Rural Water Supply

Volume II

Construction Supervision Manual

WATER
PARTNERSHIP
PROGRAM

Disclaimer

The World Bank Office Manila
23rd Floor, The Taipan Place
F. Ortigas Jr. Road, Ortigas Center
1605 Pasig City, Metro Manila, Philippines

Manila, Philippines
February 2012

Cover Design: The images on the cover were derived from two photographs courtesy of the DILG. The inset photo with a girl is from "The Innocent" by Mr. Jason Cardente. The boy filling water bottles is from "Water for Drinking" by Mr. Dan Ong. Some elements in the originals may have been altered for purposes of the design.

Rural Water Supply

Volume II

Construction Supervision Manual

WATER
PARTNERSHIP
PROGRAM

MALACAÑAN PALACE
MANILA

MESSAGE

I congratulate the institutions, agencies, and individuals of the water sector for your collaborative publication of the **Rural Water Supply Manual**.

This Manual is the latest of many multi-sectoral efforts to extend the availability of safe water to our countrymen. Water security is a critical issue that we must address, for it is essential to maintaining the well-being and dignity of human life. Thus, I am heartened by our steady progress in this regard—significantly decreasing the number of families without access to water from over 27 million in the 1990s to less than 16 million at present. These accomplishments are in no small part due to the cooperation among agencies and institutions and the support given by their leadership, who have established the necessary programs and administrative mechanisms to enable a dynamic exchange of skills and expertise.

To sustain the gains that we have achieved in securing the safety and accessibility of our water resources, our government is set on formulating and implementing a unifying framework that will harmonize the work of all engaged stakeholders in the water sector, in order to enhance support and ensure that the provision of safe water becomes a universal, self-sustaining aspect of our total development as a nation.

With your continued enthusiasm, I am confident that we can meet and perhaps even surpass our Millenium Development Goal for safe water. Equitable growth can only be accomplished by integrating social justice as the central component of our development agenda, applying a fair and equal treatment of every individual under the law and by our institutions. Let us work together to realize our shared aspiration of a sustainable Philippines.

BENIGNO S. AQUINO III

MANILA
February 2012

Foreword

Purpose of this Manual

This **RURAL WATER SUPPLY CONSTRUCTION SUPERVISION MANUAL** is the second of three related volumes prepared for the use of prospective and actual owners, operators, managements, technical staff, consultants, government planners and contractors of small Level III and Level II water supply systems in the Philippines.

Its purpose is to introduce the key policies, procedures, requirements and considerations involved in monitoring and overseeing the construction of small Level II and Level III waterworks facilities.[1] For the technical persons engaged directly or indirectly in monitoring and overseeing the construction project, hopefully it will facilitate their work by providing them with a ready resource reference for their everyday use. For the non-technical readers, such as the many who are involved in the management and operation of small water supply systems, hopefully it will aid in understanding the key points that need to be considered, giving them a more informed basis for participating in decisions related to prospective and on-going construction activities, and enabling them to avail more completely of the services of the technical consultants and contractors they must deal with.

Overall, the local and international partners who cooperated in making these Manuals possible hope that they will help the participants in the rural water supply sector to understand better the nature of the water supply business, its responsibilities to the stakeholders, and the role of the government agencies and regulatory bodies that seek to help them operate sustainably while protecting the consumers.

On the Use of the Manual

This **RURAL WATER SUPPLY CONSTRUCTION SUPERVISION MANUAL** and the companion volumes in the series can at best serve as a general reference and guide. As they refer to the information, recommendations, and guidelines contained in them, readers are urged to consider them always in relation to their own specific requirements, adapting and applying them within the context of their actual situation.

Even as they refer to this Manual for information, its users are advised to consult with qualified professionals – whether in the private sector, in the local governments, or in the regulatory and developmental agencies concerned with the water sector – who have had actual experience in the construction, management, operation, maintenance,

1 A few of the topics covered may also be relevant to Level I systems, which consist of a single well or pump serving a limited number of beneficiaries at source. However, it was felt unnecessary to focus on Level I systems requirements in this work as the design, engineering, operational and maintenance requirements of Level I systems – as well as the organizational and training support – are adequately provided by the relevant government agencies and supported by non-government agencies.

and servicing of water supply systems and utilities – including those other professionals who can help them in the financial, legal and other aspects of their small water supply business.

Manual Organization

The three volumes in this series of RURAL WATER SUPPLY MANUALS are as follows:

Volume I: DESIGN MANUAL. – Its purpose is to introduce and give the reader the key design concepts in the design of waterworks facilities. For non-technical readers who are involved in the management and operation of small water supply systems, rather than in their actual design and construction, the text of Volume I will be useful in understanding and in making decisions that would enable them to avail more usefully of the services of the technical consultants and contractors they must deal with.

Volume II: CONSTRUCTION SUPERVISION MANUAL. – This volume presents the considerations, requirements, and procedures involved in supervising a waterworks project. How these are implemented should be clear to one who supervises, inspects, or manages such a project. For this reason, the details of implementation are covered in the chapters on Pipeline and Pumping Facilities Installation, Concrete and Reservoir Construction, Water Sources, Metal Works, and Painting.

Volume III: OPERATION AND MAINTENANCE MANUAL. – This volume focuses on the small water system as a public utility, and answers the question “What are the requirements to effectively manage and sustainably operate a small utility?” It covers the institutional and legal requirements of setting up a water supply business, the demands of ensuring water safety through proper treatment, the nature and requirements of operating and maintaining the water distribution system, and its administration, commercial, financial, and social aspects.

Acknowledgements

Deep appreciation is extended to the following for the cooperation and support given during the pilot activities and preparation of the Manuals:

Department of Interior and Local Government

Hon. Jesse M. Robredo, Secretary
Hon. Austere A. Panadero, Undersecretary
Ms. Fe Crisilla M. Banluta, Project Manager
Mr. John M Castaneda, Director, OPDS
Ms. Rolyn Q. Zambales, Assistant Director, OPDS
Senior Staff of the WSSU

National Water Resources Board

Mr. Vicente S. Paragas, Executive Director
Atty. Nathaniel C. Santos, Deputy Executive Director
Mr. Jorge M. Estioko, Division Chief
Senior staff of NWRB

Local Water Utilities Administration

Mr. Salvador C. Ner, Acting Administrator
Mr. Edgardo C. Demayo, Acting Manager, WD Development Department
Mr. Ernesto de Vera, Manager, Project Planning Division
Mr. Angelito C. Bernardo, Manager, Project Monitoring & Evaluation Division

Department of Public Works and Highways

Hon. Rogelio L. Singson, Secretary
Mr. Ernesto S. Gregorio, Jr., Project Director, PMO-RWS/CARP
Mr. Virgilio G. Gacusana, Assistant Director, PMO-RWS/CARP
Mr. Dindo S. Taberna, Technical Coordinator, PMO-RWS/CARP

Department of Health

Hon. Enrique T. Ona, Secretary of Health
Mr. Joselito M. Riego de Dios, Chief Health Program Officer
Engr. Ma. Sonabel S. Anarna, Supervising Health Program Officer

National Anti-Poverty Commission

Hon. Jose Eliseo M. Rocamora, Secretary
Hon. Patrocinio Jude H. Esguerra, Undersecretary
Ms. Cynthia A. Ambe, Senior Technical Officer III

The project team also acknowledges **Engr. Ramon L. dela Torre**, **Engr. Yolanda Mingoa**, **Mr. Victoriano Y. Liu, Jr.**, **Mr. Simplicio C. Belisario, Jr.**, **Mr. Nasser Sinarimbo**, and **Ms. Mariles R. Navarro** for their collaboration and unfailing support.

For the professional advice and their comments and inputs in enhancing the Manuals, the team also extends its gratitude to the following: **Ms. Elizabeth L. Kleemeier,** Senior Water & Sanitation Specialist, TWIWA, World Bank (WB); **Ms. Ly Thi Dieu Vu,** Consultant, EASVS, WB; **Mr. Shyam KC,** Disaster Risk Management Specialist, EASIN, WB; **Mr. Alexander V. Danilenko,** Senior Water Supply and Sanitation Engineer, WSP, WB; and **Mr. Virendra Kumar Agarwal,** Consultant, WB.

The team would also like to express profound thanks to the WB Country Management Unit and fellow EASPS colleagues for their encouragement, invaluable support and commitment: **Mr. Motoo Konishi,** Country Director, **Mr. Bert Hofman,** former Country Director; **Mr. N. Vijay Jagannathan**, Sector Manager, Infrastructure Unit, Sustainable Development Department, East Asia and Pacific Region (EASIN); **Mr. Sudipto Sarkar**, Practice Leader for Water, EASIN; and **Mr. Mark C. Woodward,** Sustainable Development Leader, Philippines.

Finally, acknowledgements are extended to the **Water Partnership Program (WPP)**, which made funds available for the development and publication of these Manuals.

These Manuals were prepared under the guidance of **Mr. Christopher C. Ancheta**, Task Team Leader, World Bank. The Project Team was composed of the following: **Engr. Antonio R. de Vera**, Lead Consultant, **Mr. Gil S. Garcia**, **Mr. Jerome Vincent J. Liu**, **Mr. IoanNikhos Gil S. Garcia**, **Ms. Abegyl N. Albano**, **Ms. Demilour R. Ignacio**, and **Ms. Jeannette Ann R. Wiget**.

Acronyms & Abbreviations

Government and Other Organizations

ASTM	American Standard for Testing Materials
AWS	American Welding Society
AWWA	American Water Works Association
BIR	Bureau of Internal Revenue
CDA	Cooperative Development Authority
DAR (ARISP)	Department of Agrarian Reform, Agrarian Reform Infrastructure Support Program
DILG	Department of Interior & Local Government
DOH	Department of Health
DPWH	Department of Public Works & Highways
LWUA	Local Water Utilities Administration
NIOSH	National Institute for Occupational Safety and Health (United States)
NSO	National Statistics Office
NWRB	National Water Resources Board (formerly NWRC)
NWRC	National Water Resources Council
SEC	Securities & Exchange Commission
WHO	World Health Organization

Technical & Operational Terms, Units of Measure

AC	alternating current
ADD	average daily demand
AL	allowable leakage
BOD	Biological Oxygen Demand
CAPEX	capital expenditure
CBO	Community-Based Organization
cc	cubic centimeter
CIP	cast iron pipe
cm	centimeter
COD	chemical oxygen demand
CPC	Certificate of Public Conveyance
CT	Contact Time
cumecs	cubic meters per second
dam	dekameter
Dep	depreciation expenses
D or diam	diameter
dm	decimeter
Elev	elevation
EV	equivalent volume
F/A	Force/Area
g	grams
G.I. pipe	Galvanized iron pipe
GPM	gallons per minute
HGL	hydraulic grade line
hm	hectometer
HP	horsepower
HTH	High-Test Hypochlorite
IDHL	Immediately Dangerous to Life and Health
kg	kilograms
kgf	kilogram force

km	kilometer
kPa	kilopascals
KPIs	key performance indicators
LGUs	Local Government Units
lm	linear meter
lpcd	liters per capita per day
lps	liters per second
m	meter
m^2	square meter
m^3	cubic meter
m^3/d	cubic meters per day
MaxNI	maximum allowable net income
MDD	maximum day demand
mg/l	milligrams per liter
mm	millimeter
mld	million liters per day
mm/hr	millimeters per hour
MOA	Memorandum of Agreement
N/m^2	Newtons per square meter
NGO	Non-Government Organization
NPSH	net positive suction head
NPSHa	net positive suction head available
NPSHr	net positive suction head requirement
NRW	non-revenue water
NTU	Nephelometric turbidity unit
O&M	operation and maintenance
OD	outside diameter
Opex	operational expenses
Pa	Pascal
PE pipe	polyethylene pipe
PEER	property and equipment entitled to return
PNS	Philippine National Standards
PNSDW	Philippine National Standards for Drinking Water
psi	pounds per square inch
PVC pipe	polyvinyl chloride pipe
PWL	pumping water level
ROI	return on investment
RR	revenue requirements
RWSA	Rural Water & Sanitation Association
SCBA	self-contained breathing apparatus
SMAW	shielded metal arc welding
SSWP	Small-Scale Water Provider
SWL	static water level
TDH	total dynamic head
TDS	total dissolved solids
VC	volume container
VIM	variation in mass
Wc	container
Wcm	container + material
WHP	water horsepower
WL	water level

Table of Contents

List of Tables

List of Figures

Chapter 1

General Policies and Procedures

This Chapter illustrates the main functions and qualifications of a Construction Inspector or Site Inspector.

A. CONSTRUCTION INSPECTOR JOB DESCRIPTION

The job of a Site Inspector (or Construction Inspector) of a waterworks project is to ensure compliance with the plans and specifications of the project, applicable local and national codes and regulations, safety codes and standards. To do this, he/she must observe the construction, expansion, improvement or repair of water supply system facilities and/or site development in all stages of the works.

The Site Inspector normally acts with limited authority as agent of the owner who may be either the LGU or the CBO, thus he reports to the Owner or his Engineer.

The Site Inspector uses measuring devices and test equipment, takes photographs, keeps a daily log, and writes reports on the progress of the construction project.

The Site Inspector also keeps records of the amount of work performed and the materials used so that proper payment can be made.

The Inspector is not authorized to revoke, alter, enlarge, or release any requirements of the plans or specifications; neither to approve or accept any portion of the completed work, nor to issue instructions contrary to the plans and specifications.

B. FUNDAMENTAL REQUIREMENTS OF A GOOD INSPECTOR

The Inspector works under the strict orders of his superior and is guided by the strict requirements of contract plans and specifications. As he observes the activities of the Contractor's daily works, he should have the following fundamental knowledge and skills to achieve good results:

1. Knowledge

It is essential for the Inspector to have knowledge of the work he is inspecting. The Inspector's background and knowledge should include, among others, the following:

1. Actual practical experience in engineering construction; an understanding of the principles involved; and a thorough knowledge of the policies, procedures and specifications applicable to waterworks projects;

2. Mastery of the applicable engineering terminology and good familiarity with the materials and equipment and with the standard good practices in their use; and

3. Construction safety requirements and practices.

2. Skills

In combination with fundamental knowledge, an Inspector should have the natural ability and skills to make certain he can do his job well. A good Inspector should be able to do the following:

1. Read and interpret engineering drawings and specifications for construction control purposes;

2. Perform mathematical calculations requiring the application of fractions, percentages, ratios, and proportions, and algebra, geometry and trigonometry;

3. Plan and schedule inspections and related activities to accommodate emergencies or changing situations and the needs of the owner and the Contractor;

4. Use computer databases for reporting and record keeping;

5. Monitor and observe objects to determine compliance with prescribed specifications or safety standards;

6. Communicate well verbally and using written communication at all levels of the organization;

7. Perform physical tasks that require climbing, balancing, stooping, kneeling, crouching, crawling, visual acuity (near and far), depth perception and color vision; and

8. Establish and maintain open, effective working relationships.

C. THE INSPECTOR'S REPORT

The Inspector's Report is a proximate record of present events that serves as a future reference when these events need to be reviewed. It is often an important – and sometimes the only source of clues on how these present events might have contributed to malfunctions and failures that have to be investigated.

1. The Inspector's reports should contain all information pertaining to the work being inspected. Any information item should be recorded in sufficient detail to make it fully understandable.

2. The format and topical sequence of reports that cover similar or a series of related events should be standardized, so that the report at one period would be readily comparable to reports at other periods.

3. Where the Contractor or Contractor's representative, or any other party is supposed to receive a report prepared by the Site Inspector, its receipt should be acknowledged. The recipient's name, signature, designation and time received ideally should be reflected in the report. At least two copies of the form (or as many as needed) should be prepared, with one copy to be left with the recipient and at least one retained by the Inspector.

The following sub-sections present suggested forms and some of the contents usually covered by Inspector's reports. Note that the actual contents need not be limited to those listed:

Form 1.1: Inspector's Daily Report	
Date	Weather
Project	
Note: Detail the work description, approximate quantities, materials and equipment incorporated in the works, problems encountered and solution taken, suspension and resumption of works, delays, accidents, and other information pertinent to the project.	
SEE #1 – 9 BELOW	
Prepared by:	
	Engineer/Inspector
Received by:	
	Contractor's Representative

1. Inspector's Daily Report

A daily report or log should be maintained by the inspector. The report should as much as possible, contain the following information:

1. General job progress;
2. Delays caused by weather;
3. Any incident or adverse conditions that caused a delay or hampered the Contractor's activities, e.g.: a breakdown of equipment;
4. Manpower-related incidents affecting the work;
5. Time and place any incident occurred;
6. Any deficiencies and violations which affect the work or the safety of the workmen and the public;
7. Record of any tests taken by type and location;

8. Record faults, materials, labor and equipment associated with any active claim or dispute or anything that could evolve into a claim or dispute;
9. Any slippage in the general job progress.

A template of the Inspector's Daily Report is shown as Form 1.1.

2. Daily Record of Contractor's Input

If the work involves a lot of equipment to be used, the Inspector should include Form 1.2, which indicates the following:

1. Arrival on the job of construction equipment;
2. Arrival on the job of material and equipment to be used in the work.

Form 1.2: Daily Record of Contractor's Input			
Date:			
EQUIPMENT (specify number of each equipment, W=working, I=idle)			
Back Hoe		Jack Hammer	
Bulldozer		Compactor	
Dump Truck (ton)		Concrete/Asphalt Cutter	
Loader		Vibrating Plate Compactor	
Pick-up Truck (ton)		Welding Machine	
Mobile Crane (ton)		Grader	
Mobile Crane (ton)		Track Type Tractor	
Concrete Mixer Truck		Wheel Type Tractor	
Concrete Mixer Drum		Water Truck	
Concrete Mixing Plant		Dewatering Pump	
Concrete Vibrator		Generator	
MANPOWER (specify number of staff)			
Engineer		Operator	
Foreman		Welder	
Technician		Labor	
Survey Crew		Driver	
Administration Staff			
Material delivery at site:			
Prepared by: Engineer/Inspector		**Received by:** Contractor's Representative	

3. Field Instruction Sheet

Every time the Inspector gives an instruction to the Contractor or his representative, it should be in writing. A format, shown in Form 1.3, is intended to be used by the Inspector to issue written notices in case of the following:

1. Violations or non-compliance with plans, specifications, legal requirements and standards;
2. Need to stop work on any portion of the job if the Contractor's methods cause unsafe conditions or will result in defective work which would be impracticable to correct or to replace subsequently if other portions of the work are allowed to proceed;
3. The Field Instruction Form should be prepared in at least 2 copies, to be signed at issuance by the Site Inspector and upon receipt by the Contractor's representative. The Site Inspector shall retain his copy or copies as the case may be, leaving one copy with the contractor's representative.

Form 1.3: Field Instruction Form	
Work Item	
Date	
Subject	
Instruction/s:	
Issued by: Engineer/Inspector	
Received by: Contractor's Representative	Date/time

4. Quantity Sheet

The Quantity Sheet, shown below as Form 1.4, is necessary to record accomplishment per work item.

Form 1.4: Quantity Sheet					
Work Item					
Bid Quantity			**Unit**		
Dates	**Station**	**Location**	**Installed**	**Balance**	**Remarks**
Prepared by: Engineer/Inspector					
Conforme: Contractor's Representative					

D. INSPECTION PROCEDURES

This section outlines some basic procedures pertaining to the inspection of small water supply construction projects being implemented either by administration or by contract. These inspection procedures are intended to assure conformance with project requirements and on-time progress of the construction works. The Inspector should observe the following basic procedures:

1. The Inspector should direct all of his attention to discharging his primary function and responsibility to inspect the work for compliance with plans and specifications.
2. The Inspector first should have received and familiarized himself with all the plans, approved drawings, specifications, and other documents pertaining to the assigned project. An inspector who has thorough knowledge of the contract requirements can recognize deviations almost immediately.
3. The Inspector must remain available at the project site to respond to any request for inspection service or to answer questions regarding the work.

4. Inspection activities must be regular and in line with the Contractor's operations. This should enable the Inspector to adequately check the work for compliance without delaying the Contractor's operations.

5. The Inspector should report in advance to his supervisor any situation that he thinks may cause delay in the completion of the project. When problems arise which may be beyond the experience or authority of the Inspector to resolve, he should immediately consult his superior for advice.

6. The Inspector may leave the project site only when instructed by his superior or for urgent reasons connected with his responsibilities.

7. Public safety should be foremost in the mind of the Inspector. Whenever a dangerous condition is anticipated or recognized on the job, the Inspector should call the attention of the Contractor to it and then note it in his Daily Report.

8. When there is an accident at a site, the Inspector must remain on the job until the reports have been completed.

9. For safety reasons, the Inspector should not operate any vehicle or equipment belonging to the Contractor, except when required in an emergency.

10. The Contractor should be given advance Notice for materials testing.

11. When the Inspector recognizes unacceptable work in its early stages, he must immediately inform the Contractor before it develops into an expensive and time-consuming correction. And whenever the Contractor is supposed to correct unacceptable work, the Inspector should note it in his Daily Report and follow up regularly.

12. The Inspector shall promptly give the Contractor's representative on the job the appropriate verbal instructions for non-compliance and safety violations. These instructions shall be noted by the Inspector in Form 1.1: Inspector's Daily Report. Copies must be kept for the project file.

E. RELATIONS WITH THE CONTRACTOR

Most of the poor relations that develop on the job between the Inspector and the Contractor are triggered by information or field instructions related to unacceptable performance. When poor relations develop, the work suffers and they place stress on those involved in the project. To avoid strained relations, the Inspector should practice the following:

1. While the Inspector works under the strict requirements of contract plans and specifications, he should establish cordial relations with the Contractor without being overly familiar or personal. At all times, the Inspector should have the emotional strength to stand firm on his reports.

2. For the Inspector to gain respect and compliance, his decisions should always be based on a thorough knowledge of the work, and made in reference to the plans and the specifications under which it is to be accomplished. They should be communicated directly and only to the person/s who should receive them, without emotional or personal color.
3. While an Inspector does not have the authority to allow deviations from essential contract requirements, he must avoid an inflexible stance when it comes to requirements of minor construction details or technicalities.
4. He should not give any directions which are not justified by the contract documents and should not interfere with the Contractor's method of performing the work. Such interference may become the basis for releasing the Contractor, in whole or in part, from the responsibility he has assumed under the contract to obtain specific results.
5. If the Inspector through his observations finds the Contractor's methods are visibly improper, inadequate, unsafe, or likely to result in irreparable damage or future expense for the agency, he should call the Contractor's attention at once. He should give prompt instructions or formal orders directly to the Contractor or his superintendent, or, in their absence, to the foreman only, using of Form 1.3: Field Instruction Form.

F. WORK STOPPAGE ORDERS

When non-compliance or violations warrant the suspension of construction work, any notice of total stoppage shall be issued only by or at the direction of the Supervisor having jurisdiction over the work, or by a higher authority.

Chapter 2

Installation of Pipelines

This Chapter deals with the installation of pressure pipelines and their appurtenances as a major component facility of a water supply project.

A. PIPE HANDLING

Pipelines are simple to install, requiring only a minimum of specialized installation equipment and knowledge of correct methods and procedures. The fundamental steps in installing pipelines are the same regardless of the pipe material used.

The proper handling, moving, and storing of pipe materials should assure the integrity of the materials regardless of size, type or classification.

The following sub-sections give general guidelines for the different stages in the handling of pipes.

1. Inspection of Delivered Pipe Materials

Normally pipe materials undergo a final inspection at the factory before being delivered to the job site. The Inspector must check for the following before accepting the delivery:

1. Damage on any of the pipe materials before or during unloading;
2. Conformity of all piping materials (e.g., pipes, rings, gaskets and fittings) against a tally sheet for quantity and correct sizes and class.

2. Loading/Unloading

The Inspector must see to it that the pipe materials are not damaged while being loaded or unloaded. The following practices are prescribed:

1. If possible, pipe materials should be loaded/unloaded using some form of mechanical lifting equipment. Whatever the method used, it should prevent abuse and damage to the pipe materials.
2. In handling the pipes, no hooks, chains, or similar metal devices should contact the pipe at any failure points.
3. Single slings should not be used. Pipes should be lifted with 2 slings (minimum) at their third points to avoid bending them and cracking their lining or coating.
4. At the jobsite, pipes should be unloaded as near as possible to where they are to be used, so as to avoid excessive handling.
5. Pipes should never be dragged along the ground or road.

3. Stacking/Storage

Generally, pipes, fittings and gasket materials should be stacked and stored in accordance with the manufacturer's recommendations. The Inspector must also ensure compliance with the following:

1. All pipes, fittings and gasket material should be kept as clean as possible and be protected from any contamination.
2. Pipe stockpiles should be built on a flat base, above the ground to minimize contamination. (See Figure 2.1).
3. The bottom layer should be supported uniformly along the barrel of the pipes to prevent bending.
4. Pipes of the same size and classes should be stacked together.
5. When stacking pipes, the bell ends should project beyond the end of the barrel in alternate layers.
6. Stacks should be kept within the limits of safety and practicality. Generally, a stack should not be more than 1.5 m high.
7. The stacked pipes should be secured against rolling down.
8. PVC pipes should be protected from sunlight. The stockpiles should be covered with opaque material in a way that permits adequate air circulation above and around the pipe and prevents the excessive accumulation of heat.
9. The interior of the pipes, as well as all end surfaces, should be kept free from dirt and foreign matter from the time they are delivered to their actual installation.
10. Coils may be stored stacked one on top of the other, but they should be kept away from hot surfaces.
11. Short pipes, fittings, adapters and gaskets should be placed in separate piles.
12. When issuing pipes, fittings, adapters and gaskets, the principle of "first in-first out" should be followed.

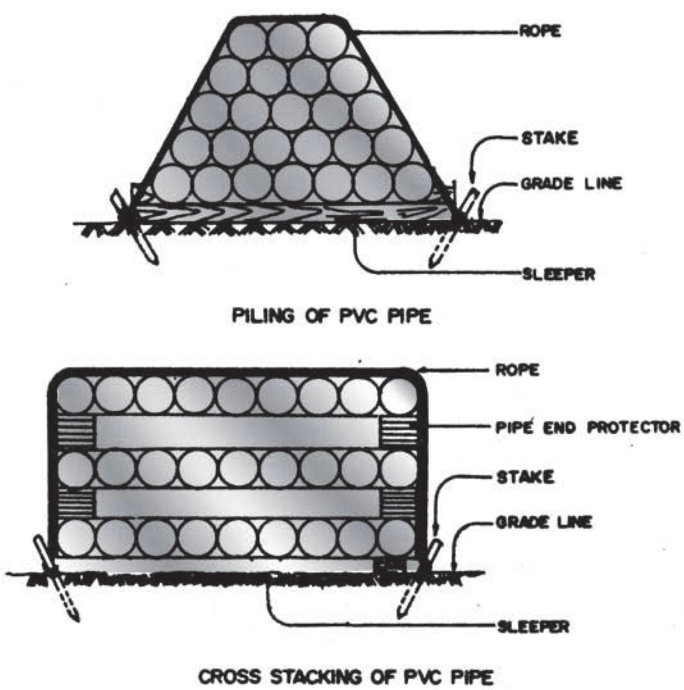
4. Stringing

Pipe stringing means the unloading of pipes along the line of the trench. If pipes are to be strung, the Inspector must ensure that the proper practices are applied:

1. Pipes should be laid as near to the trench as safely possible to avoid excess handling.

2. The pipe should be laid on the side opposite the excavated material or equipment, or, if trench is not yet opened, opposite where these will be positioned.
3. Pipes should be secured against rolling into the trench and kept safe from traffic and heavy equipment.
4. The bell end of the pipe should be placed towards the direction of the work, as during the installation the spigot end will enter the bell end of the previously laid section.
5. Lifting equipment should be used to lower larger pipes; for which a webbing sling should be attached to the pipe.
6. The pipe ends should be covered to prevent contamination and entry of any object.

Figure 2.1: Field Stacking/Storage of Pipes



NWRC RWS Volume II, Construction and Installation Manual

B. JOINTING PIPES

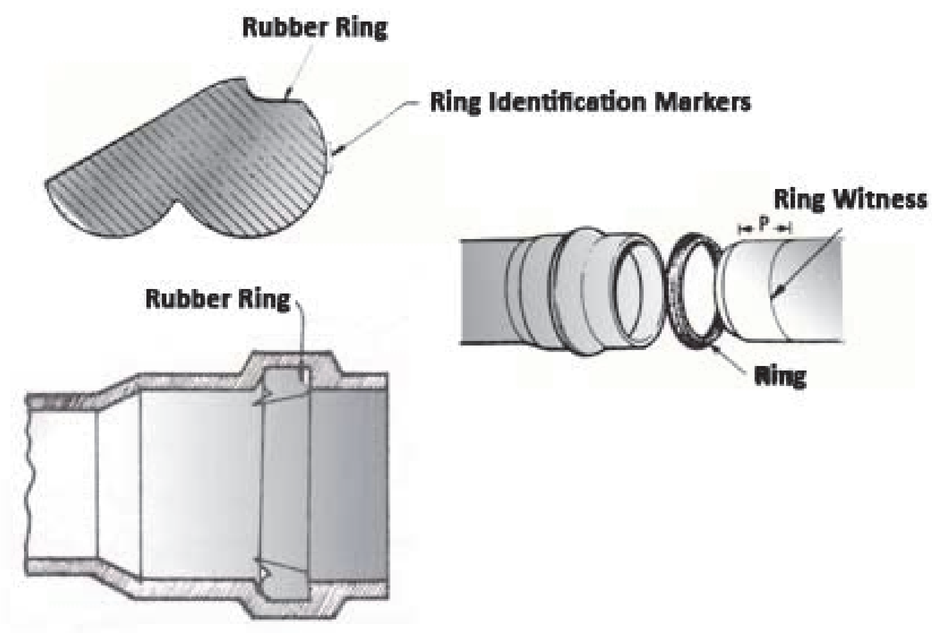
The method for jointing pipes depends on the type of pipe material and the type of joint. In all cases, jointing pipe during pipe installation must be done correctly to ensure a long watertight service. The three (3) most common joint types are described in the succeeding discussions:

1. Push-on Joints

The push-on joint is the most popular, quickest and easiest-to-assemble joint for potable water pipes. This joint consists of a single rubber ring or gasket placed in a groove inside the socket at the bell end of the pipe (Figure 2.2). Although the assembly of push-on joints is simple and fast, it must be done properly, following standard procedures that the Inspector must ensure:

1. The socket of the previously laid pipe and the spigot of the next pipe to be laid should be clean.
2. The rubber gasket must fit securely in the bell socket groove.
3. A thin film of recommended lubricant should be applied to the beveled/chamfered spigot as far as the witness mark. The rubber ring and the socket groove should never be lubricated.
4. With the pipes in a straight line, the spigot end should be introduced into the socket end and pushed completely into the bell until the witness mark remains just visible.
5. Jointing may be assisted using a forked tool and wooden block.

Figure 2.2: Push-on Joints

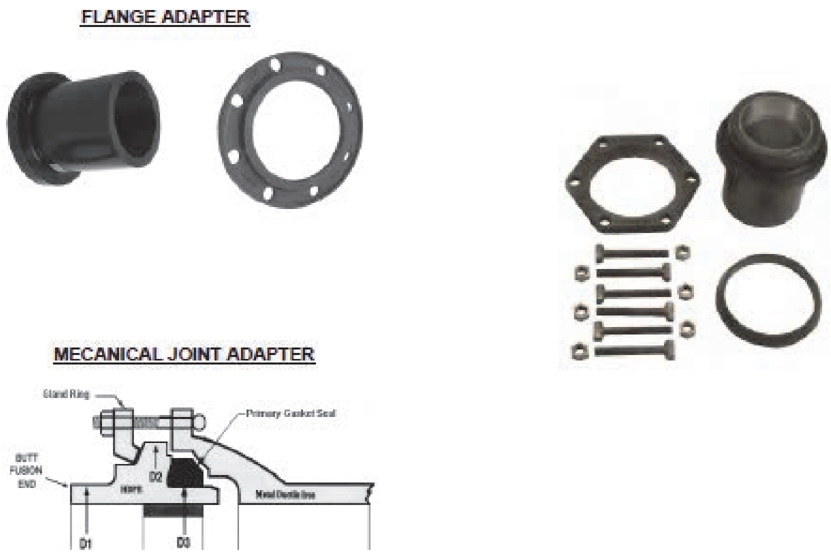


NWRC RWS Volume II, Construction and Installation Manual

2. Flanged Joints

The flanged joint is made up of two machined surfaces that are tightly assembled by bolting. This type of joint is not flexible and normally not used underground. It is used above ground when rigidity and tightness are required. This joint is easy to assemble and requires no special tools (Figure 2.3).

Figure 2.3: Flanged Joint & Mechanical Joint



3. Mechanical Joints

The mechanical joint is used when it is important for the pipe or the joint itself to remain firmly in place. The joint is flexible, with the amount of deflection dependent on pipe diameter. The joint has four parts:

1. A flange cast with a bell;
2. A rubber gasket that fits in the bell socket;
3. A gland, or follower ring, to compress the gasket;
4. Tee head bolts and nuts for tightening the joint.

The assembly of the mechanical joint is labor-intensive but very simple and requires only ordinary tools.

4. Fittings

The Inspector must ensure that all pipeline fittings (such as crosses, tees, valves and hydrants) are properly installed as the pipeline is laid. All pressurized pipeline fittings are subject to internal forces, thus they must be fitted with thrust supports to keep them from moving.

C. INSTALLATION OF THRUST BLOCKS AND ANCHORS

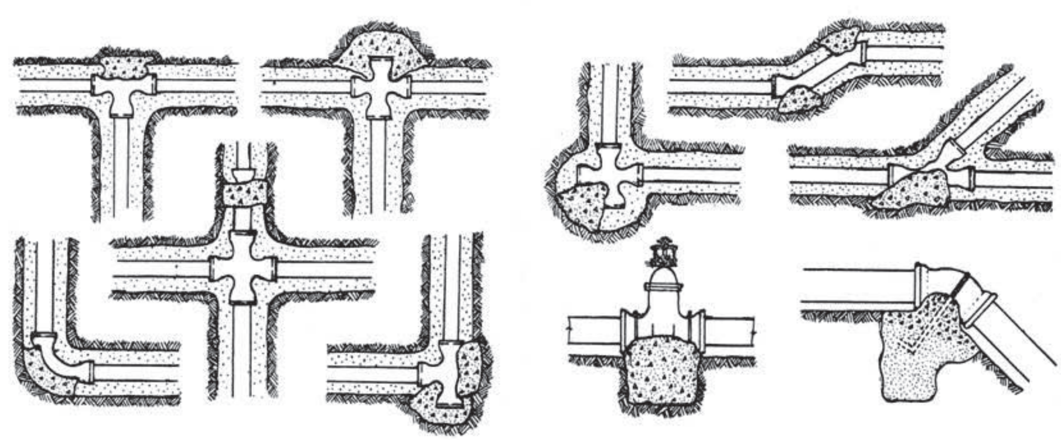
Any pressurized pipeline will generate thrusts that tend to cause a gradual movement in fittings or the pipeline that could eventually cause leakage or completely separate the coupling or fitting. Pipe thrust is generated at locations where any of the following situations exist:

- A change in pipe direction, such as at bends, tees and crosses;
- A change in pipe diameter, such as at reducer fittings;
- Where the flow of water is controlled, such as at valves and hydrants;
- Where the flow of water is stopped, such as at closed valves, dead ends or blind flanges.

1. Pipe Thrust Blocks

A thrust block is a mass of concrete poured in place between the pipe fitting and undisturbed soil at the bottom or side of the pipe trench. It effectively transfers the load from the pipe fitting to a wider surface area on the soil (Figure 2.4).

Figure 2.4: Thrust Blocks & Anchors



THRUST BLOCKS and ANCHORS

LWUA Inspector's Construction Manual

2. Pipe Thrust Anchors

A thrust anchor is a mass of concrete with embedded steel strap rods to resist upward thrusts induced by pressure on pipes or fittings. Generally the concrete mass is poured in place below the fitting to be anchored.

3. Important Features of Thrust Control

There are three important features to observe about thrust control:

1. The thrust block or anchor should be centered on the thrust force.
2. The thrust block or anchor should partially cradle or support the fitting.
3. The bearing face should be cast against undisturbed soil.

4. Procedure for Locating and Installing

The installation of thrust blocks and anchors should be based on the plans for their detailed design and locations.

1. Non-structural concrete (2000 psi) should be placed between the fitting and the undisturbed bearing soil.
2. The concrete should be kept behind the bell of the fitting. It should not be allowed to run over against the pipe or into the joint.
3. The concrete should fill in completely around the fitting. The pipe or fitting should not be encased, as there should be allowance for slight movement due to changes in temperature and pressure.
4. Thrust blocks are not needed at the welded flanged joints of steel pipes.

D. PIPELINE EXCAVATION

The trench for underground pipelines should be kept as narrow and shallow as practical for safety and economic considerations. The trenching work also entails clearing or grubbing and staking of the trench line.

1. Preparation/Preliminary Inspection

1. Refer to the detailed plans for correct field location before excavation begins.
2. Refer to trench and bedding specifications, alignment and grade for field compliance.
3. Excavation permits should have been secured from the agencies that have jurisdiction over the trench line.
4. Advance notice should be given to other utilities that pose obstructions to trench lines.

5. The proper excavation method and equipment should be selected, considering safety, economy and speed of work.
6. The excavation area should be properly marked in advance with warning devices or whatever is needed to protect the safety of the construction crew and the public.
7. Records should be kept showing location, depth and other quantities related to excavations for possible extra work payment/s.

2. Trenching

1. The trench should be straight, with vertical sides centered on the pipe centerline.
2. Trench excavation should not extend too far ahead of pipe laying for safety reasons. An open trench presents a danger to the construction crew and the public, especially after working hours.
3. No trenching should be allowed to start and proceed without the required warning devices, barricades, signals and flaggers.
4. Local regulations should be observed. Usually these require that some sections of an open trench should be filled up or protected in specific ways overnight in order not to disrupt certain services and emergency vehicles should be observed.
5. If the trench is below asphalt or concrete pavements, power saws should be used to ensure smooth edge cuts.
6. All asphalt or concrete debris should be hauled away before the excavation starts to prevent their use as backfill material.

3. Trench Widths and Depth

1. The trench width and depth are governed by the following factors/specifications:
   - Pipe size;
   - Safety considerations;
   - Economic considerations;
   - Need to minimize the superimposed loading on the pipe;
   - Surface restoration requirements; and
   - Future changes in ground-surface elevations due to construction or erosions.
2. The trench width should be no more than 0.30 to 0.60 meter greater than the outside diameter (O.D.) of the pipe (See Table 2.1):

- The minimum of 0.15 m on each side of the pipe permits proper installation and adequate room to properly place the backfill under and around the pipe.
- The 0.30 m on each side prevents excessive loading directly on the pipe during backfilling.

Table 2.1: Trench Dimensions

Pipe Diameter (OD) in mm	75 mm and under	100	150	200	250	300
Minimum "W"	200	400	450	500	550	600
Maximum "W"	300	700	750	800	850	900

3. For curve alignments, the trench width should be greater than usual to accommodate the permissible deflection of the joints.
4. Where the pipe is to be welded, bell holes must be excavated large enough for a welder to properly work without obstruction. Bell holes should be laid out and excavated just before the pipe section is laid, to ensure that the hole falls at the location of the joint.

