2.7. CONSTRUCTION SCHEDULE

The schedule of the whole construction, the intake facilities and head tank, and of pipeline installation are shown respectively on Figs. 2-7-1, 2-7-2 and 2-7-3.

Fig. 2-7-1 WHOLE CONSTRUCTION SCHEDULE

NOTE: ═══ CONTINUOUS ACTIVITIES; ╍╍╍ INTERMITTENT ACTIVITIES

DESCRIPTION	UNIT	QUANTITIES
…LIZATION AND GENERAL TEMPORARY WORKS		
Mobilization		
Land Acquisition		
Access to Sites		
Contractor's Camps		
Batcher Plant		
…KE FACILITIES		
Site Preparation		
Embankment	Cu.m	23,000
Temporary Bridge & Caisson Setting Rig	L.S.	
Excavation in Reservoir	Cu.m	7,000
Foundation Concrete, Caisson Settlement	Cu.m	1,200
Dry Dock (30x24x6.6m)	No.	1
Caisson Concrete	Cu.m	3,800
Control House	Sq.m	
Pumping Equipment	L.S.	1
Intake Bridge (160m Length)	L.S.	1
Air Chamber	L.S.	1
…LINE		
Material Arrangement		
Pipe Fabrication	t	10,400
Site Preparation & Temporary Works	L.S.	1
Pipe Installation	Km	26.1
Valve Chambers & Boxes (Main Φ1 350)	Pieces	17
Blow Offs	-do-	23
Highway Crossing (Jacking) (28m+20m)	-do-	2
-do- (By Pass & Reconstruction)	-do-	2
Water Pipelines for Casava Factory (Φ150)	Km	2.8
Miscellaneous Works (Branches, Air Valves, etc.)		
…D TANK		
Site Preparation		
Excavation	Cu.m	1,000
P. C. Tank (Φ16 x 25.1m)	Cu.m	
Spillway (Φ900x426m R.C Pipes & 2-Dissipators)	L.S	
Steel Works (Pipes & Others)	L.S.	
…VING FACILITIES		
Excavation	Cu.m	9,400
Embankment	Cu.m	24,100
Backfill	Cu.m	4,700
Membrane Sheeting	Sq.m	12,400
Concrete	Cu.m	1,300
Pipes, Gates & Valves Installation	L.S.	
…DINGS		
Dok Kroi (Administration Office, Camp, Garage, Warehouse, Compressor Room, Sub station)	Sq.m	
Head Tank Site (Maintenance Hut Camp)	Sq.m	
Nob Ta Pud (Main Office, Generator Room, Repairing shop, Garage, Warehouse Camp)	Sq.m	
…TRICAL FACILITIES	L.S.	
…ECTION & TEST RUN		
…OBILIZATION		

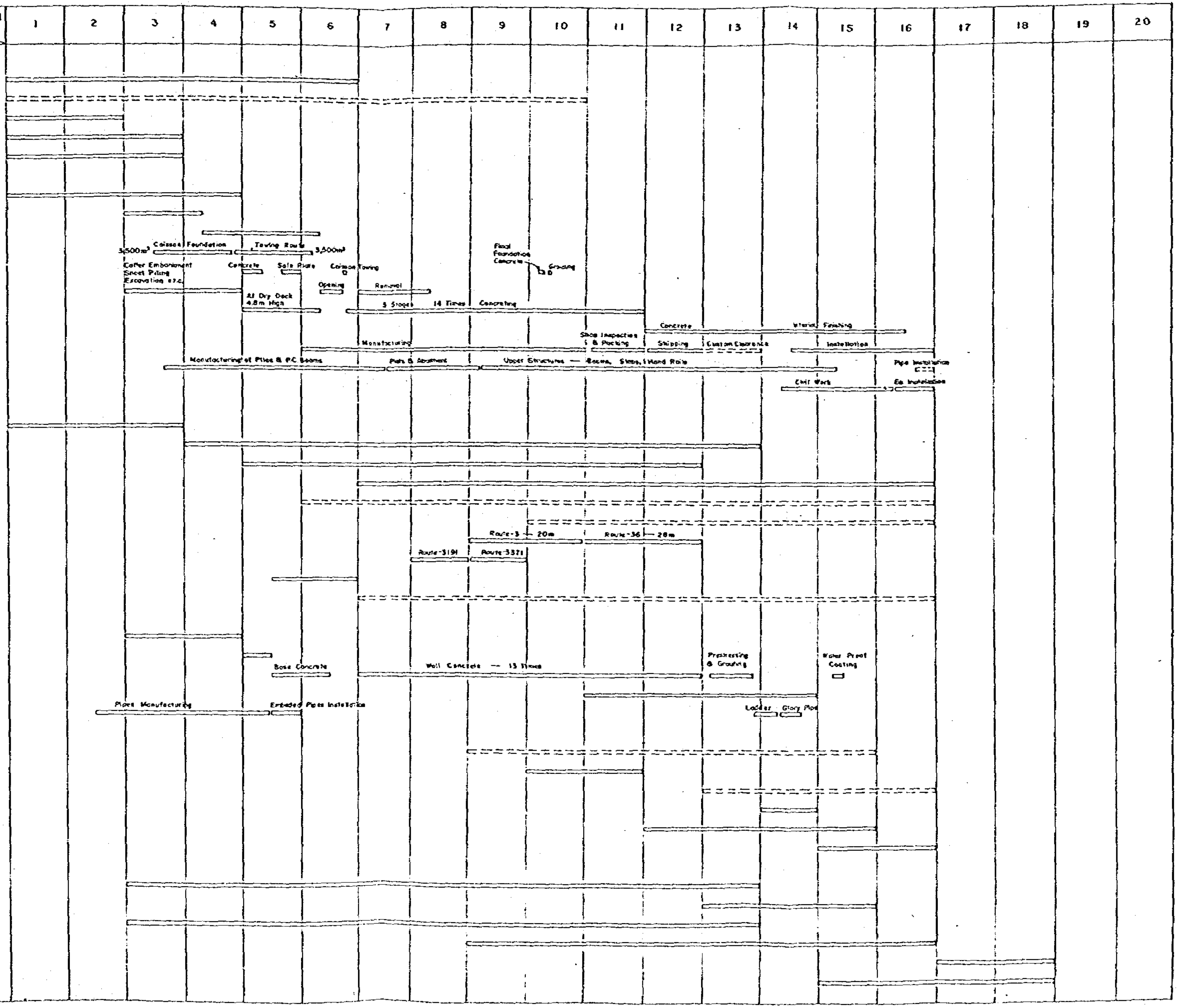
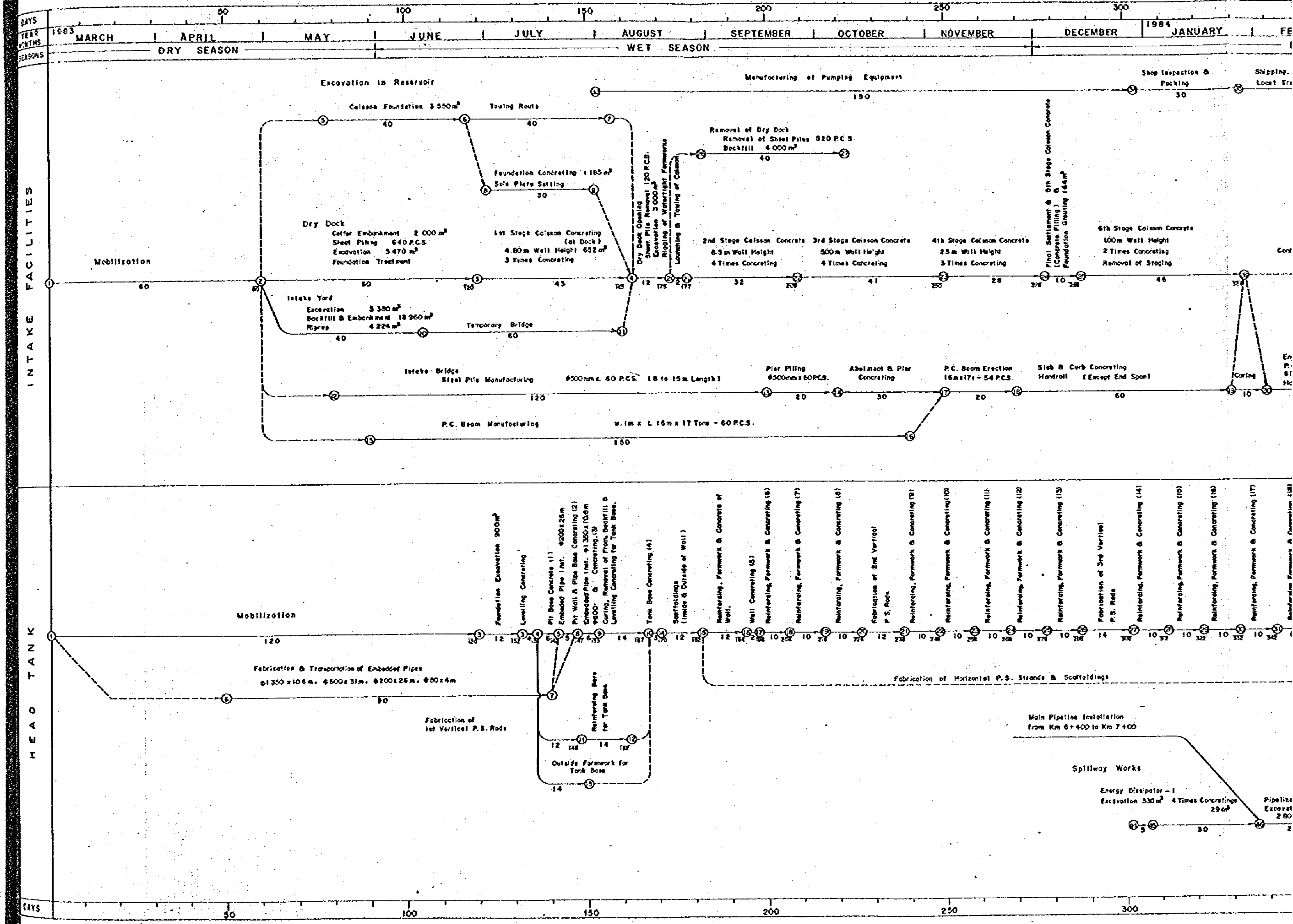


