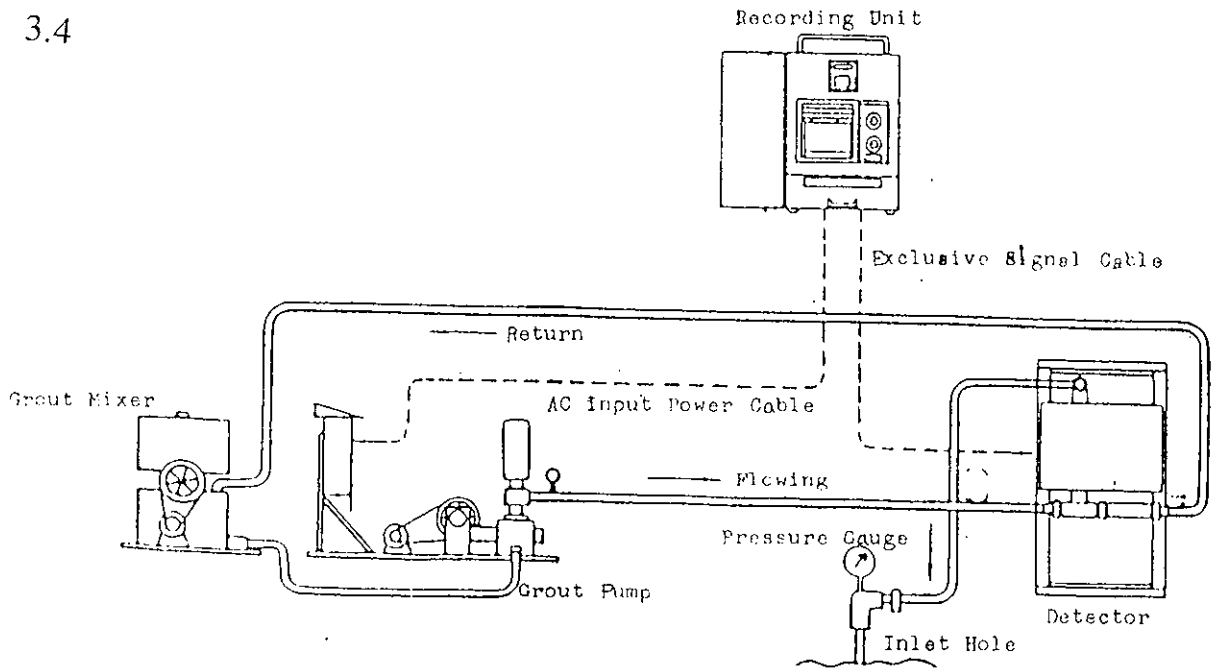
for backfill grout

3.2



# Standard grout circulation system

3.4



# recording chart

3.5