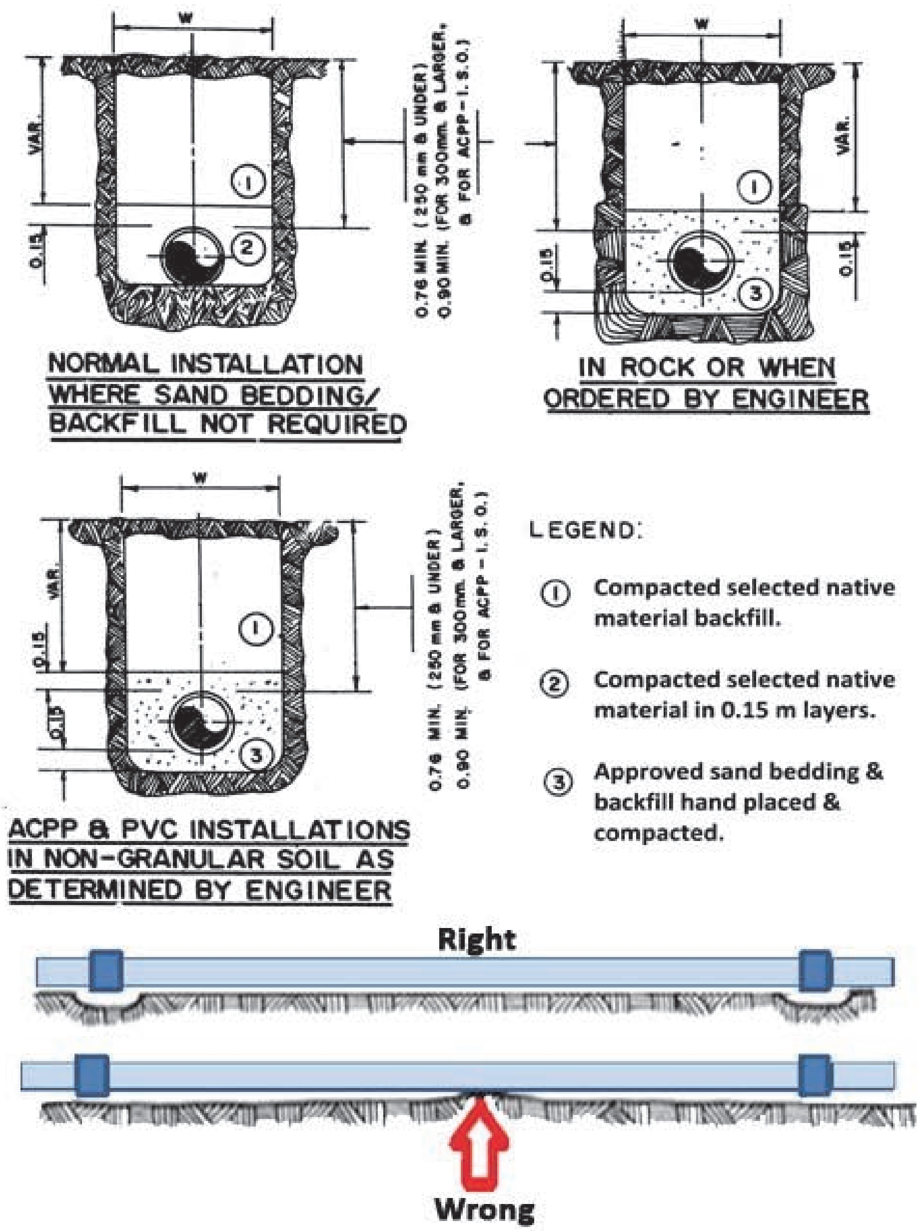
4. Other Trench Specifications

1. When the ground is unstable, the trench walls may have to be "stepped" or "sloped". The trench wall slope should be at about ¾ : 1 and must not extend below the top of pipe.
2. The trench bottom must be uniform. It should be free of humps, abrupt changes of direction, hard objects, large stones, and tree roots. (See "Trench Bedding" below.)
3. Where surface loads will be encountered, the depth of the trench should be sufficient to allow for the pipe diameter, bedding, and the minimum recommended pipe cover of 0.75 m. Vehicles should not be allowed to pass over the line of pipe under shallow cover until the backfill has completely compacted.
4. Water must be kept out of the trench during construction so that the pipe will not become contaminated. Pumps should be used in the trench, if necessary, to remove any buildup of water.

5. Trench Bedding

Bedding (Figure 2.5) usually refers to the material in which the pipe is partially or completely embedded. Proper pipe bedding increases the load bearing capacity of the pipe. Bedding is used when the trench bottom does not provide load-bearing capacity suitable for the pipe. The bedding required depends on the pipe material, size and loading over the backfilled trench.

Figure 2.5: Trench Bedding



LWUA Inspector's Construction Manual

As also indicated in Figure 2.5, proper trench bedding practice calls for the following conditions to be met:

1. The trench bottom must be properly leveled and compacted so that the full length of the pipe will have continuous, firm support.
2. Bedding material should be spread over the trench bottom to the full width of the trench.
3. Bedding material should be well graded granular material up to 25 mm in size.

E. LAYING PIPES

After the trench bottom has been prepared, the pipes may be set in place. The proper procedure varies somewhat with the type of pipe, but the following general directions for laying pipes apply to all types.

1. Preparation/Preliminary Inspection

Before the pipes are lowered into the trench, the Inspector must ensure the following:

1. Pipes should be free from damage. Any unsatisfactory sections should be rejected.
2. The inside of each pipe length should be clean. Any dirt, oil, grease, animals, and other foreign matter should be removed.

2. Placement of the Pipes

1. A pipe should be lowered into the trench by mechanical equipment, if possible. It should never be rolled into the trench from the top. A smaller diameter pipe may be lowered into the trench by two people using ropes, one rope looped around near each end of the pipe.
2. Larger pipe sizes are best handled with appropriate equipment. When a pipe is lowered by machinery, it is usually supported by a sling in the middle of the pipe length. The sling must be removed once the pipe is down.
3. Pipes jointed by coupling may be laid in either direction. Belled-end pipes are normally laid with the bells facing in the direction in which the work progresses, except downhill, where the direction is reversed.
4. A conscious effort should be made be made to keep the inside of the pipe clean. When pipes are not being laid, the open ends of installed pipes should be plugged to prevent the entry of animals, dirt, and trench water.
5. It is very important for the entire length of the pipe sections to be evenly in contact with the ground.
6. Pipe lengths should never be deflected in the joints to any degree than that recommended by the manufacturer.

F. BACKFILLING AND COMPACTING

In backfilling and compacting pipe trenches, the general procedures and suggestions in the following paragraphs apply regardless of the type of pipe. The Inspector should see to it that these are followed and be done gently and thoroughly. The purpose of the compacted backfill material, which is placed around and over the pipe, is to:

1. Provide support for the pipe;
2. Provide lateral stability between the pie and the trench walls;
3. Form a cushion over the pipe to prevent damage.

1. Backfilling

Prior to the hydrostatic testing of pipes, selected sandy material is placed 0.15 m over the pipeline, leaving the joints exposed for observation during leakage tests. A portion of the material is used for the remainder of the trench to furnish weight to resist movement due to pressure.

1. Clean granular material such as sand and gravel is generally recommended for the first layer of backfill. This can be either suitable existing soil or soil introduced from another source.
2. Before backfilling, water should be removed from the trench using a pump or other means.
3. Backfill always follows pipe installation as closely as possible. This protects the pipe from falling boulders, eliminates the possibility of the pipe getting lifted due to flooding of the open trench, and avoids the pipe shifting out of line due to cave-ins.
4. The first layer of backfill should be shoveled evenly along both sides of the pipe, making a layer about 0.15 m thick. Then the tamping bar is used to tamp this soil firmly around the pipe.
5. An initial backfill should be placed around the upper half of the pipe and compacted, by hand or by approved mechanical equipment, to avoid damage or movement of the pipe. The trench should be filled in layers to a depth of 0.30 m. This initial backfill will protect the pipe during the remainder of the backfilling process.
6. The remainder of the trench should be backfilled by placing the material in layers and compact the layers thoroughly. This backfill does not need to be as carefully selected, placed, or compacted. The fill should, however, be uniformly dense.
7. If trenches are in a road right-of-way or where there will be a sidewalk, the completed backfill must meet the compaction requirements of the agency concerned. Backfill in other trenches need not be compacted to such a degree.

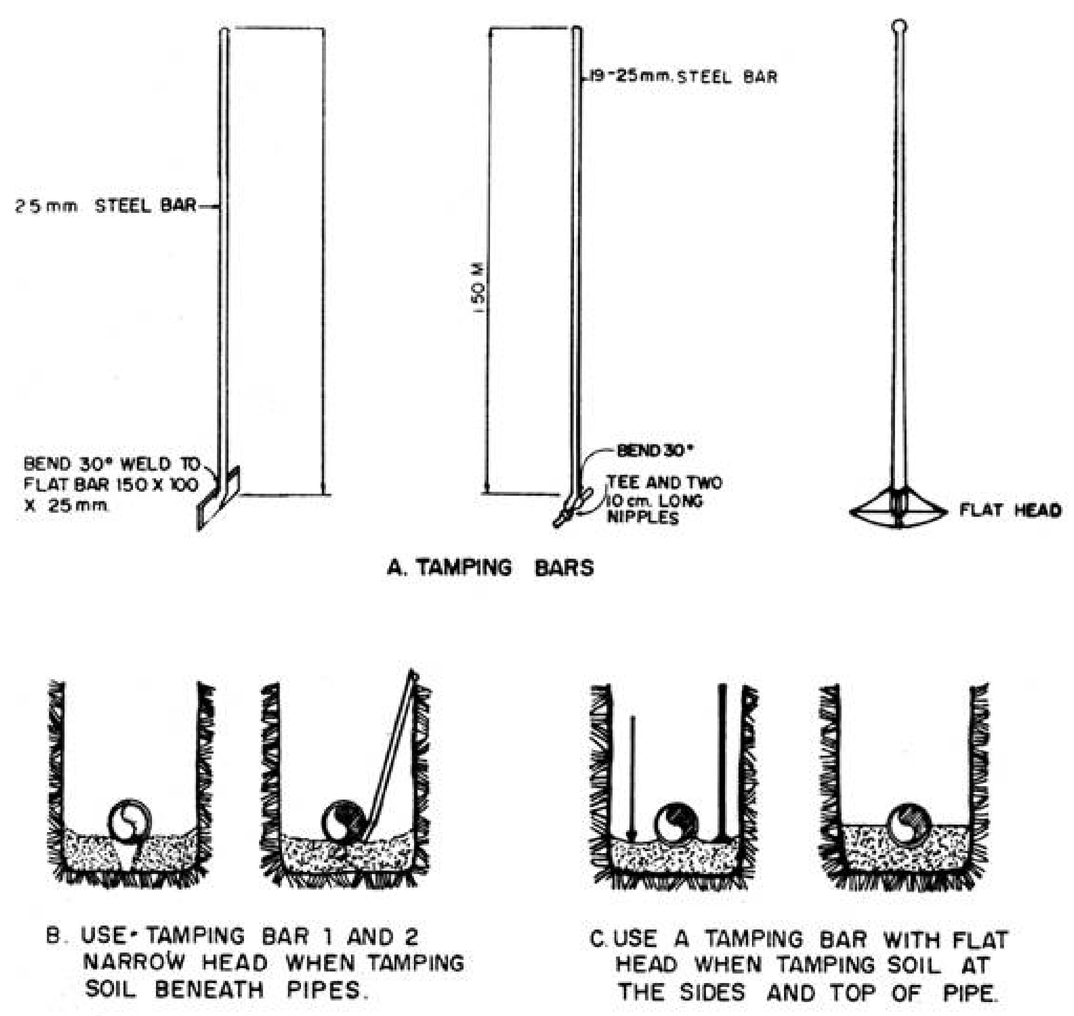
2. Compacting

The person in charge should insist that the backfill be done gently and thoroughly. The key to it is in the amount of soil that is thrown in to be tamped around the pipe. Generally, compacting of the backfill can be done in one of three ways:

a. Manual Compacting or Hand Tamping

Hand tamping may be done in the area adjacent to and immediately above the pipe. Two types of tamping bars are required for a complete job. First a bar with a narrow head or blade is used to tamp under the couplings. Then a bar with a flat head is used to compact soil at the sides of the pipe as depicted in Figure 2.6. These bars are quickly fabricated in the shop and can be used to easily do a satisfactory job.

Figure 2.6: Compaction by Hand Tamping



LWUA Inspector's Construction Manual

b. Water Flooding or Settling

Where water is economically available and the soil is sandy and free-draining, water settling can be used. However, this method cannot be used in clay since clay expands when wet and shrinks as it dries out, thereby creating voids which lead to eventual settling. For this method, the Inspector should ensure that compaction follows these procedures:

1. Backfill should be placed in layers not greater than 0.90 meter. The backfill material should become saturated and rodded at intervals sufficiently close (usually 0.60 m), to settle the fill.
2. Precautions should be taken to avoid damaging the pipe with the rod.
3. Sufficient water should be used to settle the backfill around pipe; otherwise voids may be formed around the pipe.
4. If the pipe zone backfill was compacted by flooding and vibrating, then at least 4 hours must lapse before the next layer is started. This gives the water used in flooding sufficient time to percolate out of the trench.
5. If the pipe trench is on a slope, jetting should proceed from the lower elevation.

c. Mechanical Compaction

Mechanical compaction is normally done when settling must be kept to a minimum and when the backfill must support the surface loads. The equipment used for this purpose (shown in Figure 2.7) is often mechanically driven, and the backfill must be placed and compacted in 0.15-0.30 m lifts.

Figure 2.7: Mechanical Equipment for Compaction

Chapter 3

Installation of Pumping Facilities

This Chapter discusses and illustrates the various aspects of pump selection and installation which are critical to the proper functioning of the utility's pumping facilities.

A. GENERAL

Well pumps have to be selected on the basis of the characteristics of the well, particularly the safe pumping level and other parameters determined by tests. Thus, they are installed only after the well is completely developed and tested. If the pumping equipment is properly installed, tested and maintained, it can function efficiently and reliably over its service life.

In small water supply projects, the electro-mechanical works are usually jobbed out to a Contractor/Supplier. The Contractor will furnish, deliver, install, test and commission all specified electro-mechanical equipment. Also, the Contractor will accomplish the work complete with supervision and tools, delivering the finished commitments of his contract. In such a case, the role of the assigned Inspector is simply to conduct general observations and keep records during the progress of the works to ensure compliance with specifications.

B. DEFINITIONS

The Inspector must understand the key terminologies and know the definition of some terms normally encountered during the work of installing well pumps:

1. **Setting** – the normal distance from the centerline of the column pipe connection of the discharge head to the column pipe connection at the bowl assembly.
2. **Static Level** – the difference in elevation between the suction level and the discharge level when there is no pumping.
3. **Pumping Level** – the vertical distance from the center line of the discharge pipe to the water surface in the well while pumping. During a pumping test, the pumping water level is the depth of water surface when the amount of water withdrawn from the well and the amount of replenishment of water to the well is equal.
4. **Drawdown** – the difference between the pumping level and the static level.
5. **Capacity/Yield of Well** – the volume of water per unit time that could be pumped from the well as determined by a pumping test.

6. **Efficiency** – the ratio of output power to input power based on total head, capacity and total horsepower.

1. Types of Pumps

There are two general types of pumps used to move water:

a. Positive-Displacement Pumps

This type of pump uses the suction created by a vacuum to draw water into a closed space. An example of this type of pump is the lift pump (or reciprocating pump) used commonly in the rural areas. This pump displaces a volume by mechanical action.

The lift pump, sometimes called a pitcher pump, is normally used in shallow wells when the pumping water level is less than 6 meters. It is operated by working a pumping handle that is attached to a piston encased in a pipe. At the down-stroke of the handle, the piston is lifted to create a partial vacuum beneath it in the pipe. This causes water to be drawn from the well below, through the pipe, into a chamber in the pump. A one-way valve closes after water is pumped into the chamber, keeping the water from flowing back down into the well. Subsequent strokes of the piston pull more water up into the chamber, which eventually overflows through the pump's spout.

Refer to Figure 3.1 on the following page for details of an electrically driven positive-displacement pipe.

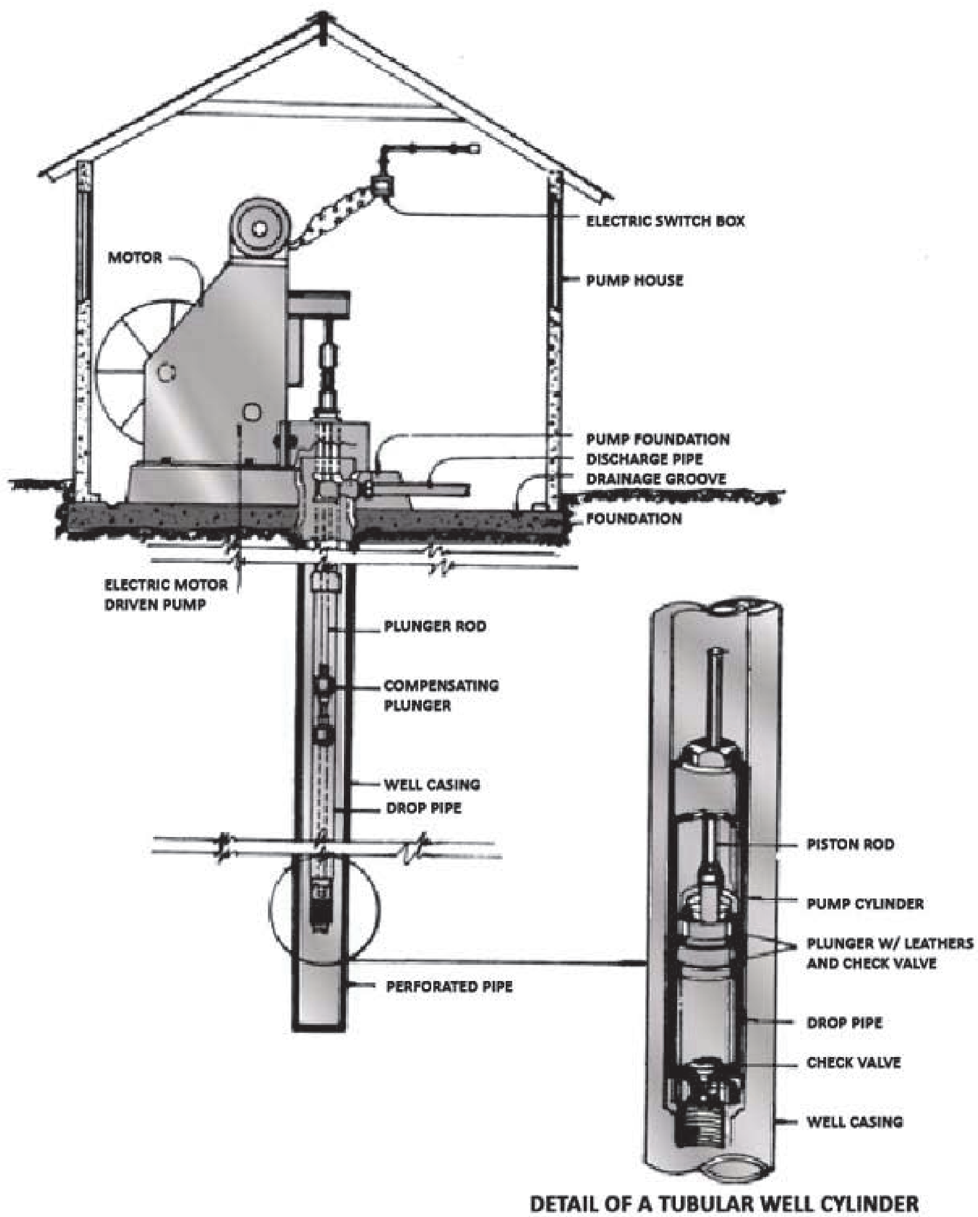
b. Velocity Pumps

Velocity pumps use motor-driven propellers that create a flow of water when they rotate. The blades of the propeller are immersed in the water to be pumped. As the propeller turns in a tight casing, water enters the pump near the axis of the blades and is swept out toward their ends at high pressure by centrifugal force.

In rural water systems, the three designs of velocity pumps that are widely used are:

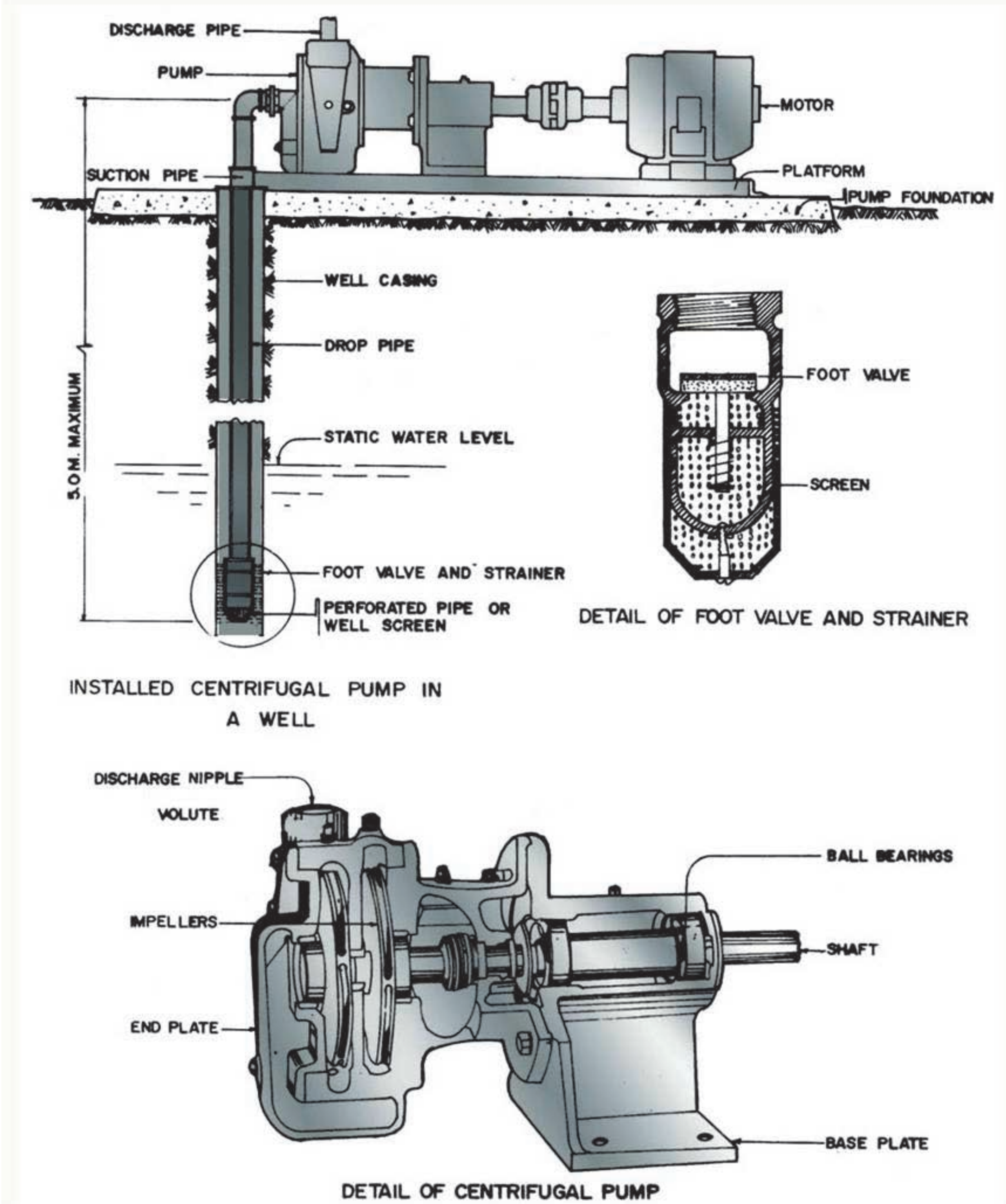
1. **Centrifugal Pumps** - normally used in shallow wells when the pumping water level is less than six (6) meters. A typical centrifugal pump is shown in Figure 3.2 (pls. turn to Page 3.4).
2. **Vertical Turbine or Submersible Pump** - normally installed in deep wells with pumping water levels of more than twenty (20) meters. These pumps are designed and installed so that the pump motor and bowl (impellers) are set below the well at approximately 5 to 8 meters below the pumping water level. This type of pump is illustrated in Figure 3.3 (pls. turn to Page 3.5).
3. **Jet Pumps** - employed in low-yield wells where the pumping water level is not more than twenty (20) meters. Pls. see Figure 3.4 on Page 3.6.

Figure 3.1: Positive-Displacement Pump



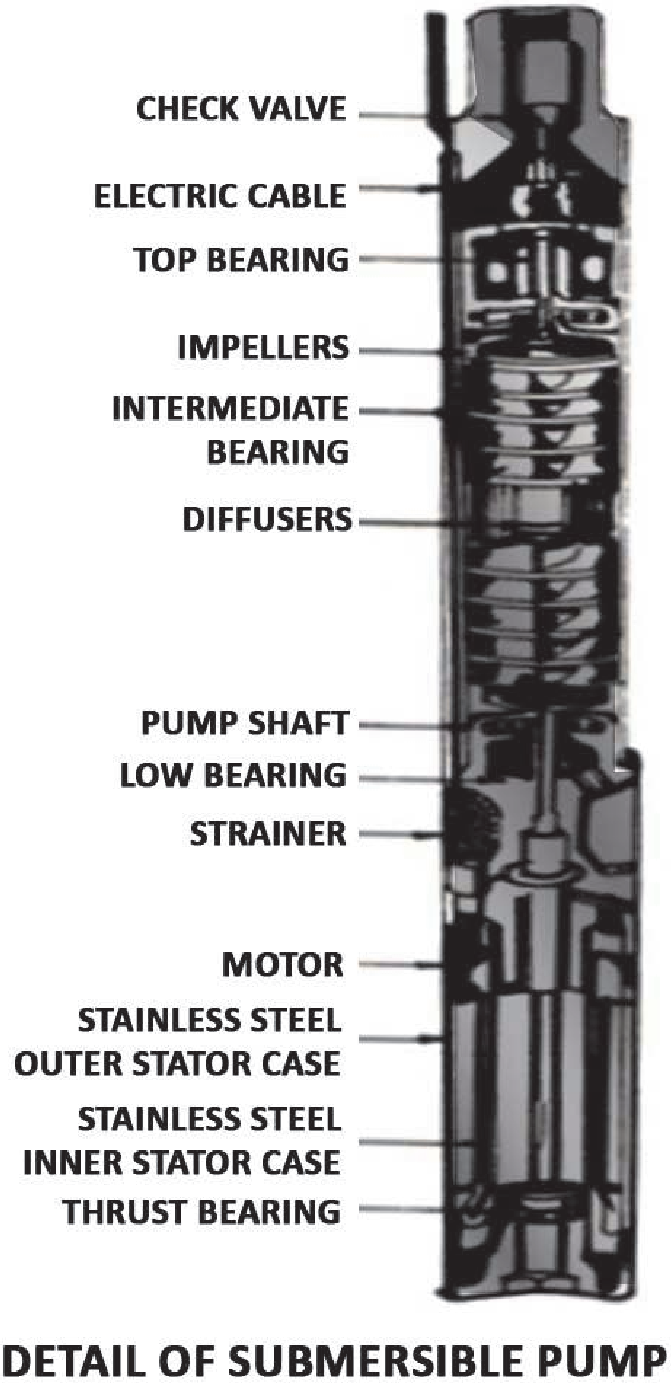
NWRC RWS Volume I, Design Manual

Figure 3.2: Centrifugal Pump



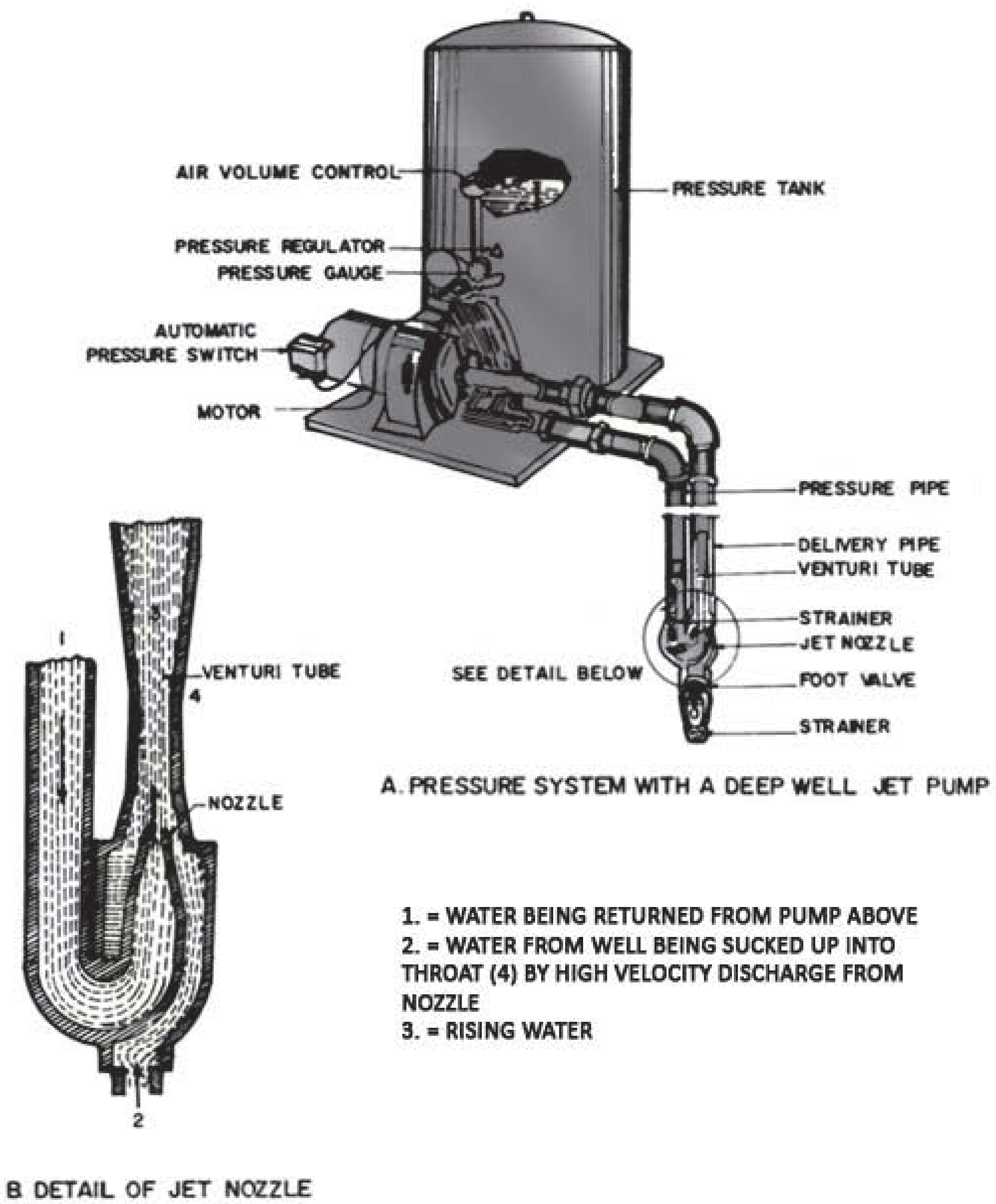
NWRC RWS Volume I, Design Manual

Figure 3.3: Vertical Turbine (Submersible) Pump



NWRC RWS Volume I, Design Manual

Figure 3.4: Jet Pumps



NWRC RWS Volume I, Design Manual

C. PUMP INSTALLATION

As with all aspects in the construction of water works that he must monitor, the Inspector should study and become familiar with all pertinent plans and specifications. The basics of pump installation standards and procedures that an Inspector must typically observe are the following:

1. General Preparation

1. A copy of manufacturer's shop drawings and installation instructions should be available at the work site.
2. The work area should be clean and safe.
3. The complete parts should be at the work site before installation is begun.
4. All pump parts and appurtenances should be kept clean.
5. Flanges and exposed finished metal parts should be coated with an anti-corrosion compound.
6. The pump foundation should be properly prepared and ready.

2. Setting the Submersible Pump

The following activities and record of all measurements should be included in the Inspector's Daily Report:

1. The manufacturer's detailed installation instructions should be followed.
2. The Contractor should keep a list of all tools being used and check the tools against the list daily. If a tool is missing, everyone should be alerted to the possibility that a tool might have dropped into the well.
3. Preventive measures should be in place to keep any object from dropping into the well.
4. The distance from the water level in the well to the top of the pump foundation should be taken and recorded.
5. The water indicator tubing should be installed with the pump.
6. The integrity of system/equipment grounding should be ensured.

3. Setting a Horizontal Centrifugal Booster Pump

The manufacturer's detailed installation instructions should be followed.

1. All factory alignments should be field-checked as the alignment may have been disturbed in shipping.
2. Foundation bolts should be in good alignment with holes in the base plate. Forcing the plate will put an unnecessary strain on the pump alignment.
3. The base plate grouting must be placed before piping connections are made. This should be a non-shrink grout to allow free flow under the base plate
4. Any lateral shifting should be prevented to minimize vibration.
5. The pump and pipe should not be forced together, as any strain on the pump should be avoided.

6. The pipe flanges should be installed squarely together before the bolts are tightened.
7. The suction and discharge pipes, valves and other required equipment must be properly supported and anchored.
8. The system/equipment should be properly grounded.
9. The direction of pump driver rotation must be verified to be correct before the pump is connected.

D. PUMP MOTOR CONTROLS

Pump controls may be manual or automatic. In older electric pump motors, simple manual Start/Stop switches were used. Today, magnetic starters are used, allowing pump motors to be operated automatically.

Pump motor-control equipment is made up of different devices. The Inspector must understand that automatic motor controls serve two general functions:

- To protect the motor and its feeder cables; and
- To regulate when and how the motor will operate.

Normally, the Inspector will encounter some of the component devices used in automatic motor-control system, which are listed and briefly described below:

1. Circuit Breaker Switch

A circuit breaker "trips" or a fuse blows when the circuit is overloaded or a short takes place in the wiring. The breaker reacts to a fault condition by "breaking" the circuit, instantaneously cutting the electrical flow and thereby protecting the electrical circuit from damage. A circuit breaker can be reset (either manually or automatically) to resume normal operation. Circuit breakers such as the example shown in Figure 3.5 on the following page are normally used to protect the circuits feeding the pump motor.

2. Motor Starter Switch

This is a starting device with built-in current overload protection. It carries the high amperage required when starting the motor, and supports its normal operating amperage on a continuous basis. However, in an overload situation when the current exceeds the rated range for safe operation, it disconnects the motor.

Figure 3.5: Circuit Breaker Switch

3. Flow Switch

This type of switch detects the movement of air or liquid in a duct or pipe. Normally it is installed at the discharge of the pump to cause the motor to stop automatically when the flow ceases once the reservoir is full.

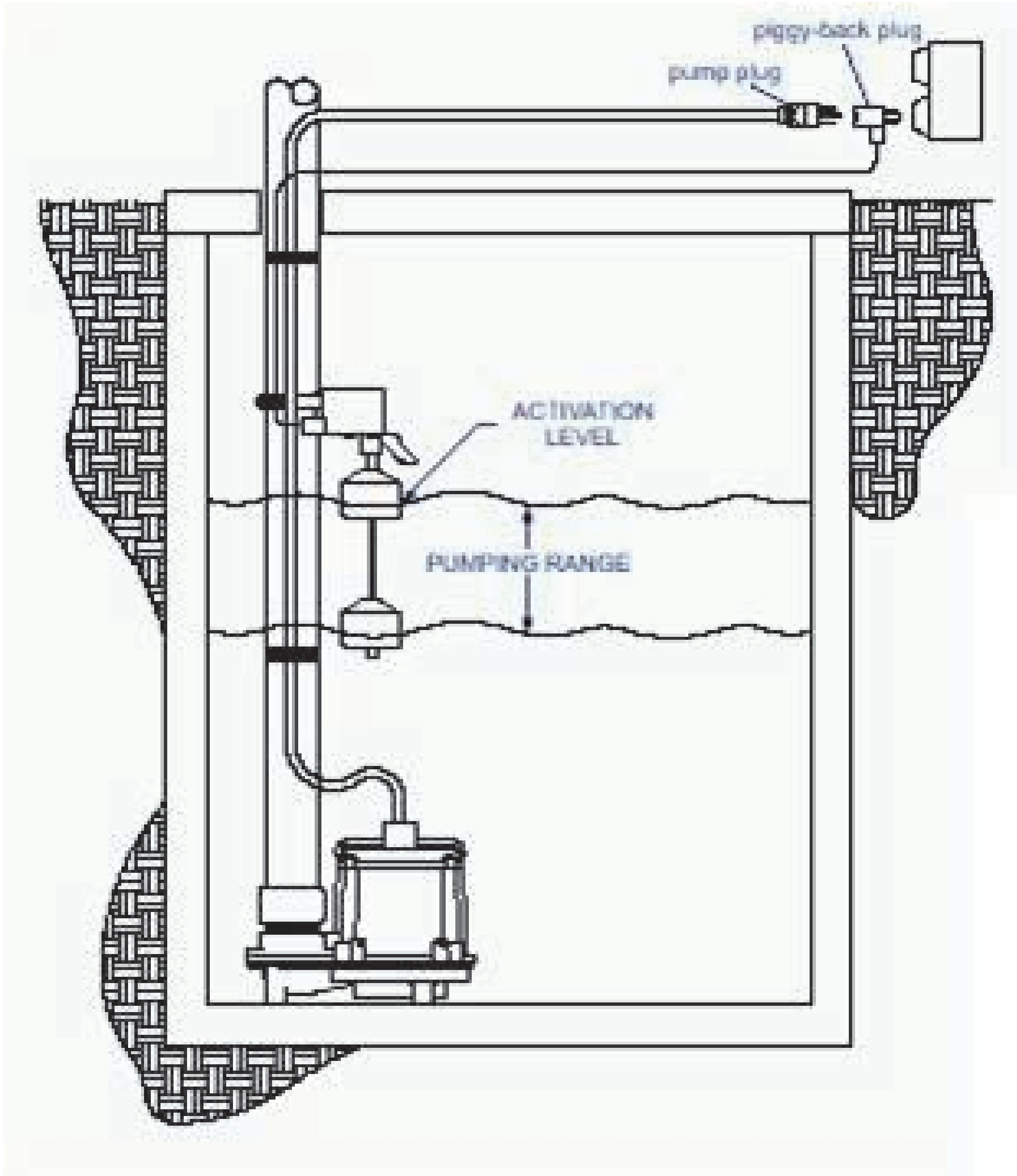
4. Pressure Switch

A pressure switch is designed to make electrical contact when a certain set pressure has been reached on its input. This is used to provide on/off switching from a hydro-pneumatic tank. The switch may be designed to make contact either on pressure rise or on pressure fall. The pump motor is started when the pressure in the tank is at the set minimum, and is stopped when the pressure is at the set maximum.

5. Float Switch

The float switch controls the action of a pump as it relates to the level of liquid in a tank. As illustrated in Figure 3.6 below, it is used with electrodes that detect the liquid level.

Figure 3.6: Float Switch with Water-Level Electrodes



6. Water-Level Electrodes

Electrodes are installed at the minimum and maximum water levels of the reservoir. The electrode set at the minimum water level starts the pump automatically, and the electrode at the maximum water level stops the pump motor automatically.

E. PUMP TESTING

At times the Inspector will be required to observe the field tests of pumps and record test results. Testing of any electro-mechanical equipment should proceed in an organized manner so that damage will be minimized in the event of a malfunction.

As a general observer, the Inspector should be particularly watchful for the following tests to determine the actual performance of any pump:

1. Measurement of pressure from pressure gauge readings;
2. Determination of total head from gauge readings;
3. Determination of the depth of water in a well (presented in **Volume 1: Design Manual**);
4. Measurement of capacity (presented in **Volume 1: Design Manual**);
5. Electrical data from power measurement by Watt-Hour-Meter.

Chapter 4

Concrete Construction

This Chapter deals with various aspects of concrete, from its properties to its usage in various water supply structures.

A. PROPERTIES OF CONCRETE

Concrete is produced by mixing a paste of cement and water with inert materials. The most commonly used inert materials are sand and gravel (or crushed stones). These inert materials are called aggregates, which provide most of the volume of the concrete. The cement is the chemical ingredient that reacts with water to form a paste, which hardens with time and binds the aggregates together.

To fulfill concrete requirements, it is essential for the concrete to have all of the following qualities.