Fig. 2-7-2 CONSTRUCTION SCHEDULE OF INTAKE FAC



SCHEDULE OF INTAKE FACILITIES & HEAD TANK

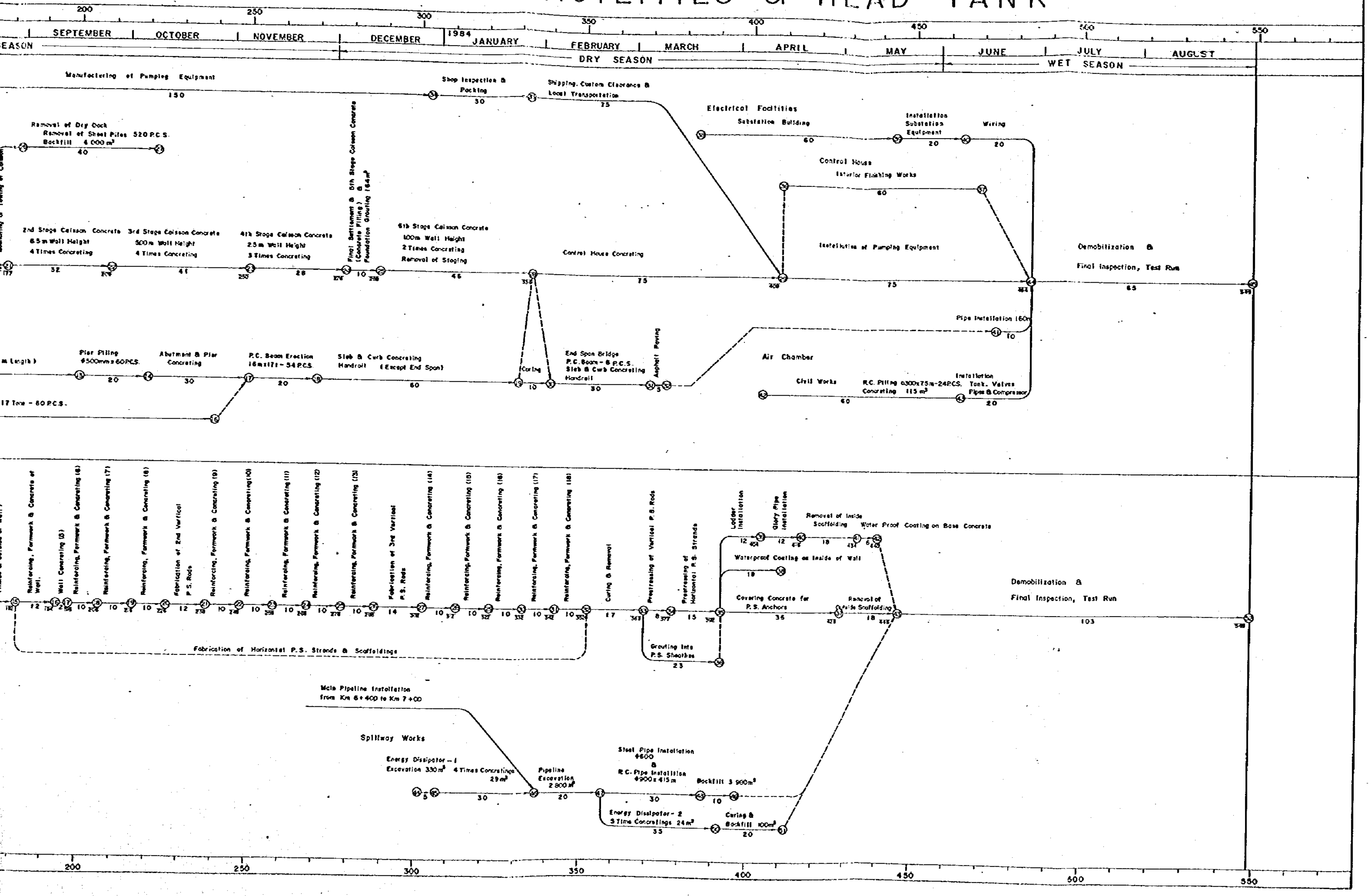
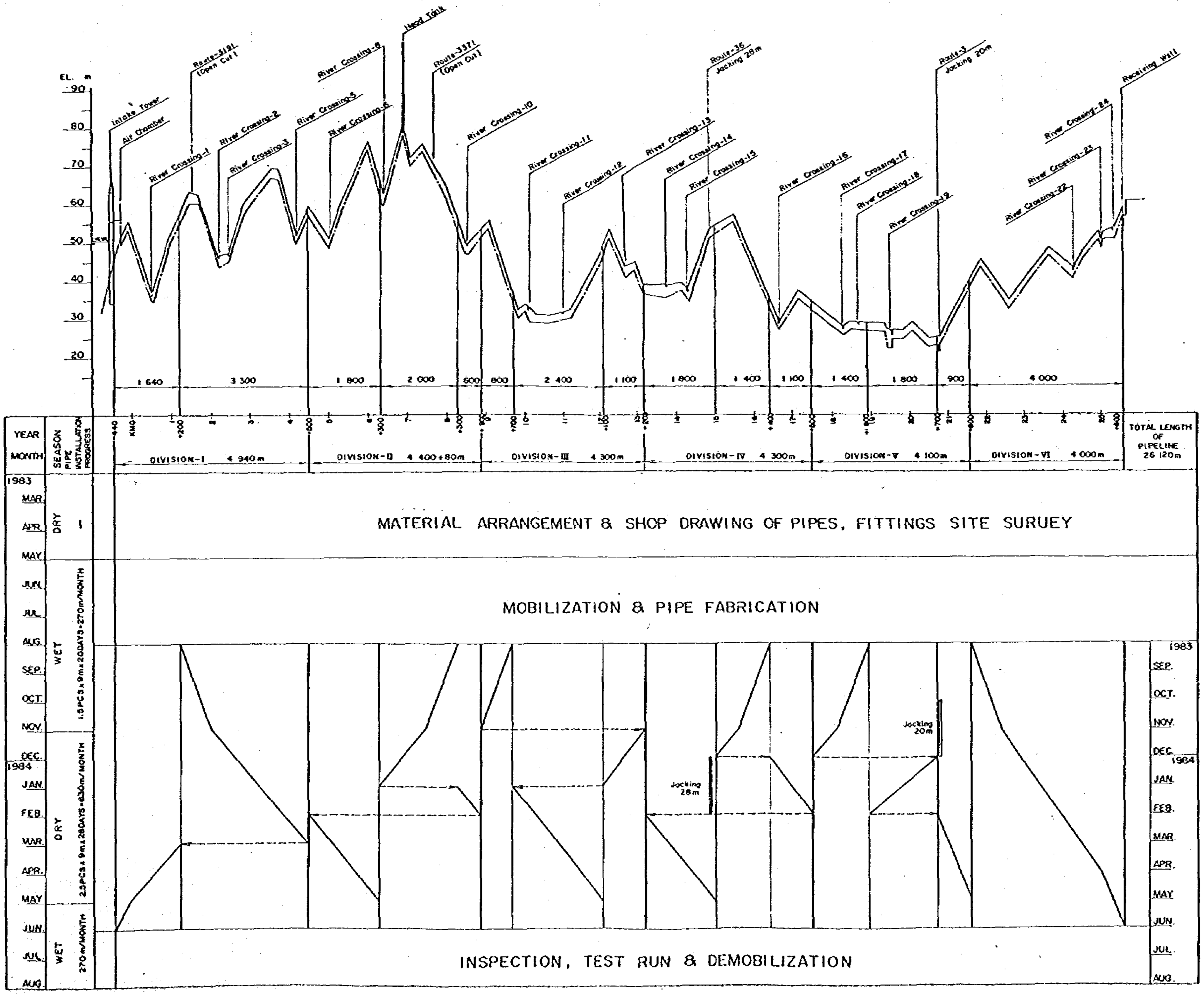


Fig. 2-7-3 CONSTRUCTION SCHDULE OF PIPELINE INSTALLATION



APPENDICES

1. ENGINEERING REPORT NO. 4

   PROPOSAL ON ORGANIZATION
   FOR PIPELINE OPERATION
   AND MAINTENANCE

2. ENGINEEERING REPORT NO. 7-2

   HYDRAULICS AND OPERATION OF PUMP
   UNIT NUMBER CONTROL SYSTEM

3. ENGINEEERING REPORT NO. 9

   COMPARATIVE STUDY OF
   PIPELINE SYSTEM
   DOK KRAI - MAB TA PUD - SATTAHIP

Note: The Appendices above are the excerpts from previously submitted Engineering Report that have been referred to in this Design Report. Of the two APPENDICES, some values presented in Engineering Report No. 9 have been altered in the present report after development of study. This alteration, however, is minor in its nature and does not have influence as to the end result of the study or the conclusion.

NO.4 PROPOSAL ON ORGANIZATION FOR PIPELINE OPERATION AND MAINTENANCE

January, 1982

Prepared by OSAMU WAKAMOTO
Co-Leader, Civil Engineering
Detailed Design Team, JICA

CONTENTS

1. Introduction

How to manage the pipeline system after completion in 1984 raises problems which are of legal, administrative, institutional, technical nature.
They are now mostly being prepared for by Thai Government.
The Detailed Design team will propose about some issues here from the view points of operation and maintenance.

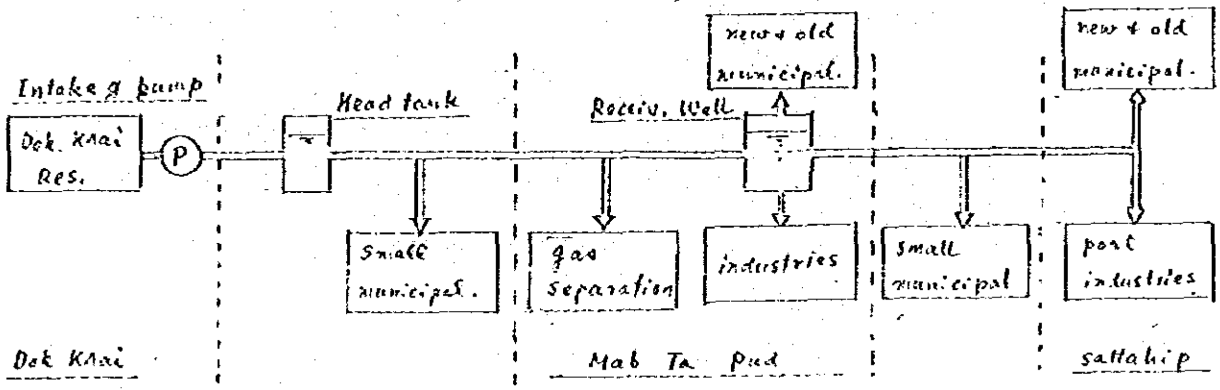
The proposal is only about the matters concerning to the operation and maintenance.
Other matters shall be conseived by Thai side and together with this proposal, a larger organizational concept shall be formed.

2. Displays of System

2.1. Flow Diagram

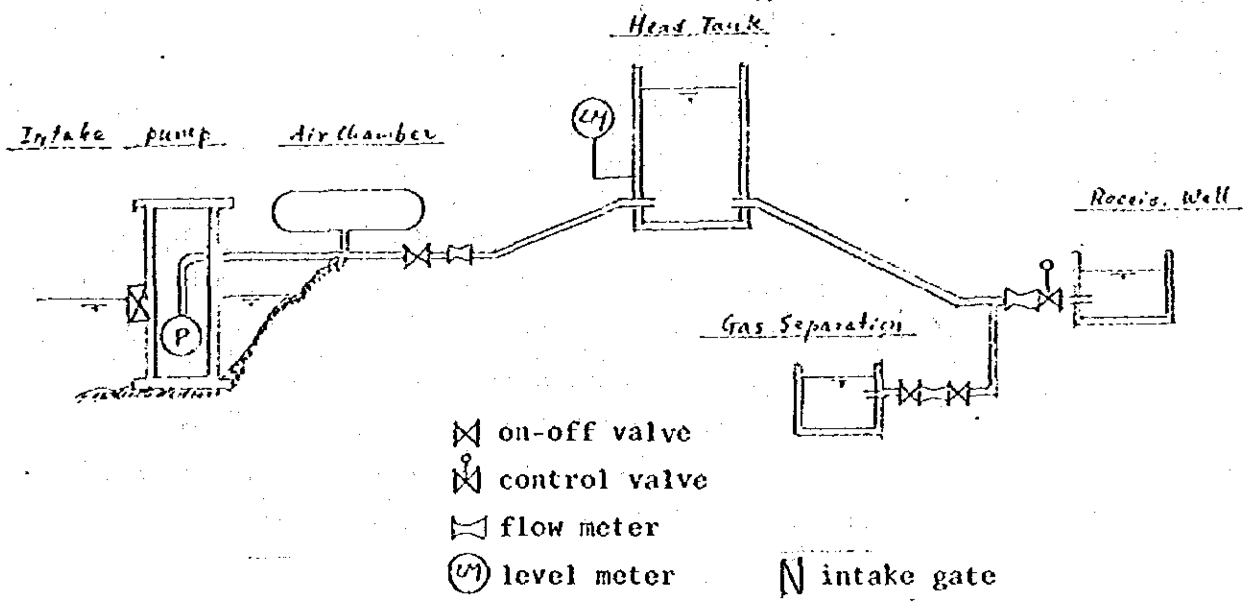
The flow diagram concerning the supply, demand and the locations of demand is as follows:

Flow Diagram



2.2. Facilities in System

The major facilities to be included in the system are shown as follows:



3. Operational Principle

3.1. Background

The Detailed Design Team had a meeting with the engineers of Metropolitan Water Works Authority (MWWA) to collect informations about operational practice in Thailand. The findings are as follows:

* A similiar pipeline is a 0.90 m dia. ductile cast-iron pipeline of 10 km length for transmission from Chaophya river to Thonburi filtration plant.

* The pump MWWA is using are mostly of axial flow or mixed flow type. The largest ones' capacity is 400 m^3/sec.

* Control of the flow rate is by changing the number of pumps under operation.

* Power failure will occur 1 to 2 times per year.

* Orders from the headquater to the stations are sent by public telephone and/or wireless. MWWA has its own radio stations authorized officially.

* Operations are carried out throughout 24 hrs. In each key station, 4 teams are engaged alternatively on 8 hrs' shift. A team is consisted of one engineer, one to two technicians, two skilled laborers.

3.2. Conditions to be considered

3.2.1 Location of Operation Center

To control the flow rate and the level of pipeline system under planning, various methods have been conceived and evaluated comparatively. The conclusion is that the center of operation is to be at the receiving well. The discussion will be reported in other Report. Aside from the said technical reason, other following factors are considered in the conclusion:

* Adjacent to the Receiving Well, a large Receiving Reservoir will be constructed very possibly for storage of water. Furthermore, in case a collective filtration plant is found necessary in the area, it will be better set up near the Well and Reservoir than in other locations. These facilities can be easily operated in coordination because of closeness.

* From the Receiving Well, the water shall be transmitted to Sattahip area. When the line comes under operation, the Receiving Well will be located around the middle of Dok Krai and Sattahip in a strategie point.

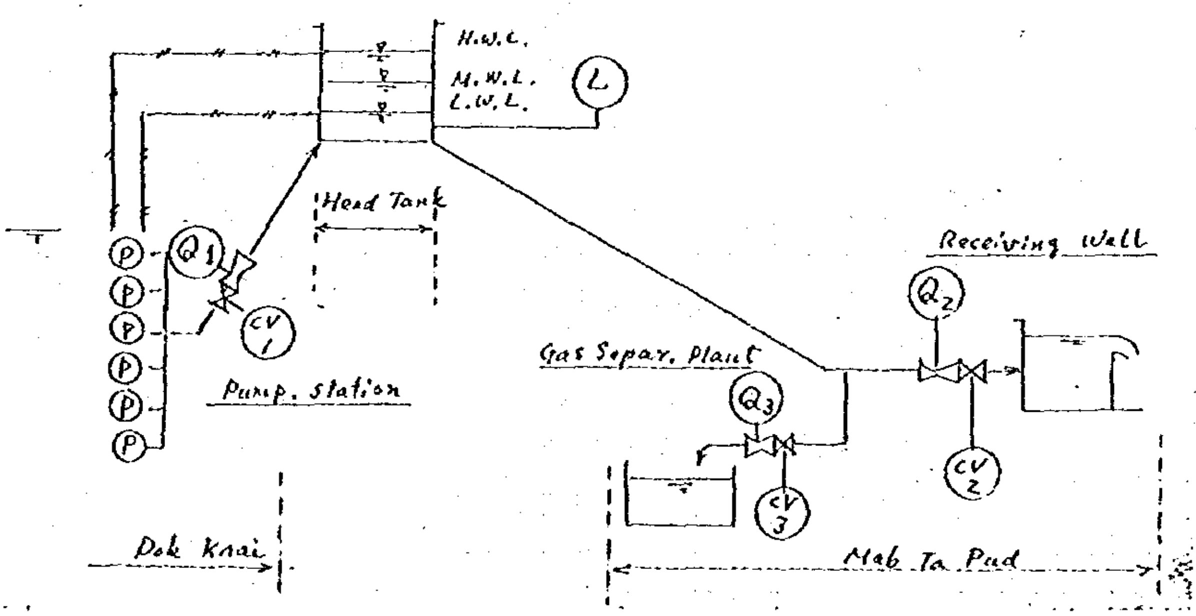
* In principle, a water supply system is an institution to serve the customer. It must be sensitive and responsive to the customers' changing requirements, alert and waiting. The largest and the second largest customer is Mab Ta Pud and Sattahip area.

3.2.2 Conditions of Operation, Normal and Extraordinary

In order to understand the operation, we will see what conditions will occur during normal operation and what will be the extraordinary conditions we must prepare for.

(1) Normal Operation

Normal Operation



The above picture contains following apparatus:

* Flow Meter	(Q1) (Q2) (Q3)	at pumps' delivery, Receiving Well, Gas Separation Plant
* Level Meter	(L)	at head tank
Control Valve	(CV 1) (CV 2) (CV 3)	at pumps' delivery, Receiving Well, Gas Separation Plant
* Pumps		5 No.s at the maximum with one Stand-by
* Electrode		High and Low water level of Head Tank

The functions of each component will be :

* Flow Meter	(Q2)	for the Engineer's judgement to control the flow
	(Q1)	for confirmation of pump's delivery
	(Q3)	for confirmation of Gas Separation Plant's inflow
* Level Meter	(L)	for the Engineer's judgement to control the flow.
* Control Valve	(CV 2)	for controlling the flow and the head tank level
	(CV 1)	usually open, closed only when necessary
	(CV 3)	usually open, closed in case of the power failure by the Engineer's order.
* Pumps		Seasonally and yearly the number is set. One pump is operated in relation with the electrolde in the head tank.
* Electrode		The high and the low actuate on-off of one pump.

Under the normal operation, the Engineer set a flow rate after controlling (CV 2) and the operator at the Receiving Well is ordered to keep watch on (Q2) whether the flow rate is kept. The operator is also to keep contact with the pump station and the Gas Plant to be informed about periodic (Q1) (Q3) reading.

As the flow rate is controlled at the Receiving Well with (CV 2), the pumps' number under operation is controlled by the head tank's level. For instance when the set flow rate is between two and three pumps'capacity, two pumps run

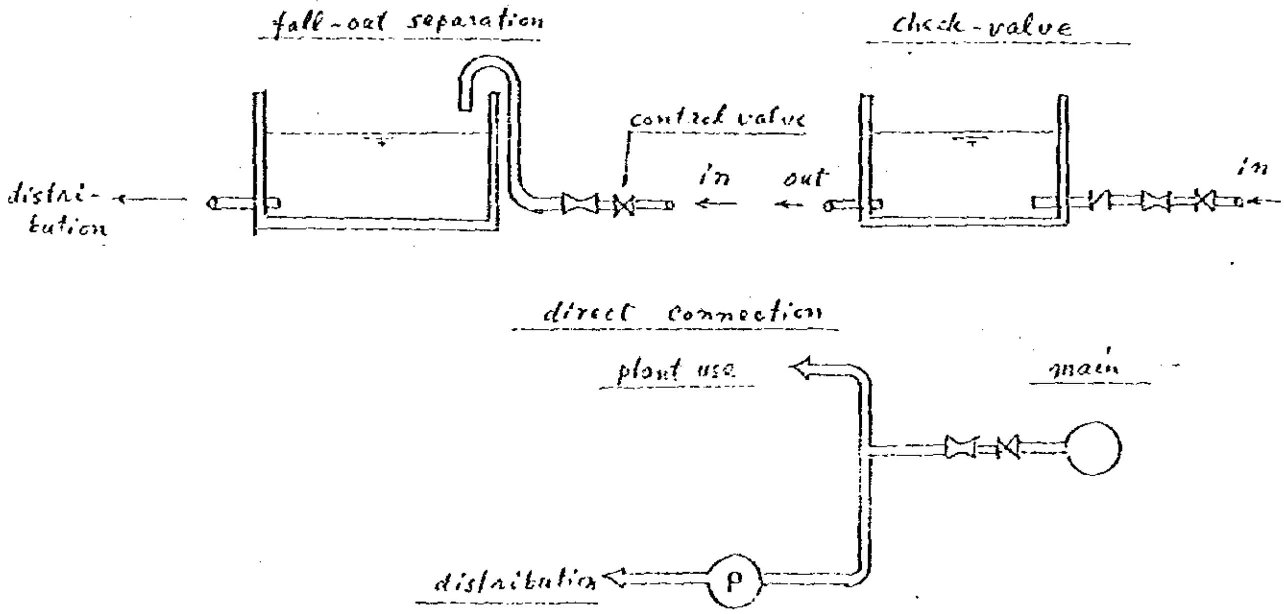
continuously and the number three pump, controlled by the head tank's level, starts and stops periodically according to the set flow rate.
In this way the pump operation is automatic.

When the set value of the flow rate is changed by adjustment of the control valve (CV 2), the period of on-off of the number three pump changes corresponding to the new flow rate.

(2) Requirements on Gas Separation Plant

The Gas Plant is requested of the following conditions:

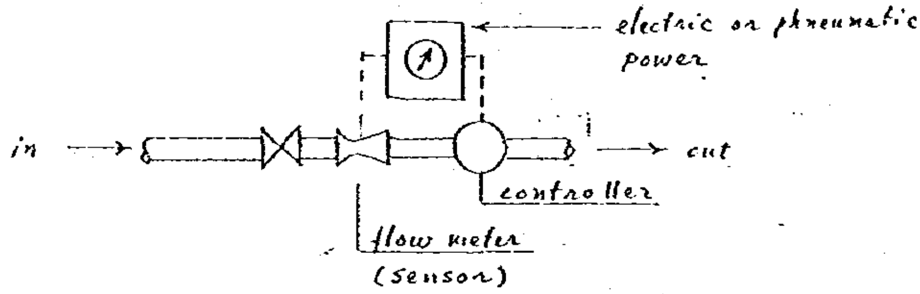
* Prepare its own storage tank in the plant so that the plant can manage with the storage, in case of emergency.
* As the connection is branched before the Receiving Well, in order to avoid any effect on the main's flow condition, the "fall-out" separation is most preferable. Installing a check value may be tolerable. The direct connection to the plant's distribution, especially with a booster pump in it must be prohibited.



* The control valve, even if it belongs to the plant ownership and it is installed within the property, must be operated only under the approval of the Engineer or by the operator of the supplier.

* To keep a steady flow, an automatic control system consisting of the flow meter and the control equipment is preferably to be installed by the Plant.

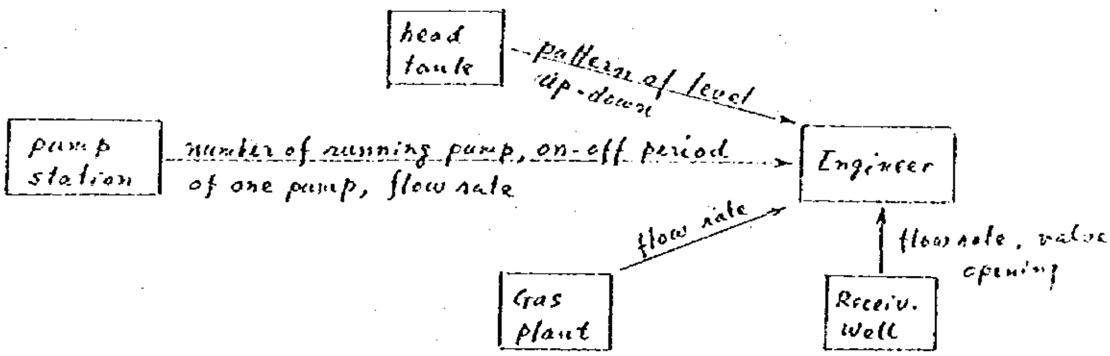
Automatic Control



(3) Flow of Information under Normal Operation

The flow of information necessary to operate the system is shown below.

everyday operation



When the flow rate is changed

The Engineer orders the Receiving Well to control the valve and wait to see if the desired rate is attained.

(4) Extraordinary Operation, Power Failure

In case of the power failure, all the running pumps will stop. The level of the head tank starts to fall down until the valves at the receiving well and the gas plant are closed immediately.

Precaution by Detailed Design

The detailed design team takes precaution against emptying of the head tank. It assumes that the time required for closing the valves is 20 minutes and the tank is to have 20 minutes minimum storage for it.

Flow of Information and Means taken

The information shall be conveyed and the means be taken as follows:

* The pump station report the power failure to the Engineer and then checks about pump, air chamber, electrical equipments.

* The Engineer alert all stations and put the system in "alert station".

* The Engineer orders the receiving wall and the Gas plant to close the valve and request reporting back to him after the operation.

* The Engineer orders the head tank to report to him the change of level, continuously untill it stops.

* When the situation of pump station, head tank, receiving well is confirmed concerning the complete stop of the pipeline, the Engineer reports to his superior and makes inquiry about the possibility of power's resumption. Then if necessary, he informs the customer about the situation.

* The Engineer orders the operator in reserve to make inspection of the pipeline, especially about the air valves on it.

When the power supply is resumed, the following steps are needed until the pipeline comes under the normal operation.

* The pump station reports about the power supply's resumption to the Engineer.

* The Engineer informs all stations and checks about the water level of head tank.

* The Engineer orders the pump station to start the pump one by one, checking with the head tank's level and with the valves opening of the receiving well and of the gas plant.

* The Engineer orders the air valves' situation to be reported by the operators in reserve. Where air-sucking was apparent in the inspection after the power failure, they shall be waiting to receive the order, preferably with a walkie-talkie and stay till the air is exhausted.

* At each stage of the increase of running pumps number, the steady flow condition as indicated by stable flow rate and the head tank level, must be attained before proceeding to the next stage.

* The operators at the valves of Receiving well and the Gas plant must report the flow rate and the valve opening simaltaneously.

* When the flow condition, same as before the power failure, is attained, the Engineer will order the operators in the field back to office and release all stations from "alert station" to "normal station".

3.3 . Other Equipments

With the above discussion of operational conditions, the equipments will be necessitated as follows:

(1) Communication Means

The discussion includes automatic start and stop of the pumps corresponding the limit of head tanks' level. It necessitates a signal line between the pump station and the head tank. Although only the electrodes are mentioned there, the level sensor for continuous measurement can also be used.

Besides the signal line, a telephone system is necessary for everyday's operation. However, the problem with the public telephone system is the limitation of number of the circuit. In case an emergency occurs when they are fully engaged, nothing can be done.

Both for everyday's operation and for emergency, the radio communication seems desirable. Approval of a radio system by the relevant authority including allotment of the frequency, preparing for qualified radio operators, purchasing the equipment and setting up the radio stations at the pump station, head tank and the receiving well must be arranged as early as possible. Walkie-talkie will be very handy for inspection patrol of the pipeline to communicate. In case its range is short to reach the Engineer, the message can be relayed through a nearby station within the range.

(2) Mobility

For inspection patrol, a jeap and/or a land cruiser is convenient. 3-4 cars will be enough.

4. Maintenance Principle

4.1. Conditions to be considered

Generally speaking, transmission pipelines do not have much maintenance problems, when compared with distribuiton pipelines and service connections.

Usually along the pipeline, the pipe stockyards for spare pipes, joints, small valves shall be prepared, in order to meet accidents like leakage and burst. Spare pipes will be almost unnecessary as the pipeline is made of steel and other materials can be easily brought to any place as the pipeline runs along the good highway.

Warehouse, Yard, Workshop

A warehouse with yard, located at Dok Krai, shall be used to store the small idems like air valves, check valves, joints and the spare parts like rubber rings, packings, bolts and the large items indoors and outdoors.

Also to be stored are the spare small electrical and mechanical gadgets for upkeeping the pumping station.
A workshop with tools and simple machineries shall be prepared for minor works of repairing.

4.2. Check List and Record

Major items like pumps, motors, compressors for the air chamber, flow and level meters (including sensors) and electric circuits shall be inspected regularly. Also needed will be overhauling of some equipments.
The checking schedule must be fixed and observed and the checking list for various items be prepared.
The record of inspection, overhauling and reparing must be preserved.

4.3. Water Analysis

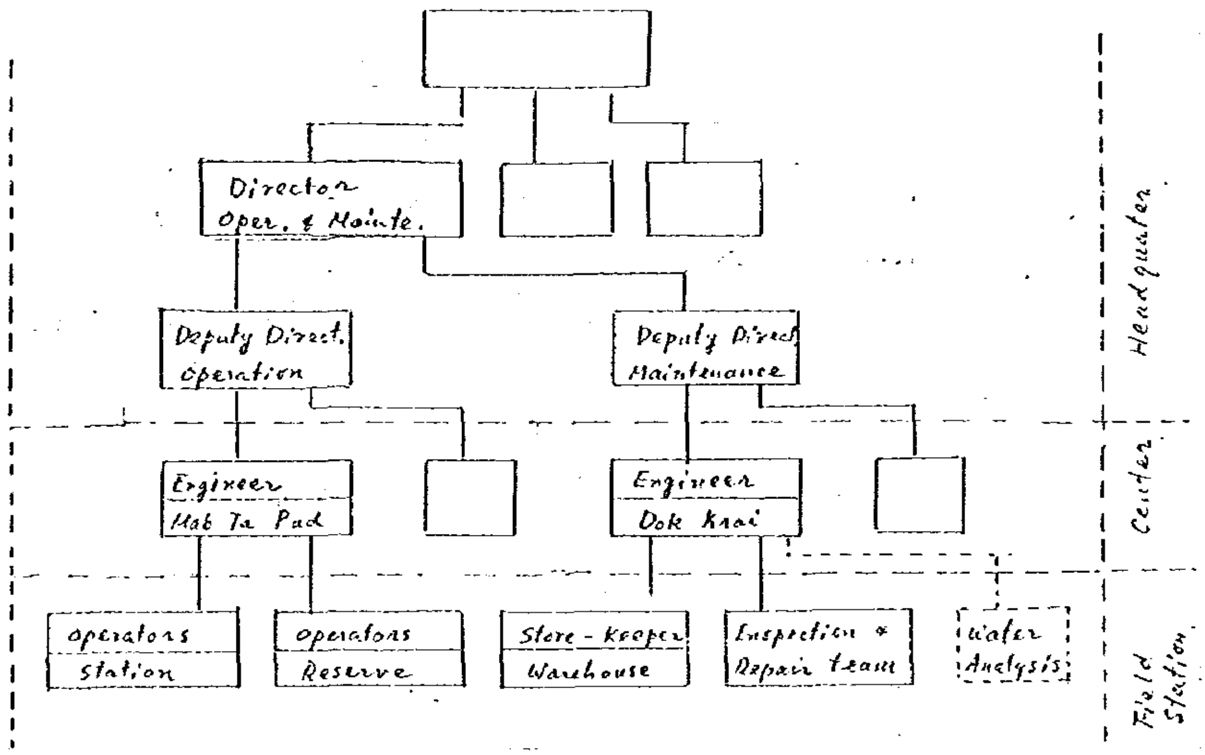
The pipeline system is for delivering water to the customers. The customers are entitled to learn about the quality of delivered goods, the water. Consequently,making the water analysis and reporting about the result is the suppliers obligation, if not responsibility.
The water of Dok Krai Reservoir is satisfactory for general use of industries as far as the available information shows. One thing which may occur but has not been experienced is high turbidity.
The frequency of water analysis is to be considered here. About inorganic matters, remarkable difference will be seen between the dry season and the rainy season. About the inorganic matters, seasonal change will be slight while it is sometimes noticable due to the algae growth in countries of the temperate zone. Probably four times per year including the dry and rainy seasons will be sufficient in making the analysis.
A laboratory will be unnecessary for some years until the water is put to use for drinking purpose. Then the frequency must be increased, the items of analysis must be decided and the laboratory shall be set up.