1. **Strength:** Concrete is tested for strength in the laboratory. Its strength depends upon the quality and proportion of the materials used (cement and aggregates) and the curing conditions such as age, temperature and moisture.
2. **Durability:** Durability refers to the ability of the finished concrete to withstand weathering, chemical action and wear when subjected to service. The use of a mix with low water-to-cement ratio will prolong the service life of concrete. Durability may also be enhanced by some admixtures.
3. **Workability:** Workability is the quality of concrete in its plastic condition that permits it to be placed readily in the concrete forms, and its capacity to be finished without harmful segregation.
4. **Consistency:** Consistency is the wetness of the uncured concrete mixture. It is measured in terms of slump. The greater the slump, the wetter the mixture.
5. **Water tightness:** Water tightness of concrete is of extreme importance in certain structures such as tank walls, below-grade slabs, and roof slabs. Water tightness can be improved by reducing the amount of water in the mix and using non-porous, durable aggregates.

B. GUIDELINES IN PRODUCING GOOD CONCRETE

The Inspector must see to it that the following guidelines are observed in order to ensure that good concrete of the desired quality is produced:

1. Using the Right Materials

- **Portland Cement**: If the requirement is for the concrete to achieve its maximum strength at the earliest possible time, the High-Early-Strength Portland Cement should be used; otherwise general purpose cement will suffice.
- **Aggregate**: This consists of gravel of suitable size for the purpose and/or sand.
- **Water**: Should be free from salts, oils, acids, alkali and organic substances.
- **Admixtures**: Admixtures are materials other than cement, aggregate and water that are added to concrete either before or during its mixing to alter its properties, such as workability, curing temperature range, set time or color.

2. Obtaining the Right Mix Proportions

All concrete is a combination of aggregate (gravel and/or sand), cement, and water, but the proportions of the mix can be varied. A larger proportion of water causes a softer, wet concrete mix, which is easier to handle during the pour and requires less care when curing. It results in a slightly softer and less durable finished product. A smaller amount of water causes a stiffer, wet concrete mix, which is harder to manage but makes a stronger and more durable finished product.

Two general methods used in ensuring the right concrete mix proportions are discussed in **Section E** in this Chapter.

3. Controlling the Proportion and Mixing Method

Both the proportion of the ingredients and the mixing method must be controlled to produce a homogeneous mixture. Uniform batches are desirable to ensure that all parts of the structure will be of equal strength and durability.

4. Placing

The newly mixed concrete must be transported and placed properly to produce a dense, well-compacted mass free of honeycombs.

5. Curing

“Curing” refers to the procedures used to prevent freshly poured concrete from drying out too quickly. Curing is needed because concrete, if left to dry out of its own accord, will not develop the full bond with all of the ingredients in the mix. It will be weak and prone to cracking. The curing process ends when the concrete has attained its design strength.

C. CONCRETE INSPECTION

The Inspector necessarily must refer to the design drawings and specifications, to ensure that these are complied with, and to keep a record that shall cover the following:

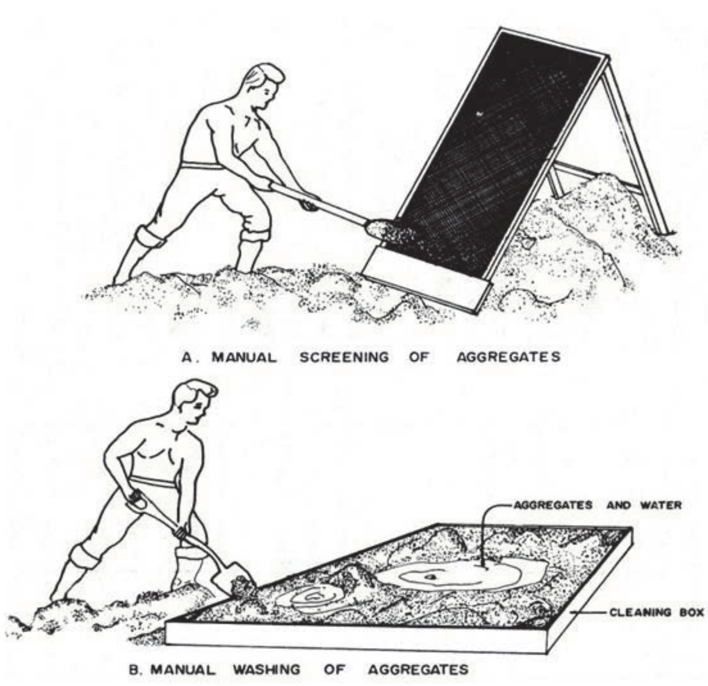
1. Quality and proportions of concrete materials and strength of concrete;
2. Construction and removal of forms and shoring;
3. Placing of reinforcements;
4. Mixing, placing and curing of concrete;
5. Sequence of erection and connection of walls; and
6. General progress of work.

D. MATERIALS FOR CONCRETE

1. Preparation of Aggregates

All sources of aggregates must be ascertained and approved well before the start of concrete operations.

Figure 4.1: Preparation of Aggregates



NWRC RWS Volume II, Construction and Installation Manual

The preparation of aggregates consists in making their grading uniform by screening and washing out and otherwise removing undesirable materials. For small jobs, aggregates may be screened and washed using a wooden trough and a portable screen mounted on wood frame, as depicted in Figure 4.1.

2. Fine Aggregates or Sand

Sand should consist of lean, hard, strong and durable particles. These should be free of chemicals or coatings of clay or other fine materials that may affect the bonding of the cement paste. Any unavoidable clay contents should not exceed 3 percent of the total weight.

a. Guide Notes:

1. Beach sands are entirely unsuitable for concrete mixtures.
2. Grading of sand is very important because of the effect of aggregate size on the water-to-cement proportions, workability, economy, porosity and shrinkage. Very fine sands are uneconomical since they require more cement. On the other hand, very coarse sands result in harsh, unworkable mixes.
3. For fine aggregates, the suitable gradations are as shown in Table 4.1 below:

Table 4.1: Grading Requirements for Fine Aggregates

Mesh No.	Screen Opening or Aperture		% of the total sample passing specified sieve
	inches	mm	
4	0.250	6.35	95 – 100
16	0.047	1.19	45 – 80
50	0.012	0.30	10 – 30
100	0.006	0.15	2 – 10

b. Removing Clay and Silt

Clay and silt present in excessive quantities can be detected by conducting the following test:

1. Fill a quart jar (1.14 liter) or Erlenmeyer flask with sand to a depth of 5.0 cm (2 inches);
2. Add water until the jar or flask is 3/4 full;
3. Shake the contents for about one minute with the last few shakes in a sidewise direction;
4. Allow the jar to stand for 30 minutes;
5. Observe the top of the sand. If there is more than 3.2 mm layer of sediment, the sand where the sample was taken is unsuitable for

construction purposes. However, the aggregates in question can be used after washing and removing the undesirable materials.

3. Coarse Aggregates

1. Proper gradation is more important for coarse aggregates than for the fine aggregates. The smaller stones should fill the spaces between the larger particles so as to give a dense mixture. Table 4.2 below shows a suitable gradation for coarse aggregates in concrete mixes

Table 4.2: Grading Requirements for Coarse Aggregates

Screen Opening or Aperture	Percent by Weight
Passing Maximum Allowable Size	95 – 100
Passing one-half of Maximum Allowable Size	35 - 70
Passing Sieve No.4	0 – 10

2. Generally, the maximum size of aggregates should be the largest that is economically available and consistent with the dimensions of the structure. The reason for selecting the maximum size of aggregates is to minimize the amount of cement mortar and hence, the cost of construction.
3. Aggregates should never exceed the following maximum size specifications:
    - One-fifth (1/5) of the narrowest dimension between the sides of forms;
    - One-third (1/3) the depth of the slabs;
    - Three-fourths (3/4) of the minimum clear spacing between individual reinforcing bars.
4. Gravel is usually obtained from stream deposits. The rounded particles are particularly suitable for concrete aggregates as they present less surface area and are more economical in demand for cement paste. Also its semi-spherical shape lends a structural advantage over angularly shaped crushed rock as it resists crushing or shear.
5. Concrete can be made from crushed rock but the particles should be more or less cubical in shape. Stones which break into long slivery pieces should be avoided. Crushed rock requires more sand and cement than rounded gravel.

4. Stockpiling Aggregates

1. When aggregates are stockpiled on the ground, the ground should first be cleared of all vegetation and rubbish, and then leveled; otherwise the piles of aggregate should be placed on concrete slabs or wood planks.

2. Stockpiles should not be built up in a cone shape nor allowed to run down slopes as this causes segregation. To minimize segregation, materials should be placed and removed from stockpiles in horizontal layers.
3. Insofar as it is possible, the moisture content should be kept uniform to avoid problems in determining the proper amount of water to be added when mixing.

5. Portland Cement

The following are the types of Portland cement, which can be used for small waterworks:

- **Type I** (Normal)**:** used for general purposes.
- **Type II** (Moderate Sulfate Action and Moderate Heat of Hydration): used in large piers, heavy abutments, heavy retaining walls and other mass structures of considerable size where moderate heat of hydration will tend to minimize temperature rise or where protection is needed against sulfate attack where conditions are higher than normal but not severe.
- **Type III** (High-early-strength): used when very high strength is required at an early age.

6. Storing Bagged Cement

1. Cement bagged in sacks should be stored in a warehouse or shed as nearly airtight as possible, with the bags stored close together to reduce air circulation, and away from outside walls.
2. If no shed is available, the bags should be placed on a raised wooden platform and a waterproof cover placed over and covering down the sides of the pile so that rain cannot reach the cement.
3. Sacked cement in storage will occasionally develop a “warehouse pack”, a condition resulting from packing too tightly. The cement retains its quality in this condition, which can usually be corrected by rolling the bags on the floor.

E. CONCRETE PROPORTION AND CONSISTENCY

The selection of concrete proportions involves a balance between reasonable economy and achieving the required placeability, strength, durability, density and appearance. The required characteristics are governed by the purpose and use of the concrete work when it is completed, as well as the conditions anticipated at the time of placement.

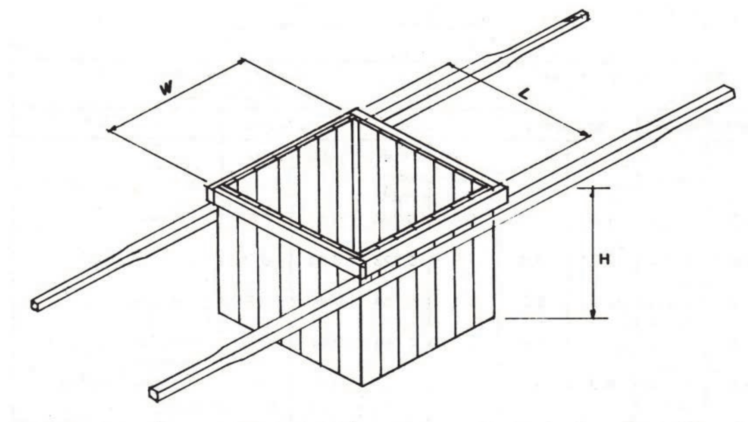
As earlier mentioned, the two widely used methods in selecting the right proportions are the volumetric method, and the trial mix or batch method.

1. The Volumetric Method

The conventional volumetric method of proportioning the ingredients is widely used in rural areas. The process consists of measuring the different ingredients of a concrete mixture using a container of known volume and then mixing them.

Figure 4.2 shows a typical volumetric measuring box. The inner dimensions should be measured to give the total volume of mix to be prepared at a time.

Figure 4.2: A Typical Volumetric Measuring Box



Capacity (m^3)	Inside Measurements		
	Length (m)	Width (m)	Height (m)
0.10	0.4	0.4	0.63
0.20	0.6	0.6	0.56
0.30	0.8	0.8	0.47

NWRC RWS Volume II, Construction and Installation Manual

Table 4.3 presents the classes of typical concrete mixes and their uses.

Table 4.3: Typical Concrete Mixes and Their Uses

Class	Typical Concrete Mixes (volume proportions)				Quantity of Materials per m^3 of Concrete				Usage
	Cement	Water	Sand	Gravel	Cement		Sand	Gravel	
					bags	m^3	m^3	m^3	
AA	1	0.7 – 1.0	1.5	3.0	10.4	0.294	0.44	0.88	Foundation
A	1	0.7 – 1.0	2.0	4.0	7.9	0.223	0.45	0.9	Beams & Slabs
B	1	0.7 – 1.0	2.5	5.0	6.5	0.184	0.46	0.92	Columns
C	1	0.7 – 1.0	3.0	6.0	5.5	0.156	0.47	0.94	Flooring on fill, and pavements
D	1	0.7 – 1.0	4.0	8.0	4.8	0.136	0.48	0.96	Big Mass Footings

2. The Trial Mix/ Batch Method

The Trial Mix or Batch method of proportioning materials is employed only if it is necessary to ascertain the final characteristics (strength, slump, etc.) of the concrete. Batching is applied for critical constructions, where an error in the mix could cause its collapse or failure. This method is complicated and falls beyond the scope of this Manual. For the small waterworks projects envisioned in this Manual, concrete mixes using this method – if at all necessary, would best be jobbed out to a concrete batching plant.

F. TESTING OF CONCRETE MIXES

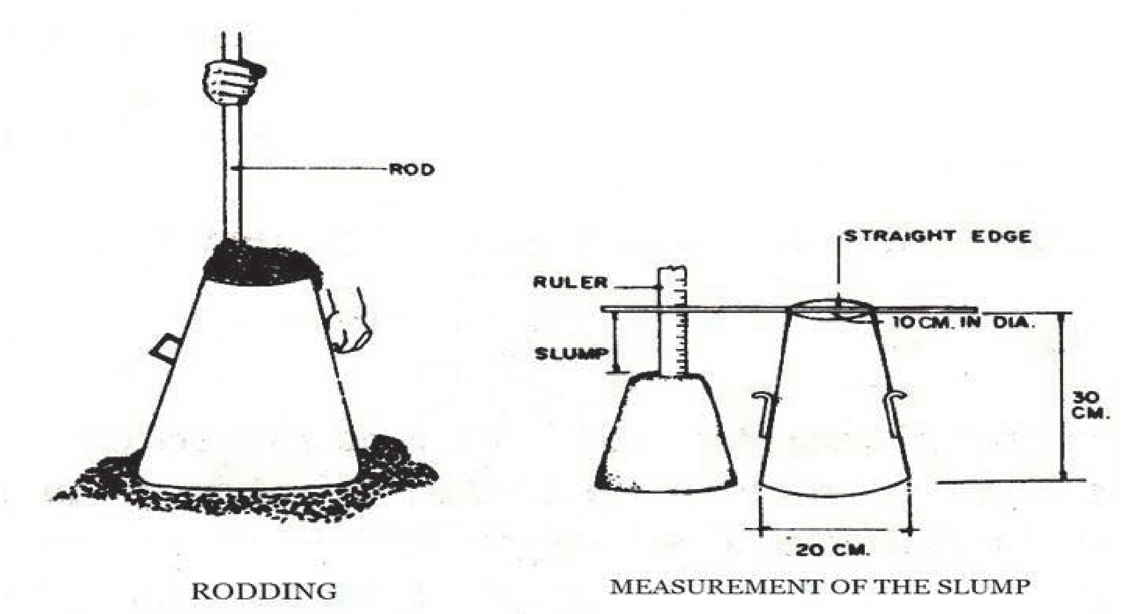
1. Slump Test

The slump test is an empirical test based on a simple procedure and apparatus, used to measure the consistency and workability of fresh concrete. It is also used under field conditions to ensure uniformity of different batches of concrete for a similar use. It employs an inverted cone whose dimensions are shown in Figure 4.3.

a. Procedure

1. Dampen the cone and place it on flat surface such as a smooth plane or concrete slab.
2. Fill the cone with its first layer of concrete to about 1/3 its volume (about 63.5 mm or 2 ½ inches). Hold it down as it is being filled.

Figure 4.3: Slump Test

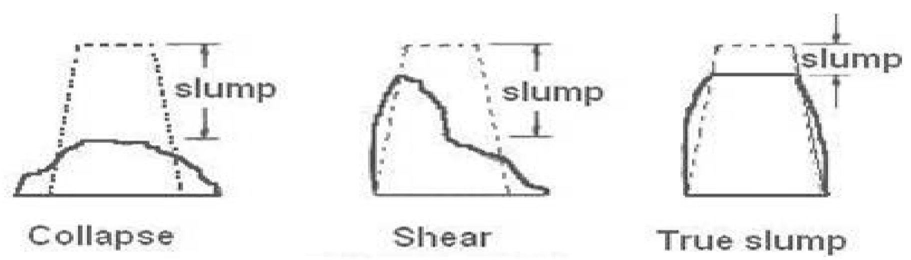


3. Rod the first layer 25 times with a 15 mm (5/8") bullet-pointed steel rod about 60 cm (24") long. Strokes should be distributed evenly over the cross section of the cone.
4. Repeat the procedure, adding a second layer that fills cone to about 15 cm (6") and third layer up to the top. Each layer is rodded 25 times with the rod penetrating the lower layer.
5. After the top layer has been rodded, scrape off the excess cement.
6. Gently remove the cone by raising it vertically, and place it beside the specimen. Do not jar or tilt the cone or otherwise disturb the specimen in the process.
7. Measure the difference between the top of the cone and the top of the specimen. This measurement is called the "slump".
8. After the slump measurement is complete, tap the side of the concrete specimen gently with the tamping rod. The behavior of the concrete is a valuable indication of its cohesiveness, workability and placeability. A well-proportioned workable mix will slump gradually and retain its original identity; a poor mix will crumble, segregate, and fall apart,
9. Any change in slump on the job indicates changes have been made in grading or proportions of the aggregate or in the water content.

b. Interpretation of Results

The slumped concrete takes various shapes, and according to the profile of slumped concrete, the slump is termed as true slump, shear slump or collapse slump. These are illustrated in Figure 4.4.

Figure 4.4: Types of Slump



NWRC RWS Volume II, Construction and Installation Manual

1. If the result is a shear slump or a "collapse" slump, a fresh sample should be prepared and the test repeated until a true slump is achieved. A collapse slump indicates the mix is too wet, or that it is a high workability mix, for which the slump test is not appropriate.
2. Wetness and workability effects/applications:

- Very dry mixes with slumps of 0 – 25 mm are used in road making
- Low workability mixes with slumps of 10 – 40 mm are used for foundations with light reinforcement
- Medium workability mixes with slumps of 50 – 90 mm are used for normal reinforced concrete placed with vibration
- High workability mixes have slumps greater than 100 mm.

Note that the less the slump, the stronger and more waterproof the mixture will be.

2. Unit Weight Test

The unit weight test is employed to determine the density of the prepared concrete mix. This is done after mixing is complete. The equipment needed is a weighing scale and a cylindrical container of 0.014 m^3 (0.5 cubic foot) for aggregate whose maximum size is not more than 5 cm (2"); and 0.035 m^3 (1 cubic foot) when maximum size is greater than 5 cm (2").

Procedure

1. Fill 2 layers, each approximately ½ the volume of the container, and vibrate each layer for about 2 seconds. (Rod if a vibrator is not available);
2. Scrape off the top to remove excess mix;
3. Weigh with a scale accurate to 0.5%±;
4. Compute the density (unit weight) using the formula below.

$$\boldsymbol{Unit\ Weight = \frac{Wcm - Wc}{Vc}}$$

Where:

$$Wcm = weight\ of\ container + material$$
$$Wc = weight\ of\ empty\ container$$
$$Vc = volume\ of\ container$$

The density or unit weight of normal concrete ranges from 1750 – 2400 kg/m^3.

3. Strength Test (Compression Test)

Tests for concrete strength are done in a materials testing laboratory, which works on the basis of samples submitted to it.

a. Procedure for Taking Samples

1. Take samples from the batch at 3 or more regular intervals throughout discharge. Avoid taking samples at the beginning or end of the discharge process;
2. With a shovel, mix individual portions of the sample into one uniform sample;
3. Note batch and location in the structure, and describe any unusual conditions that may affect the sample;
4. Fill a mold in 3 equal layers, rodding each layer 25 times. For the 2nd and 3rd layers, the rod should not penetrate the lower layer. The rod should be 15 mm (5/8") round steel piece, 60 cm (24") long and bullet shaped at one end. Do not use deformed reinforcing rod;
5. Strike off top and cover the sample mix to prevent evaporation.

b. Storage of Samples

1. Place in rigid horizontal surface free from vibration;
2. Remove concrete from mold after 24 hours;
3. Cure the samples for either the 7 or 28 day test in a curing pan with water.

c. Transporting Samples

Pack and transport the concrete samples in a way that they will be protected from damage.

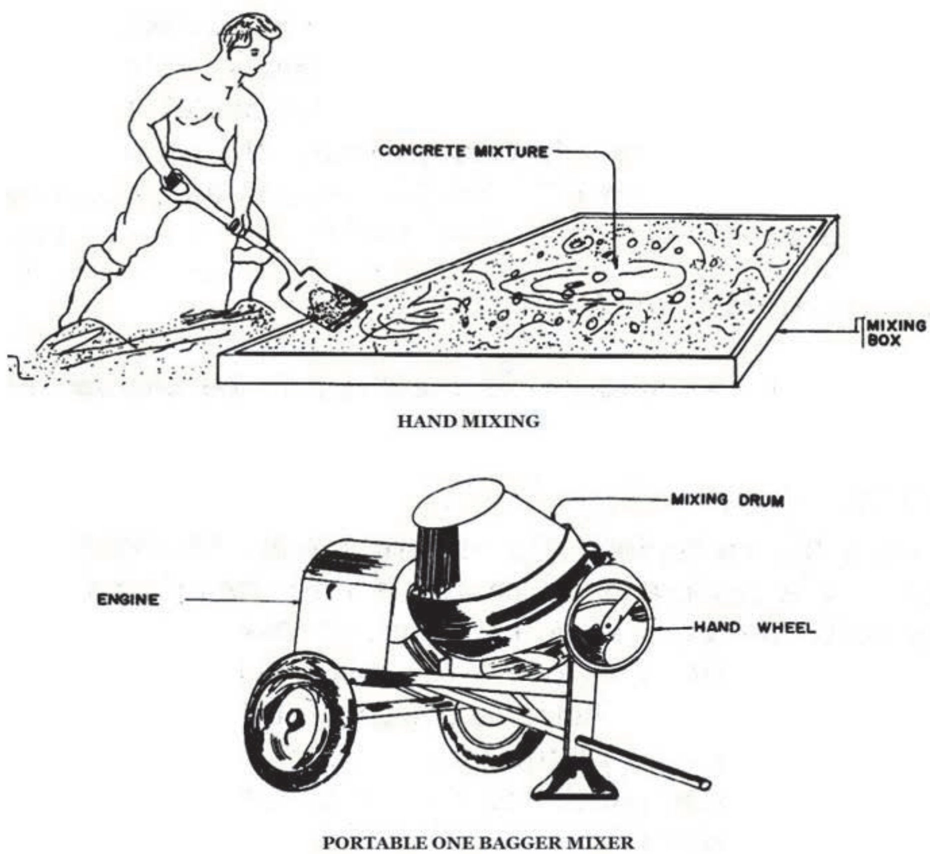
G. MIXING OF CONCRETE

Mixing is the process of making the mixture of sand, gravel, cement and water homogeneous. It may be done by hand or by machine (see Figure 4.5). Generally, machine mixing is superior to hand mixing, both in quality of concrete produced and in economy of time and labor, hence, it should be employed whenever a machine is available.

1. Procedure for Hand Mixing

1. Hand mixing is usually accomplished in a mixing box as shown in Figure 4.5. The mixing box commonly used has an approximate area of 3 square meters. The volume of batches for hand mixing is usually limited to 0.76 cubic meters (1 cubic yard) or the amount that can be placed in ***30 minutes or less;***
2. Spread sand evenly to a depth of roughly 9 cm on a water tight-platform or mixing box.

Figure 4.5: Mixing of Concrete



NWRC RWS Volume II, Construction and Installation Manual

3. Spread the cement evenly over the sand and mix until mixture is uniform in color. Three (3) turnings are usually sufficient.
4. Add approximately 10-20 percent of the required quantity of water as determined by the water-cement ratio and mix. Allow the water to be absorbed by the mixture and then turn it until a homogeneous mixture is obtained. Usually, three turnings are sufficient.
5. Add coarse aggregate to the water-sand-cement mixture and then add the remaining 80-90 percent of the required amount of water. In case mixing is accomplished on concrete pavements, adding of water should be carefully regulated to prevent its escape to the surroundings.
6. Turn the mixture three or four times until a homogeneous mixture results.

2. Procedure for Machine Mixing

1. In portable concrete mixers (also shown in Figure 4.5), the mixture is placed is appropriate batches in a revolving drum equipped with blades. Usually, a 0.76 cubic meter (1 cubic yard) capacity mixer is used, run either by an engine or an electric motor.
2. The batch is loaded into the cement mixer. To keep the cement from balling, it is preferable to charge the mixer with the dry cement and aggregates, and to mix them before adding water and other solid ingredients.
3. Approximately ten percent (10%) of the mixing water should be introduced first. The remainder should be added continuously during the entire time that the solids are being added to the mixer.
4. Concrete should be mixed for at least 1½ minutes and preferably 3 minutes after all materials have been placed in the mixer
5. All concrete should be mixed thoroughly until it is uniform in appearance, with all ingredients homogenously distributed.
6. No part of the charging time should be considered part of the mixing time.
7. Batch mixers should be checked frequently to ensure that portions of the mix have not "hung up" on the blades. If this takes place, the mixer drum must be stopped and the blades cleaned.
8. Concrete should be placed/deposited within 30 minutes after mixing.

> ***NOTE: If a batch has been kept idle for more than 30 minutes, it should be remixed prior to discharge.***
>
> ***A batch that is not used within 1.5 hours should be rejected.***
>
> ***The Inspector should not vary the approved mix design without authority from the Engineer.***

H. INSPECTION GUIDE

1. Each day before mixing starts:

1. Record weather conditions and temperature;
2. Balance or "zero" all scales;
3. Check operation of batchers, dispensers, meters, valves, gates, etc.;
4. Check moisture in sand;
5. Inspect stockpiles for contamination;
6. Inspect cement sacks for hard cement;
7. Be sure there is a sufficient supply of all materials for the scheduled work, including emergency provisions for water if being supplied by pipeline;
8. See that forms are adequately braced or have not been displaced since last inspection;

9. See that the subgrade has been properly dampened;
10. Inspect reinforcing steel to make sure it is still adequately supported and in its proper location;
11. Review contractors preparation for protecting fresh concrete in case of rain;
12. Observe that the contractor has the proper tools, adequate staff of workmen and vibrators are in working order;
13. Be sure the contractor has assigned carpenters to watch for any form movement during placing of concrete.

2. During mixing operation:

1. Verify that proper materials are being used;
2. Test aggregate for gradation, cleanliness, and moisture content;
3. Verify that proper mix is being prepared;
4. Make occasional check of mixing time;
5. Observe condition of mixers – skips, blades, discharge, etc. – and be sure that they are clean and in good condition. Avoid accumulation of cement or concrete;
6. Make sufficient slump tests to provide control of slump;
7. Confirm that the concrete is thoroughly mixed at the time of discharge from the mixer and see that waste and segregation are avoided;
8. Make necessary test samples;
9. Keep a record of wasted concrete and reason for wasting;
10. Compute water: cement ratio.

I. FORMWORKS

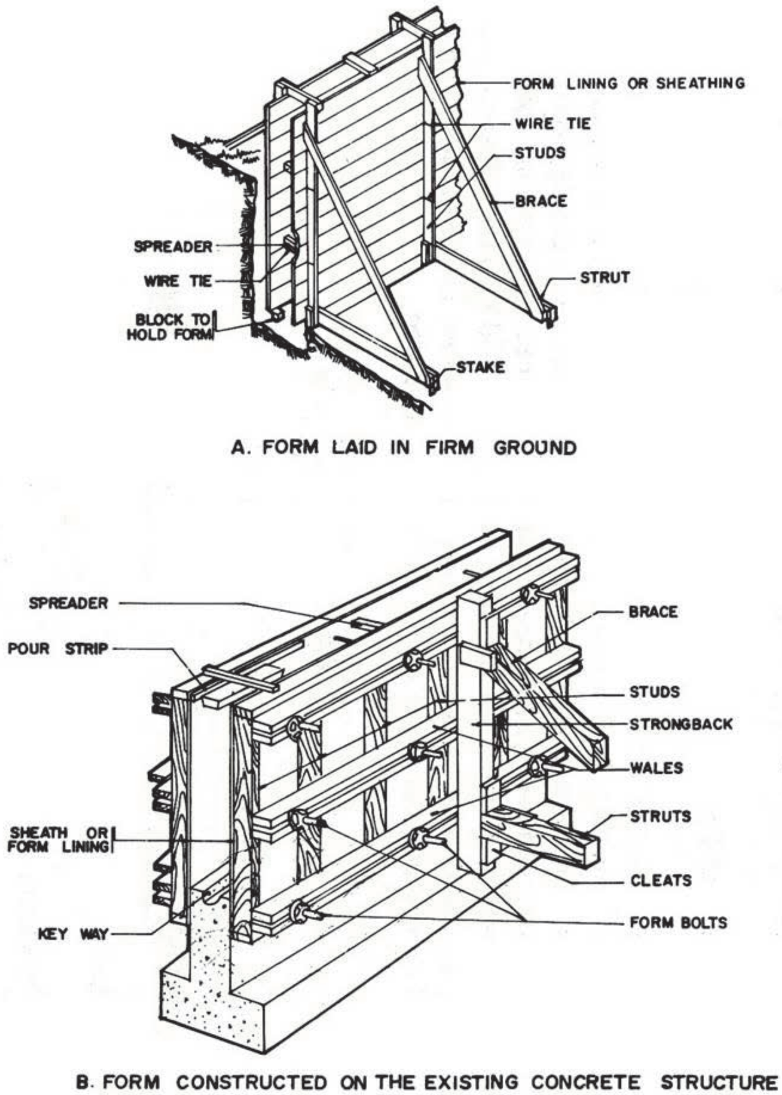
Concrete forms are necessary to mold concrete to conform to its final shapes, lines and dimensions as required by the design drawings and specifications.

1. Parts of Concrete Forms

Figure 4.6 on the following page illustrates a concrete form and its different component parts. The major parts and their functions are as follows:

1. **Form Sheathing**: Part of the form which is in contact with the concrete and is usually made of plywood or lumber.
2. **Studs**: Support the form sheaths.
3. **Wales**: Support the studs so that every stud will have full bearing on the concrete surface.
4. **Strongback**: Supports the horizontal wale for high walls and long spans.

Figure 4.6: Parts of Concrete Forms



NWRC RWS Volume II, Construction and Installation Manual

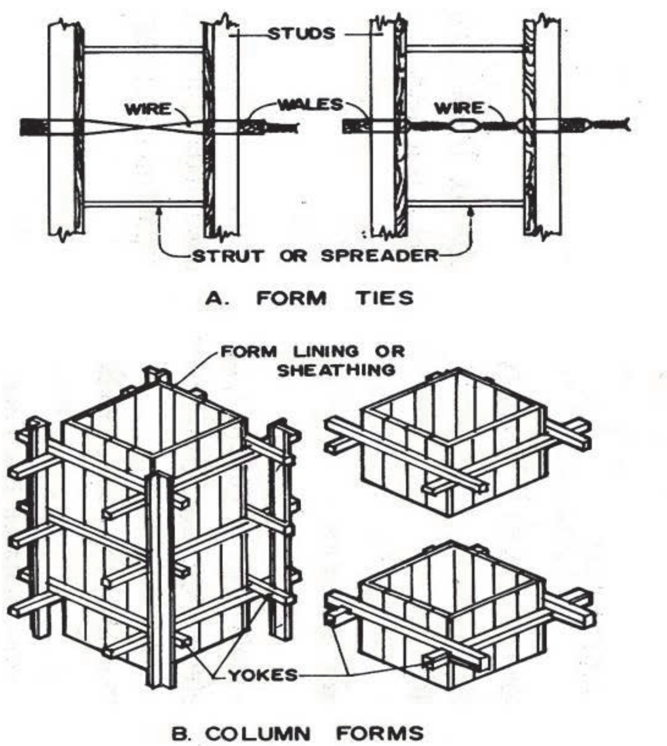
5. **Form Ties**: Used to keep the two opposing forms from spreading under the pressure of the fluid mass of concrete. There are many types and sizes of form ties. The more conventional types are stud-rods, plain steel rod and clamp assemblies, coil ties, and snap ties (Figure 4.7).
6. **Bracings**: Inclined or diagonal member to support the vertical studs or strongbacks.
7. **Form Anchors**: Devices to secure forms on firm ground or previously placed concrete.

2. Preparation of Forms

The preparation of concrete forms prior to placement of concrete includes the following:

1. Removal of debris from the inside of forms such as sawdust, tie wires, nails and all dry concrete if the form material has been used previously;
2. If forms have holes, they must be patched up to be watertight;
3. Application of oil to form surfaces that will be in contact with concrete. Oil is usually applied to prevent the concrete from adhering to form surfaces.

Figure 4.7: Form Ties



NWRC RWS Volume II, Construction and Installation Manual

3. Construction of Forms

a. Inspection Guidelines:

1. Good formwork is accurately dimensioned and constructed of material of sufficient strength to maintain deflection or distortion within acceptable limits.
2. It should be adequately braced and supported to withstand the weight and pressure of concrete and the superimposed construction loads.

3. Irrespective of what materials are used to fabricate forms, the completed forms must have adequate rigidity and strength to withstand the concrete pressures without displacement.
4. Where plywood is used on horizontal or vertical studs, the Inspector must determine that the spacing between studs is not so excessive as to cause a bulging due to deflection of the plywood between the studs.
5. Plywood installed with the long dimension of the sheet at right angles to studs furnishes the maximum strength for resisting deflection.
6. The spacing of wales depends upon the height of a wall, the anticipated rate of the concrete placement, and the spacing of the form ties.
7. Before the concrete is placed, it is important for the Inspector to see that the studs are sized (checked to see that all have the same dimensions) and that the wales are straight so that every stud will have full bearing on the wales.

a. Oiling Forms

1. Before concrete is placed, the form surface should be oiled so that the form will easily release from the concrete during form removal.
2. Coatings should not be so thick as to stain or soften the concrete surface. The oil should be applied before the steel reinforcement is placed or it will get on the reinforcement and destroy the bond.
3. The form oil used must be approved by the engineer. The oil used should not interfere with the function of the curing compound nor impart a taste and odor to water in a reservoir.

4. Removal of Forms

1. The forms should be removed at the earliest practicable time so that surface defects may be repaired and curing can start. Table 4.4 provides a guide as to the timing of form removal.

Table 4.4: Time Required Before Removal of Forms

Structure	Time (Days)
Walls and Columns	3
Thin Walls	5
Roof and Above Ground Floor Slabs*	7

* Until test cylinders attain a minimum of 2,250 psi compressive strength.

2. When forms are removed, it is important to do so in a way that does not impair the safety and serviceability of the concrete structure.
3. To avoid damage when the forms are removed, the concrete should have sufficient strength before the form is removed and the structure exposed.
4. Crowbars or large pry bars must not bear against the concrete; wood wedges should be used instead.

5. Keyway forms are best removed after they dry out and shrink away from the concrete.
6. The Stripping crew should be trained in both the order and method of form removal. Stripping requires considerable care on the part of the workmen to avoid damage to the green concrete.
7. Forms that are to be used again should be carefully removed and handled so they remain dimensionally accurate. The edges must stay in good condition to make accurate alignment and clean joints possible.

J. HANDLING AND TRANSPORTING CONCRETE

The following guidelines should be observed in handling and transporting concrete:

1. Handling and transporting must be rapid, otherwise the concrete will dry out and lose its workability or plasticity between mixing and placing.
2. Concrete should be placed in its final position within 1½ hours after water has been added to the mixture (less if conditions contribute to quicken the stiffening of the concrete). Generally, it is good practice to place concrete in forms within 30 to 60 minutes.
3. Segregation of the aggregates and paste must be reduced to a minimum to assure uniform concrete. The loss of fine material cement and water should be prevented.
4. Transportation should be organized so that there are no undue delays that would cause undesirable constructional joints.

K. THE PLACING AND CONSOLIDATION OF CONCRETE

1. Placing of Concrete

The following guidelines should be observed in placing concrete:

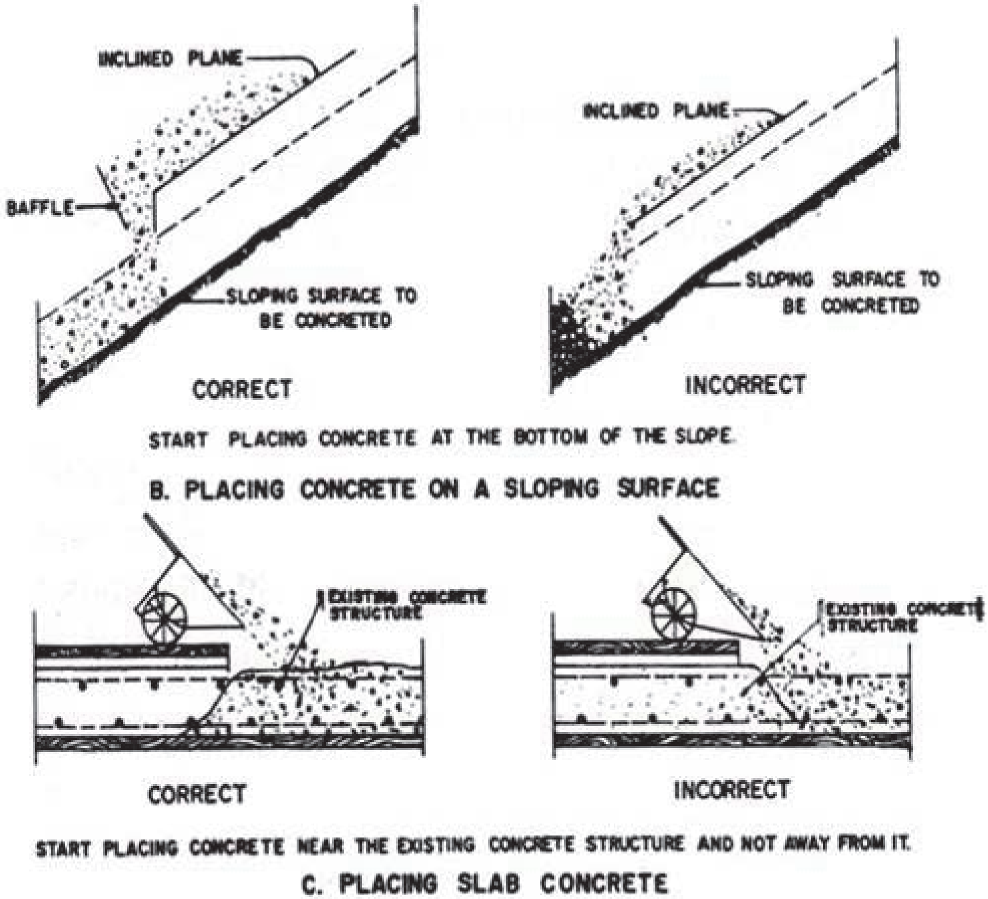
a. Preparation

1. Subgrade or construction joint and forms should be cleaned of chips, dirt, nails and other debris.
2. Subgrade and forms should be wetted to minimize their tendency to absorb water from the mix. The subgrade should be moistened to a depth of 15 cm.
3. Forms should be tight in order to prevent loss of mortar.
4. All reinforcement should be free of concrete spatter from a previous concrete placement.
5. The bracing of forms should be checked.

b. Placement in Slabs

1. Concrete should be placed as close to its final position as possible. Excessive movement causes segregation (See Figure 4.8).

Figure 4.8: Placing Concrete Slab



LWUA Inspector's Construction Manual

2. Concrete should never be in piles and then leveled off.
3. Concrete should be consolidated by vibration as it is placed. A pattern of vibration should be established so that all concrete is consolidated.
4. The operator should work well around reinforcements, waterstops and corners. Waterstops must be completely embedded in concrete and should not be disturbed during placement. Concrete around waterstops should be placed by hand.
5. New concrete should be placed against previously placed concrete, not away from it.
6. When concrete is placed on a slope, placement should begin at the lower end and progress to the upper end. Ensure that vibration compacts the concrete instead of pulling it apart.
7. Concrete should be placed first at the ends towards the middle to prevent water from forming in corners.

c. **Placement in Walls and Vertical Structures**

1. The concrete should be directed through drop chutes as close to its final location as possible. Do not allow the mix to bounce off the reinforcements of forms. Openings (windows) in the form may be used to eliminate long drops. A pocket should be built on the outside of the opening to receive the concrete.
2. The pocket should allow the concrete to be introduced into the form in a slow, even flow which minimizes segregation.
3. As much as possible, the concrete mix should be placed in horizontal layers not exceeding 60 cm in depth. A succeeding layer should be placed while the underlying layer is still responsive to consolidation. Layers should be sufficiently shallow to permit the knitting of the 2 layers together through tamping, rodding or vibration.

d. **Bonding of Fresh Concrete to Existing Concrete Structure**

1. In joining fresh concrete to an existing concrete structure, the old surface should be roughened with a pick or old chisel and all loose materials and dirt should be removed.
2. The cleaned surface should be moistened, and a coat of water-cement mixture about 13 mm thick is applied, after which it may be covered carefully with a concrete layer.
3. The placing of concrete may then resume.

2. Rate of Placement

1. A condition can be produced where an excessive amount of water bleeds to the surface of the concrete, resulting in formation of a laitance on top of the concrete. This can be minimized by:
   - Reducing the rate of placement
   - Reducing the slump in the upper portion of concrete.
2. The amount of pressure that is exerted on the form is directly related to the height of plastic concrete in the form. If the placement rate is too great the outward pressure can cause the forms to bulge or fail. For this reason, the rate of rise should be monitored or controlled (rate of rise should be in the specifications).
3. The specifications should also limit the depth of each lift. As soon as possible after a lift is placed, it is consolidated. The consolidating device should penetrate the freshly placed layer and the previously placed layer to insure that the lift becomes monolithic.

3. Consolidation of Concrete

Proper consolidation of concrete is extremely important, especially in watertight structures. The Inspector must make sure the methods used are adequate to accomplish good consolidation. The correct procedures in vibration and rodding should be observed to avoid compromising concrete quality, such as having honeycombs in the finished work.

a. Consolidation by Vibration

The most effective method of consolidating concrete is by vibration. It permits the placement of concrete containing less water than usually required. There are always pockets of trapped air or excess water when concrete is poured. The vibrator will help consolidate it by releasing the water and air.

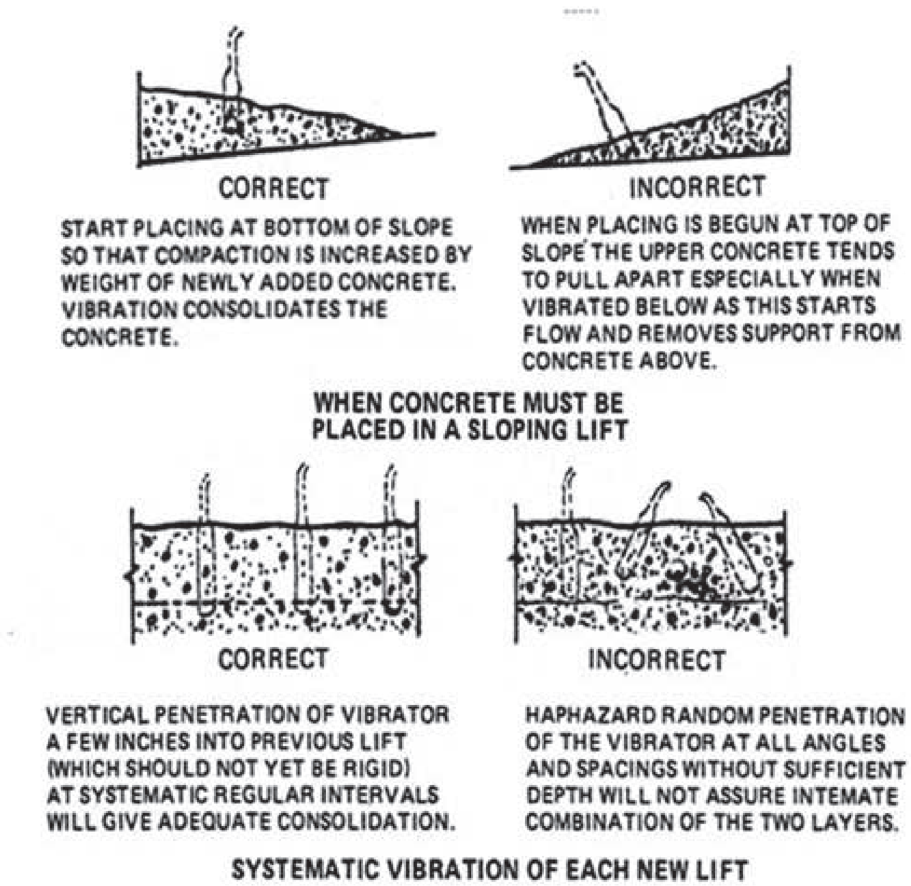
The most common vibrator used for consolidating concrete in structures is the immersion vibrator (Figure 4.9).

Figure 4.9: Immersion Vibrator

Guidelines on Use:

1. The vibrator should operate at speeds of not less than 5000 cycles per minute.
2. The vibrator should be inserted vertically into the concrete at points 15 to 30 cm apart and withdrawn slowly (Figure 4.10). It should not be dragged through the concrete.
3. A vibration period of 5 to 15 seconds is usually sufficient with high speed vibrators.
4. Under-vibration should be of more concern to the Inspector than over-vibration.
5. Systematic spacing of the points of vibration should be established to ensure that no portions of the concrete are missed.
6. Usually an indication of completed vibration is when the vibrator resumes its normal speed after an initial slowdown.
7. If concrete operations stop for a period of time, there should be no deficiency from cold joints if full advantage is taken of vibration and re-vibration. If the underlying concrete will still respond to re-vibration, the vibrator should be allowed to penetrate it deeply at each insertion. This procedure will cause the new concrete at the joint to be monolithic with the concrete placed before operations stopped.
8. If during vibration the surface of the concrete appears very wet and consists of a layer of mortar containing practically no aggregate, the slump, and not the amount of vibration should be reduced.

Figure 4.10: Systematic Consolidation



LWUA Inspector's Construction Manual

b. Consolidation by Rodding

Consolidation by rodding is done by raising a rod up and down through the layer of newly placed concrete until the entire area being concreted is covered. The rod should at least penetrate a few centimeters into the previously placed concrete to produce a monolithic concrete structure.

L. CONSTRUCTION JOINTS

Construction joints are usually provided in preparing concrete surfaces where bonding between two sections of concrete is required.

1. All Construction Joints

1. The surfaces of all concrete construction joints should be cleaned and laitance removed.

2. Immediately before new concrete is placed, all construction joints should be wetted but standing water must be removed.
3. Construction joints must be made and located in places where they cannot impair the strength of the concrete structure.

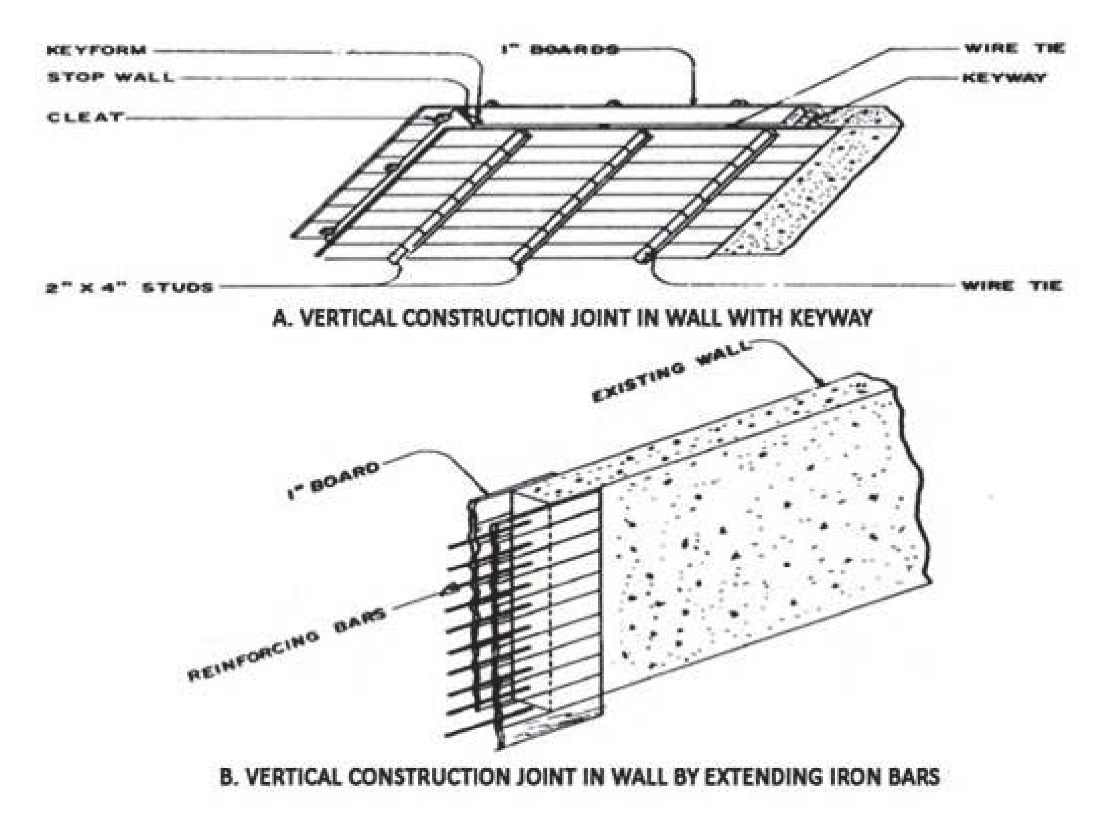
2. Horizontal Construction Joints

Horizontal construction joints are used when joining two sections of concrete in horizontal structures such as floor slabs and beams. These usually involve extending reinforcing bars across the horizontal joints. Construction joints in floors should be located within the middle third spans of slabs, beams and girders.

3. Vertical Construction Joints

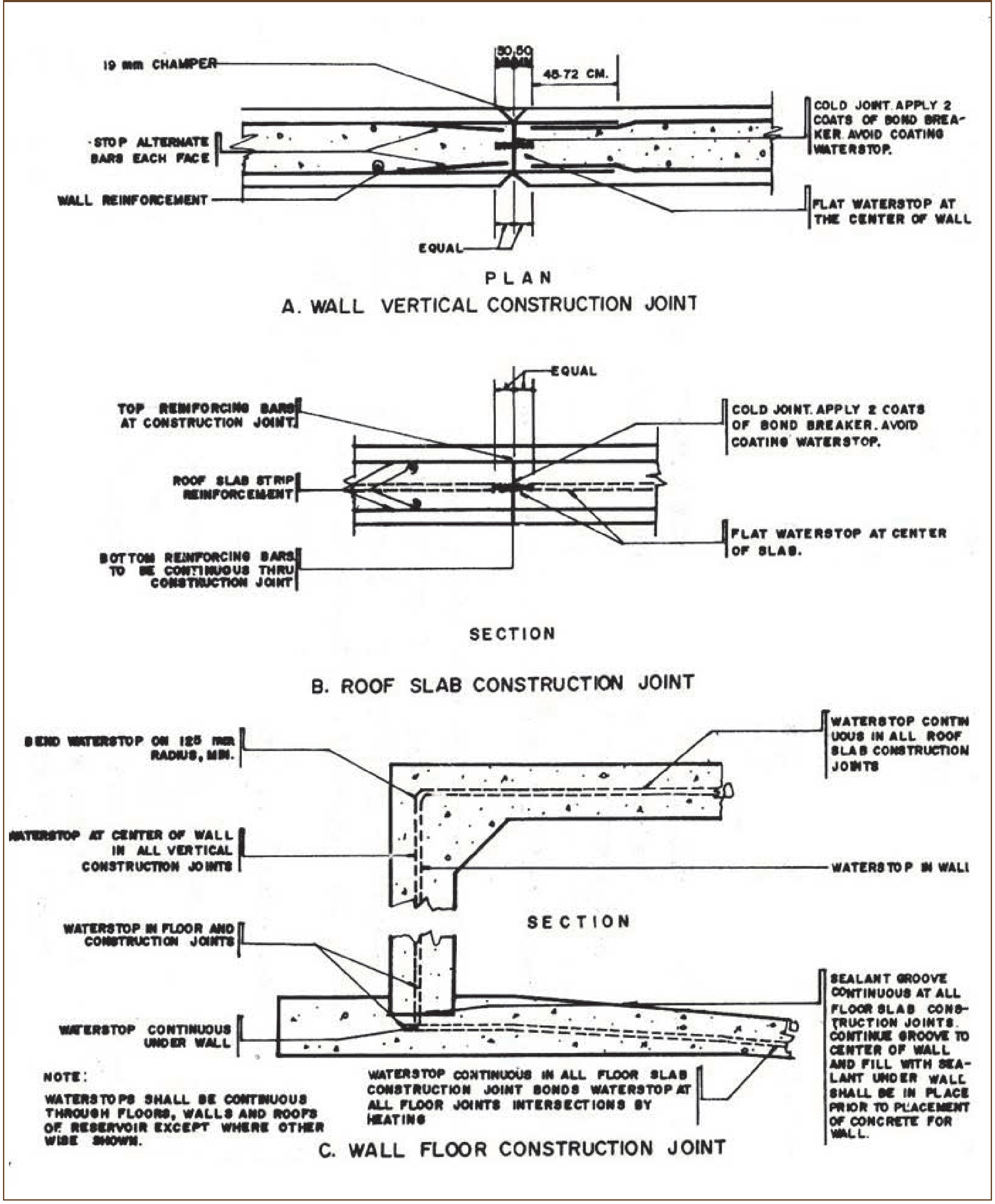
Vertical construction joints are used to hold separately poured sections of walls in a vertical line so as to form a monolithic concrete structure. This is accomplished usually by extending reinforcing bars across the vertical joints (Figure 4.11); but the joint may also be accomplished by using a "V" or a beveled key form (Figure 4.12).

Figure 4.11: Vertical Construction Joints



NWRC RWS Volume II, Construction and Installation Manual

Figure 4.12: Wall and Slab Construction Joints

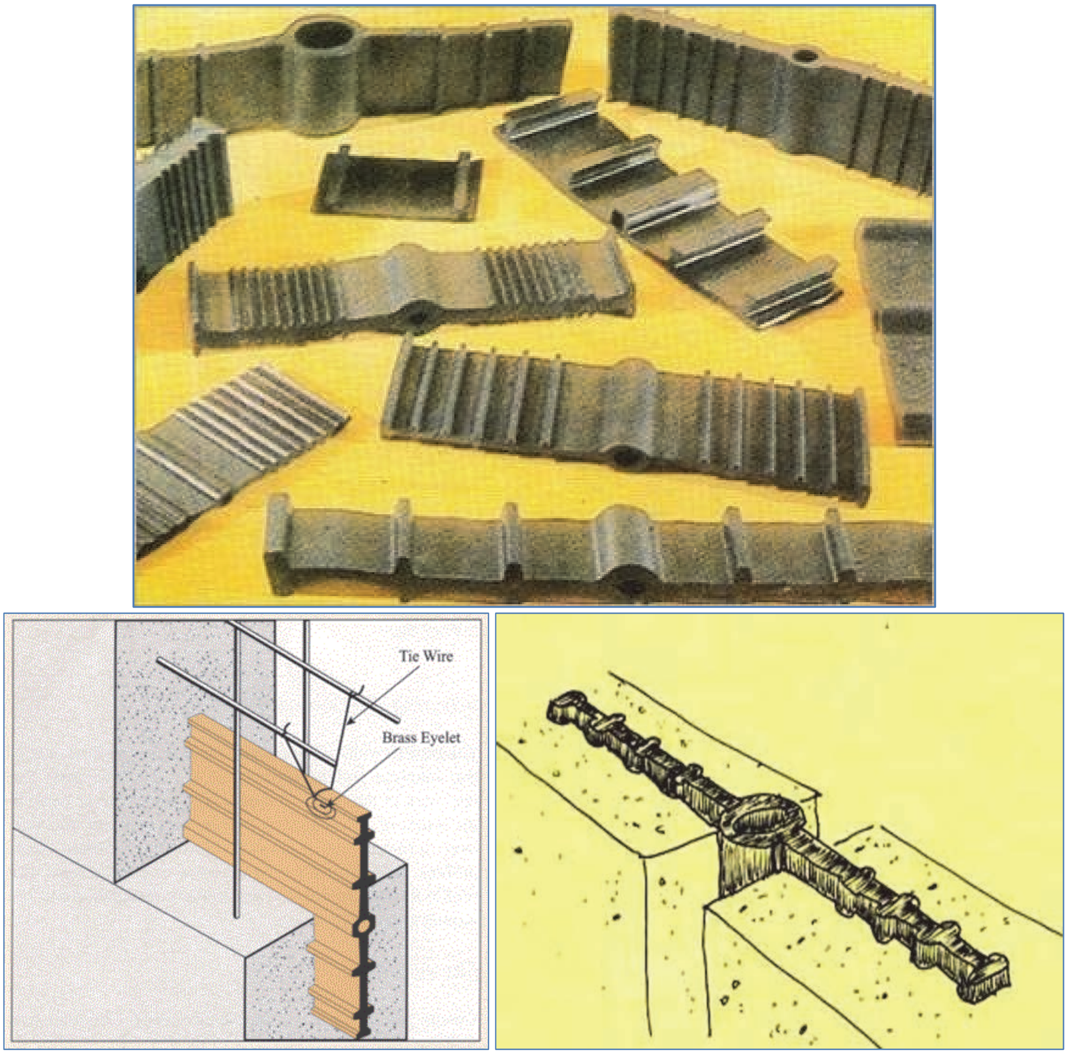


NWRC RWS Volume II, Construction and Installation Manual

4. Reservoir Construction Joints

Reservoir construction joints must be constructed strictly in accordance with plans and specifications.

Figure 4.13: Waterstops and Their Use



a. Waterstops

1. Waterstops are usually employed in reservoir construction joints.
2. A waterstop is an element in a concrete structure that prevents the passage of fluids (such as water) through joints.
3. They are commonly manufactured from extruded plastics such as flexible polyvinyl chloride (PVC).
4. They are embedded in and run continuously through the concrete joint at the center of a wall to form a moisture barrier. (Figure 4.13).

b. Procedure for Installing Waterstop Joints:

1. Fittings and splices are made by heating and melting ends, then pushing them together so they bond. The heating iron must not be so hot as to burn the plastic.
2. Butt welds should be used wherever possible.
3. Every weld should be carefully checked by visual inspection and by actually bending to test if the fitting will pull apart.
4. After a waterstop has been placed, the work must be examined to make sure that that holding devices are only on the edge of the waterstop.
5. Concrete should be placed very carefully around the waterstop, and should be completely vibrated to eliminate voids and rock pockets.

M. CURING OF CONCRETE

The Inspector must ensure that all concrete is cured for not less than fourteen (14) days after placing, in accordance with the following methods for the different parts of the concrete work:

1. Unstripped Wooden Forms

1. Wooden forms shall be wetted immediately after the concrete has been poured and shall be kept wet with water until removed.
2. If forms are removed within fourteen (14) days of placing the concrete, curing shall be continued in accordance with the applicable method for the particular structure as presented in the succeeding enumerations.

2. Joints between Footings and Walls, and Floor Slabs and Columns

1. The surface shall be covered with burlap mats, which shall be kept wet with water for the duration of the curing period.
2. No curing compound shall be applied to surfaces cured under this method.

3. Encasement Concrete and Thrust Blocks

The concrete surface shall be covered with moist earth between 4 to 24 hours after the concrete is placed.

4. Floor Slabs in Hydraulic Structures and Exterior Surfaces of Exposed Roof Slabs

1. Immediately after the concrete has been placed, it shall be given a coat of curing compound.

2. Within 1 to 4 hours after the curing compound is applied, the surface shall be wetted with water.

3. Concrete curing blankets shall be placed on the slab.

5. Exterior Buried Wall Surfaces

1. Immediately after the wall forms have been removed, the concrete surface shall be sprayed with waterproofing agent consisting of an asphalt emulsion.

2. Two (2) coats should be applied following the manufacturer's instructions.

3. As soon as the applied asphalt emulsion has taken initial set, the entire coated area shall be coated with whitewash.

6. All Other Concrete Surfaces Not Specifically Mentioned

1. The surface shall be sprayed with a liquid curing compound in accordance with the manufacturer's instructions.

2. A curing compound shall be applied within 2 hours after the completion of the finish or unformed surfaces.

3. The curing compound is not to be sprayed on construction joints if bonding between joints is required.

4. If the concrete surface is dry, it shall be sprayed with water before applying compound.

5. Care shall be exercised to avoid damage to concrete seals during the curing period.

N. FINISHING OF CONCRETE SURFACES

1. Unformed Surfaces

1. **Screeding –** Leveling to true grade must take place before any excess moisture or bleed water comes to the surface.

2. **Hand tamping** – Is used to force the large aggregate slightly below the surface so it does not interfere with the final finish. This should be used sparingly and only on concrete of low slump.

3. **Float (Wood)** – Should take place shortly after screening while concrete is still plastic and workable. The purpose is to embed aggregate particles just below the surface and to remove slight imperfections, high spots and low spots. Do not overwork concrete while it is still plastic, as this will bring excess cement and water to the surface.

4. **Troweling (Steel)** – Roughly the proper time to steel trowel is when the surface can no longer be dented by the finger. Troweling too early tends to

produce a layer of scum (laitance) on the surface; too long a delay results in a surface that is too hard to finish properly. Concrete cannot be finished in the rain. Preparation should be made in advance to protect the fresh concrete from rain.

2. Formed Surfaces

1. When forms are removed, the Inspector should be on hand to inspect the condition of the concrete surface before repairs begin.
2. If any serious defects are found (such as voids throughout the entire section) the Inspector's Supervisor should be notified immediately.
3. A grout should be prepared with one part Portland cement, one part fine sand, and sufficient water to attain a thick paste.
4. The concrete surface to be repaired should be wetted before the freshly prepared grout is applied on it with a wood float to fill all air holes.
5. The surface must be kept moist, usually for more than an hour, until the grout hardens enough for the excess to be scraped from the surface without disturbing the grout fillings.
6. Remove all excess surface grout using a steel trowel and allow the surface to dry.
7. After drying, remove and clean completely all surface grout with burlap.
8. The cleaning for any area must be completed the day it is started. No excess grout should be left on the concrete surface overnight.

O. TREATMENT OF SURFACE DEFECTS

1. Repairs

Repairs develop the best bond if they are done immediately after stripping. Repairs should be performed within 24 hours after the forms have been removed.

2. Preparation of Concrete Surfaces to be Repaired

1. The imperfections should be thoroughly examined.
2. All concrete of questionable quality should be removed and the resulting holes cleaned thoroughly.
3. The edges of the holes should be cut as straight as possible at right angles to surface or slightly undercut to provide a key for the patch.
4. The surface within the trimmed holes should be kept wet for several hours before the new concrete is placed. The best method is to pack them with wet burlap.

5. Immediately before the concrete is placed, the holes should be cleaned again. Their surfaces should be completely free of chipping dust, dried grout and all other foreign materials.

3. Treatment of Surface Defects Using a Dry Pack

In making dry-pack mortar, it is important to dry mix the mortar before adding water. This ensures that each particle of sand becomes coated with cement. A flat sand-and-gravel shovel works well when mixing on a flat surface such as a concrete slab or a sheet of plywood. The idea is to shift the material back and forth until it is completely blended. Water is added only to the point that the mortar becomes evenly damp. Continuing to mix the mortar will eliminate much of the clumping — unless the cement content is too rich.

a. Use Dry Pack:

- For holes where depth is equal to or greater than the least surface dimension, such as form tie holes.

b. Do not use Dry Pack:

- For relatively shallow holes where lateral restraint cannot be obtained;
- For filling in back of considerable lengths of exposed reinforcement;
- For filling holes which extend through the section.

c. Application Procedures:

1. The interior surface of holes left by cone bolts, she bolts, etc. should be roughened to develop bond.
2. The holes should not be painted with neat cement grout as this would make the dry pack too wet and cause high shrinkage.
3. Mix dry pack 1 part cement to 2 ½ parts of sand that will pass a No. 16 screen.
4. For packing cone bolts, a leaner mix of 1:3 will be sufficiently strong.
5. The dry pack should be placed and packed in layers having a compacted thickness of 9 ½ mm (3/8”). Thicker layers will not be well compacted at the bottom.
6. The surface of each layer should be scratched to facilitate bonding of the next layer.
7. One layer may follow another immediately unless rubbering develops, in which case work on the repair should be delayed 30 to 40 minutes.
8. Under no circumstances, should alternate layers of wet and dry be used.

9. Pack each layer over its entire surface using a hardwood stick and a hammer. These sticks are usually 20 cm – 30 cm (8”-12”) long and 25 mm (1”) diameter. Much of the tamping should direct the force a slight angle toward sides of the hole.
10. Finishing may be completed at once by laying the flat side of a hardwood piece against the repair and striking it several good blows. A few light strokes with a rag may improve the appearance.

4. Treatment of Surface Defects by Concrete Replacement

a. Use:

1. When holes extend entirely through the section;
2. When holes in unreinforced concrete are more than 0.1 m2 (1 square foot) in area and 100 mm (4”) or more in depth;
3. When holes in reinforced concrete are more than 0.05 m2 (½ square foot) in area and deeper than the reinforcement steel.

b. Preparation Method:

1. Clearances should be 25 mm (1”) around reinforcement bars.
2. The top edge of holes should be cut fairly horizontal with a 1:3 slope from back to front. This is essential to eliminate air pockets.
3. The bottom and sides should be cut straight and at right angles to the face.
4. All interior corners should be rounded.

c. Application Procedures:

1. For irregularly shaped holes, chimneys (pour holes) may be required at different levels of the form.
2. Concrete should have the same mix design as the original structure.
3. Low slump should be used to minimize shrinkage.
4. The placement in lifts should not be continuous. A minimum period of 30 minutes should elapse between lifts.
5. Immersion type vibrators should be used if accessibility permits.
6. Forms may usually be removed the day after casting. Projections left by chimneys should normally be removed the second day.

5. Treatment of Surface Defects by Mortar Replacement (Gunite)

Gunite is a mixture of dry cement and sand. It is sprayed on a surface with a gunite gun, which is a cement gun that forces air through a tube attached to a nozzle that hydrates the gunite. This makes a dense, durable material that adheres to a form.

a. Use:

1. For holes too wide to dry pack or too shallow for concrete replacement.
2. For all comparatively shallow depressions, large or small, which extend no deeper than the far side of the reinforcement bars nearest the surface.

b. Preparation Method:

1. Flare holes outward at 1:1 slope.
2. Corners should be rounded.
3. Moist the surfaces to be repaired.
4. Remove all loose concrete and other foreign materials.

c. Application Procedures:

1. Best results are obtained when a small gun is used.
2. No initial application of cement, grout or mortar.
3. Mix ratio: 1 part cement to 3 parts of well graded sand that passes the No.16 screen.
4. Water should be mixed with sand to the same consistency as dry pack.
5. Mortar should be applied in layers no more than 19 mm (3/4") thick to avoid sagging and loss of bond.
6. The hole should be filled slightly more than full. After the material has partially hardened the excess material should be shaved off with the edge of a steel trowel, working from the center to the edges.
7. A satisfactory finish may be obtained by lightly rubbing the surface with a soft rag.

6. Curing of Repairs

1. The curing medium must provide sufficient moisture to the concrete under repair.
2. It must also minimize temperature changes during the early life of the repair and prevent early drying shrinkage because these produce volume changes detrimental to the bond.

3. A moist curing period of about 5 days is usually adequate. Wet burlap, soil soaker hoses, or perforated water pipes are usually good methods.
4. When repairing new work, the patch should be cured along with the remainder of the concrete.

Chapter 5

Metal Works

This Chapter deals with reinforcing bars, form ties and arc welding rods which are widely used in construction of water supply systems. The Inspector needs to have a working knowledge of how these materials are used in the construction of waterworks.

A. REINFORCING STEEL BARS

Steel is the most widely used reinforcing material for almost all types of concrete construction. It is an excellent partner of concrete in resisting both tension and compression stresses. Comparatively, steel is 10 times stronger than concrete in resisting compression load and 100 times stronger in tensile stresses.

1. Reinforcing Steel Bar Grading

Reinforcing bars are made in accordance with Philippine National Standards for Steel Bars for Concrete Reinforcement, under PNS-49. The three grades under the specifications Grade PNS 230, 275 and 415, trace their roots to ASTM specifications.

Table 5.1 provides a brief reference as to the common understanding in the local market regarding these grades.

Table 5.1: PNS Reinforcing Steel Bar Grading

ASTM/ PNS Codes	Popular Nomenclature	Yield Strength (MPa)	Tensile Strength (MPa)	TYPICAL APPLICATIONS
Grade 33/ PNS 230	Structural Grade	230	390	Low-rise Building & Low Loading Conditions
Grade 40/ PNS 275	Intermediate Grade	275	480	Medium-rise Structures/ Infrastructure Works
Grade 60/ PNS 415	High-Tensile Grade	415	620	Medium & High-rise Structures/ Infrastructure Works

Each reinforcing bar contains the manufacturer's logo and the rebar size as shown in Figure 5.1.

Figure 5.1: Steel Bar Identification Mark

The three grades are distinguished by the different color markings painted at the ends of each bar, as shown in Table 5.2.

Table 5.2: PNS Grade Color Code

CLASS	PNS GRADE	ASTM GRADE	COLOR CODE
Non-weldable Deformed Bars *same color on both ends*	230	33	White
	275	40	Yellow
	415	60	Green
Weldable Deformed Bars *different colors on each end*	230	33	White / Red
	275	40	Yellow / Red
	415	60	Green / Red

2. Nominal Size of Steel Bars

The nominal diameter of a bar, say 20 mm, refers to the mean diameter of the cross sectional area of the bar. It is a theoretical diameter, which cannot be accurately measured using a ruler, caliper or micrometer. It can only be measured by accurately weighing and measuring a length of bar and calculating the mean diameter from these measurements.

Table 5.3 below indicates the standard weights of deformed round steel bars.

Table 5.3: Standard Weight of Deformed Round Steel Bars

Diameter (ϕ mm)*	Unit Weight (kg/m)	Weight of Commercial Length Bars				
		6.0 m	7.5 m	9.0 m	10.5 m	12.0 m
10	0.616	3.696	4.620	5.544	6.468	7.392
12	0.888	5.328	6.660	7.992	9.324	10.656
16	1.578	9.468	11.835	14.202	16.569	18.936
20	2.466	14.796	18.495	22.194	25.893	29.592
25	3.853	23.118	28.898	34.677	40.457	46.236
28	4.834	29.004	36.255	43.506	50.757	58.008
32	6.313	37.878	47.348	56.817	66.287	75.756
36	7.990	47.940	59.925	71.910	83.895	95.880

*ϕ 40 mm and ϕ 50 mm bars are available by special order.

Because variations in cross sectional area occur during manufacturing, PNS-49 provides for an allowable variation in mass (VIM) of plus or minus 6%, measured using one linear meter of the rebar

3. Testing of Steel Bars

1. <u>Test Specimens</u> – Three (3) pieces, 1 m long of steel bar samples should be secured for every 10 tons of each size of reinforcing steel.
2. <u>Number of Tests</u> – There should be three tests to cover
   - Tension
   - Bends
   - Variations in Weight.

4. Handling and Storage

1. When power hoisting equipment is not available, the bundles may be skidded from the truck over timbers or rails extending from the truck bed to the ground.
2. When storing bars on the ground, timbers must be placed under the steel to keep the bars free from mud.

3. Any mud coating on the bars should be washed off before use.
4. Steel is to be stored under cover.

5. Fabrication of Rebars

Before and during fabrication of rebars, the following should be inspected:

a. Preparation of Reinforcing Bars

1. Remove all loose rust and other related materials. Any loose rust and mill scale that fly off when the bar is bent or struck with a hammer must be removed.
2. If the rust is firmly attached to the bar, it is recommended to leave it intact. This may improve the holding capacity of the bar and increase the bar-concrete bond.
3. If a bar appears to have rusted excessively and its cross-sectional area been reduced significantly, it is suggested that it should be rejected.
4. Remove all objectionable coatings such as paints, oils, grease, dried mud and loose concrete on bars because they tend to decrease the bar-concrete bond.

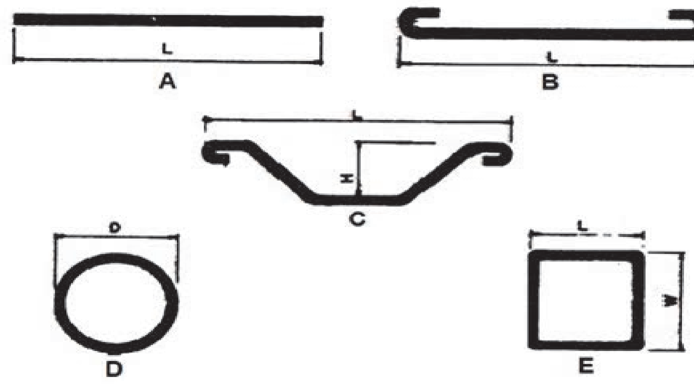
b. Cutting and Bending of Bars

1. Steel should be cut and bent (fabricated) in the shop rather than on the job.
2. Bending of bars may be done cold or with heating.
3. If bending and straightening is aided by heating, heat the steel bar without exceeding the cherry red color in order to maintain its structural strength.
4. A heated bar should be air-cooled slowly and uniformly.
5. Field bending, if necessary, should be done cold.
6. Bending and re-straightening of dowels to accommodate forms should be done only once.

c. Cutting and Bending Tolerances

Cutting and bending fabrication tolerances are shown in Figure 5.2. The rebar bending tolerances are summarized in Table 5.4.

Figure 5.2: Fabrication Tolerance



NWRC RWS Volume II, Construction and Installation Manual

Table 5.4: Rebar Bending Tolerances

Figure	Bar Diameter	Tolerance
A	All Sizes	± 25 mm (1”) for “L”
B	20 mm or SMALLER 25 mm or LARGER	± 13 mm (½”) for “L” ± 25 mm (1”) for “L”
C	ALL SIZES 20 mm or SMALLER 25 mm or LARGER	± 13 mm (½”) for “H” ± 13 mm (½”) for “L” ± 25 mm (1”) for “L”
D	ALL SIZES	± 13 mm (½”) for “D”
E	ALL SIZES	± 13 mm (½”) for “L” ± 13 mm (½”) for “W”

6. Installation of Reinforcing Bars

During installation of reinforcing bars, the Inspector should check the following:

a. Placement Tolerance

As far as practicable, reinforcements should be placed as specified. However, some tolerances are necessary. The allowable tolerances are as follows:

1. Reinforcement of beams and slabs should be within ± 6mm (1/4”) of the specified distance from the tension and compression face. Lengthwise, a placement tolerance of ± 50mm (2”) is normally acceptable. If length of embedment is critical, the length of bars should be 75 mm (3”) longer than the computed minimum to allow for accumulation of tolerances.
2. Spacing of reinforcements in wide slabs and walls may be permitted to vary ± 12mm (1/2”). If necessary to clear obstructions, these may be exceeded as long as the required number of bars is present.

b. Distance of Reinforcement from the Concrete Surface

Main reinforcement bars should be at least ± 25 mm (1") from the nearest face of the concrete section for slabs or light structural members, 38-50 mm for heavy structural members, and 50-100 mm for important members exposed to sea or alkaline water.

c. Spacing

The spacing of reinforcements affects the distribution of load throughout the concrete structure. In case the spacing is unequal, an unequal distribution of load will result which will eventually cause a crack in the concrete surface. For reinforced concrete structures, the maximum spacing of principal slab reinforcements should not exceed 3 times the slab thickness. Also, the minimum spacing in slabs, beams and columns should not be less than 63 mm except at laps or intersections.

d. Splicing

Splicing is the bonding or jointing of two or more lengths of steel bars. It is usually employed in forming the reinforcement steel network in floor slabs, columns, beams and other structures. Splicing may be done with tie bars or by welding.

7. Types of Ties

The type of ties to be used when securing reinforcing bars depends primarily on the type of structure. The tie wires usually employed for the ties are the No. 16 gauge blacks, soft-annealed wires. Heavier gauge such as No. 15 or No. 14 gauge wire may be used when tying bars in heavily reinforced walls to maintain the proper position of the horizontal reinforcement.

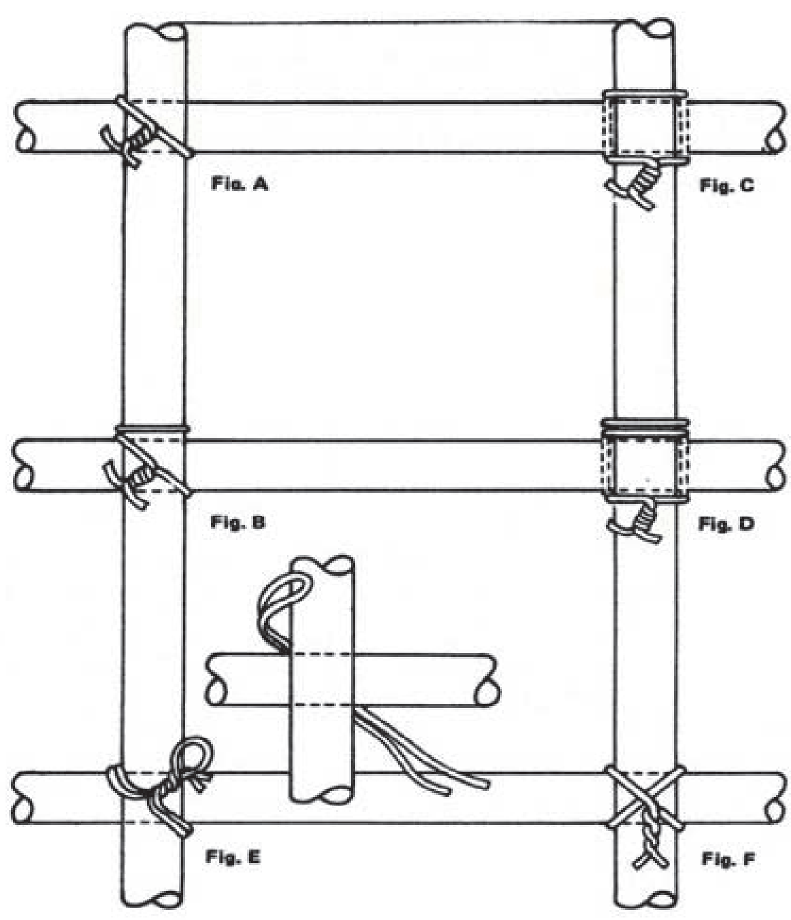
Figure 5.3 illustrates different ties typically used in reinforced construction.

As mentioned, the type of ties used when securing reinforcing bars depends primarily on the type of structure. Presented below are the different types of ties used in reinforced concrete construction, as illustrated in Figure 5.3.

1. Snap of Single Tie (A): Wire is wrapped once around the two crossing bars in a diagonal manner with the two ends twisted together, cut and then flattened to prevent them from snagging clothing and from protruding through the top of concrete. Used in flat horizontal work.
2. Wrap and Snap Tie (B): Wire is wrapped 1 ½ times around the vertical bar, and then diagonally around the intersecting horizontal bar. Used when tying wall reinforcement to prevent the shifting of horizontal bars.
3. Saddle Tie (C): The wire passes halfway around one of the bars on each side of the crossing bar, then brought squarely around the crossing bar, then up and around the first bar where the ends are twisted. Used for tying of footing or other mats.
4. Wrap and Saddle Tie (D): Similar to the saddle tie except that the wire is wrapped 1 ½ times around the first bar before proceeding as in saddle tie.