Till then, the water analysis will be better taken care by some public institution which has facilities of water analysis.

5. Organization for Operation and Maintenance

An organization chart including some requirements is to be discussed,then a table of personnel with working condition is to be proposed.

5.1. Organization Chart, Qualification of Key Personnel



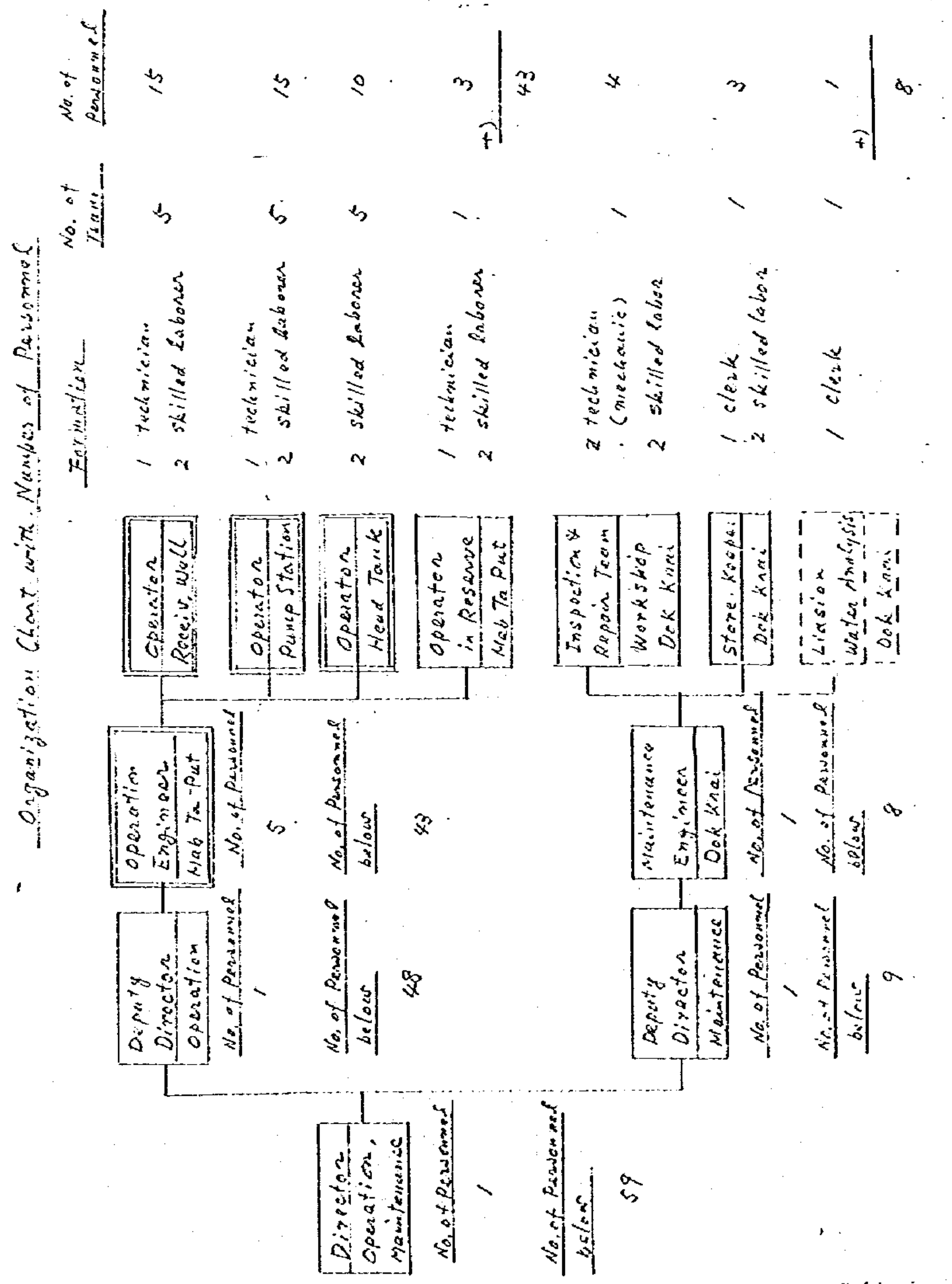
The above chart shows how the operation and maintenance will be organized and how it will fit in the whole organization. The requirements of personnel will be desribed below:

* The director and deputy directors are to have sufficient educational and vocational background and some administrative experience.

* The Engineer in charge of the operation and the maintenance are to have educational background of civil and/or mechanical engineering.

6. Organization Chart with Number of Personnel

The organization chart in 5.1. will be completed with the number of personnel for each part as shown below;



* The Chief Operator heading two to three operators and the chief of inspection and repair team are to be technician, having years of vocational experience.

* The operators are to be skilled laborers.

* The store-keeper shall be selected mostly on the experience.

* The water analysis is included in the work of Engineer in charge of the maintenance.

5.2. Formation of Operators' team and Inspection & Repair team

(1) Operators Team

Depending upon the importance of each station and considering the hardness of operating conditions, both physical and mental, the following formation is thought out;

Station

* Receiving Well	1	Chief operator
	2	Operators
* Head Tank	2	Operators
* Pump station	1	Chief operator
	2	Operators

Reserve

* Engineer's office	1	Chief operator
	2	Operators

(2) Inspection and Repair Team

* Engineer's office	1	Chief mechanic
	1	Mechanic
	2	Skilled laborers

5.3. Working Conditions

(1) Daytime only

The headquarters staff,the store keeper, the operators in reserve and the inspection and repair team are to work only in the daytime, following the organization's rule.

(2) Shift

The Engineers and operators are to work at 8 hrs. shift in rotation, so that 24 hrs operation is being kept.
MWWA seems to take 8 hrs shift by 4 teams' rotation.
By calculation it will mean 42 hrs work per week, more working hours than ordinary which will need some extra pay. 5 teams' rotation and 33.6 hrs per week may be better.
It should be concluded considering labour law, government regulation and labor practice.

Note

* The table does not include common laborer for miscellaneous use.

* The Gas Separation Plant's operation is to be under Operator at the Receiving Well. It is not on the table.

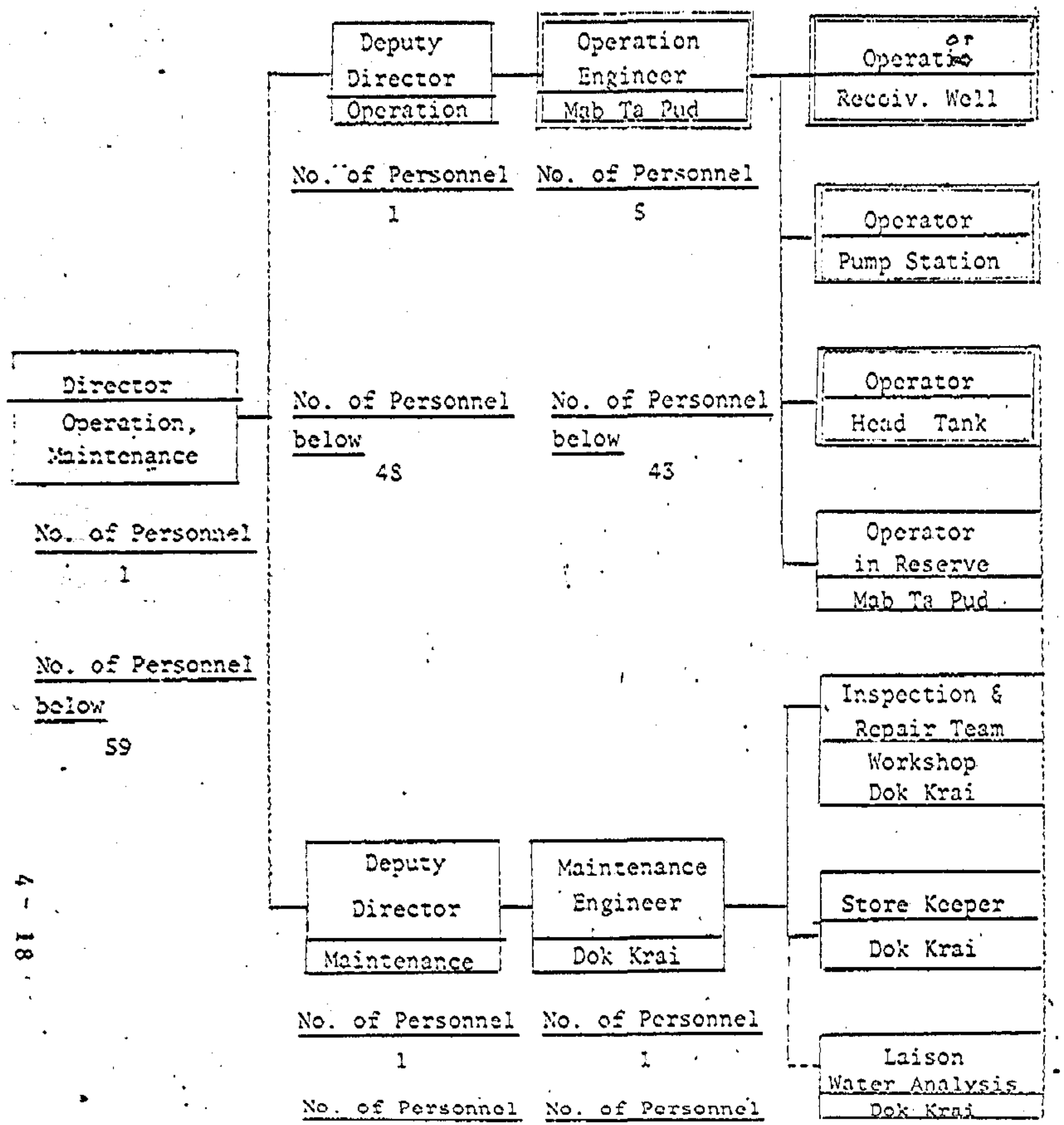
* No. of shift team is assumed as 5.

* The double framed part is for shift work.

THE PIPELINE SYSTEM FROM DOK KRAI TO MAB TA PUD

Fig.-2

Organization Chart with Number of Personnel



Formation	No. of Team	No. of Personnel
1. technician 2. skilled laborer	5	15
1. technician 2. skilled laborer	5	15
2. skilled laborer	5	10
1. technician 2. skilled laborer	1	3
		+) 43
2. technician (mechanic) 2. skilled labor	1	4
1. clerk 2. skilled labor	1	3
1. clerk	1	1
		+) 8

NO.7-2 HYDRAULICS AND OPERATION OF PUMP UNIT NUMBER CONTROL SYSTEM

JANUARY 1982

Prepared by YOSHIYUKI TOMIOKA
Water Facilities Engineer
Detailed Design Team
JICA

CONTENT

1. INTRODUCTION

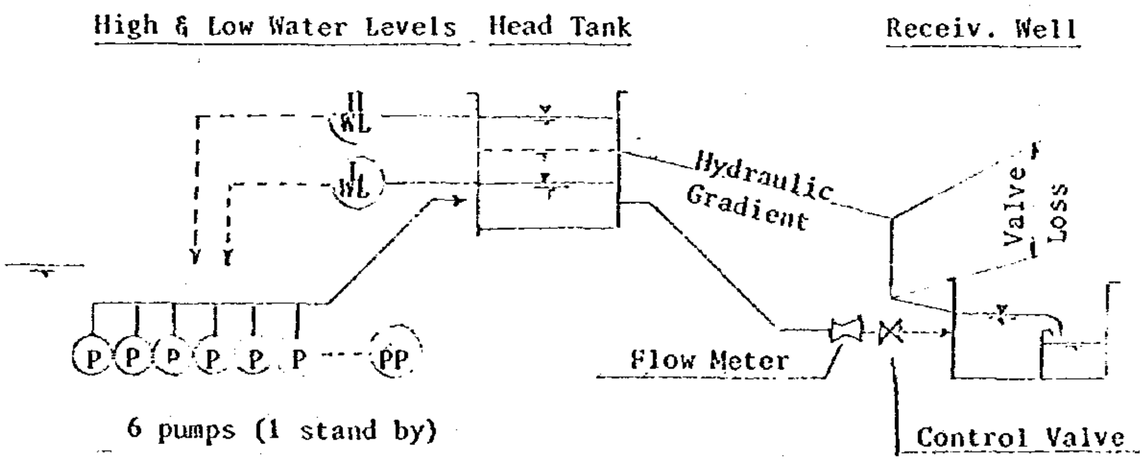
Comparative Study of Flow Control System has proved and concluded that the simplest, lowest in cost, most reliable method in controling the flow is Pump Unit Number Control.
Needless to say, in the report the control method is discussed in principle and practical matters, in order to be compared with two other methods.
In this report, hydraulic study will be made to examine the fluctuation of flow and the periodical surging of the head tank's water level.
Also here, the pumps' schedule of operation will be studied, in relation to the head tank's water level.