5. Double Strand Single Tie (E): A variation of the single tie, used for heavy work.
6. Figure Eight Tie (F): Used in tying reinforcements to a nail employed as spreader or spacer to hold bars away from the forms. The tying process consists of wrapping a wire once around the nail head; then around the outside bar of the wall and then drawing the bars securely against the nail head by twisting the ends of the wire.

Figure 5.3: Typical Reinforcing Steel Bar Ties



NWRC RWS Volume II, Construction and Installation Manual

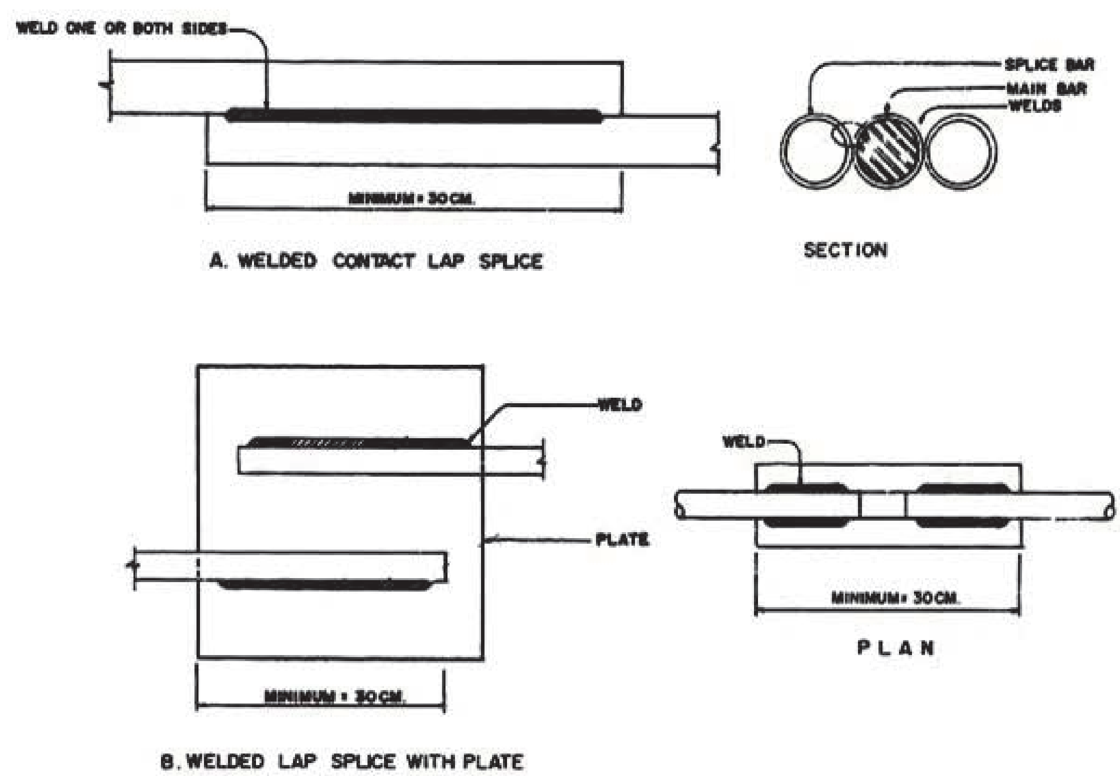
8. Lap Splicing

Lap splicing is employed in jointing two parallel bars together either by use of tie wires or welding. The minimum length of the joint should be 40 times the bar diameter but shall not be less than 30 cm (12"). Lap splicing can be done by:

1. **Using Tie Wires** – Bars with diameters 36 mm (#11) and below may be spliced by overlapping and wiring them together.

2. **Welding** – Welded lap splicing is recommended only for 20 mm ϕ (#6) bars or smaller. It may be accomplished with or without a back-up plate. Shown in Figures 5.4A and 5.4B are lap splicing without a back-up plate and with back-up plate, respectively. For splicing bars in narrow concrete members where the offset between bars in a single lap splice may buckle the members, a double lap joint (Figure 5.4) is recommended.

Figure 5.4: Typical Welded Lap Joints

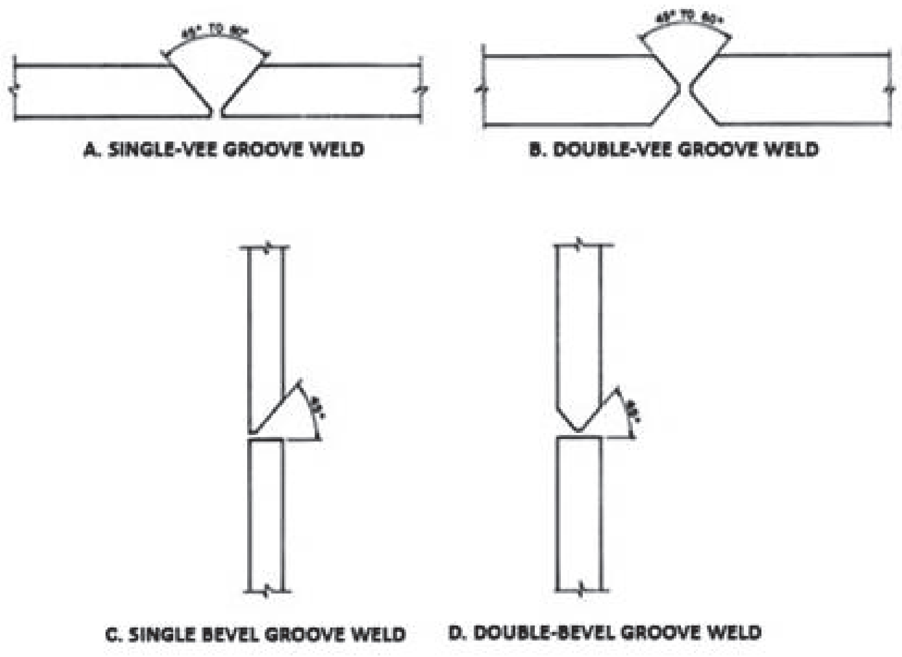


NWRC RWS Volume II, Construction and Installation Manual

3. **Butt Welding** – Butt-welding is one of the widely used methods in splicing. There are several types of welded butt splices, some direct and others indirect, employing angles, plates or sleeves.

   Shown in Figure 5.5 are typical welded splices. Single-Vee Groove Weld (Figure 5.5A) and Double-Vee groove Weld (Figure 5.5B) are employed for welding horizontal bars together. Single-bevel Groove Weld (Figure 5.5C) for vertical bars and Double-beveled Groove Weld (Figure 5.5D) are used for jointing column verticals.

Figure 5.5: Splicing by Butt Welding



NWRC RWS Volume II, Construction and Installation Manual

B. ELECTRIC ARC WELDING

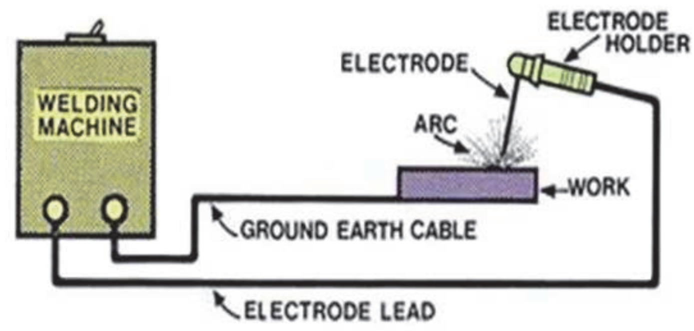
Electric arc welding is commonly used to join metal surfaces. The process consists of melting and fusing a metal electrode with the contiguous metal surfaces to be joined. The welding heat is obtained from the electric arc formed between the electrode and the parts to be welded. The arc temperature is approximately 10,000^{o}F.

1. Arc Welding Equipment

For general purpose welding, an arc welder is the most economical equipment. An arc welder is basically just a big AC transformer. Like any transformer, two windings are used. In rural areas, electric mains voltage of 240V at 10 or 15 amps is applied to one set of windings, while the others generate a much lower voltage at a much higher current – say 120 or more amps. The welding current is adjustable and is usually marked in ‘amperes’.

Shown in Figure 5.6 is a simple set up of arc welding machine with an on/off switch.

Figure 5.6: Simple Arc Welding Machine



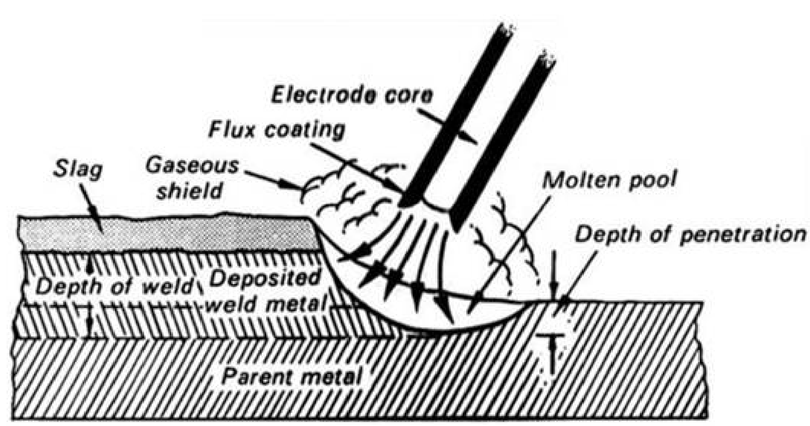
2. Operation of Arc Welder

To operate an arc welder, one wire (the earth or ground wire) must be attached to the material to be welded, or to a metal table on which the material is placed. The other cable runs to the hand-piece, in which the welding electrode is clamped. When the electrode touches the work, electrical current flows from the welder through the rod and work-piece back to the welding machine. When the current flow is established and the electrode is quickly pulled back slightly from the work-piece, a very high-temperature arc forms between the end of the rod and the work-piece. This melts both the welding rod which becomes the filler material, and the material being welded.

3. Welding Electrodes

A welding electrode completes the electrical circuit formed by the piece being welded, the power supply, and the torch. (See Figure 5.7) It is coated with a flux that is laid onto the base metal during welding. The type of electrode selected determines the strength of the weld, welding position, type of coating and other characteristics.

Figure 5.7: Simple Arc Welding Electrode



a. Considerations in Selecting Welding Electrode

1. There are many specific electrodes available for the welding of different kinds of metals like mild steel, cast iron, stainless steel, copper, bronze or brass, and high tensile steels.
2. The welding electrode has an inner core of metal similar to the material being welded. This core also has a diameter that is proportional to the material – as the work-piece gets thicker, so too should the rod.
3. Despite "general purpose" welding rods that are available at hardware stores, rods in fact should always be matched to the application.
4. The inner portion of the rod is surrounded by a welding flux. When the molten material solidifies, the flux forms a separate layer on top that can later be knocked away with the chipping hammer. The flux on welding rods serves these functions:
   - Provides a gas shield;
   - Gives a steady arc by providing a 'current bridge';
   - Cleans the surface and slows the cooling of the weld;
   - Introduces appropriate alloys into the weld.

b. Electrode Identification

Arc welding electrodes are identified using the A.W.S. (American Welding Society) numbering system (Figure 5.8) and are made in sizes from 1/16" to 5/16".

An example would be a welding rod identified as a 1/8" E6011 electrode.

1. The electrode is 1/8" in diameter.
2. The "E" stands for arc welding electrode.
3. The letter is followed by either a 4- or 5-digit number stamped on the electrode. The first two numbers of a 4-digit number and the first 3 digits of a 5-digit number indicate the minimum tensile strength (in thousands of psi) of the weld that the rod will produce. Thus,
   - E60xx would have a tensile strength of 60,000 psi;
   - E110XX would be 110,000 psi.
4. The next to the last digit indicates the position in which the electrode can be used:
   - EXX1X is for use in all positions;
   - EXX2X is for use in flat and horizontal positions;
   - EXX3X is for flat welding.

Figure 5.8: Welding Rod Numbers, Meanings and Uses

c. Some Electrode Types

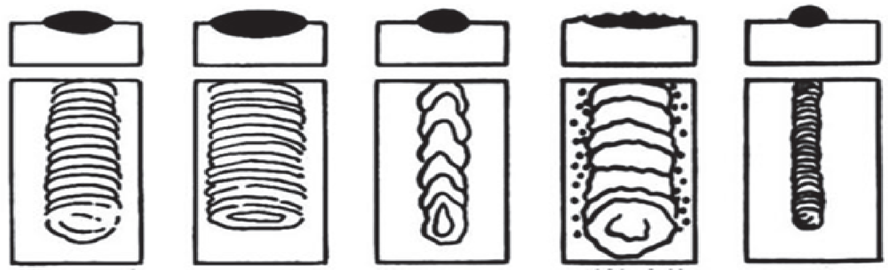
Many different types of electrodes are available for use in shielded metal arc welding (SMAW). For the Inspector, the four types of electrodes commonly used in shielded metal arc welding are important:

1. **E6010** – This is a good rod for welding material that cannot be cleaned totally. Commonly used in pipeline work:
   - Requires DC+ polarity;
   - Considered a fast freeze rod that does well in vertical and overhead positions;
   - Produces a deep penetrating weld ;
   - Works well on dirty, rusted, or painted metals.
2. **E6011** – This electrode has the same characteristics of the E6010, but can be used with AC and DC currents.
3. **E6013** – This electrode can be used with AC and DC currents. It produces a medium penetrating weld with a superior weld bead appearance.
4. **E7018** – This electrode is known as a low hydrogen electrode and can be used with AC or DC.
   - Coating on the electrode ensures low moisture content that reduces the introduction of hydrogen into the weld;
   - Produces welds of x-ray quality with medium penetration;
   - Must be kept dry. If it gets wet, it must be dried in a rod oven before use.

d. Welding Errors

It is important for the Inspector to know what good and bad welds look like, and the reasons why bad ones are like they are. The illustrations of the plain and cross-sectional views of welds in Figure 5.9 provide a good start in recognizing errors.

Figure 5.9: Basic Forms of Welding Errors



C. TYPES OF WELDED JOINTS

The selection of the type of welded joint depends on kinds of forces to which the joint will be subjected. As a rule, the larger the surface being fused together, the stronger is the joint. However, the cost of welding also proportionately increases with the quantity of electrodes used and the power cost involved.

Please refer to Figure 5.10 on the pages that follow for illustrations of some of the different types of welded joints.

D. WELDING PROCEDURE

1. Gap and Groove Preparation:

1. Rim the surfaces to be jointed in accordance with weld ends preparation drawing. This may be accomplished by machining and grinding or by flame cutting and grinding;
2. Smooth out the surfaces in the welding groove by removing all the notches and other irregularities;
3. Clean the edges to be welded by removing all grease, oil, rust, scale and other foreign materials.

2. Welding of Joints

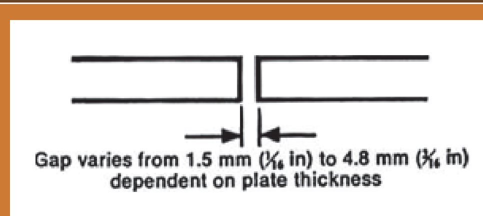
Arc welding should not be carried out when the surfaces to be welded are wet, when it is raining, and during high winds – unless the work and the operator are properly shielded. The Inspector should be familiar with these precautions, as well as with the basic steps in welding:

a. Basic Steps in Arc Welding:

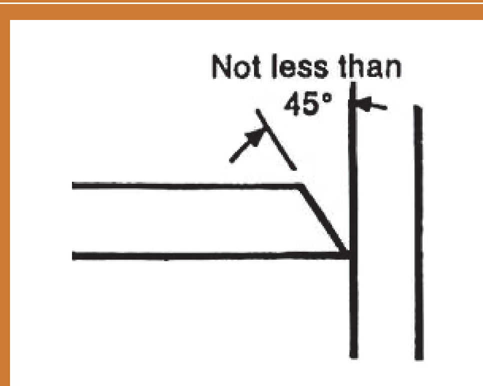
1. Attach the "ground" of the electric welding machine to be in contact with the metals to be welded;

Figure 5.10: Types of Welded Joints

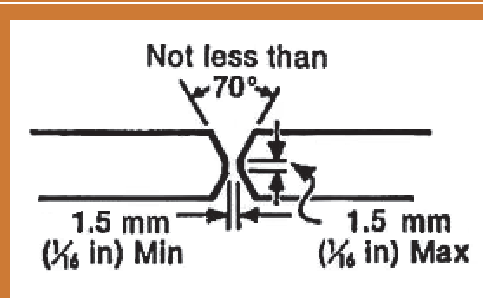
A BUTT JOINT occurs where two pieces of metal are just nearly up to one another. They are on the same level and a small gap is left in between. The weld fills the gap, penetrating through the thickness of the sheet.



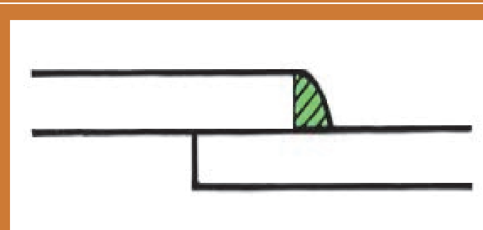
Where either access is more difficult and/or the material is thicker, the edge should be ground away to allow better penetration. This is called a SINGLE V BUTT JOINT.



Material that is thick and which can be accessed from both sides can use a DOUBLE V BUTT JOINT, where material is bevelled away on both sides.



A LAP JOINT, where the two pieces of material overlap each other, can be a much stronger join than a simple butt joint. Not only is the weld guaranteed but full penetration on the exposed ends is possible.



Holes or slots can also be cut to allow PLUG WELDS (left) or SLOT WELDS (right) to be made. With appropriate penetration, these welds can be very strong. penetrating through the thickness of the sheet.

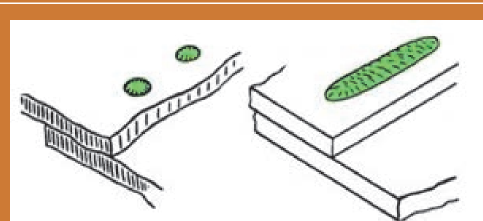
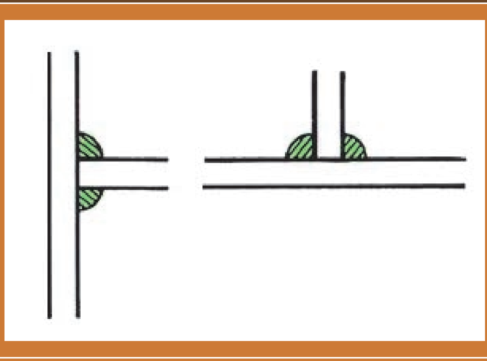
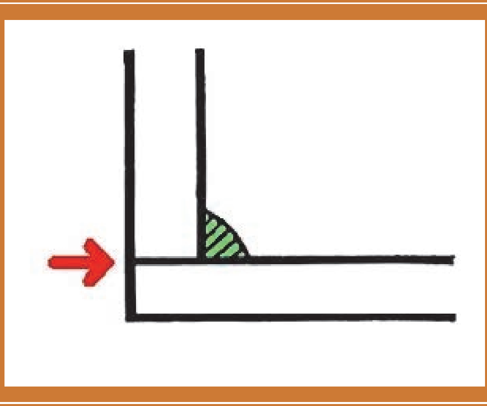
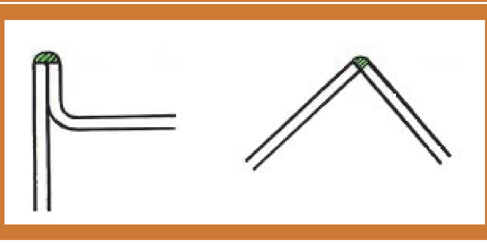
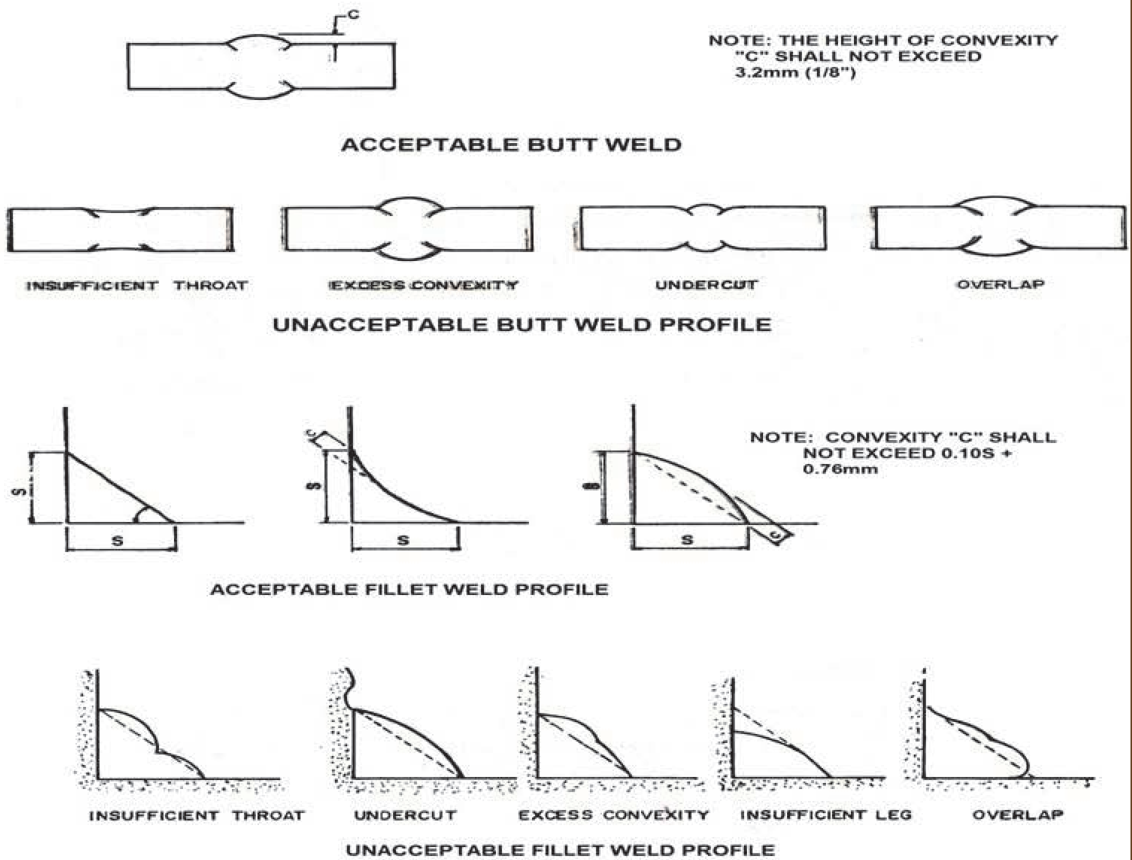


Figure 5.10: Types of Welded Joints

Another type of join is a T-JOINT. As with butt joints, the material can be bevelled to allow better access and weld penetration	
A FILLET WELD used where surfaces join at 90 degrees. This type of weld can have another bead added at the arrow, the latter being especially effective if the surfaces are bevelled to allow better penetration	
Finally in common welds, there are EDGE WELDS.	

2. Touch the contact (tip) of the electrode, the holder of which is connected to the electric welding machine, to the metal surface in the welding groove. Upon contact, an electric arc is generated and the electrode begins to melt, giving up metal that gets fused in between the two surfaces being joined;
3. If more than one welding layer is desired, clean each deposited layer of the weld before additional welding metal is applied to its surface;
4. Check the welded surfaces and trim all irregularities. Finished weld heads should be central to the seam and the finished joint should be free from depressions, undercut edges, burrs, irregularities and valleys (See Figure 5.11).

Figure 5.11: Acceptable and Defective Welds



NWRC RWS Volume II, Construction and Installation Manual

E. WELDING DEFECTS

Outlined in Table 5.4 are the different weld defects, their causes and remedies.

Table 5.4: Weld Defects, Causes and Remedies

Defects	Causes	Remedies
Spattering	1. Current too high 2. Faulty electrodes	1. Whitewash parts in weld area 2. Adjust current to proper arc length, 3. Change Electrodes
Weld Stresses	1. Faulty welds. 2. Rigid joints.	1. Move parts slightly in welding to reduce stresses. 2. Anneal according to thickness of weld.
Distortion	1. Uneven heating. 2. Deposited metal shrinks.	1. Form and clamp parts properly before welding. 2. Distribute welding to prevent uneven heating.
Cracked Welds	1. Wrong electrode used. 2. Welds unbalanced. 3. Faulty welds. 4. Faulty preparation. 5. Rigid joints.	1. Design structure and welding procedure to eliminate rigid joints. 2. Adjust weld size to parts size. 3. Work with amperage that is as low as possible.
Poor Fusion	1. Current improperly adjusted. 2. Faulty preparation. 3. Improper electrode size.	1. Adjust electrode and "V" sizes. 2. Welding heat must be enough to melt sides of joint. 3. Adjust current to a level enough for the penetration and deposition of electrode. 4. Keep welded metal from curling away from plates.
Undercutting	1. Faculty electrode manipulation. 2. Current too high.	1. Use a uniform weave when welding. 2. Use moderate current. 3. Weld slowly.

Chapter 6

Construction of Water Reservoirs

This Chapter illustrates the general procedures for constructing concrete and steel reservoirs.

A. GENERAL

A reservoir is a vital component in a water supply system. It stores water for use during peak hours and emergencies, and serves to equalize the pressure within the distribution system. For rural and other small water systems, reservoirs could be constructed using reinforced concrete or steel for economic reasons.

B. REINFORCED CONCRETE RESERVOIRS

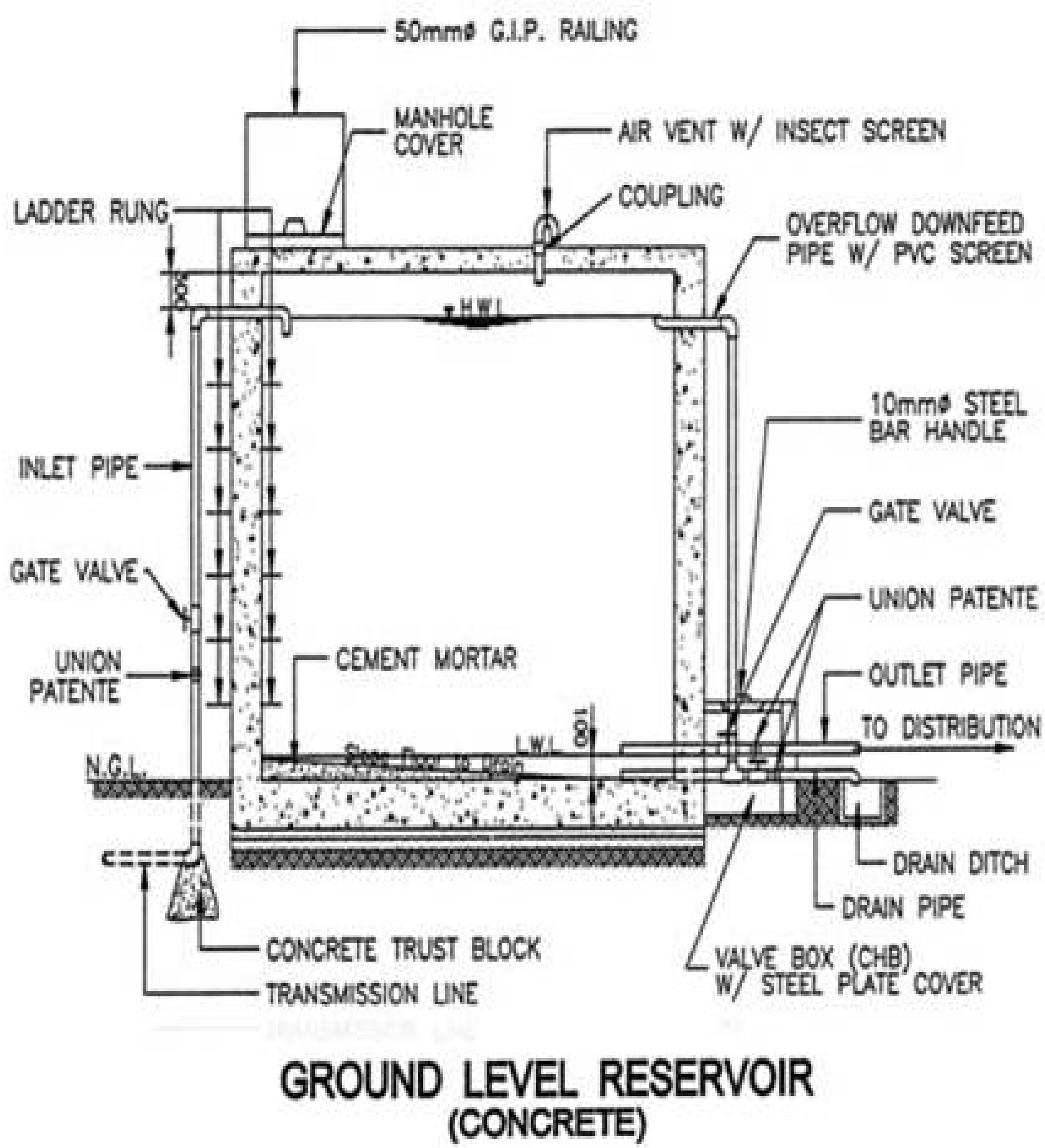
In small water supply systems, a concrete reservoir is often used and constructed using concrete reinforced with steel bars. The construction process consists of eight stages, namely:

1. Construction of Reservoir Foundation;
2. Construction of the Columns (for Elevated Reservoir);
3. Construction of the Reservoir Body;
4. Curing of Concrete;
5. Installation of Reservoir Appurtenances;
6. Finishing;
7. Waterproofing;
8. Testing and Disinfection.

A typical ground level concrete reservoir is shown in Figure 6.1. An elevated concrete reservoir is shown in Figure 6.2.

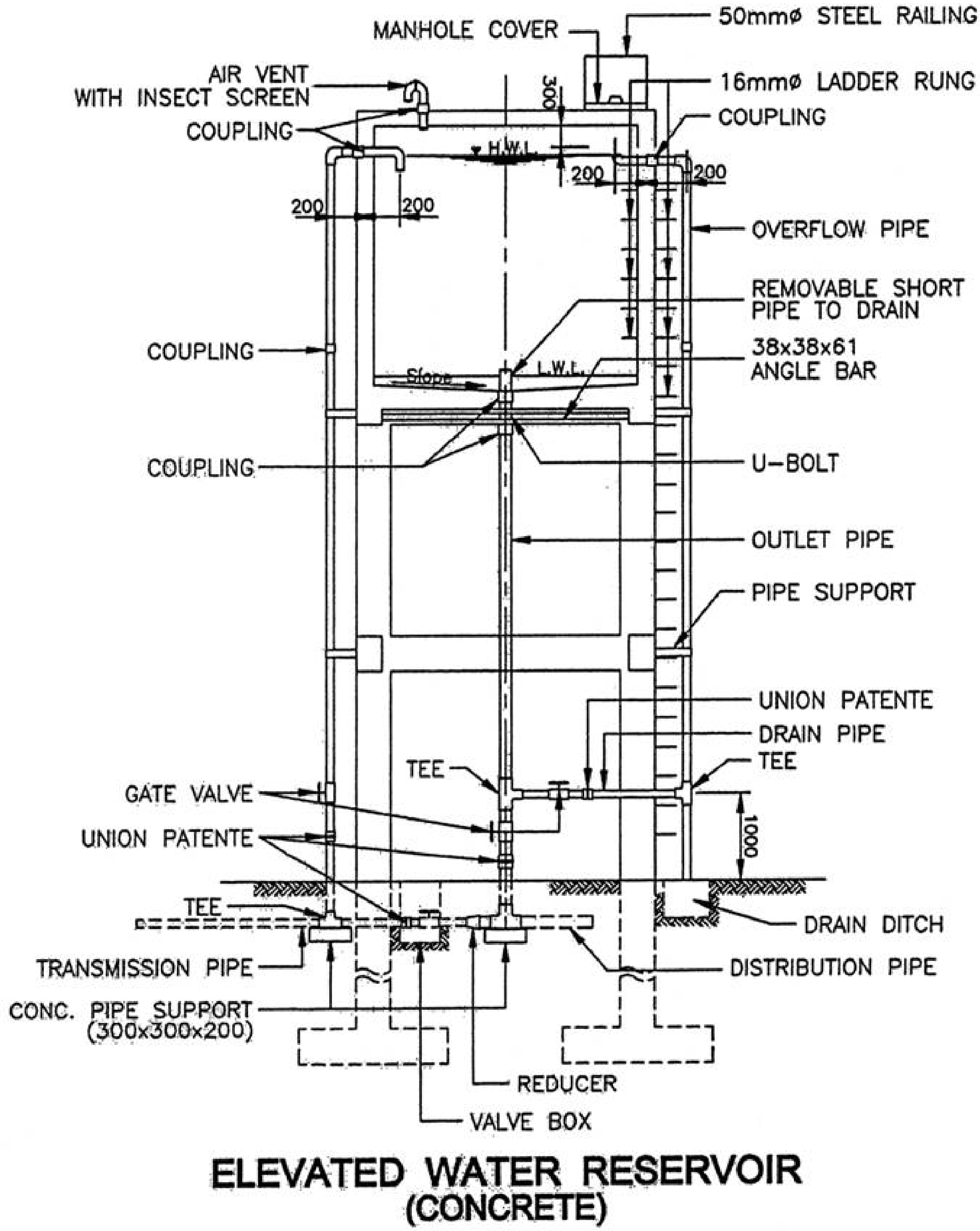
Prior to the start of the construction work on a reservoir, the Inspector should refer to **Chapter 4** and **Chapter 5**, as well as to the information in the present Chapter.

Figure 6.1: Typical Ground Level Concrete Reservoir



DAR (ARISP) Implementation Manual-Potable Water Supply Development Component

Figure 6.2: Typical Elevated Concrete Reservoir



DAR (ARISP) Implementation Manual-Potable Water Supply Development Component

1. Reservoir Foundation

Key points that the Inspector should look into, aside from other points of inspection, are:

a. Earthwork

1. The location of the reservoir should be marked as specified in the plans.
2. At the start of construction the Inspector should indicate two areas for stockpiles that are away from the construction area as follows:
   - One stockpile for the bulk of the excavated material that will be used as backfill; and
   - Another stockpile for the topsoil that will later be used for replacement on slopes.
3. After the excavation is complete, the Inspector should carefully watch and ensure that the reservoir subgrade is to be scarified at least 15 cm (6 in) and recompacted to 95% of maximum density.

b. Underdrains

Underdrains are necessary to drain water at the base of the reservoir to prevent flotation when empty and when the water table is above the base of the reservoir.

1. For a ground level reservoir, the Inspector should refer to the drawings for the underdrain trench width, which is normally 45 cm (18”), while the depth is variable. Generally, the minimum depth will be 45 cm (18”) plus the outside diameter of the drainpipe.

2. The underdrain trench must be made water tight with the use of 20-mil flexible PVC sheet. All joints and laps should be sealed according to the PVC sheet manufacturer’s recommendations.

3. Check that pea gravel is placed to a depth of 7.5 cm (3”) and the underdrain pipe is laid on this bedding. The pea gravel should be clean and must not contain any material that could plug the holes of the underdrain pipe.

4. Each underdrain pipe should be checked by the Inspector while it is being installed.

5. The pipe should have a bell and spigot joint or slip-on coupling with holes along the barrel in a pattern, as shown on the standard drawing. The pipe is placed with the holes down and the bell and spigot ends are joined without a gasket; or, in the case of a welded socket, they are joined without welding.

6. After the pipe is laid, the remainder of the pea gravel should be carefully placed so as not to disturb the pipe location; no compaction is required.

c. Under Slab Excavation/Backfill

1. For ground level reservoirs, all excavations under the floor slab such as column footings, pipe trenches and underdrain trenches should be completed before the drain rock is placed.
2. Excavations should be neat and to the correct width and depth so that only the necessary area will be disturbed.
3. The inspector should assure himself that the under slab backfill has been placed according to the specifications through observation and testing.

d. Drainrock

1. The drainrock (crushed rocks graded 3/8 to ¾ inch) is placed in a 15 cm (6") thick layer on top of the subgrade and compacted by making at least two passes with a vibratory compactor.
2. No compaction tests are required.
3. The Inspector must closely check the finished grade of the rock with a minus tolerance of not more than 6 mm (¼ inch).
4. After the rock is compacted and the grade has been carefully checked, the surface is stabilized by the application of asphalt to hold the drainrock in place until concrete is placed.

2. Floor Slab

a. Forms

1. The form material should be smooth; not rough lumber.
2. Forms must be oiled with a mineral oil to give an easy release when stripping.
3. Forms for the floor slab should be split for positioning the waterstop and either drilled holes or notches should be provided in the forms for the rebar dowels to extend to the adjacent slab.
4. The Inspector must ensure that floor slab forms will not allow excessive water loss before concreting.
5. Form elevations and lines must be checked for alignment and elevation. The Inspector should check to maintain a tolerance of 3.2 cm (1/8") plus or minus in setting of forms to line or grade.

b. Reinforcing Steel

1. Shop drawings must be submitted to and approved by the engineer before fabrication of the reinforcing bars.
2. The Inspector should not rely entirely on the shop drawings but must use the contract drawings when checking rebar placement, bending and cutting.

3. Field checking shop drawings will enable the inspector to be acquainted with the rebar layout and be alerted to mistakes.

c. Waterstop

1. The Inspector must test each waterstop joint by making a visual inspection and by bending to ensure that all joints are acceptable. All joints which fail or appear to be improperly completed must be cut apart and redone.
2. When joints are made, the waterstop is joined by melting the materials of each piece and pressing (fusing) the ends against each other.
3. When joints are made, there are four steps that must be closely watched by the Inspector:
   - The waterstops must be cut to match squarely.
   - The heat applied must not be too hot, as excessive heat will scorch the waterstop thereby preventing a good bond. The best way to maintain the proper heat is by using a thermostat-controlled heating iron.
   - In melting the waterstop, the entire face of both pieces must be melted.
   - The pieces must be joined quickly before the melted surfaces cool. They must come together accurately so that the pieces match perfectly without being offset.

d. Placing Concrete

1. The Inspector should require the concrete around waterstops to be placed by hand.
2. Care must be exercised to ensure that the waterstop does not fold over when the concrete is placed.
3. The Inspector must make certain that the slab sections are placed in accordance with the designated size and placement sequence shown in the drawings.
4. Normally, floor slab sections are placed in a checkerboard pattern with the preceding adjacent section having been cured for at least seven (7) days.
5. After placing the concrete, and from the time the concrete has started to take its initial set, the Inspector must not allow workmen to walk on the steel that extends into the freshly placed concrete unless the steel is rigidly supported.

e. Curing

1. The Inspector should require the curing concrete to be sprayed with an approved curing compound before being covered with plastic sheets.

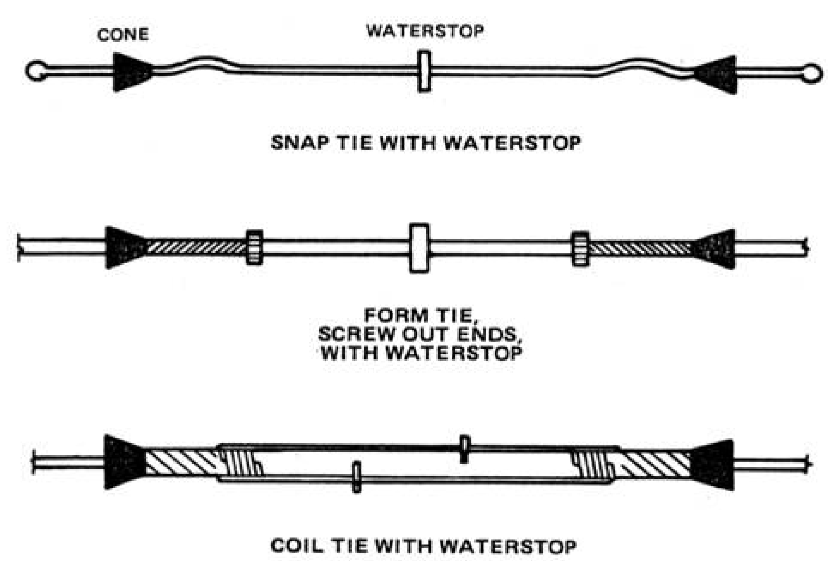
2. The plastic sheets should not be placed until the concrete is hard enough so that workers will not mark the surface.
3. Water must remain on the underside of the plastic sheets to prevent further evaporation of water from the concrete.
4. During the curing period, the Inspector must make certain of the following:
   - Care must be taken to prevent damage to the curing sheets;
   - No foot traffic or storage of materials should be allowed on the slab during the first 7 days;
   - If the sheet is damaged, it should be repaired immediately as one small hole can destroy the effectiveness of the curing process over the entire slab area;
   - Water must be added daily to maintain moisture underneath the curing sheets.
5. Keyways, such as in the wall footing, are cured by keeping wet sacks or burlap on them until the wall is placed. The inspector should see to it that water is added periodically to keep the sacks wet.

3. Walls and Columns

a. Forms

1. The Inspector should require that suitable materials (either steel or plywood) are used for the forms for walls, and that the edges are sealed.
2. Forms should be oiled between uses so that when they are stripped they will easily break away from the concrete.
3. Before wall forms are allowed to be re-used, the inspector should see to it that they are still in good condition.
4. Any form tie which extends through the concrete must have an integral device that serves as a waterstop to prevent seepage of water along the form tie (See Figure 6.3).
5. Each wall panel on the inside and outside faces of the wall, for all vertical wall joints, must be provided with chamfer strips as shown on standard joint details. The chamfered edge prevents chipping of the concrete when removing forms and furnishes a smooth well-formed corner.
6. The Inspector should make sure that the necessary corrections are made to prevent leakage of paste at the bottom of the wall and column forms.
7. The inspector should satisfy himself that the forms have been adequately braced to prevent movement as the columns must be plumb in their proper positions.

Figure 6.3: Types of Form Ties



LWUA Inspector's Construction Manual

8. Before column forms are placed, the construction joints between the footing or floor slab must be cleaned of all laitance.
9. The Inspector should see that tie wires do not touch the column or wall forms.

b. Reinforcing Steel

1. The exact spacing of rebar in the wall is not critical and may vary 25 mm (1") from its proper location.
2. It is more important that the number of bars per panel comply with the plan, so the proper coverage will be maintained.
3. The Inspector must assure that all rebars in any part of the structure are at least 50 mm (2") clear of any pipe or metal insert passing through the wall and that the insert is not be welded to the rebar. This prevents corrosion of the rebar.

c. Waterstops

1. The Inspector must ensure that all waterstops in the vertical joint will be held in place by attaching a wire to the edge of the waterstop and tying it on the rebar at intervals not greater than 45 cm (18").

2. The Inspector must be sure that the hole for the wire is on the edge of the waterstop; not near the middle where leaks can occur through the holes.

d. Placing Concrete

1. Generally, there must be a 7-day waiting period before an adjacent wall panel may be cast. A wall panel cannot be poured until the footing has cured for 14 days.
2. When placing the concrete, each lift should be started at one end with placement progressing to the other end to prevent a buildup of water.
3. A free fall of more than 1.2m (4") is not allowed, so the conduits or windows should be used to place the concrete properly.
4. Concrete should be placed so that when it is vibrated and leveled out, the lift will not exceed 0.45 m.
5. When column concrete is placed, the Inspector should observe closely to ensure that the rate of rise does not exceed 1.50 meters (5 feet) per hour. Faster placement could cause undue pressure to build up against the column form.
6. The inspector must also ensure that all concrete in the wall has been adequately vibrated as nothing can cause more leakage problems in a water-retaining structure than concrete with honeycombs.
7. Extra care should be taken in vibrating at the end of the wall panel so that the concrete is fully compacted around the waterstop.

e. Removing Forms

1. The Inspector must allow removal of forms only after the concrete has been in place for three (3) full days.
2. When forms are being loosened and removed, the Inspector must ensure that only the proper tools are used, otherwise the concrete could be damaged.

f. Repairs

1. Immediately after removing the forms, the concrete should be inspected for possible needed repairs.
2. If no repairs are needed, the curing compound may be applied immediately.
3. If the concrete is to be repaired, the specifications should be strictly followed.

g. Curing

1. For a ground level reservoir, the Inspector must make sure that any exterior portion of the wall that will be in contact with earth will receive 2 coats of an approved asphalt emulsion immediately after the forms are removed and any necessary repairs are made.
2. The Inspector must ensure that all other concrete components are cured continuously for 28 days. Refer to **Chapter 4** for curing procedures.

4. Roof Slabs

a. Forms

1. The Inspector should require that forms for roof slabs be made of suitable material, preferably plywood.
2. The Inspector should see that the maintenance and oiling of the forms are completed prior to their installation.
3. Special care should be taken to ensure that roof slab joints, in the same manner as those for the wall, are tight.

b. Reinforcing Steel

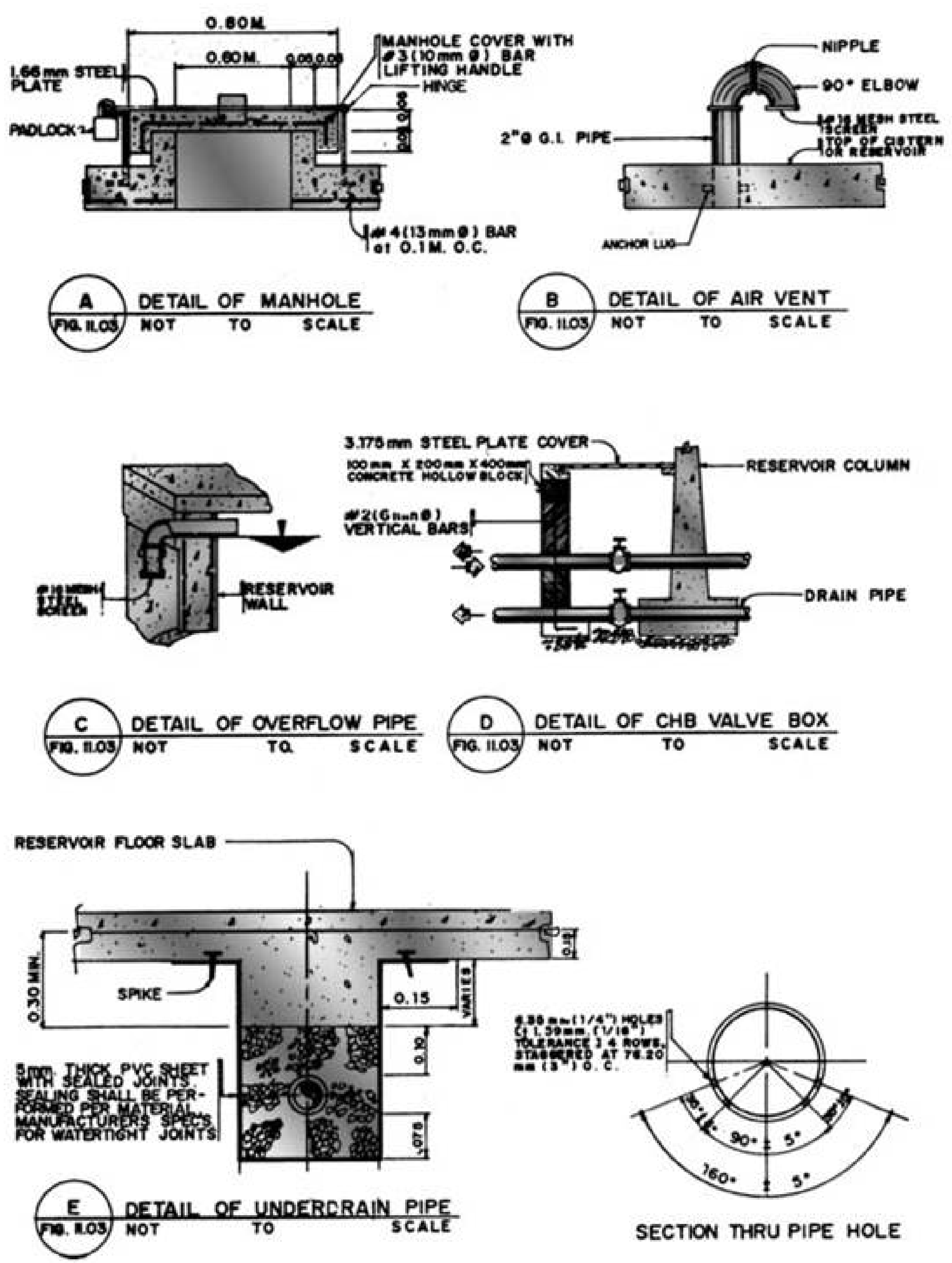
1. Rebars for the roof should be installed to tolerances not less than specified, although these may be allowed to be exceeded by not more than ¼".
2. Just as with floor slabs, as discussed earlier, precautions should be taken about persons walking on the steel dowels.
3. Procedures in placing waterstops, placing the concrete in a checker-board pattern, placing concrete around the waterstop, applying the bond breaker, and the method of curing and cleaning laitance from the column construction joint are similar to those for floor slabs.

c. Removing Forms from Roof Structures

1. The removal of forms from roof structures is somewhat different from that of the structures for other parts of the reservoir.
2. Importantly, the concrete of the roof slabs must have reached strength of at least 2,500 psi before forms are removed. Test cylinders should be made at the time the first wall panels are cast to establish when the concrete will reach this strength.
3. When removing the plywood form or shoring, it should not be dropped to the floor, as this will cause chips and damage to the concrete floor, which would then have to be repeated. Overhanging edges of the roof

slab should never be allowed to be unsupported. Normally, headers supported on wood posts are needed to provide effective support.

Figure 6.4: Typical Details of Ground Level Concrete Reservoir



NWRC RWS Volume II, Construction and Installation Manual

d. Curing

Curing of roof slabs is similar to that for floor slabs or for exposed concrete.

e. Installation of Reservoir Appurtenances

1. After at least 14 days of continuous curing, the reservoir appurtenances could be secured in place with cement mortar and/or asphaltic seal.
2. Note that it is also possible to place the appurtenances earlier, specifically during the installation of reinforcing bars and formworks, before the concrete is poured.
3. The installation of appurtenances is depicted in Figure 6.4.

f. Sealing the Reservoir

1. One of the last operations before the reservoir is tested and disinfected is the application of sealant.
2. The Inspector must ensure that before the sealant groove form is removed, the reservoir is swept. Dirt must be prevented from going into the construction joint after the groove form has been removed.
3. In removing the form, care must be exercised so the edges of the joint do not spall off creating an oversized joint at that location.
4. The sealant groove must then be cleaned by careful sandblasting to remove all laitance on the concrete after which it is blown clean with high pressure air.
5. Following sandblasting, the primer and sealant is fully applied to the concrete and allowed to dry, strictly following the manufacturer's directions.
6. After the sealant has cured, the Inspector should check for voids caused by trapped air bubbles. Any bad spots are to be cut out and new sealant applied.
7. Water should not be placed on the sealant until it has cured for at least 7 days.
8. After the forms are removed, all concrete surfaces should be examined and repaired in accordance with treatment of surface defects as discussed in **Chapter 4** of this Manual.
9. Waterproofing membrane admixtures, membranes, and external coatings are used in waterproofing the concrete reservoir. The application procedures are described in **Section D – "Waterproofing of Reservoirs"**.

10. The Inspector must observe that the water retaining body of concrete reservoirs is never painted. All other exposed surfaces and material are to be painted in accordance with **Chapter 9** of this Manual.

C. STEEL RESERVOIRS

In small water supply systems, steel reservoirs are quite common. They are usually fabricated using 3 to 10 mm thick steel plates. Normally they are anchored in place on a reinforced foundation. The major construction works for a steel reservoir consist of three (3) stages, namely:

1. Construction of reservoir foundation;
2. Fabrication of reservoir steel body;
3. Placement of the reservoir body on the foundation.

The information in **Chapter 4** and **Chapter 5** of this Manual are relevant references for the Inspector as he prepares to monitor the construction of steel reservoirs.

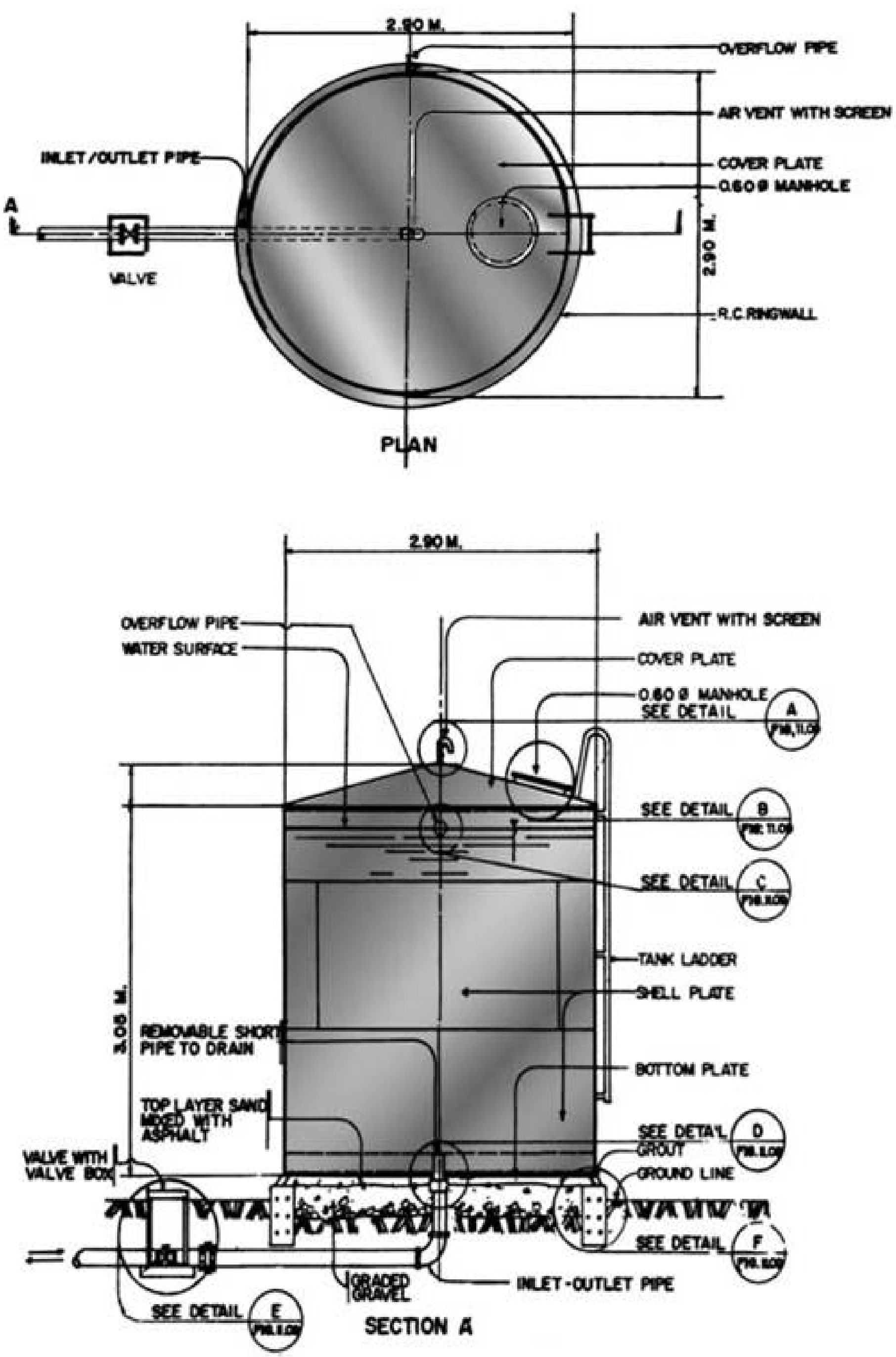
1. Ground Level Steel Reservoir

Shown in Figure 6.5 and Figure 6.6 are two types of ground level steel reservoirs, including details of their foundations and appurtenances. The general construction procedures are as follows:

1. Preparing the concrete foundation of the reservoir. – Two kinds of foundations are shown:
   - Reinforced Concrete Ring Wall as in Figure 6.5
   - Concrete Floor Slab as in Figure 6.6.
2. Assembling the reservoir body. – The assembly process consists of:
   - Cutting the steel plates;
   - Molding or rolling of the cut steel plates into the specified reservoir shape;
   - Jointing of the shaped steel plates by welding.
3. Placement of Reservoir on Foundation. – This consists of the following:
   - Raising and positioning the reservoir body on the ready foundation, using a rope-and-pulley system or a crane.
   - Securing the welded reservoir body in place on the foundation using cement grout.
4. Following the above major stages of construction, the proper appurtenances as shown in Figure 6.7 and Figure 6.8 may then be installed.

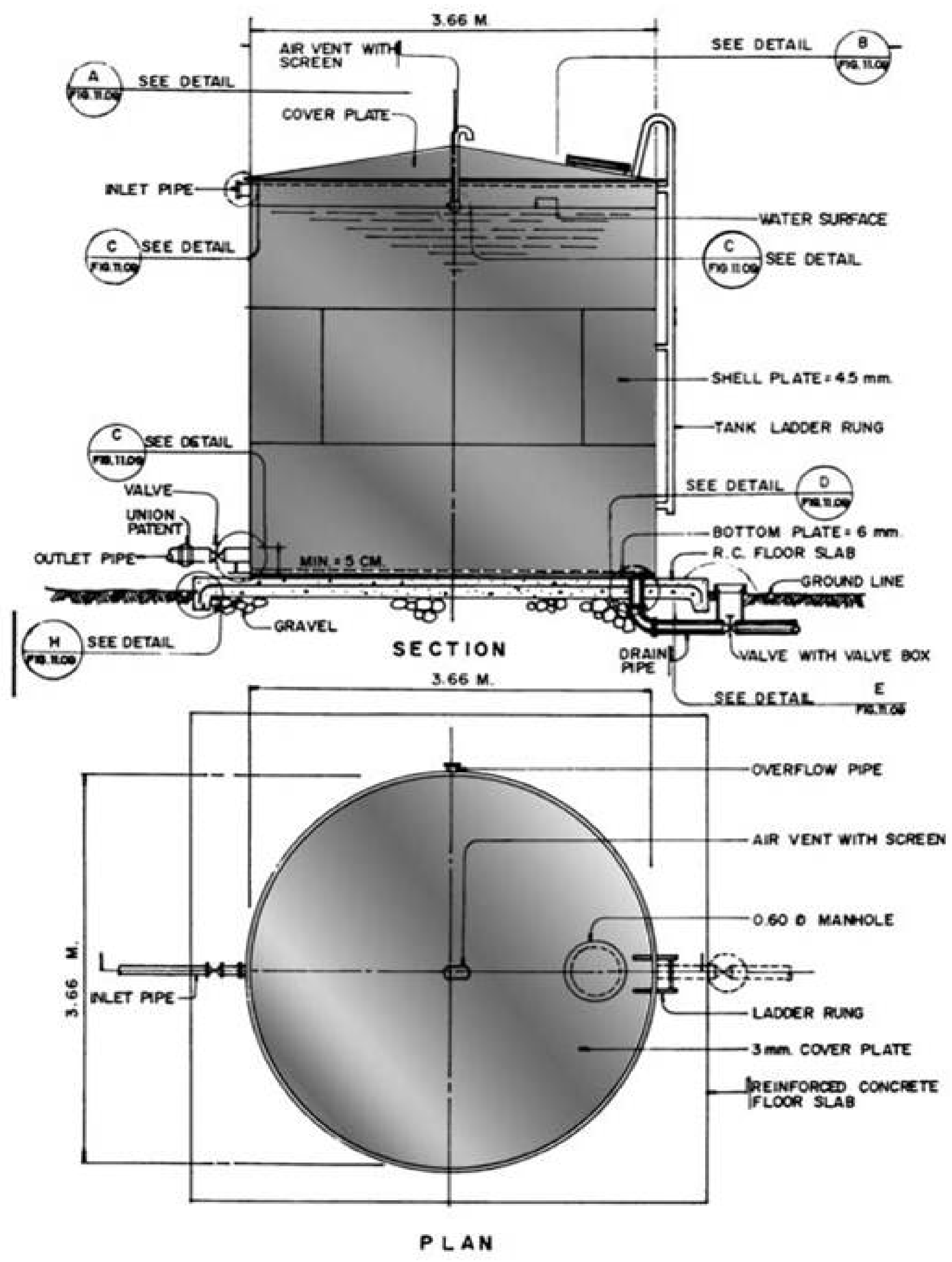
5. The steel surface of the reservoir should then be painted with anti-rust paint. The Inspector should refer to **Chapter 9** of this Manual for the proper type of paint and its application. A most important concern is to ensure that the type of paint used is non-toxic and does not impart odor or taste to the water.

Figure 6.5: Steel Tank on Reinforced Concrete Ringwall



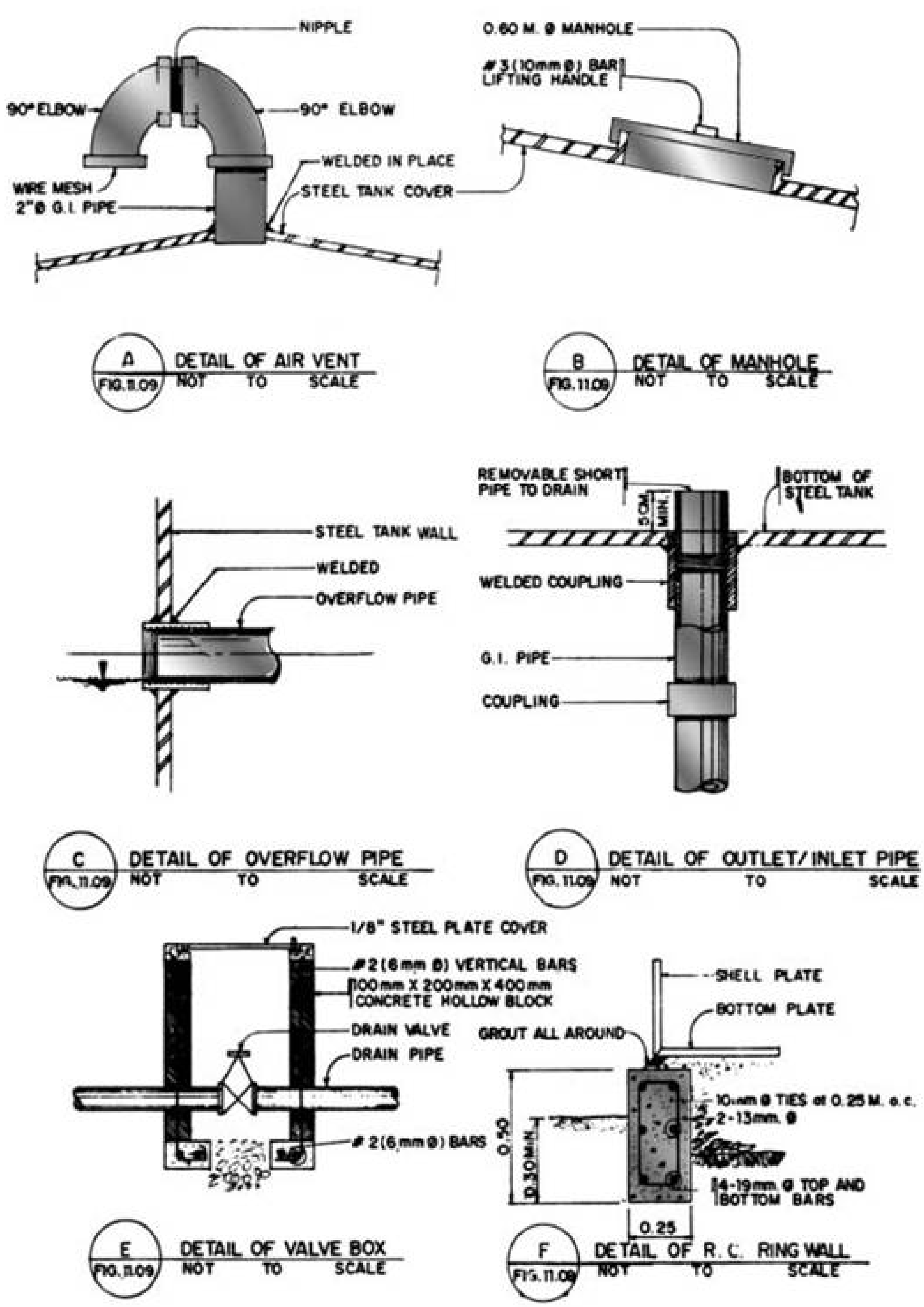
NWRC RWS Volume II, Construction and Installation Manual

Figure 6.6: Steel Tank on Reinforced Concrete Floor Slab



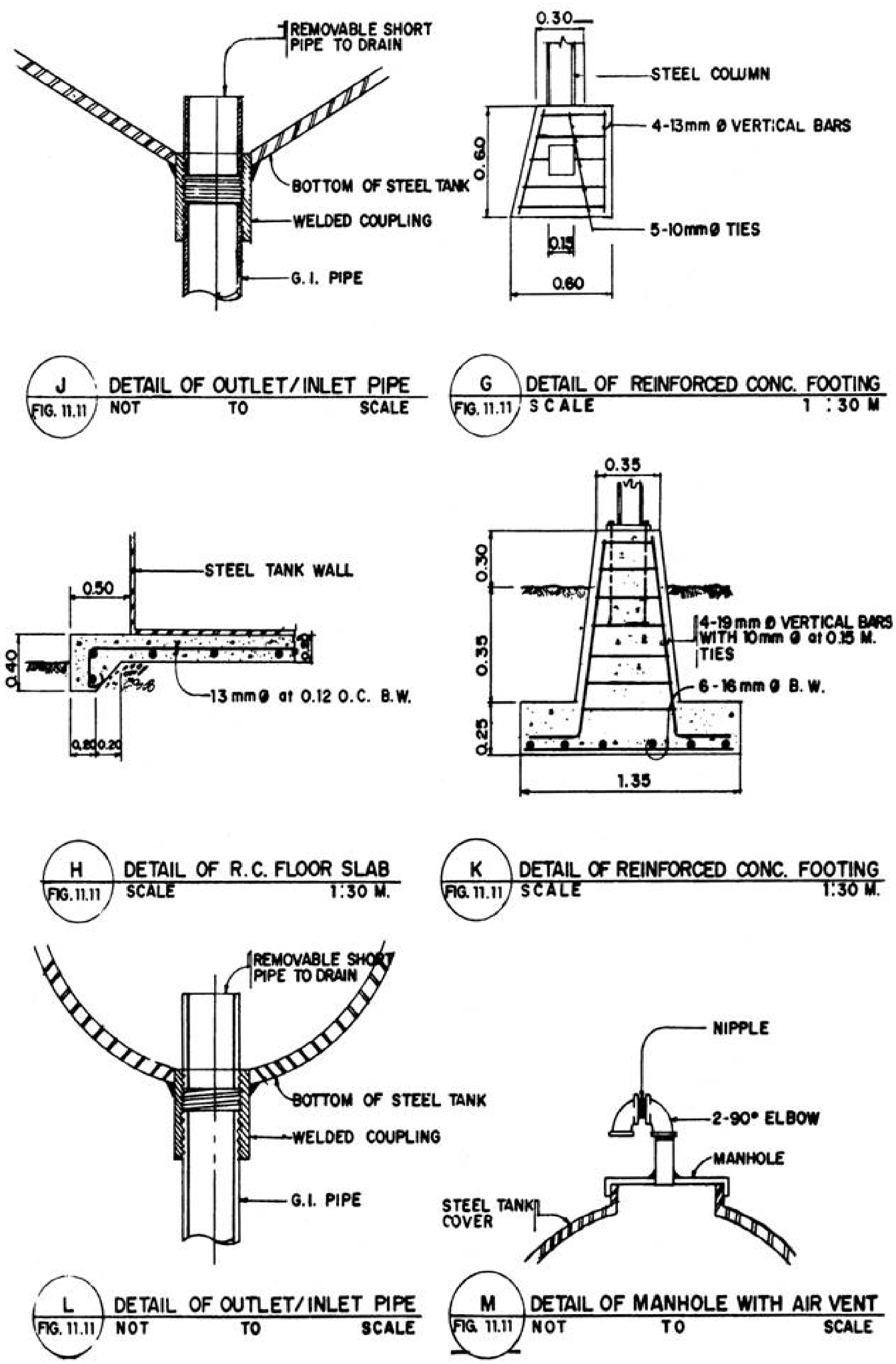
NWRC RWS Volume II, Construction and Installation Manual

Figure 6.7: Typical Details of Steel Tank Appurtenances (I)



NWRC RWS Volume II, Construction and Installation Manual

Figure 6.8: Typical Details of Steel Tank Appurtenances (II)



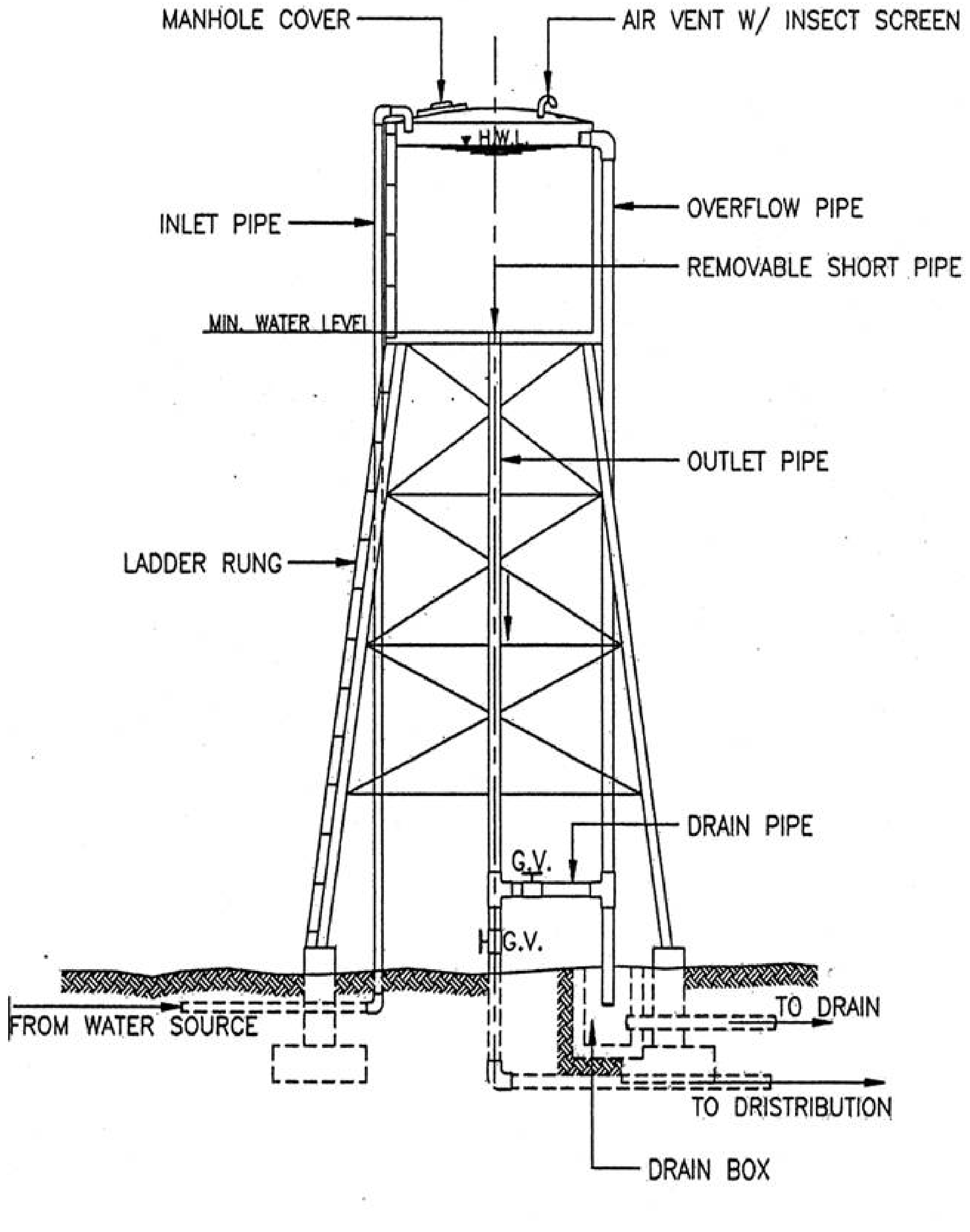
NWRC RWS Volume II, Construction and Installation Manual

2. Elevated Steel Reservoirs

Shown in Figure 6.9 and Figure 6.10 are two typical elevated steel reservoirs, including their foundations and appurtenances. Figure 6.9 shows a fill-and-draw system, whereas Figure 6.10 is a floating-on-the-line system. The general construction procedures are as follows:

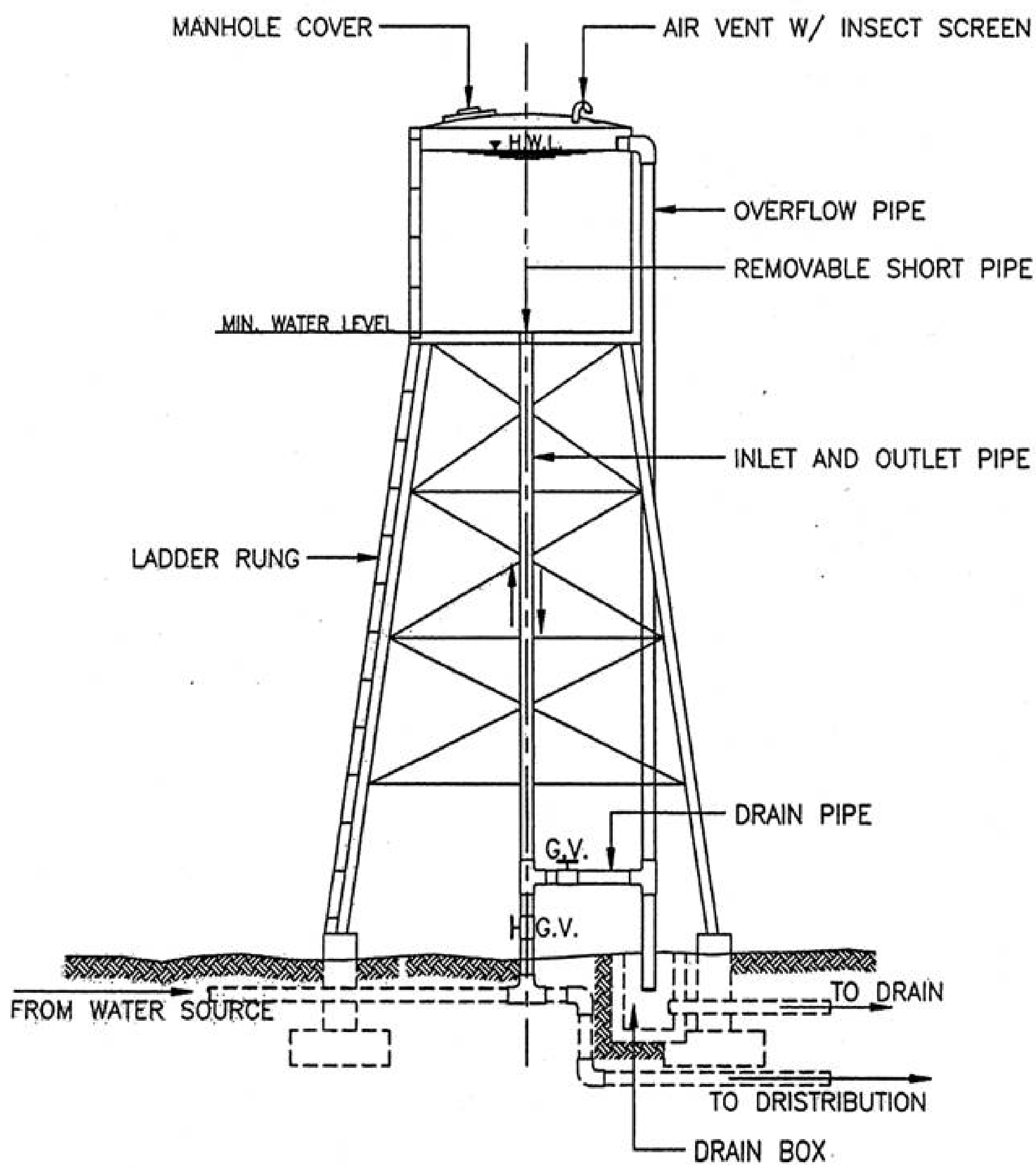
1. Preparing and constructing the concrete foundation of the reservoir in accordance with plans and specifications. Typical details of a reinforced concrete footing, anchor bolts and base plate are presented in Figure 6.8(K) and Figure 6.11.
2. Constructing the columns and bracings. The steel members are usually assembled by welding or by bolting. Typical details of steel columns and bracings are shown in Figure 6.9 and Figure 6.10.
3. Assembling the reservoir body in accordance with the specified type of reservoir.
4. Lifting and positioning the assembled reservoir body on the ready foundation and steel column using a crane, if available, or a rope-and-pulley system.
5. Securing the reservoir body by bolting and/or welding to the supporting steel tower.
6. Installing the appurtenances. (As previously detailed in Figure 6.7 and Figure 6.8.)
7. Applying waterproofing materials to make the reservoir watertight, using a brush, by spraying, or by any other appropriate method.
8. Painting the steel surfaces with anti-rust paint. The type of paint to be used should not be toxic, nor should it impart odor and taste to the water.