2. EXPLANATION OF CONTROL

2.1. Facilities and Equipments

Fig.1 shows the facilities and equipments used in controling the flow.

Fig.-1 Facilities



(1) Pumps and Pumps' Programmer

Depending on the set flow rate, from 1 to 5 pumps will lift water. Actually 6 pumps are prepared to have 1 stand-by in case 5 pumps are run. For maintenance reason, each pump is run in turn and the programmer is used for the purpose. On Fig.1 (P) and (PP) are the pumps and pump programmer respectively.

(2) Level (Pressure) Switches in Head Tank

To start and stop the pump, two level switches must be installed in the head tank, one for the high water level and another for the low water level. They are symbolized as (H WL) and (L WL) on Fig.1.

The gap of the two levels relates to the period or cycle of surging in the head tank. The level switches can be of various types, such as electrode, contacts on pressure gauges, etc.

(3) Control Valves and Flow Meter at Receiving Well

These are for setting the flow rates.

The control valve, electrically driven, can be turned both directions and be stopped at any position. The operator can adjust the valve delicately, checking with the reading of flow meter, until the desired rate is set and steadied.

Here, caused by the surge in head tank, the reading of flow meter will sway and it will seemingly make the adjustment rather difficult.

The sway is practically very small by hydraulic reason, as it is explained later.

The valve causes the loss in the pipeline and it is effective in steadying the flow.

2.2. Hydraulics of Pipeline

(1) Hydraulic Gradient

Substituting the roughness coefficient C = 120 and the pipe diameter D = 1.35 m into Hazen-Williams formula, it can be transformed to :

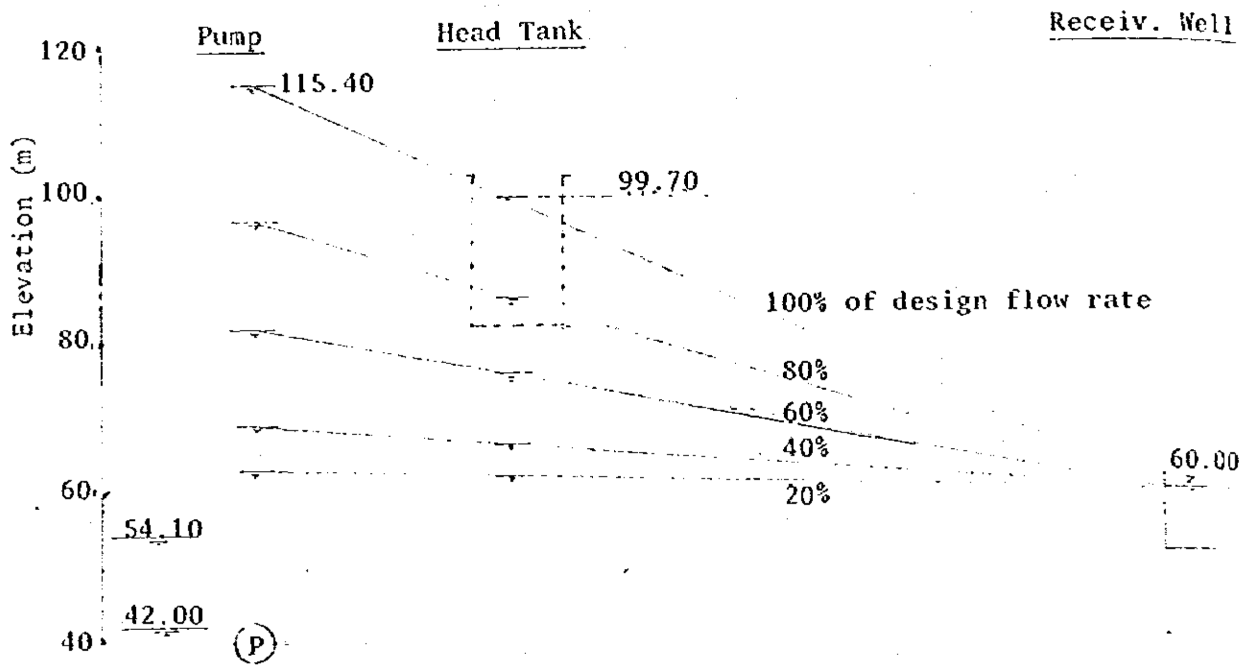
$$I = 3.522 \times 10^{-4} \times Q^{1.85}$$

Q : flow rate, m^3/sec

I : hydraulic gradient

With the fomula, calculation is made on 5 cases of Q, that is, 100, 80, 60, 40, 20% of the design flow rate 2.62 m^3/sec. The result is shown on Fig.2.

Fig-2 Hydraulic Gradient

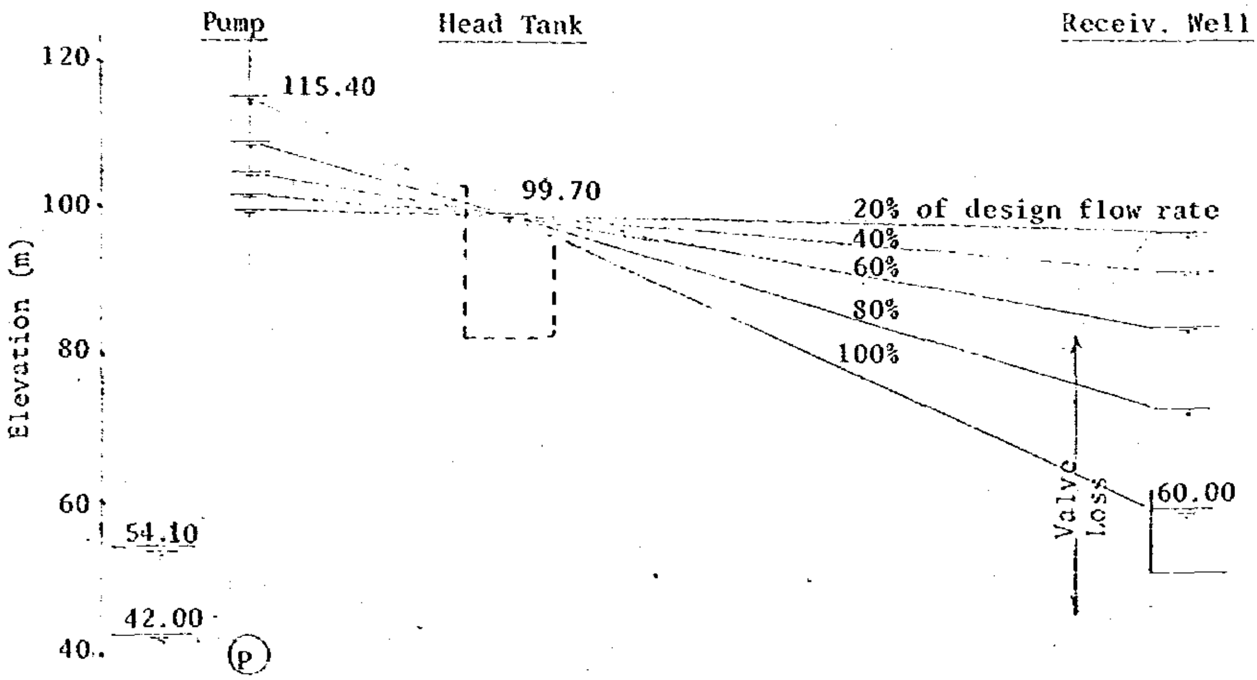


(2) Controling Valve at Receiving Well

As is seen on Fig.2, except the two cases 100% and 80% the 60, 40, 20% lines fall below the head tank, also shown by dotted line.

It leads that the valve must be so controlled that all the lines can stay in the tank, in order to let the pipeline work and to make pump unit control possible.

Fig-3 Controling Valve at Receiving Well



As is seen on Fig.3, nearly 40 m head loss shall be given by the valve, in case of 20% flow of the design rate. For purpose of control, the head tanks level shall not necessarily be kept at 99.70 accurately.

2.3. Fluctuation of Flow between Head Tank and Receiving Well

As it is quoted before, the flow rate is proportional to 0.54 powers of the hydraulic gradient.

Generally, the equation is :

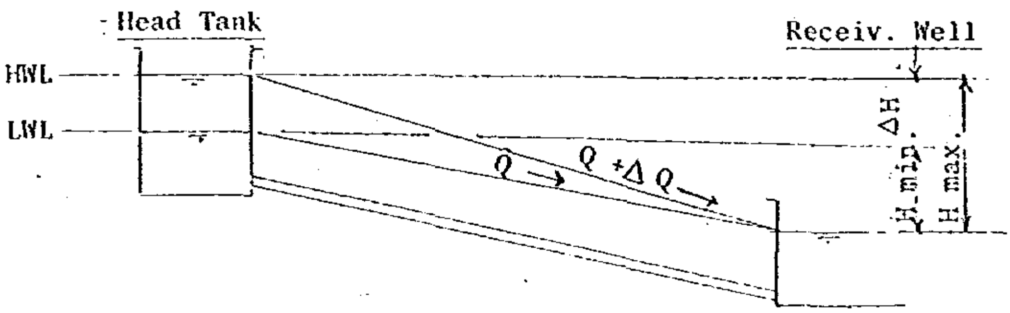
$$Q = k\ I^{0.54}$$

As the hydraulic gradient is equal to the head loss divided by the pipeline length, the above equation becomes :

$$Q = k'\ H^{0.54}$$

When the water level in head tank rises from LWL (Low Water Level) to HWL (High Water Level) and accordingly the head loss changes from H min to H max, as shown on Fig.4, the flow rate also changes from Q to Q + ΔQ.

Fig-4 Fluctuation of Flow



ΔQ, the increase of flow, is caused by the increase of head loss which is designated as ΔH = H max-H min.

Using the previously quoted equation :

$$Q = k' \text{ H min}$$

$$Q + \Delta Q = k' \text{ H max} = k'(\text{H min} + \Delta H)$$

From the two equations, an approximate equation is lead:

$$\frac{\Delta Q}{Q} \fallingdotseq 0.54 \frac{\Delta H}{\text{H min}}$$

In the case of the project pipeline, as shown on Fig.3, H max = 99.70 - 60.00 = 39.70 m and H, the gap between HWL and LWL can be reasonably assumed about 2.50 m.

Then, H min = 39.70 - 2.50 = 37.20

Substiting the values of H min and H :

$$\frac{\Delta Q}{Q} \fallingdotseq 0.54 \times \frac{2.50}{37.20} = 0.036 = 3.6\%$$

Under the discussed condition, the flow rate increases only by 3.6 per cent and as the change is so small that the flow rate can be considered as steady for practical purpose.

2.4. Fluctuation of Flow between Pump and Head Tank

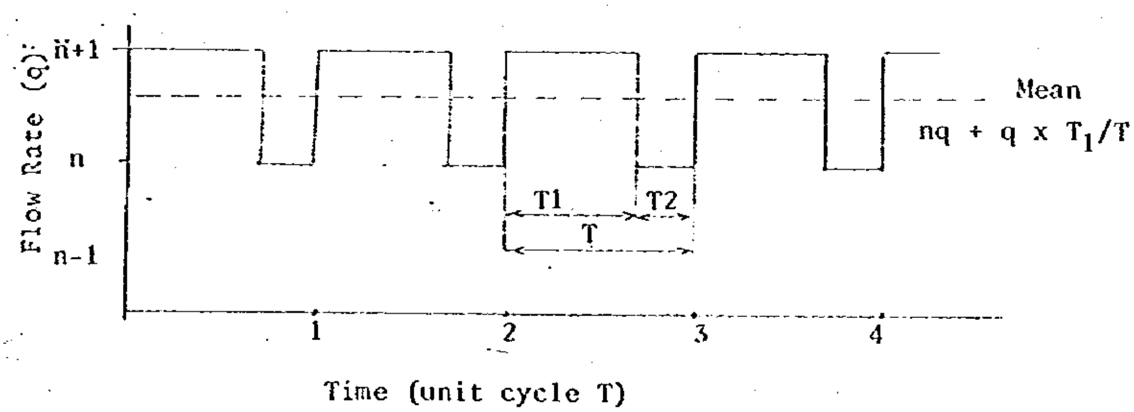
(1) Setting Flow Rate

At the receiving well, the inflow is practically steady and the desired flow rate can be set without difficulty by controling the valve.

The control of flow by Pump Unit Number is a stepping control flow as it is explained in Report on Comparative Study of Flow Control System.
Accordingly, the set flow rate can be put down as $nq+\alpha q$, where q is the flow capacity per pump and α is between o and 1.
The set flow rate is between nq and (n+1)q and it shall be attained by running n number pumps continuously and the (n+1)th pump intermittently.

(2) Pump's Operation
Fig.5 shows how the pumps output changes against time. The abscissa and ordinate are graduated with the cycle (period) time and the capacity per unit pump.

Fig-5 Change of Pumps Output



As shown on the figure, n number pumps run continuouly while the (n+1)th pump repeats T1 time running and T2 time stopping during one cycle time T, the mean output is calculated as :

$$nq + q \times \frac{T1}{T1+T2} \quad \text{or} \quad nq + q \times T1/T$$

While in the foregoing paragraph, the set flow rate is expressed as $nq + \alpha q$.
As the pumps' output is equal to the set flow rate :

$$\alpha q = q \times T1/T \text{ or } \alpha = T1/T,\ o<\alpha<1$$

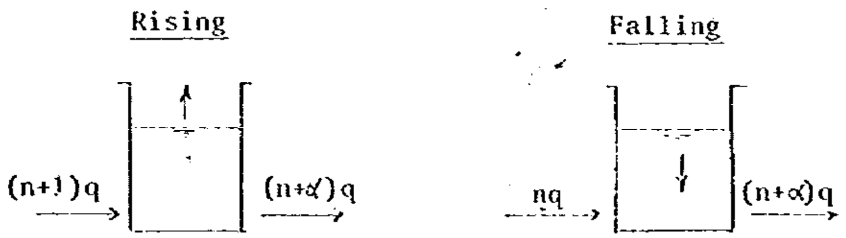
Needless to say, the (n+1)th pump stops when the water level comes up to HWL, as (n+1)q is larger than the set rate nq + αq and the balance is gradually stored in the tank, pushing the level up. And the pump starts when the water level comes down to LWL.