Figure 6.9: Typical Elevated Steel Tank (Fill and Draw System)



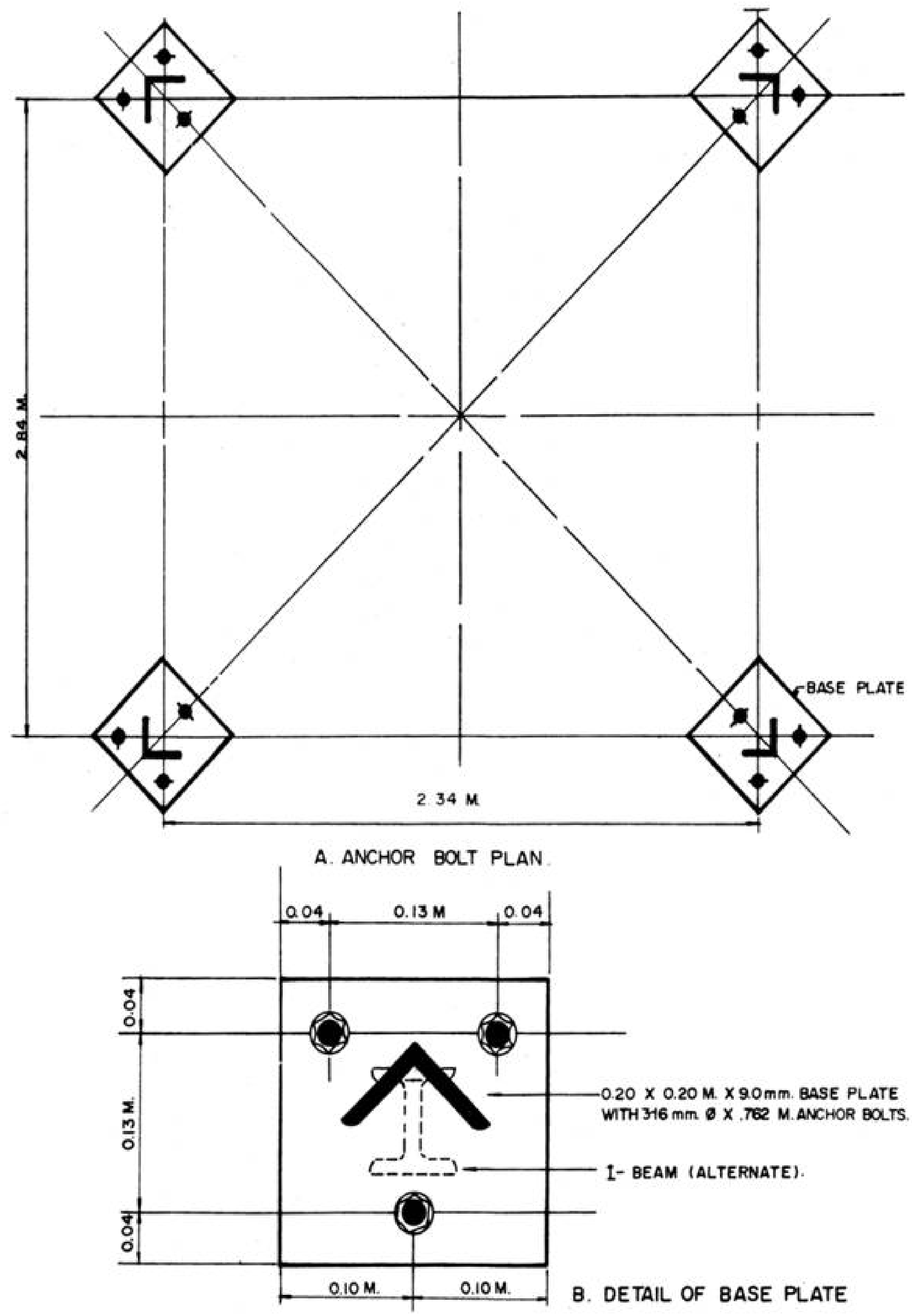
DAR/ARISP– Implementation Manual-Potable Water Supply Development Component

Figure 6.10: Typical Elevated Steel Tank (Floating on the Line System)



DAR/ARISP– Implementation Manual-Potable Water Supply Development Component

Figure 6.11: Typical Anchor Bolt Plan and Base Plate Detail



NWRC RWS Volume II, Construction and Installation Manual

D. WATERPROOFING OF RESERVOIRS

In small water supply systems, concrete reservoirs are made watertight by the application of waterproofing materials. Normally, these materials are locally available and are classified into three types as discussed below:

1. Admixtures

A waterproofing admixture is applied by blending it with the concrete mix. It is prepared by mixing water repellant and dispensing compounds. Its incorporation into the concrete mix creates a chemical change that forms a non-wettable lining on the side walls of all pores and voids in the concrete making them water repellant. The addition of the admixture also results in a denser, harder, impermeable concrete. For application details, the Inspector must refer to the product-specific literature and instructions supplied with the product.

2. Membranes

A water proofing membrane is applied by causing it to adhere to the concrete surfaces to be waterproofed. It is a very thin plastic used to form a barrier between water and the concrete structure. For details of its application, the Inspector must refer to the product-specific brochure and instructions.

3. Coatings

The principle in using a coating material to waterproof a reservoir is similar to the principle of using membranes. Coating materials are formulations usually derived from silica and cement. They are applied with steel trowels. Before usage, the Inspector must refer to the product brochure.

Chapter 7

Water Sources

This Chapter shows the proper works and construction methods for the various water supply sources, to enable the Inspector to give guidance in the proper development of these water sources and the construction of the appropriate facilities to tap them.

A. GENERAL

Groundwater is one of the major sources of water supply and is frequently used for Level II and Level III water systems without prior water treatment.

The type of facilities to be provided and the construction procedures to be followed depend to a large extent on the nature of the water source, and the cost and availability of local construction materials and skilled labor.

For detailed descriptions of wells, it will help the Inspector to refer to **Chapter 7** of **Volume 1: Design Manual**.

B. DRILLED DEEP WELL

There are several methods of well construction. The following sections describe the typical methods of constructing and/or improving various types of wells. No single method is applicable throughout the country. In any case, well drilling must be contracted to an experienced and competent well drilling contractor.

Drilled wells can be constructed practically in all types of ground formations. They are usually 100 to 600 millimeters in diameter and can be installed to depths of 300 meters or more. Drilled wells are generally constructed by using rigs designed and manufactured for the purpose.

1. Rotary Well Drilling Procedure

Drilling is accomplished by the rotary action of the drill bit, which loosens the materials encountered. The loosened materials are bailed out by the flushing action of the water.

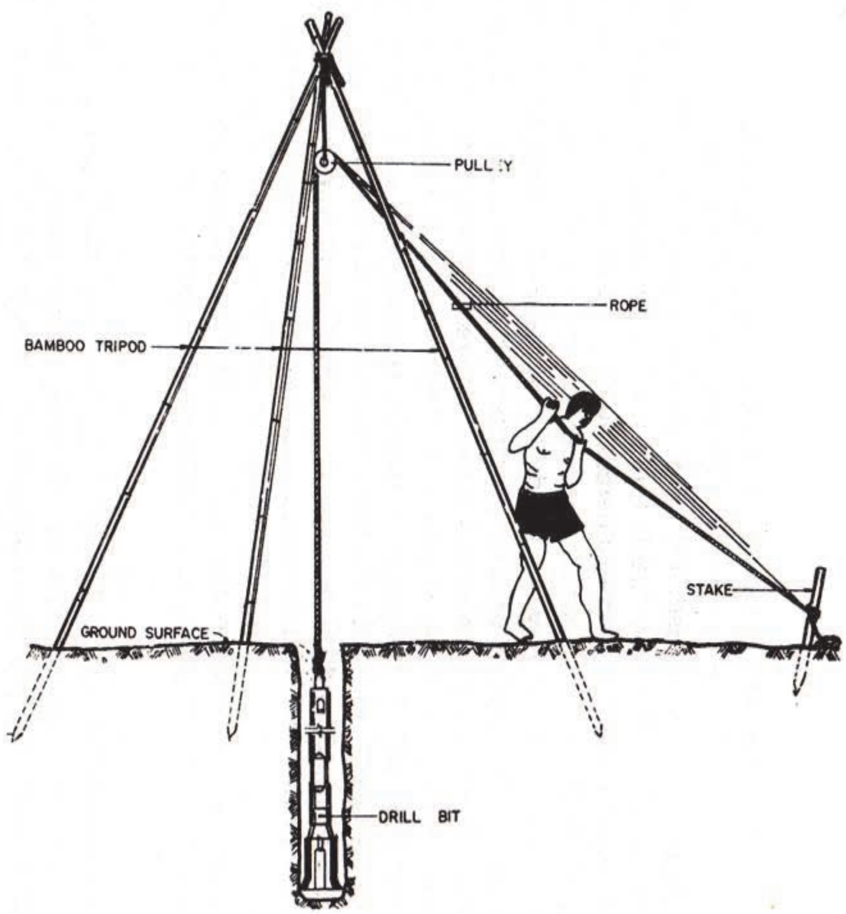
1. Drilling fluid, which is a mixture of water and bentonite, forms an artificial mud that is pumped down through the drill pipes and out through the drill bits. It then flows out upward in the space between the drill pipe and the hole.
2. At the surface, the drilling fluid is directed to mud pits and recirculated down the hole with the use mud pumps. This cycle is repeated until the desired depth is attained.

3. Drilling a well with this procedure requires the use of a rotary drilling rig with experienced and skilled operators.

2. Manual Percussion Well Drilling Procedure

This type of drilling relies on locally available materials and labor. Drilling is accomplished by continuously raising and dropping of the drill bit from a tripod as shown in Figure 7.1.

Figure 7.1: Manual Percussion Well Drilling



NWRC RWS Volume II, Construction and Installation Manual

While not as sophisticated and efficient as rotary drilling, this method is the least expensive and the most adaptable process for drilling wells in rural areas. It is easy can drill wells of 75-150 mm (3-6 inches) in diameter to depths of 50-100 meters (150-300 feet) depending upon the geology of the area

The procedure can be outlined as follows:

1. Prepare the site and set up the drilling equipment as shown in Figure 7.1.
2. Bore a hole to a depth equivalent to the length of the drill bit, usually ranging from 0.5 – 1.0 meter, using an earth auger to serve as drilling guide.
3. Start the drilling of the well hole. As mentioned, this is done by repeatedly raising and dropping of the string of tools with a chopping or drill bit attached to the lower end. The cuttings remain in the hole until removed by a bailer or sand pump.
4. Once the desired depth has been reached, remove the drill bit.
5. Perform preliminary pumping test to check well yield. If found insufficient to meet water demand, continue the drilling operation. (Refer to **Chapter 7** of **Volume 1: Design Manual** for source capacity measurements methods.)
6. Install the casing and well screen or perforated pipe based on the desired design of the well.
7. Check well alignment and plumbness.
8. Properly develop the well.
9. Determine well capacity.
10. Complete the construction of the well by:
    - Grouting the upper 3 meters annular space between the well hole and casing;
    - Building a concrete apron;
    - Installing pumping facilities or other water drawing equipment;
    - Disinfecting and completing the well.

3. Installing Well Casings

1. Generally, the pipe casing serves as the lining of a well. Its functions are:
    - To prevent the collapse of the well hole;
    - To prevent the entrance of dirty undesirable water into the well;
    - To prevent the escape of good water from the well to the surroundings.
2. For a Level II small water supply project, the well casing may be made of galvanized iron (GI) pipe, steel pipe or PVC pipe. Well casings may be installed during or after excavation of the well hole.
3. In firm ground formation, the casing is usually lowered after the excavation process, except in constructing driven wells where the pipe casing goes with the sinking of the well point.

4. In loose ground formation, the permanent or temporary pipe casing is lowered as the hole is excavated in order to prevent cave-ins.

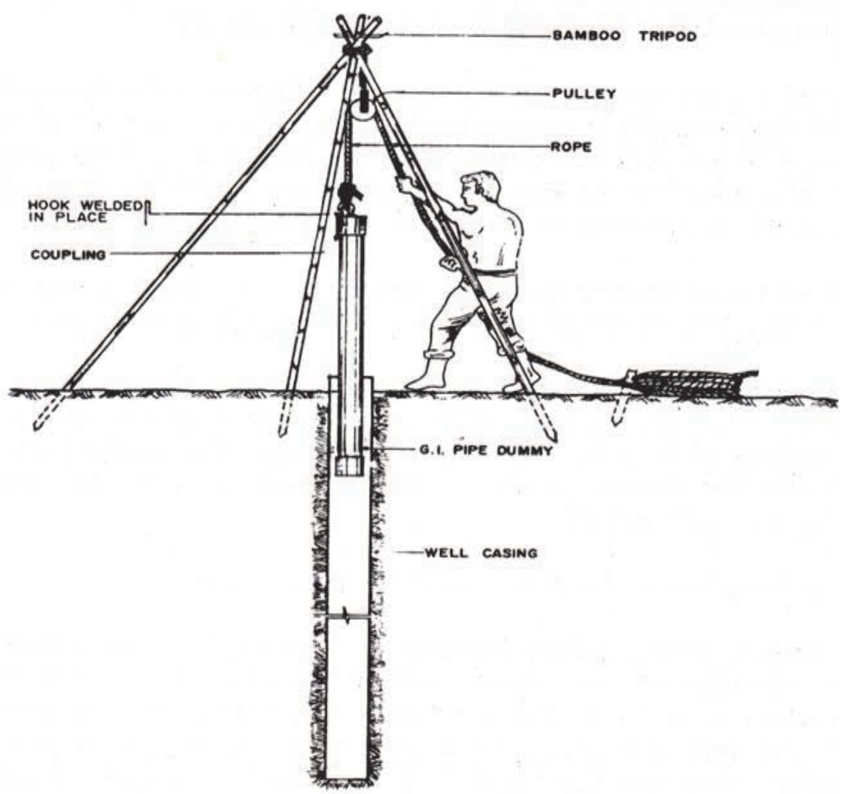
C. CHECKING WELL ALIGNMENT AND PLUMBNESS

The Inspector must observe and record the determinations made of well alignment and plumbness; and to see, prior to the installation of pumping facilities, that they are within the allowable limits. Alignment refers to the straightness or crookedness of the well hole, whereas plumbness is the deviation of the well hole from the vertical.

1. Checking Well Alignment

The well's alignment can be tested using a dummy pipe with diameter slightly smaller than the well casing, and a length (normally 12 m) sufficient to detect deviations from the straight line. In general, the well is acceptable if the dummy pipe moves freely throughout the length of the casing or to the depth the pump column is intended to be lowered.

Figure 7.2: Equipment Set-Up for Checking Well Alignment



To check for alignment, the procedure is as follows:

1. Assemble the tripod and install the pulley system (Figure 7.2).
2. Tie the upper end of the dummy pipe with a rope and suspend it from the tripod. Make sure that the lower end of dummy pipe is pointing directly to the center of the well.
3. Lower the dummy into the well slowly in order not to damage screen or casing.
4. For a well to be acceptable, the dummy pipe should be able to reach freely the depth to which the pump column is intended to be lowered.

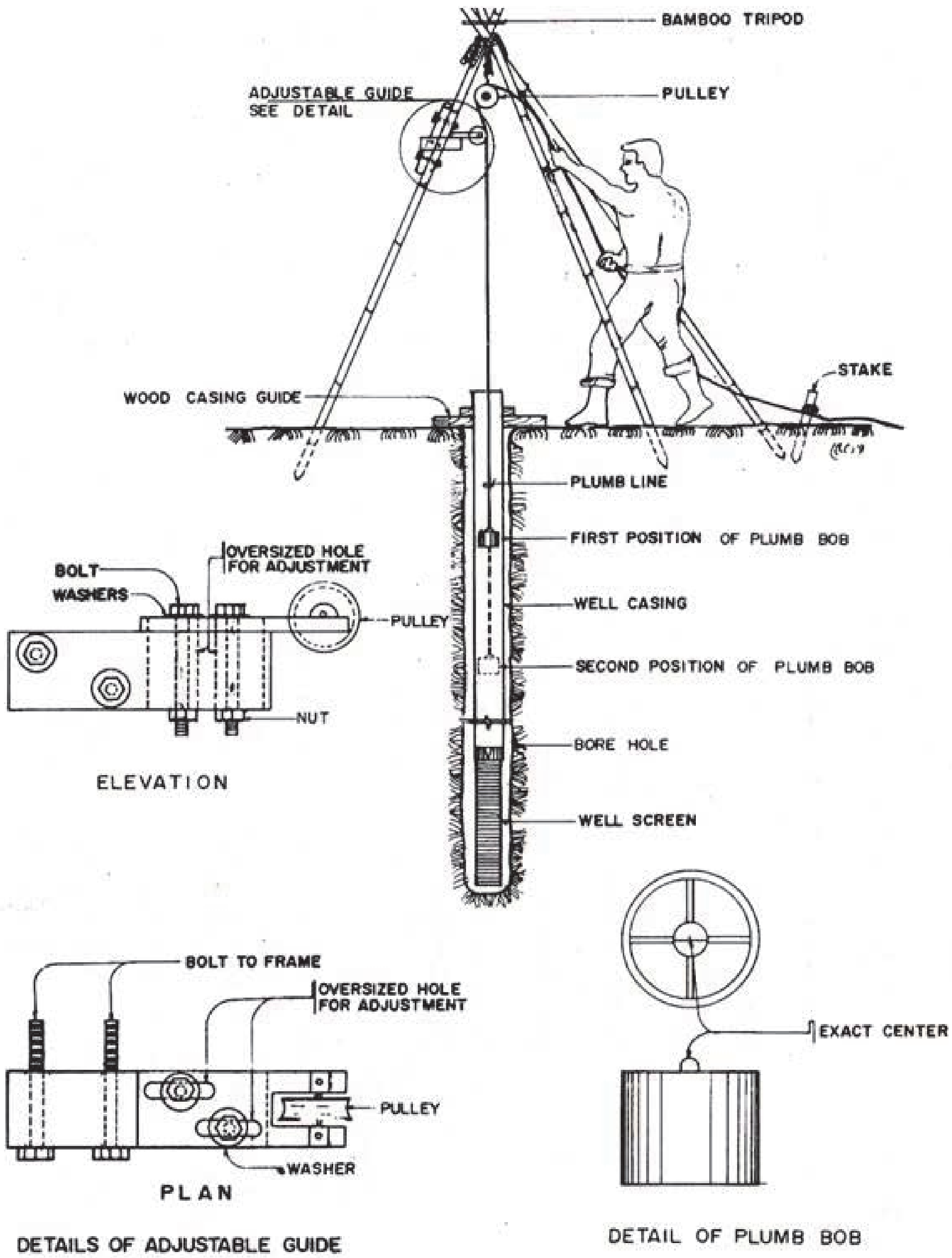
2. Checking Well Plumbness

Well plumbness or the deviation of the well hole from the vertical can be tested using a plumb bob. In general, for a well to be acceptably plumb, it should not deviate more than 0.70 times the casing diameter for each 30 m length of well casing.

The procedure for checking well plumbness is as follows:

1. Assemble the tripod, tools and equipment in a manner shown in Figure 7.3.
2. Hang the plumb bob slightly above the well casing and adjust the plumb guide until the plumb bob is on the exact center of the well.
3. Put four marks on the top of the well casing. These marks will serve as end points of two imaginary perpendicular lines which intersect at the center of the well and will be used as reference points during the determination of the direction of the deviation of the well hole from the vertical. Name the four points south, north, east and west.
4. Measure the vertical distance from the center of the pulley to the top of the well casing. The center of the pulley is called the datum point.
5. Lower the plumb bob and measure the distance traversed by the plumb line from the center taking your mark points (North, South, East and West) as reference points for every meter distance the plumb bob is lowered. Should the plumb line touch the well casing, shift the point before taking the measurement.
6. Calculate the deviation of the well hole from the vertical.

Figure 7.3: Equipment Set-Up for Checking Well Plumbness



NWRC RWS Volume II, Construction and Installation Manual

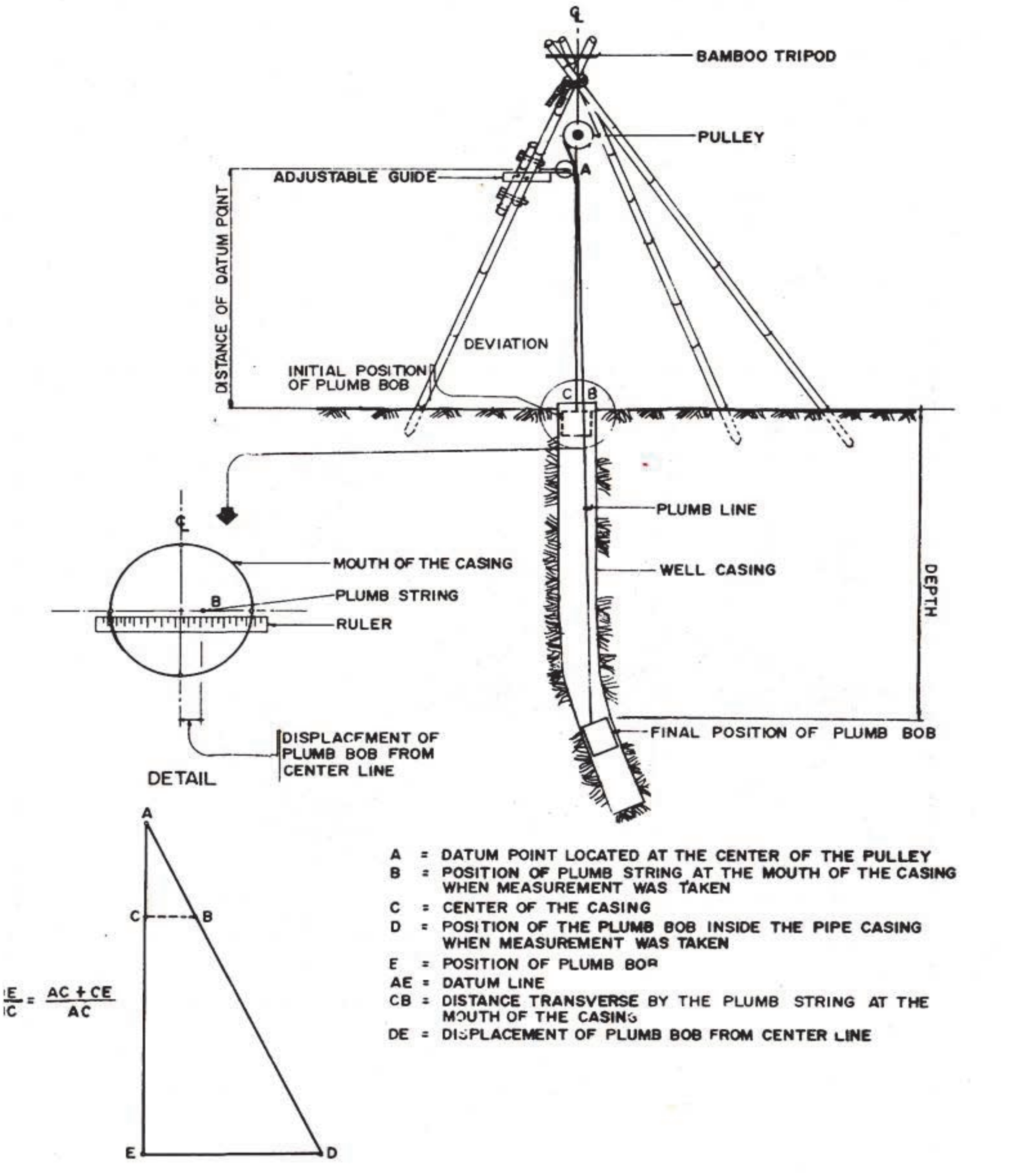
1. **If the Datum Point Is Not shifted** – Figure 7.4 illustrates the relative position of the plumb bob and plumb string from the datum point and line. From the figure, it is shown that the deviation of the well hole at point D can be computed by ratio and proportion (Triangles CAB and EAD are similar triangles). Stated mathematically:

$$DE = BC \times (AC + CE) \div AC$$

Where:

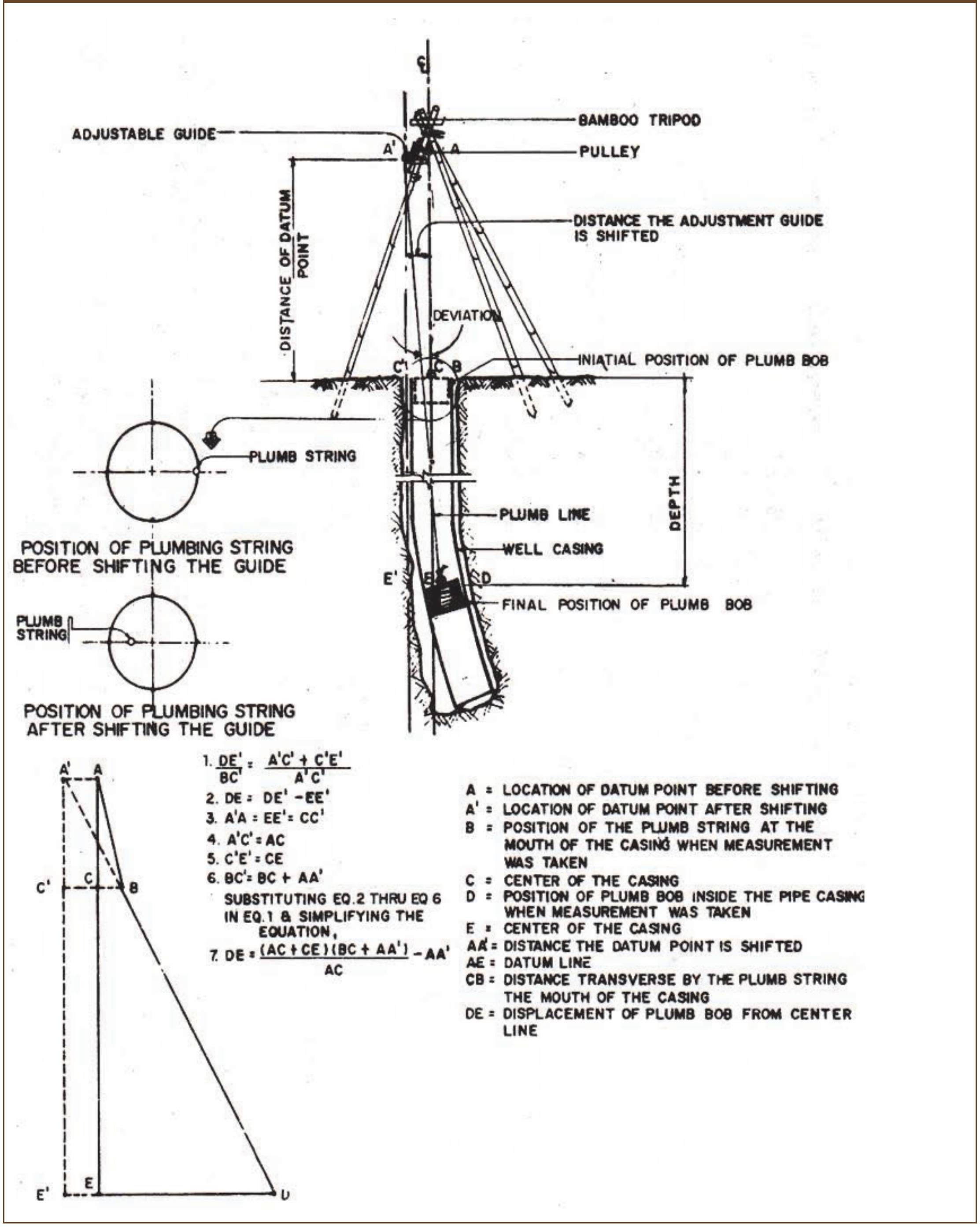
$$\boldsymbol{DE} = Deviation\ of\ well\ hole\ from\ vertical\ depth\ CE\ (mm)$$
$$\boldsymbol{BC} = Traverse\ distance\ of\ plumb\ string\ at\ mouth\ of\ casing\ (mm)$$
$$\boldsymbol{AC} = Elevation\ of\ datum\ point\ (m)$$
$$\boldsymbol{CE} = Depth\ (m)$$

Figure 7.4: Determination of Well Plumbness (When Datum Point is Not Shifted)



NWRC RWS Volume II, Construction and Installation Manual

Figure 7.5: Determination of Well Plumbness (When Datum Point is Shifted)



NWRC RWS Volume II, Construction and Installation Manual

2. **If the Datum Point Is Shifted** – Figure 7.5 (above). The deviation of the well from the vertical can be determined by the following equation

$$DE = ((AC + CE) \times (BC + AA') - AA') \div AC$$

Where:

$\boldsymbol{DE} = Deviation\ of\ well\ hole\ from\ vertical\ depth\ CE\ (mm)$
$\boldsymbol{BC} = Traverse\ distance\ of\ plumb\ string\ at\ mouth\ of\ casing\ (mm)$
$\boldsymbol{AC} = Elevation\ of\ datum\ point\ (m)$
$\boldsymbol{CE} = Depth\ (m)$
$\boldsymbol{AA'} = Distance\ the\ datum\ point\ is\ shifted\ (mm)$

D. GROUTING THE WELL

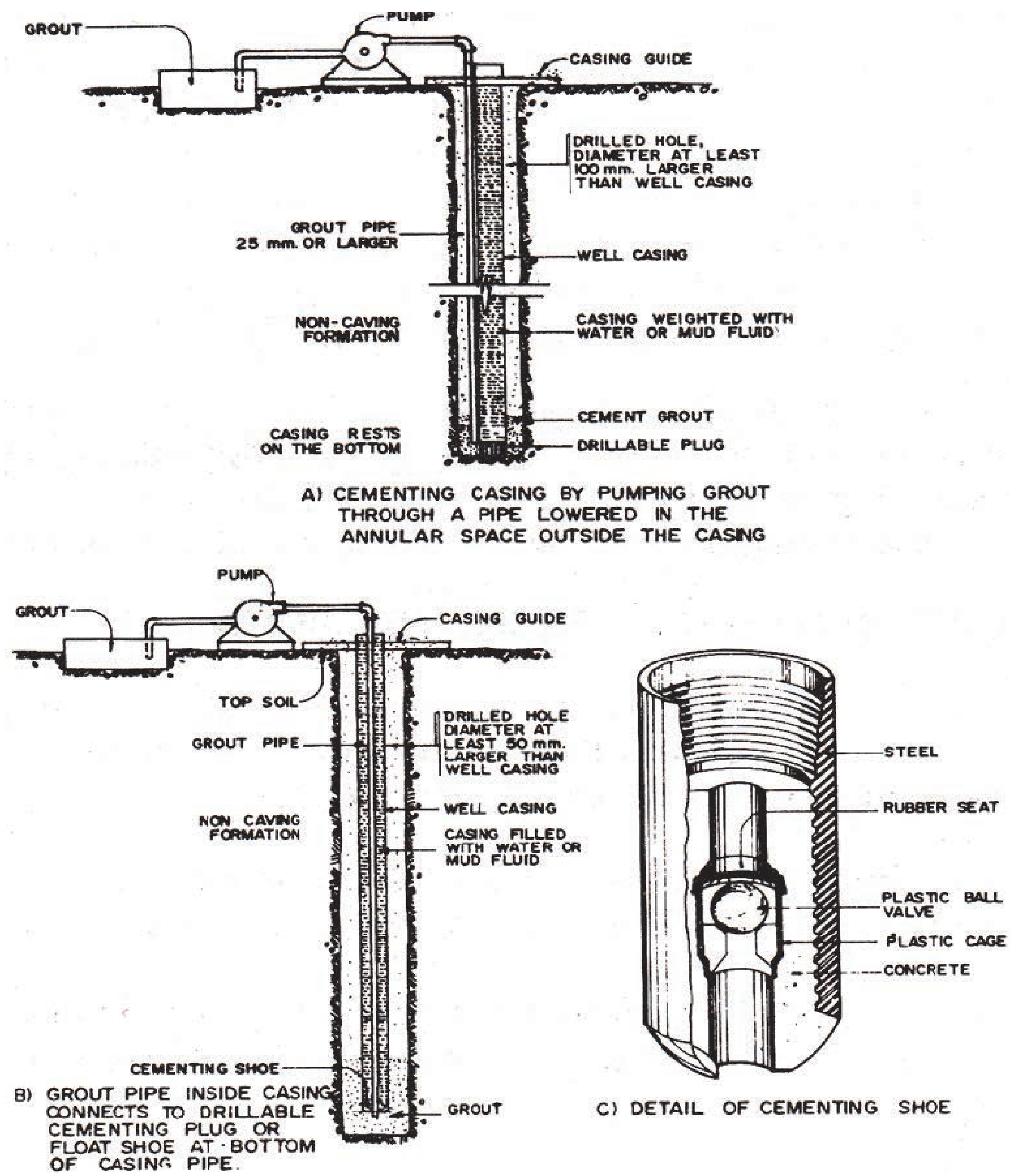
Grouting is a process of sealing the annular space between the pipe casing and the borehole to prevent the entry of undesirable water into the well, which may cause the deterioration of water quality. The process involves pumping grout from the bottom to minimize dilution, which has been proven to be effective (Figure 7.6).

Procedure:

To accomplish a uniform distribution of cement grout around the pipe casing, the Inspector must ensure the following:

1. Cement grout should be placed continuously.
2. Cement grout is prepared by mixing Portland cement and water at the ratio of 0.5 to 0.6 liter of water per kilogram of cement.
3. The grouting material is always introduced at the bottom of the space to be sealed. A grout or tremie pipe 19 mm or 25 mm in diameter is used.
4. As the grout rises, the grout pipe is gradually raised.
5. The bottom end of the grout pipe should always remain submerged in the slurry during the entire time that the grout is being placed.
6. In cases where operations are interrupted for any reason, the pipe should be raised above the grout level and should not be lowered into the slurry to continue grouting until all air and water has been displaced from the pipe.
7. Remove the tremie pipe after the grouting is completed. Allow the grout to set for at least 72 hours before proceeding to the next operation. The hardening time of cement may be reduced by adding certain materials, such as calcium chloride, to the cement slurry.

Figure 7.6: Grouting of Deep Well

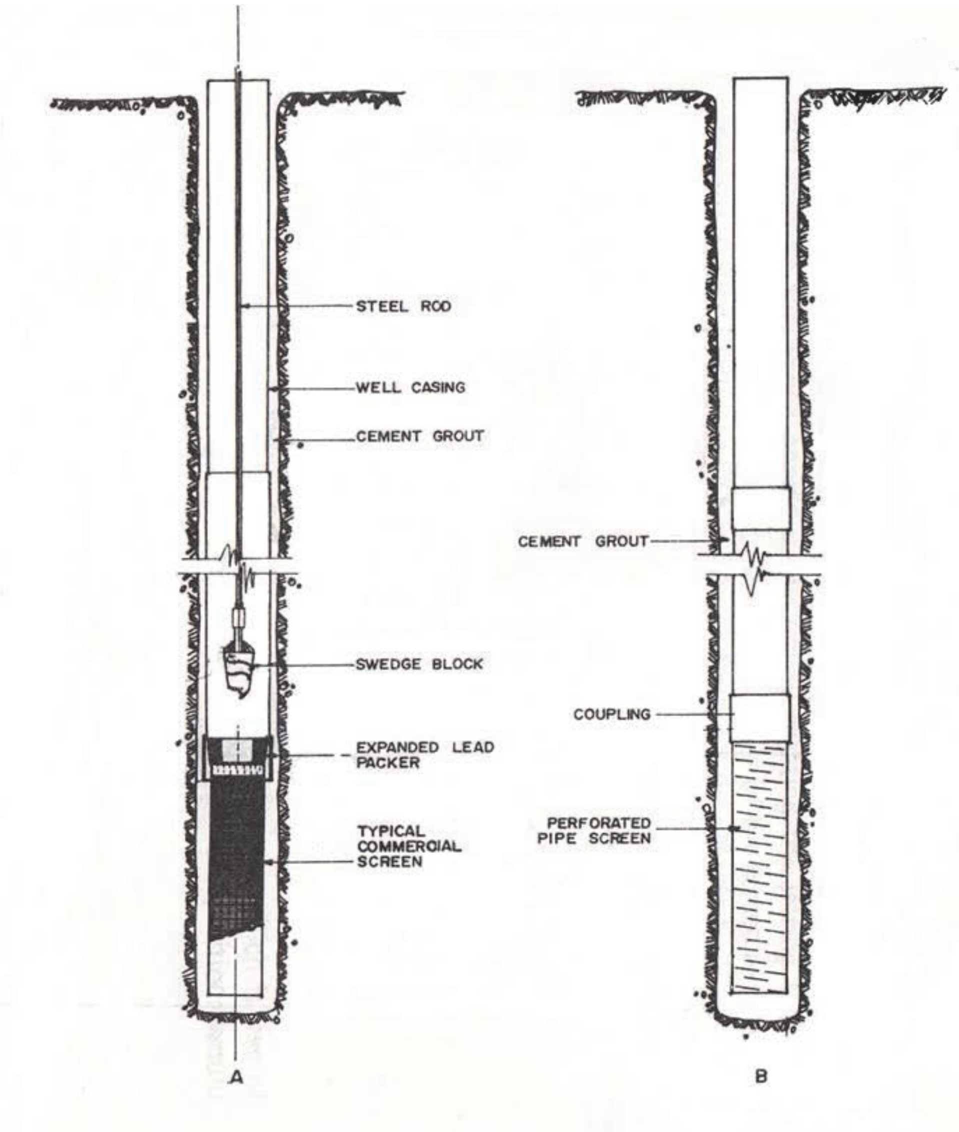


NWRC RWS Volume II, Construction and Installation Manual

E. INSTALLING WELL SCREENS OR PERFORATED CASINGS

The well screen is the water intake of the well. The screen allows water to flow into the well from the aquifer, but keeps out sand and gravel (Figure 7.7).

Figure 7.7: Installation of Well Screens or Perforated Casings



NWRC RWS Volume II, Construction and Installation Manual

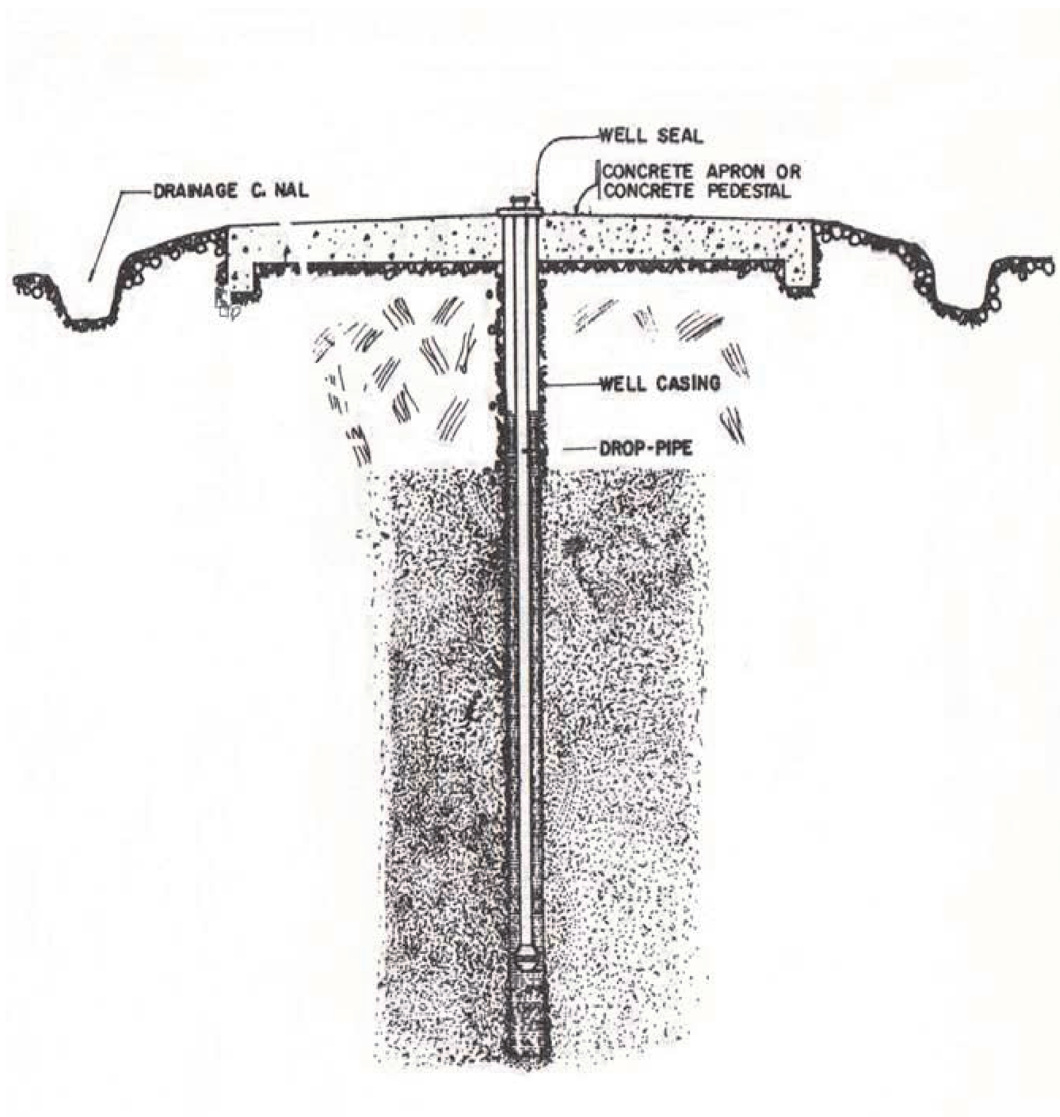
Basically, the Inspector must see to it that the well screen is installed in the productive formations of the borehole.

1. The first screen section from the wellhead (top) should be installed below the estimated deepest pumping water level.
2. Well screens can be fabricated by perforating steel or PCV pipes. A common practice is to fabricate a well screen by making perforations around the steel or PVC pipe casing by means of a cutting torch or tool.
3. If the budget allows, commercial screens are preferable as they have a longer useful life compared to fabricated screens.