3. HEAD TANK'S ROLE IN CONTROL

3.1. Change of Water Level

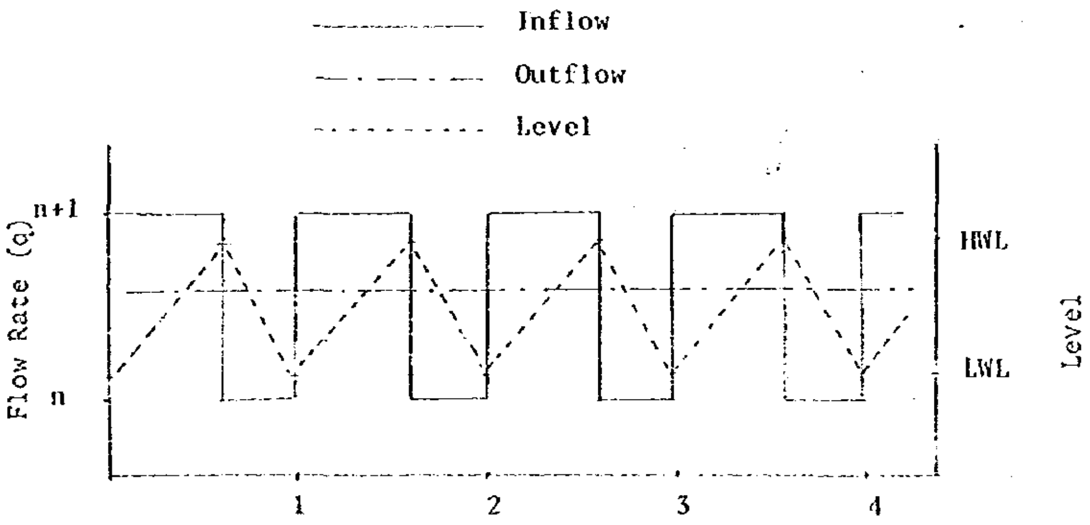
Fig.6 shows the water level's rising and falling.

Fig-6 Water Level Change



When the (n+1) pump is running, the balance of inflow and outflow (1-α)q pushes the level up and when the pump is kept stopped, the balance αq causes the level fall.
In both cases of rise and fall, the speed of level change is constant as the balance of flow is constant.
Accordingly, the change of head tank's level, the inflow and outflow relates as shown on Fig.7

Fig-7 Change of Inflow, Outflow, Level



3.2. Cycle Time

The cyclic time of rise and fall must be studied.
The tank's volume between HWL and LWL is designated as V.
The times required for rising and falling can be expressed as :

$$\text{rising} \quad \frac{V}{(1-\alpha)q}$$

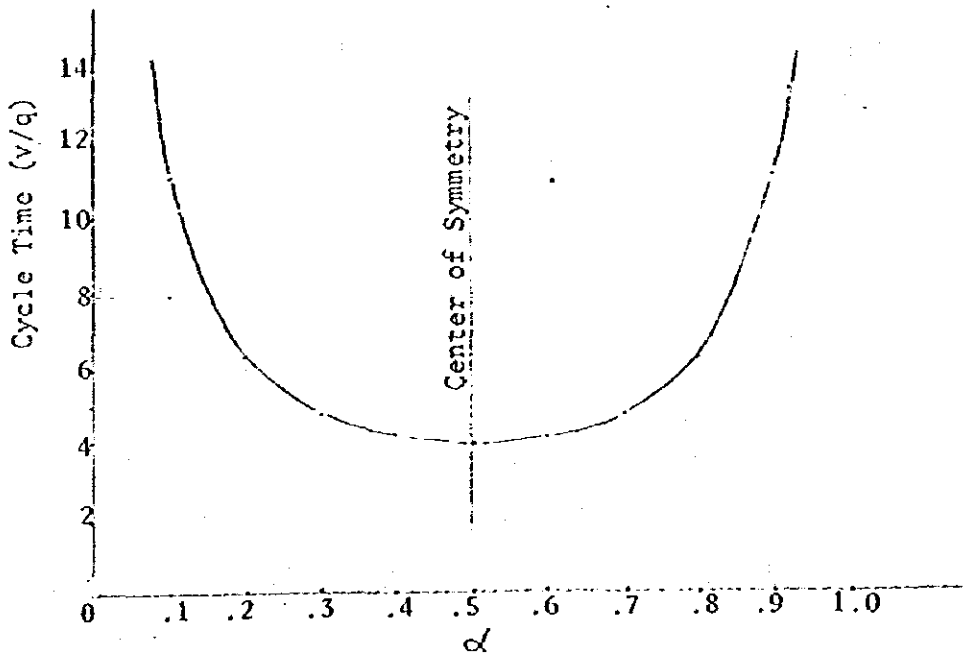
$$\text{falling} \quad \frac{V}{\alpha q}$$

And one cycle time is :

$$\frac{V}{q}\left(\frac{1}{1-\alpha}+\frac{1}{\alpha}\right)=\frac{V}{q}\cdot\frac{1}{\alpha(\alpha-1)}$$

As V/q becomes a constant valve which is determined by the tank's size, the position of HWL and LWL, unit pump's capacity, the parameter affects the cycle time.
Fig.8 shows the relationship between α ,and the cycle time.

Fig-8 α and Cycle Time



The curve on Fig.8 is symmetrical. The cycle time is the shortest at α= 0.5 and it becomes longer for both way as α increases and decreases. At α = 0.15 and α = 0.85, the cycle time is about two times of that at α=0.5, and at α=0.91, it is about 3 times.

Clearly Fig.8 shows that the cycle time becomes infinite when α and $1-\alpha$ approaches to o and 1. Hydraulically meaning, the flow rate now equals nq or (n+1)q and all the pumps are run continuously and the level is steadied, making no rise and fall any more.

The effect of cycle time on the pumps operation shall be discussed later.

As it is understood already, the cycle time of rise and fall is independent of the flow rate. Of the set flow rate $nq + \alpha q$, only αq affects the cycle time and nq does not.

3.3. Head Tank's Shape

The tanks volume between HWL and LWL is a factor to determine the cycle time. How the cycle time relates to the pump operation shall be studied later.

For control of the flow, the narrower gap between HWL and LWL is better as long as the two levels are sensed distinctively. A flat tank is preferable.

4. CYCLE TIME AND PUMP OPERATION

4.1. Pumps Capacity and Head Tank's Size

The capacity of one pump q is 0.524 m^3/sec.
The head tanks size, now in the stage of conceptual design, is 16 m in diameter and about 21 m in water depth. For purpose of controling the flow, HWL and LWL is set 2.50 m apart around the top of water depth. The volume of surging is $0.785 \times 16^2 \times 2.5 = 502.4\ m^3$

4.2. Cycle Time

The cycle time as against α q can be tabulated as follows:

α	q m^3/sec	Cycle time min.	sec.
0	0		
0.1	0.052	177	33
0.2	0.105	99	52
0.3	0.157	76	6
0.4	0.210	66	34
0.5	0.262	63	52
0.6	0.314	66	34
0.7	0.367	76	6
0.8	0.419	99	52
0.9	0.472	177	33
1.0	0.524		

As it is seen in the table, the surge is remarkably slow. Even the shortest cycle is 64 min and as the half of it is for the rise, the rising speed is 2.50 m/32 min. = 7.8 cm/min.

4.3. Pump Operation Schedule

(1) Flow Rate Pattern

The set flow rate equals $nq + \alpha q$.

n number pumps are running continuously and the (n+1)th pump periodically. The (n+1)th pump runs for T1 time and keeps stopping for T2 time.

Here, $T1 + T2 = T$ T : cycle time

$= T1/T$

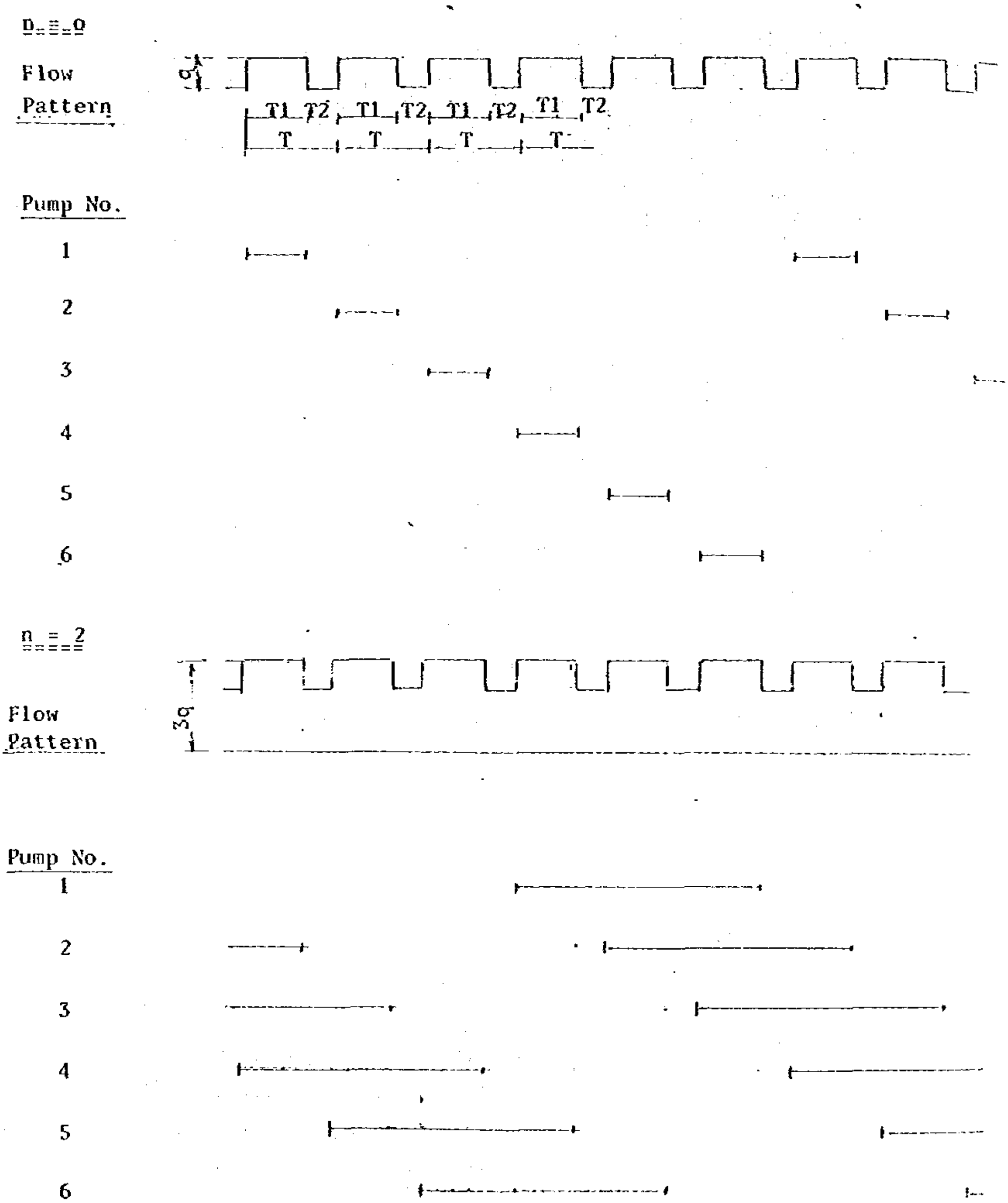
(2) Pumps' Rotation

The pump programmer lets the pumps run in rotation so that every pump is under the same condition.

(3) Pumps' Running Schedule, Rule of Programme

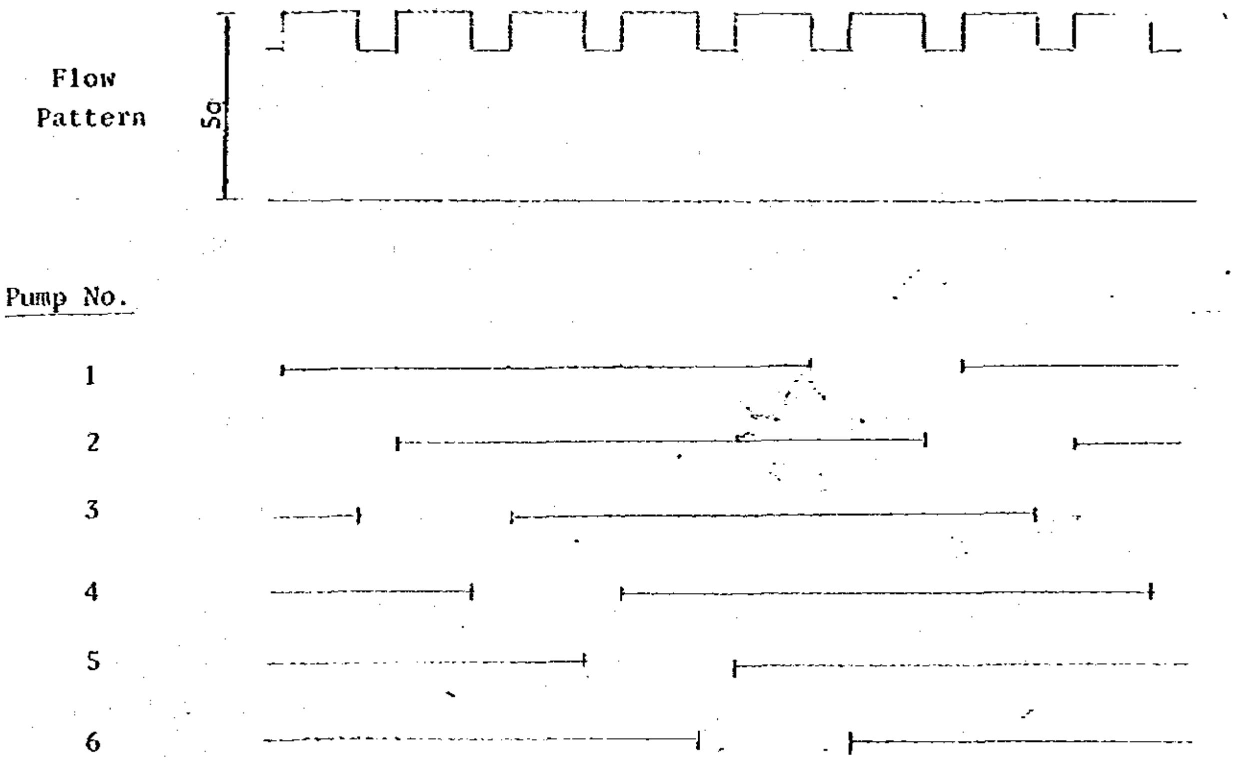
Fig.9 is the schedule of 6 pumps under a certain cycle time T, with n = 0, 2, 4, as shown on the following pages.

Fig-9 Schedule of 6 Pumps



n=4

Fig-9 Schedule of 6 Pumps (continued)



From Fig.9 the following general rules are found :

* Each pump starts and stops every 6 T.
* The running time T, is nT + T1 and the resting (kept stopped) time is (5-n)T + T2.
* The interval of every start and stop is T.

These rules are to be used in designing the pump programmer.

(4) Occurence of Strong Electric Current by Starting Pumps

When a pump is started, a strong instant current flows at the switch and in the motor and too frequent starting is detrimental to the gadgets.

Electricity is supplied through the main switch and the branch switch to each motor.

The branch switch and motor are started every 6T and the main switch is affected by the additional current every T.

As it is discussed previously, T is longer than 60 minutes and is long enough for reasonably normal operation of the motor and switches.

5. CHANGING SET FLOW RATE

5.1. Increase of Demand

Fig-10 Increase of Demand

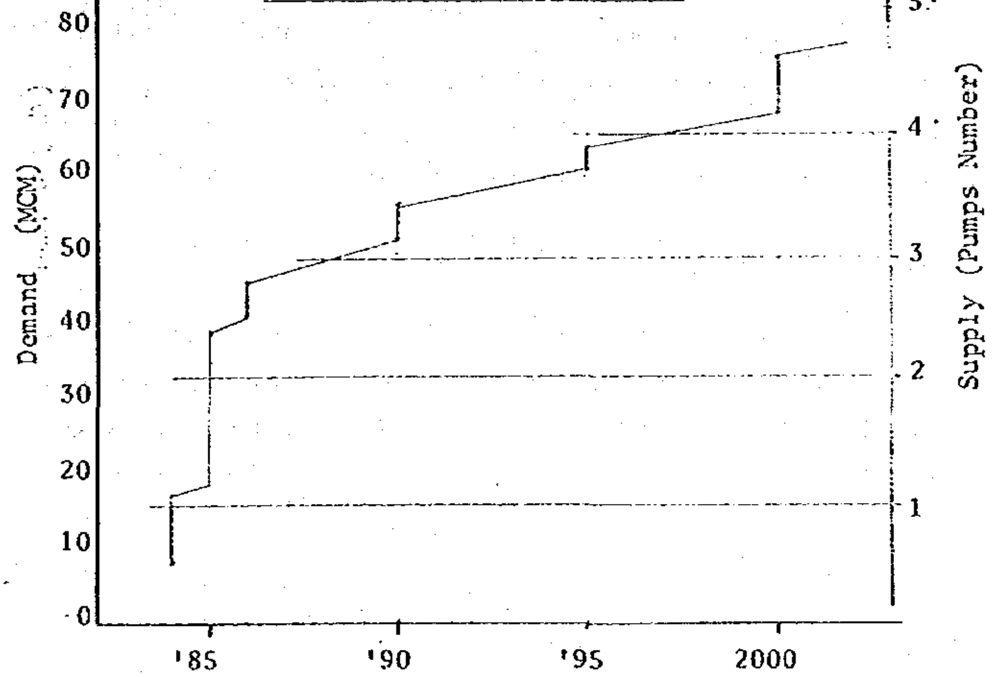


Fig.10 shows the increase of demand from 1984 to 2000. In '84, the first year of operation, initially 1 and very soon 2 pumps will be working. In '85, the 3rd pump must be placed in operation and 3 pumps stage will go on till '88.

5.2. 5 Stages

5 stages, corresponding the increase, can be expected. They are tabulated as shown below, using the same terms quoted before :

Stage	No. of Pumps: Continuous	No. of Pumps: Intermittent	Range of Flow Unit:q
1st	0	1	0 - 1
2nd	1	1	1 - 2
3rd	2	1	2 - 3
4th	3	1	3 - 4
5th	4	1	4 - 5

The pump programmer shall work the pumps rotational operation at each of the 5 stages.
The most possible practice of operation is to move from the existing stage to the next one. For instance, to go to 2nd from 1st, the operator will have to reach an equilibrium at 1 pump's continuous operation and then will set the flow rate at the desired value between 1 and 2.
However, a sudden change like jumping from 1st to 3rd must be also expected probably in case of emergency.

5.3. For Sudden Change of Flow

The pump programmer shall have 5 independent circuit for the 5 stage and shall be able to select any one of them. It will also be used for the gradual move to next stage, needless to say.

6. SUMMERY

The discussion made in this paper will be summerized here :

(1) Setting the flow rate can be worked out with no difficulty.

(2) The flow between the head tank and the receiving well is steady.

(3) The stepping flow pattern of pumps output is changed into the steady flow of the head tanks outflow.

(4) The rise and fall of head tank's water level is cyclic and the cycle time depends on the intermittence of one pump and the tank size. The cycle is rather slow practically.

(5) All the pumps shall be run in turn and the schedule of rotation can be programmed.

(6) The change of cycle time does not cause any problem on the electrical equipment and the motor of pump.

(7) A programme must be prepared for both gradual and sudden change of the set flow rate.

NO.9 COMPARATIVE STUDY OF PIPELINE SYSTEM DOK KRAI - MAB TA PUD - SATTAHIP

January 1982

Prepared by YOSHIYUKI TOMIOKA
AKIHIRO MIYAKE
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CONTENT

1. Introduction

The diameter of pipeline between Dok Krai and Mab Ta Pud was decided at the conference held at the beginning of November 1981. Consequently, 1.5 m in the Feasibility Study was changed to 1.35 m for the Detailed Design. The reason for the change was due to the modified supply capacity of 57.8 MCM/yr, resulting from the review of demand.

Though the detailed design work is undertaken now for Dok Krai - Mab Ta Pud, its extention to Sattahip in an early future is very certain.

When Mab Ta Pud - Sattahip line is completed, the whole system of Dok Krai - Mab Ta Pud - Sattahip shall be operated as a whole.

Considering the above situation, the detailed design team has worked a comparative study to see;

(1) If the decision of 1.35 m diameter for Dok Krai - Mab Ta Pud was reasonable.

(2) What size will be most economical for the Mab Ta Pud - Sattahip extention.

(3) How the selection of the elevation of receiving well will affect the whole pipeline system.

2. Conditions, Given and Assumed

2.1. Given Conditions

(1) Flow Rate, Water Demand

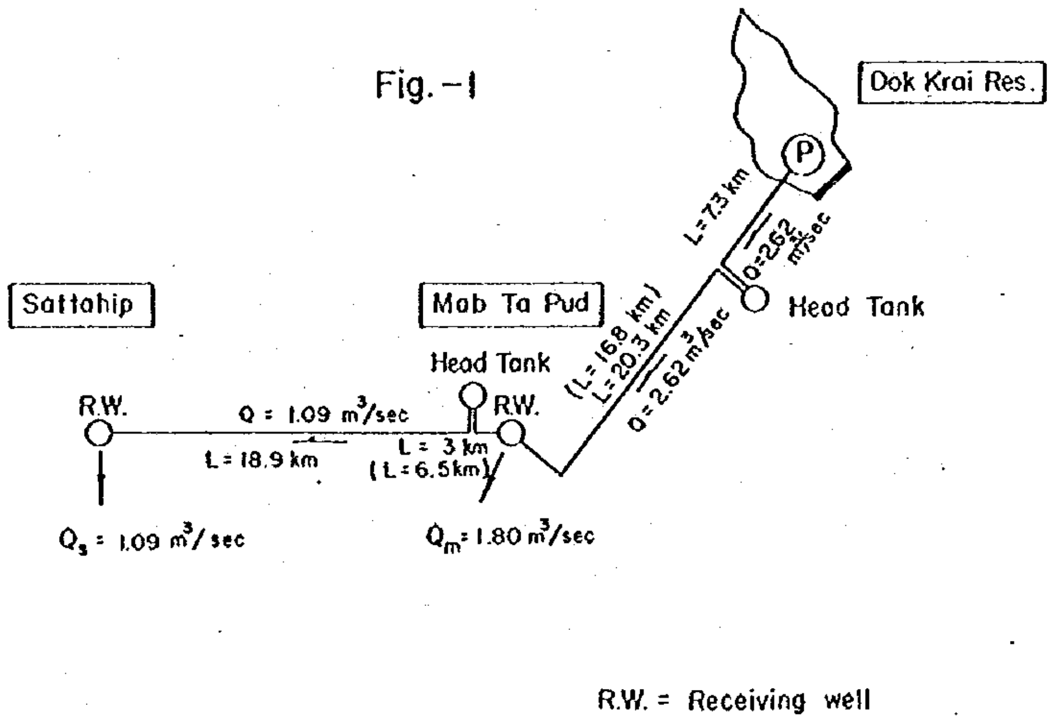
	Flow Rate(m^3/sec)	Water Demand(MCM/yr)
Dok Krai & Mab Ta Pud	# 2.62	# 57.8
Mab Ta Pud & Sattahip	1.09	* 24.0

agreed figure, * Feasibility Study, Table 3-5,

(2) Pipeline System

As shown below, the pipeline system includes pumps, head tanks, receiving wells and pipes. The pipeline length with and without the bracket corresponds to Model II and Model I which will be explained later. The difference comes from the location of Receiving Well at Mab Ta Pud.

Fig.-1



(3) Low Water Level at Dok Krai

42.00 is given

2.2. Assumed Conditions

30.00 for the level of receiving well at Sattahip is assumed, considering that the industrial supply be fed by gravity and the municipal by pumping. The industries will consume about 73% of the supply and they will be in low land of 5 to 10 m above sea level. The supply by gravity to them will save much energy in the long run.

3. Parameters for Comparative Study

3 parameters, the level of receiving well at Mab Ta Pud, the diameter between Dok Krai and Mab Ta Pud, the same between Mab Ta Pud and Sattahip are the parameters for comparative study.

These parameters are combined to make 18 cases of combination on the next page.

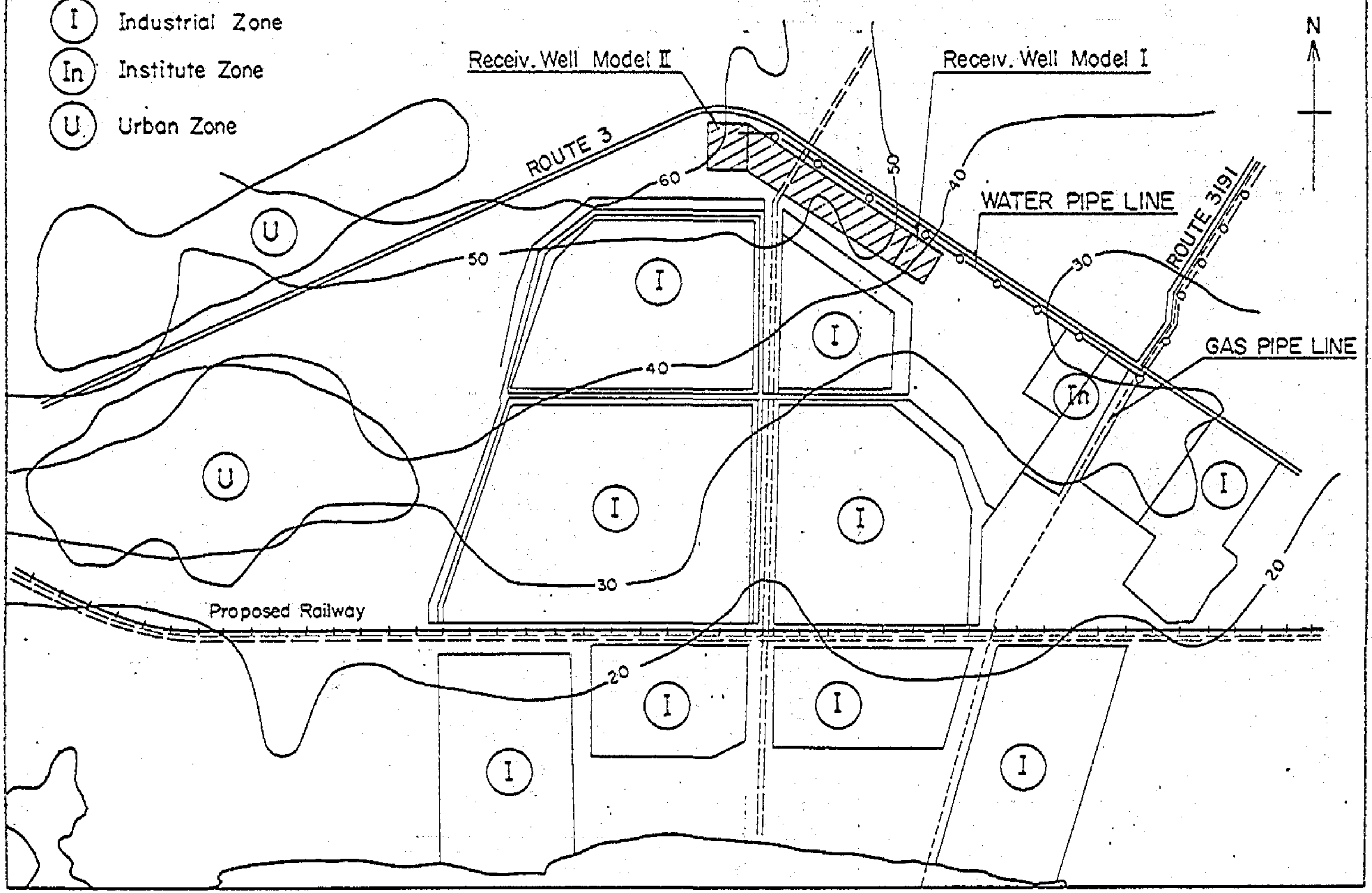
Fig.-2 on the following page to the next shows two locations, meaning two water level and the difference of pipe length in Fig.-1.

18 Cases for Comparison

Water Level of Receiving Well	Case	Pipe Diameter Dok Krai-Mab Ta Pud	Pipe Diameter Mab Ta Pud-Sattahip
	1	Ø 1,200^{mm}	Ø 800
	2	"	Ø 900
Model I	3	"	Ø 1,000
EL 45^{m}	4	Ø 1,350	Ø 800
	5	"	Ø 900
	6	"	Ø 1,000
	7*	D → H → M Ø 1,500 Ø 1,350	Ø 800
	8	" "	Ø 900
	9	" "	Ø 1,000
	10	Ø 1,200	Ø 800
	11	"	Ø 900
	12	"	Ø 1,000
Model 2	13	Ø 1,350	Ø 800
EL 60^{m}	14	"	Ø 900
	15	"	Ø 1,000
	16	Ø 1,500	Ø 800
	17	"	Ø 900
	18	"	Ø 1,000

* Dok Krai → Head Tank → Mab Ta Pud

Fig. - 2 LOCATION OF RECEIVING WELL



4. Hydraulic Conditions by Calculation

Calculation was made by using Hazen-Williams formula as shown below;

$$I = 10.666 \times C^{-1.85} \times D^{-4.87} \times Q^{1.85}$$

I : hydraulic gradient

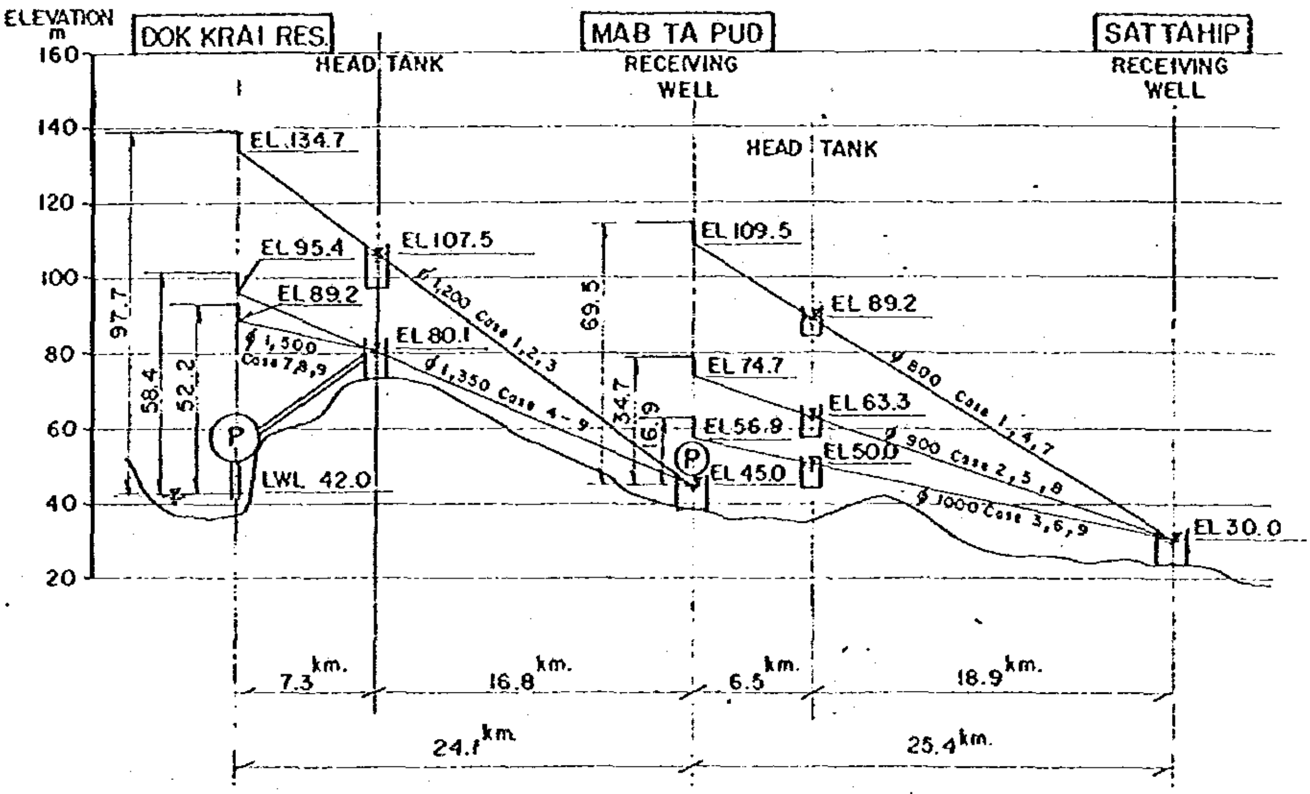
C : coefficient of roughness = 120

D : pipe diameter, m

Q : flow rate, M^3/sec

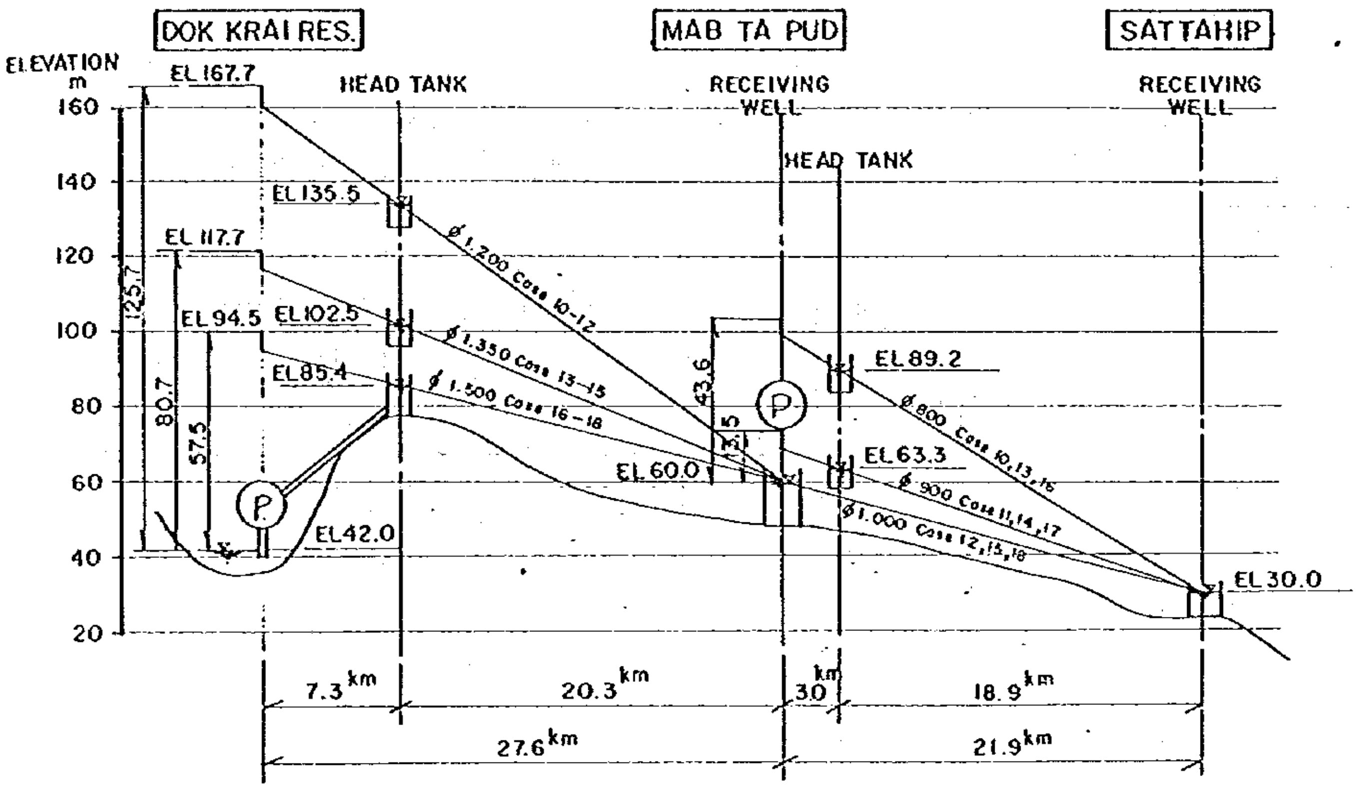
The results are shown graphically on Fig-3 & -4.

Fig.-3 Model I



* marginal loss head at pump is 5.0 m.

Fig.- 4 Model II



* marginal loss head at pump is 5.0 m.

5. Cost Estimate

5.1. Conditions

The cost estimate was made under the following conditions.

(1) The construction cost includes the pipeline, pumps and motors, electric facilities, pumping station, head tanks and the filtration plant, and excludes the intake tower and pipe bridge.

(2) The running cost is the electricity for 3 pumping stations, Dok Krai, Mab Ta Pud and the potable supply in Mab Ta Pud area.
The unit cost of electricity is assumed as 51.7 US$ per 1000 KWH or 1.17 ฿ per KWH.

(3) The maintenance cost is assumed individually for each case on yearly basis.

(4) The construction cost is discounted from 1983 to 2007 at 10% rate and is converted to the Net Present value.

(5) The running cost and the maintenance cost, calculated as a constant figure on yearly basis, are also converted to the Net Present Value.
Here, the running cost is calculated assuming as if the pipeline will work fully from the beginning of operation.

(6) The Net Present Value of construction and maintenance is named the initial cost. The initial cost and the running cost for 18 cases are tabulated on the next page.

(7) The filtration plant occupies about 40% of the initial cost and 5 to 10% of the running cost.

Table of Cost Comparison

Model	Case	Pipe Diameter D - M	Pipe Diameter M - S	Initial Cost 10^6 US$	Running Cost 10^6 US$	Total Cost 10^6 US$	Ranking
Model I EL 45^m	1	Ø1,200	Ø 800	41.6	6.0	47.6	4
	2	"	Ø 900	43.0	5.5	48.5	10
	3	"	Ø1,000	44.9	5.3	50.2	17
	4	Ø1,350	Ø 800	43.1	4.3	47.4	1
	5	"	Ø 900	44.5	3.9	48.4	7
	6	"	Ø1,000	46.4	3.6	50.0	16
	7	Ø1,500 Ø1,350	Ø 800	44.1	4.1	48.2	5
	8	"	Ø 900	45.5	3.6	49.1	13
	9	"	Ø1,000	47.4	3.4	50.8	18
Model II EL 60^m	10	Ø1,200	Ø 800	41.2	6.3	47.5	3
	11	"	Ø 900	42.5	5.9	48.4	7
	12	"	Ø1,000	42.9	5.6	48.5	10
	13	Ø1,350	Ø 800	43.0	4.4	47.4	1
	14	"	Ø 900	44.3	4.0	48.3	6
	15	"	Ø1,000	44.7	3.7	48.4	7
	16	Ø1,500	Ø 800	45.3	3.4	48.7	12
	17	"	Ø 900	46.5	3.0	49.5	14
	18	"	Ø1,500	47.0	2.7	49.7	15

The same amount is ranked as the same.

5.2. Discussion of Cost

(1) Initial and Running

Except cases 1, 2, 3, 10, 11, 12, where the pipe diameter between Dok Krai and Mab Ta Pud is 1.20 m, the running cost is less than 10% of the initial cost. The initial cost is far more influential than the running cost which is assumed for the full flow rate.

(2) Pipe Diameter

To evaluate the pipe diameters' effect on the cost, two table shown on the next page can be prepared. Each table, on different water level in the receiving well, shows the ranking.

The hatched part is for single digit or below 10.

It covers 5 cases for both Ø 1,350 and Ø 800 and moreover the combination Ø 1,350 - Ø 800 ranks 1 in the both tables.

(3) Water Level in Receiving Well

From the table, which of the two levels is better cannot be decided.

Table of Ranking vs. Pipe Diameter (1)

Model I, 45.-0 Water level

D-M / M-S	Ø 1,200	Ø 1,350	Ø 1,500
Ø 800	4	1	5
Ø 900	10	7	13
Ø1,000	17	16	18

Model II, 60.00 Water level

D-M / M-S	Ø 1,200	Ø 1,350	Ø 1,500
Ø 800	3	1	12
Ø 900	7	6	14
Ø1,000	10	7	15

6. Field reconnaisance

From the field reconnaisance around the two lots in Fig.-2 for the receiving well and receiving basin, the next matters became clear.

(1) The geological conditions of Model I (EL 45^m) and Model II (EL 60^m) are almost same and the both have enough bearing capacity of ground.

(2) The topographical conditions of Model I and II are different. Near the area of Model II, there is a ditch about 100 m away from the site which have a enough cross section area to divert the spill flow.
On the other hand, no ditch or river exist for the purpose around Model I area.

(3) The surrounding area of Model II lot is wide and better suited for the future extention.

7. Conclusion

(1) Pipe Diameter

Under the conditions given and reasonably assumed, the pipe diameter of 1.35 m between Dok Krai and Mab Ta Pud is better than 1.50 m and 1.20 m.
The choice is proved as right.
For the extention to Sattahip from Mab Ta Pud, 0.80 m shall be recommended as the best, though The Feasibility Study chose 1.0 m.

(2) Sattahip Pipeline

Pumping to Sattahip must be determined now.

(3) Receiving Well and Reservoir

Model II spot on Fig.-2 shall be decided.