F. CONSTRUCTING THE WELL APRON AND DRAINAGE

The Inspector must see to it that the well is protected from all possible sources of contamination (Figure 7.8). As such, he must ensure that after the well has been constructed, it is provided with an apron, and that the following conditions are in place:

Figure 7.8: Construction of Well Apron and Drainage



NWRC RWS Volume II, Construction and Installation Manual

1. The well apron should be at least 30 cm above the ground surface or 60 cm above the flooding level if it is constructed near a river.
2. The well apron should be watertight, preferably made of concrete. It should be at least 10 cm thick and should extend at least one meter around the well casing.

3. The surface should slope at least 1 percent (1%) from the center towards the drainage built along its edges.
4. A ditch or drainage canal should be made to collect dripping water, so that the vicinity of the well is free from mud or risk of re-infiltration of surface water into the well.

G. DEVELOPING THE BOREHOLE/WELL

The development of the borehole or well is the final stage in the construction and completion of a borehole. It involves the removal of finer materials in the aquifer and cleaning out/opening up all pore spaces through which water may pass into the borehole. The main objectives of borehole development are:

1. To correct any damage or clogging of the aquifer that might have taken place during the drilling process;
2. To increase the porosity and permeability of the aquifer in the immediate area of the borehole;
3. To stabilize the aquifer material around the screen and prevent sand infiltration into the borehole.

Borehole/well development is commonly accomplished by surging, a procedure that consists of making water flow at high velocity and pressure into the aquifer. By disturbing the water bearing formation and suspending fine particles in the water, the suspended particles can be removed by pumping.

Surging is accomplished by any of the following means:

- Over pumping;
- Using a plunger;
- High-velocity jetting;
- Air Surging.

H. TESTING FOR YIELD AND DRAWDOWN

The Inspector must refer to **Chapter 8** of **Volume 1: Design Manual** to have a general idea of the various methods of measuring water discharge and water levels in wells.

Upon well construction is complete, the Inspector must ascertain and observe the measurements of yield capacity and drawdown. All records pertaining to this activity should be kept for reference. Measuring well yield may last for 24 hours and in some cases 4 days or more depending on the time available, degree of reliability, and rate of well recovery.

I. SPRING WITH INTAKE STRUCTURE

Springs are outcrops of groundwater that often appear as small water holes or wet spots at the foot of hills or along river banks. High yielding springs can be tapped as sources of water supply. However, to use a spring as a source and obtain its maximum potential flow, it must be properly developed.

1. Development of Springs

The Inspector must observe and ensure that the following procedures are done during the development of a spring source:

1. The site must be cleaned of weeds and all undesirable vegetation.
2. The "eye" of the spring must be enlarged by excavating the area around the hole down to the impervious water-bearing layer.
3. Silt, rocks and other excavated materials must be removed.
4. During the excavation to enlarge the eye of the spring, underground rock formations must not be disturbed, so as to avoid deflecting the spring to another direction.
5. Ensuring that only stones that will serve as the foundation of the spring box are piled loosely against the eye of the spring.
6. A spring box should be constructed around the enlarged eye of the spring to protect the spring water from contamination.

2. Constructing the Spring Box

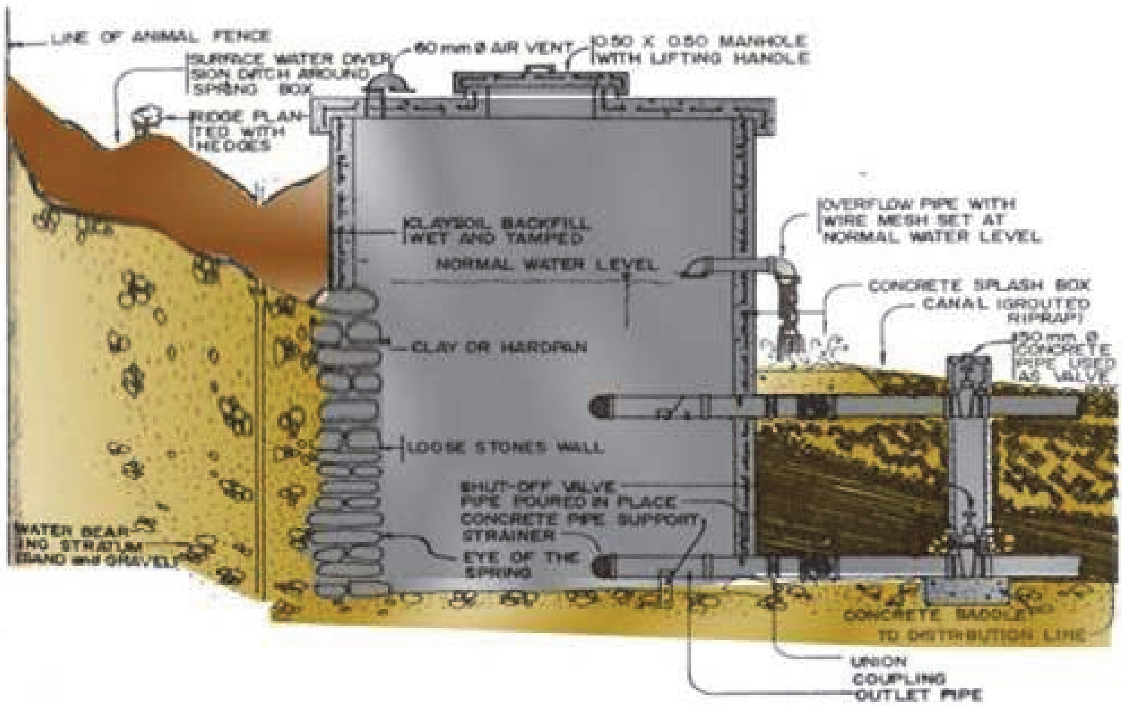
Figure 7.9 shows a typical concrete spring box. The spring box stores spring water and protects it from contamination.

The Inspector must ensure the following construction guidelines for a spring box.

1. The top of the spring box should be at least 0.30 m above the highest surrounding ground elevation.
2. The hole should have a raised edge to prevent dirty water from entering the box.
3. Also, the outlet pipe should be at least 100 mm above the bottom of the spring box.
4. To prevent stones, rubbish and frogs from blocking the pipes, the end of the outlet pipe inside the box should be covered with a screen.
5. The overflow pipe should be provided with a screen to prevent the entrance of insects. The pipe must be large enough to carry the maximum flow of the spring during the wet season.

6. The space behind the spring box should be filled with soil, the space at the bottom and at the level with the eye of the spring should be filled with gravel or sand.

Figure 7.9: Typical Concrete Spring Box



3. Drainage and Protective Structures

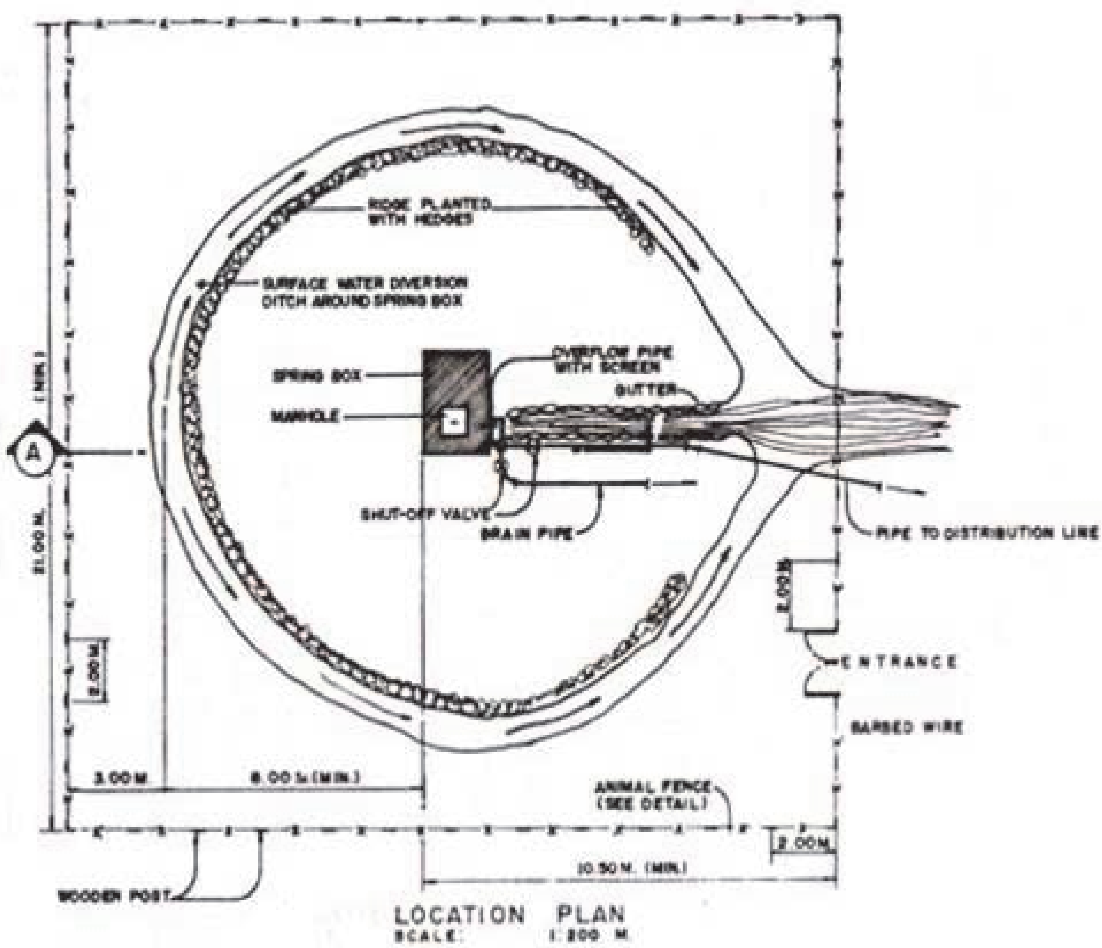
In all cases, the spring box and source should be properly protected from contamination, damage, and other eventualities that degrade their function as a source of water. Some of the protective measures include:

1. Constructing a deep drainage ditch at least 8.0 meters uphill and around the spring box to intercept surface water that might run into the spring box (Figure 7.10).
2. Building a ridge by piling excavated soil on the downhill side.
3. Fencing the area around the spring box to keep stray animals and people away. The fence can be made of interlink wire or barbed wire nailed to wooden posts.
4. Providing tightly fitted manholes and keeping them locked.

4. Testing and Disinfection

The procedures for testing and disinfection of spring sources are presented in **Chapter 6** of **Volume 1: Design Manual** and **Chapter 8** of this Manual respectively. The Inspector must observe and keep records of testing and disinfection results.

Figure 7.10: Typical Plan & Detail of Spring Perimeter Fence and Gate

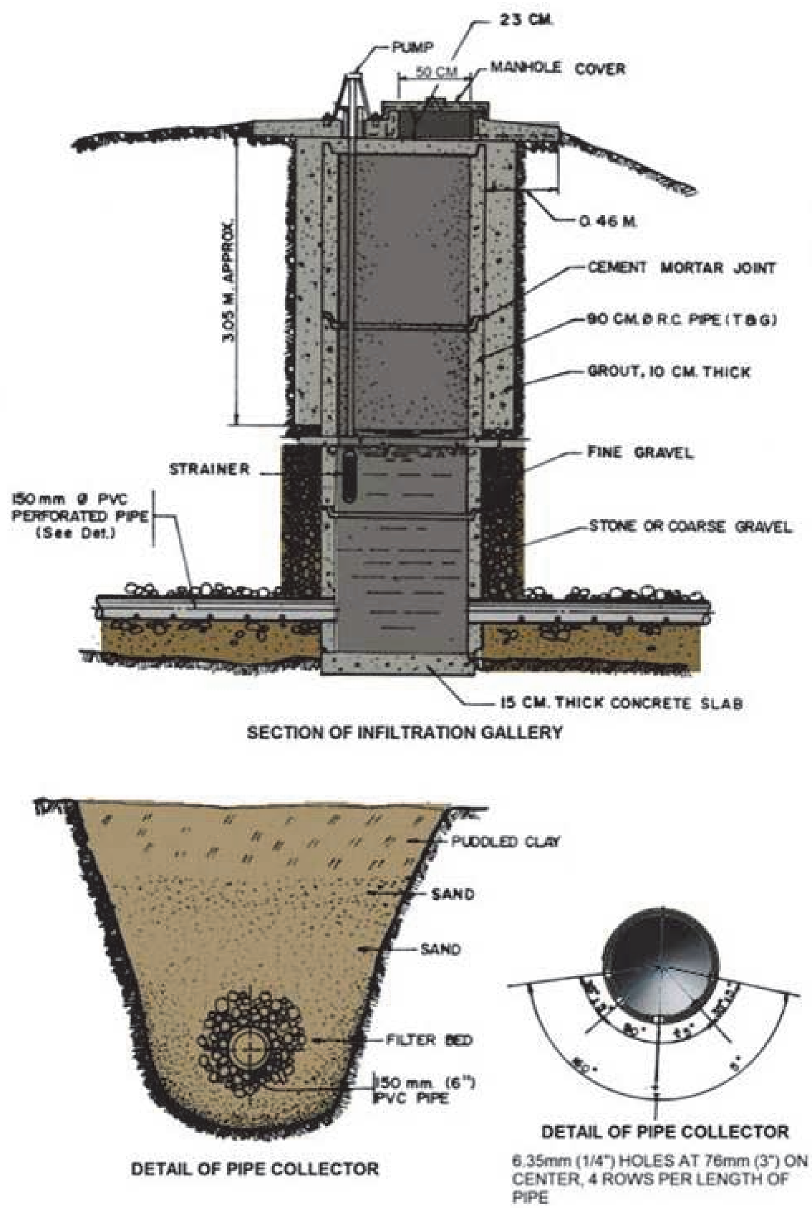


NWRC RWS Volume II, Construction and Installation Manual

J. INFILTRATION WELLS

An infiltration well collects water in its entire length as shown Figure 7.11. It is a simple means of collecting naturally filtered water. It consists of perforated pipe collectors and a well with the collector pipe closed at one end. The other end leads to a collecting well from where the water is pumped to the distribution system.

Figure 7.11: Design of a Simple Infiltration Well



NWRC RWS Volume II, Construction and Installation Manual

1. Site Location

The infiltration well is normally constructed near a body of water, which feeds the aquifer where the collector pipes are located. The collector pipes are usually installed in a porous formation such as sand and gravel at a distance of 15 meters or more from a riverbank. This enables the collecting system to intercept the groundwater flow to the river.

2. Construction Guidelines

1. If a trench will be constructed for the collector pipes, a dewatering pump should be used.
2. The perforated pipes should be laid with the perforated portion at the bottom side.
3. The space around the collector pipes must be filled up with round gravels or stones, 12 – 25 mm in diameter or whatever is in the design specifications. This is to prevent fine materials from entering the pipes. This should be followed by a 0.30 – 0.40 cm layer of filter sand up to at least 0.30 m above the groundwater table.
4. Depending on the need to pump the water, a pumping unit can be installed as discussed in Chapter 3.

3. Testing and Disinfection

1. The discharge capacity of the well is determined through pump tests similar to those used in determining well discharge.
2. The disinfection procedures are similar to those used in well disinfection.

Chapter 8

Testing, Disinfection and Commissioning

This Chapter will help the Inspector in the testing and disinfection processes of the distribution system.

A. PIPELINE TESTING

1. General

Before being put into service, new pipelines must be hydrostatically pressure tested.

Defects may be discovered that could threaten the pipeline’s ability to sustain its maximum operating pressure. If there are any critical defects in the system, the pipeline will leak and fail a pressure test. If leaks are located, the defective pipes should be repaired and re-tested. Only if the pipeline meets the pressure test should it be put into service.

The Inspector must ensure that all testing and disinfection operations are done in his presence, and generally he should take the following into account:

1. Pressure and leakage tests are usually done at the same time.
2. Testing of pipelines should be done in sections, before any permanent resurfacing of the dug-up roadways.
3. The pipeline trench may be partially backfilled, but the joints can remain exposed for observation, except in heavily travelled roadways.
4. Regardless of the type and size of the laid pipe, test sections shall be limited to 500 meters for distribution mains and 1,000 meters for transmission mains, to allow repairs and backfill to be completed as the work progresses. Mistakes in installation should be discovered and corrected early, to avoid excessive expenses of revisiting completed portions of the works.

2. Testing for Pressure and Leakage

As part of proper testing procedures, the Inspector must see to it that the steps described below are complied with. During the whole testing process, the Inspector must record test results using Form 8.1: Pipeline Pressure and Leakage Test.

a. Inspection before Testing

1. Pipe sections must be secured from movement by partially backfilling 0.45 m over the pipe, but leaving the joint sections exposed for the required visual inspections.
2. All pipe ends must be capped and restrained to prevent movement.

3. All thrust blocks should have been completed and cured for at least 7 days.
4. Provisions should be made to relieve trapped air from high points and pipe ends.

b. Visual Inspection for Leakages

1. The pipeline should be filled slowly with water at the lowest point in the line possible, with the hydrants/ and blow-offs open at high points to allow trapped air to escape.
2. Prior to any testing, the pipe section must be cleaned by flushing with a minimum flushing velocity of 0.80 m/s (2.5 feet per second).
3. After the pipe system is filled, a slight pressure of at least 20 psi should be applied, and the line should be allowed to settle and stabilize for 48 hours.
4. During the 48-hour period all exposed pipe joints, couplings, valves and fittings should be visually inspected for possible leaks.
5. Also during this period, all thrust blocks – especially those at pipe ends – should be checked for excessive movements that could be due to the thrust forces that developed.
6. In case defects are detected, the defective portions of the line should be repaired or replaced with sound material before proceeding.

Per LWUA standards, the test shall consist of holding test pressure on each section of the line for a period of two (2) hours.

The test pressure at the lowest point shall be 1.0 MPa (150 psi) according to the class of pipe installed, Class 100 or Class 150. Pressure gauges shall also be provided at all ends of the section tested.

The water necessary to maintain the pressure shall be measured through a meter or by other satisfactory means.

The leakage shall be measured through a meter or by other means. The leakage shall be considered the amount of water entering the pipeline during the two (2) hour test period.

Formula:

$$\boldsymbol{AL\ (allowable\ leakage) = \frac{1.85\ liter}{[diam\ in\ mm]}\ per\ [length\ in\ km]\ per\ day}$$

For all other types of pipes except cast iron or ductile pipe, the allowable leakage should not exceed 1.85 liters/mm of pipe diameter/km/24 hours.

Form 8.1: Pipeline Pressure and Leakage Test		
Date:		
Location (street):		
Pipe Diameter (mm):	Pipe Class (100/150):	Pipe Material:
Station:	to	Length (m):
(Max 500 m for distribution pipeline; Max. 1,000 m for transmission pipeline)		
Check flushing finished:	48 hours standing by:	
Any repairs done:		
Sketch (Indicate schematically connection of pipes, pressure gauge, pump, valves etc.):		

Test Pressure = 690 kPa for Class 100 pipes, or 1 MPa for Class 150 pipes
Allowable leakage (AL) = 1.85 liter per [diam in mm] per [length in km] per [day]
Calculations: AL = (1.85) x (diam) x (meters/1000) x (2/24) =

AL (liters) =

Time	Pressure (kPa/psi)	Meter Reading	Diff in Meter Reading	Cumulative	Remarks

Passed:	**Failed:**	
Prepared by: Contractor	**Checked by:** Inspector	**Approved by:** Engineer

c. **Pressure and Leakage Testing/Inspection**

1. Never use air to develop test pressure.
2. The Inspector should refer to the applicable specification and procedures as given, or follow the specifications in the box at the end of this enumeration.
3. Pressurize the pipe section using a smooth operating test pump to raise the pressure gradually to the required test pressure. Maintain the pressure using a hand pump or power pump.
4. Use owner-provided water meter (calibrated) to measure add-up water in maintaining the required test pressure. Test pressure must not be allowed to drop by 5 psi during the 2-hr test period.
5. Fire hydrants, laterals and service connections are tested with the main line.
6. The Inspector must ensure that all newly installed closure pipes shall be tested and pass leakage tests by subjecting the joints (of closure pipes) to a pressure of 50 psi for a period of five minutes and visually checking for leakages.

B. DISINFECTION OF PIPELINES

The Inspector, as a general practice, should ensure that the disinfection of pipelines shall be completed not more three (3) days before they are placed into service, and that care is taken to prevent recontamination of the any disinfected pipeline. Disinfection of water pipelines is normally done by chlorination.

The disinfection procedure involves four (4) steps as follows:

1. Pipeline Flushing

1. It is important to make sure that before disinfection is begun, the water main is cleaned to remove any foreign materials that may interfere with the disinfection activity.
2. Flushing should be done through a hydrant or blow-off.
3. Minimum flushing velocity is 0.8 m/s (2.5 fps) to attain proper flushing action. On how much water must be used to flush different pipe sizes at residual pressure of 28 m (40 psi), refer to Table 8.1 on the following page.

Table 8.1: Required Flow for Flushing Pipelines (lps)	
Pipe Diameter (mm)	**Flow Requirement To Produce 0.80 m/s**
100 (4”)	6.3
150 (6”)	12.6
200 (8”)	25.2
250 (10”)	37.8
300 (12”)	56.8
400 (16”)	100.9
Hydrant Discharge to Atmosphere @ 28 m Residual Pressure	
63.5 mm (2½”)	63.1
114.3 mm (4½”)	157.7

2. Introduction of Chlorine Solution

1. Determine pipeline capacity to determine amount of chlorine needed.
2. A chlorine solution of not more than fifty milligrams per liter (50 mg/l) is pumped at the beginning of a valved section of pipeline until full. Determine chlorine solution with the aid of “Chlorine Residual Test Kit”.
3. The preferred application point is usually at one end of the pipe section through a stop inserted on top of the laid pipe.
4. The high points of pipe section being disinfected should be properly vented.
5. At the opposite end of the pipe section, a draw-off valve should be provided to bleed or drain water during the injection process.

3. Retention Period of Chlorine Solution

1. The average retention or contact period for 50-mg/l-chlorine solution is 24 hours.
2. All pipeline valves and appurtenances should be operated to ensure that they are also disinfected.
3. During the 24-hour contact period, chlorinated water should not be allowed to flow into the potable water distribution system.

4. After a contact period of 24 hours, samples should be taken along the entire length of the pipeline and tested for chlorine residual. Residual chlorine shall not be less than 25 mg/l; otherwise the treatment procedure shall be repeated until satisfactory results are obtained.
5. Never discharge highly chlorinated water to the surrounding area to avoid possible damage to properties and persons.

4. Draining and Final Flushing

1. The chlorine solution is drained through the draw-off valve into a storm-sewer line.
2. Clean water is used to flush the disinfected pipeline.
3. After flushing, the residual chlorine should be between 0.20 to 0.75 mg/l.

C. TESTING AND DISINFECTION OF RESERVOIR AND PIPING

1. General

The Inspector must ensure that the testing and disinfection operations are combined and comply with procedures and specifications. No backfilling against reservoir walls should be allowed prior to the completion of the leakage tests. The reservoir must be inspected to make sure that all cracks are pinpointed and sealed before test filling starts. Both the inlet and outlet control valves should be tightly closed before and during the whole testing process.

2. Cleaning before Testing

Before disinfection, the reservoir must be cleaned. All adhering dirt particles should be brushed off and swept, then washed with clear water using a high-pressure hose and nozzle delivering a minimum flow of 3.15 lps.

3. Testing of Elevated Reservoir

Elevated steel reservoirs are tested by filling with water and being observed for leaks over a 24-hr test period.

1. Steel reservoirs shall be tested prior to the application of protective coatings/paint.
2. Ensure that only clean water is used for the testing.
3. Ensure that tank is filled up to its overflow level.
4. Visually observe the outside surfaces for the presence of leaks during the 24-hour test period.
5. Leaks shall be repaired by welding and retested until eliminated.

4. Testing of Concrete Reservoir

1. The reservoir should be filled up in stages. The increase in water level of the reservoir during any one day of filling operations should not exceed 75 cm. (30”). Observe for 24 hours.
2. During this time, if excessive leakage occurs, then the filling should be stopped at that level to allow the concrete to seal itself (autogenous healing).
3. If no improvement is noticed, the contractor should proceed with repairs. The water level should be reduced if necessary to relieve pressure.
4. If no problem is encountered, an additional 75 cm of water may be added, and the reservoir shall again be observed for 24 hours for leaks or a decrease in water level.

5. Leakage Allowance of Concrete Reservoir

1. After the reservoir is filled to its maximum water surface elevation, the Inspector must mark the water level on the wall of the reservoir.
2. After two days, the water level should be checked against the mark. Should there be an appreciable decrease in water level, the reservoir has leaks.
3. After a 30-day period, if the water surface drops more than 5.1 cm (2 inches), the reservoir should be emptied, and the Inspector shall closely examine for the cause of leakage such as any cracks or other conditions responsible for the leakage. Any cracks shall be repaired and sealed with rubber sealant.
4. During the leakage test period of thirty (30) days, the outlet valves and under drain must be inspected daily. Any leakage should be measured and recorded in the daily report.
5. Following any repair work, the testing process is repeated exclusive of the spraying operation.

6. Disinfection

The following steps are followed in disinfecting all types of reservoirs:

1. During the entire disinfection process, require all the assigned work persons to use breathing apparatus and full protective clothing.
2. As the first step, a strong chlorine solution of 200 mg/l should be sprayed on all the interior surfaces of the reservoir. If the chlorine solution is being re-used, a continual check must be made to be sure the residual is maintained at 200 mg/l. This strong solution will kill bacteria on contact and is essential in the successful disinfection of the reservoir.
3. Take measures to prevent the strong chlorine solution from flowing into the distribution line.

4. After completing the spraying procedure, fill the reservoir bottom to a depth of 30 cm with 50-mg/l chlorine solutions and allow the solution to stand for 24 hours before draining. Check the chlorine concentration of the drained solution. Should it be less than 25 mg/l, repeat the process starting from the chlorine spraying.
5. After the disinfection job, all the work persons must shower or otherwise bathe to completely wash off the chlorine.

7. Final Filling of Reservoir

1. An attendant must be present to respond to any contingency during the entire filling operation.
2. During the entire operation, a positive pressure must be maintained in the inlet line. If the inlet line pressure drops, the heavily chlorinated water could go back into the system. Should this happen, the valves must be closed immediately.
3. The reservoir is then filled to its maximum water surface elevation. The water at final filling should have a chlorine residual of between 1 and 2 mg/l.

D. DISINFECTION OF WELLS AND PUMPS

1. Determine and pour the amount of chlorine solution needed to produce 50 mg/l in the well.
2. Allow the well to stand for at least 24 hours.
3. Pump the water to waste until the chlorine odor disappears. (During the first 30 minutes, return the heavily chlorinated water back to the well via the space between the casing and the drop pipe to disinfect the area.)
4. The well is then ready for service.

E. BACTERIOLOGICAL TESTING

1. After final flushing, refill the pipeline with water from the system.
2. Take samples for “Bacteriological Tests” as prescribed by the “Philippines National Standards for Drinking Water 2007 (PNSDW-2007)” or any superseding standards more recently issued by the Department of Health.
3. If the results are safe, the pipeline can be put into service.
4. If the results fail to meet the minimum requirements, the water must be tested again until shown to be free of bacteria before the pipeline is put into service.

F. CLEAN-UP

The Inspector must ensure the following:

1. All the appropriate cleaning operations following the installation and testing of the facilities should be done thoroughly.
2. All excess materials and tools should be returned to the designated storage area.
3. All temporary structures used during construction operations should be removed.
4. All trash and dirt shall be swept/removed and taken to the designated dumpsite.

G. START-UP AND FINAL INSPECTION

1. As-Built Plans should be completed and used as the basis for inspection and payments.
2. Allow the flow of water from the system to fully fill the pipeline by opening the appropriate valves.
3. Ensure that the water is clear, colorless and free from objectionable taste and odor.
4. Observe the pressure at selected points along the pipeline with the use of installed pressure gages until the minimum design pressures are attained.
5. All valves, hydrants and other pipeline appurtenances should be operated or tested in fully open position.
6. Record the number of turns needed to open and close each of all the valves and hydrants in the system for future reference.

Chapter 9

Paints and Coatings

This Chapter is intended as a general guide to the various types of paints and coatings used in small water systems and the proper procedures in their application.

A. GENERAL

Paints and Coatings are employed to protect the exposed surface of materials from immediate deterioration. For instance, painting protects the wood from the attack of termites, carpenter ants and other boring insects; and metals from corrosion. Also, paints and coatings are used to improve the appearance of these materials, making them pleasant to look at.

B. PAINTING MATERIALS

Painting materials may be generally classified as primers and finishing paints. Primer paints are usually employed as the primary or first coat while the finishing paints are employed for the body or second coat and finishing or third coat.

1. Finishing Paints

Finishing paints may be classified according to usage and composition. Presented in Table 9.1 are the different types of paints classified according to their composition and usage. Paints may also be classified as gloss and flat if the basis of classification is the ultimate appearance desired for the painted surface. Gloss paints produce a bright painted surface while flat paints give a dull surface.

2. Primers and Sealers

Primers and/or sealers are usually employed as the primary or first coat to give body to the paint job, and provide a good base and improve the adherence of the finishing coats. Also they are employed to stop surface suction, thereby reducing the amount of finishing paints to be used in the succeeding coats. Sometimes, primers/sealers are used to fill minor surface imperfections, thereby providing a smoother surface. Presented below are some common primers/sealers:

a. Red Lead and Red Oxide Primer

Red lead and red oxide primer are general-purpose primer paints widely used for interior and exterior coatings on iron and steel surfaces. They contain a very toxic pigments, hence, they are NOT RECOMMENDED for painting the inside surfaces of reservoirs or any other surfaces that come in contact with the water supply. They are, however, highly recommended for use as coat primer for other metal works as they provide long lasting protection against corrosion.

Table 9.1: Classification of Paints According to Usage and Composition

Name of Paints	Classification According to Usage					
	Wood		Masonry		Metals	
	Exterior	Interior	Exterior	Interior	Exterior	Interior
Acrylic emulsion latex paint	X	X	X	X		
Shertex textured paint	X	X	X	X		
Gloss latex			X	X		
Flat paste paints		X		X		
Semi-gloss latex		X		X		
Flatwall enamel		X		X		
Exterior gloss paint	X					
Quick drying enamel	X	X			X	X
Semi-gloss enamel	X	X	X	X	X	X

b. Epoxy Paint Primer

Epoxy paint primer is non-toxic; hence, it is employed as the first coat when painting metals in contact with water supply.

c. Wood Primer and Sealer

Wood primer and sealer is a specially formulated material for use as first coat when painting wood surfaces. It possesses excellent adhesion properties and dries to a hard film, stops the surface suction, thereby, reducing to a great extent the amount of paint to be used in the succeeding coats. In addition, it is also good as a sealer.

d. Masonry Sealer

Masonry sealer is employed as the primary coat when painting masonry and concrete surfaces. It is employed as a barrier against moisture and salt found in concrete, which may cause efflorescence damage or eruptions.

3. Accessories

The items discussed below are materials used in conditioning the surfaces to be painted.

a. Concrete Neutralizer/Surface Conditioner

Concrete neutralizer is a very reactive solution that is used on new masonry or concrete surfaces to neutralize alkalis, thus insuring good adhesion of paint to the substrate or concrete.

b. Metal Treatment Solution

Metal treatment solution is a concentrated mixture of acids for cleaning and degreasing metal surfaces before they are painted. It also acts as phosphating agent, and being acidic, it functions both as an etching and a mild rust removing compound, thereby, improving adhesion of painting systems.

c. Wood Preservatives

Wood preservatives are applied before a primary coat to protect the wood against fungi, moisture, rot, termites, carpenter ants and boring insects.

C. PAINTING SCHEDULE

Materials to be painted are usually classed as architectural or non-architectural. Unless otherwise stated or specified, painting usually consists of three coats. This first coat is the primer paint; the second is the body coat (using finishing paint); and the third is the final coat of finishing paint. The actual practice, however, may involve other coatings (e.g., surface conditioners), and for highly critical paint jobs like automotive body painting, multiple coats of the finishing paint and other types of coating are applied.

BASIC TIPS:

(1) To the extent possible, the color of the primary coat must be lighter than the body coat, and the color of the body coat must be lighter than the finished coat.

(2) Whenever possible, the first and body coats should preferably have the same shade as the desired finish coat.

Outlined below are the different painting schedules.

1. Architectural Items

In small water supply systems, architectural items may include the pump house; reservoirs, operator’s room, office furniture, and landscaping. Table 9.2 presents the paint schedule for architectural items.

Table 9.2: Paint Schedule, Architectural Items			
	First Coat	Body Coat	Finishing Coat
Exterior Finishes			
Concrete Surfaces	Masonry Sealer	Concrete Masonry Paint	Concrete Masonry Paint
Wood Surfaces	Exterior Wood Primer	Enamel Paint	Enamel Paint
Unprimed Metal Surfaces	Rust Inhibitive Metal Primer	Enamel Paint	Enamel Paint
Interior Finishes			
Concrete Surfaces	Masonry Sealer	Enamel Undercoat	Interior Semi-Gloss Enamel
Wood Surface	Interior Wood Primer	Interior Semi-Gloss Enamel	Interior Semi-Gloss Enamel
Unprimed Metal Surface	Rust Inhibitive Metal Primer	Interior Enamel Paint	Interior Enamel Paint

2. Non-Architectural Items

In small water supply system, non-architectural items may include valves, piping and equipment. In the selection of the color of paints for these items, provisions should be made so that the color selected must match the color of architectural items.

a. Galvanized Iron Pipes & Other Galvanized Metal Surfaces

- **First Coat:** Galvanized metal primer
- **Second Coat:** Interior semi-gloss enamel

b. Ungalvanized Metals

- **First Coat:** Rust inhibitive metal primer
- **Second Coat:** Interior semi-gloss enamel

D. PREPARATION OF SURFACES TO BE PAINTED

Surfaces to be painted should be thoroughly smoothened, cleaned and dried before any painting job. This could be achieved by repairing all surface defects, leveling all the depressions and patching all cracks with plaster.

1. Preparing Concrete and Masonry Surfaces

1. Cure all concrete and masonry surfaces for at least 30 days prior to painting.
2. Inspect the cured surfaces for defects like holes, cracks or depressions. Should any be detected, they should be neatly filled with patching plaster. Allow the plaster to dry, then smoothen with a sand paper.
3. Remove from the rest of the surfaces to be painted, all dirt, dust, loose plaster and other matter, which would prevent good paint adhesion.
4. On new concrete, apply concrete neutralizer or masonry surface conditioner to neutralize alkalis and remove excess oxides. On old surfaces, these are needed to remove mildew. They insure good adhesion of paint to the substrate.
5. Apply the first coat of paint.

2. Preparing Metal Surfaces

1. Remove all dirt, scales and rusts by scraping, wire brushing or sanding.
2. Remove oil and grease with appropriate solvents.
3. Treat the surface with metal treatment solution or with any approved phosphate acid etching cleaner in accordance with manufacturers' recommendation to produce a chemically clean surface.
4. Apply the first coat of paint.

3. Preparing Wood Surfaces

1. Check the wood surfaces to be painted for cracks, depressions, knots, nail holes and other defects.
2. Fill with putty or other equivalent filler and nail holes, cracks and depressions, and clean the surfaces from knots, sap streaks and other defects.
3. Smoothen the surface of the wood to be painted using a No. 00 sandpaper.
4. Remove all dusts and dirt.
5. Apply wood preservatives and then the first coat of paint.

E. PREPARATION OF PAINTS

Paints available in the market today are concentrated; hence it is usually necessary to dilute them to the desired consistency before application. The dilution ratio depends primarily on the type of paint. The user must refer to the manufacturer's recommendation before making the dilution. After paint thinner is added, the mixture should be stirred thoroughly until it is homogenous.

F. APPLICATION OF PAINT

The quality of the finished surface depends upon the skill of the painter, the preparation of the surface to be painted, and the climate and ambient temperature. For instance, painting should not be done when the temperature is greater than 32^{o}C (92^{o}F) or when the weather is damp.

General Procedure:

1. Prepare the painting materials needed for the painting job with reference to the painting schedule presented in Section C;
2. Apply the primary or first coat evenly, free of laps and sags and cut sharply to the required lines using a brush or spray;
3. Allow the primer paint to dry for no less than 24 hours;
4. Sand the surface using sandpaper with gauge No. 50. This is necessary so that the succeeding coat will have a good bond with the preceding coat;
5. Apply the second or body coat evenly to have a uniform thickness;
6. Allow it to dry for at least 24 hours and then sand again, this time using a sandpaper No. 80;
7. Apply the third and final coat.

G. PAINT PROBLEMS: CAUSES AND REMEDIES

Outlined in Table 9.3 are the common problems, which may be encountered during the performance of painting jobs.

Table 9.3: Paint Problems, Their Causes and Remedies

Problem	Causes	Remedies
Blistering and peeling	Coat of paint develops bubbles with trapped water that later burst. This happens when excessive moisture in and underneath the siding is drawn out to the surface by the heat of the sun.	Check probable sources of moisture like seepage or leaks from eaves, roofs and plumbing. Seal all these sources of moisture, and provide vents for interior moisture. Sometimes in low weather, blistering occurs during or right after painting. Unevaporated solvent is trapped in deep surface pores. When exposed to the heat of the sun, it vaporizes and ruptures the dried surface film. This happens most often with dark color paints which absorb more heat than lighter colored ones. To minimize problem, paint while in the shade.
Flaking and cracking	Occurs when the wood swells and shrinks due to wetting and drying out	Use well dried wood and keep wetting. Have a good surface preparation and have proper sealing.
Intercoat peeling	Occurs when there is no adhesion between coats	Sand the problem area with sandpaper No.100. Repaint with one or two coats of paint undercoated and then apply two coats of finishing paint.
Alligatoring	Faulty application of paint causes the top coat to dry faster and harder than the coats underneath. As the material under the surface film dries and hardens, it shrinks causing the surface coat to pucker, wrinkle and even crack.	Follow manufacturers' recommendation/instruction s to type and drying time of the under coater and the spreading rates of the materials.
Wrinkling	Usually results when thick heavy films of paint are applied in cold weather.	Follow manufacturers' recommendations on proper spreading rates and favorable painting temperatures. When repainting over wrinkled surfaces the old surface should be sandpapered to eliminate the irregularities.
Suction spotting	This is caused by inadequate priming of porous wood surfaces. This leads to abnormally high absorption of the binder by certain porous areas of the substrate. These areas will now experience excessive chalking (due to the decreased amount of binder in the film) and weather away exposing the wood surface underneath to more serious problems.	The entire job should be given another coat of finish paint. The correct use of a high quality primer or sealer especially formulated for use with its companion top coat is the best insurance against this problem.

Chapter 10

Public Safety and Convenience

This Chapter concerns itself with the need to keep constructions safe for the workers and the public and to minimize the inconvenience that normally accompanies their implementation.

A. GENERAL

The Inspector is the first line of defense against accidents and injuries at job sites. The Inspector should help maintain safe job sites during construction. During pre-construction meetings and at least in monthly meetings during construction, the job-site safety issues should be discussed with all parties involved in the project.

The discussions should put specific focus on hazards peculiar to the upcoming phase of construction, as well as keep the discussants alert to the more general, continuing ones that are features of any such constructions. They should address any problems that need to be corrected and set reminders on potential health and environmental hazards.

In addition, the Inspector should routinely check first-aid supplies weekly, and continuously check the job site for debris and hazards.

B. CONSTRUCTION SAFETY

The need for safety precautions in any specific project area must be recognized and observed before and during construction activities. The Inspector should be alert to the following:

1. Any construction will draw on-lookers, especially children. Onlookers should be kept away from the operating equipment and from the edges of excavations.
2. Traffic must be controlled at all times unless permission has been received from the proper authority to completely close a road.
3. When a pipeline trench crosses any road intersection, steel plates should be put in place to allow traffic to cross the trench. The Inspector, Contractor, and all workers should be alert to situations when these are dislodged from their proper placement.
4. Emergency vehicles must not be delayed.
5. Vehicular access to homes and places of business should be maintained. If this is not possible, the occupant should be apprised of the situation by the Contractor or the Inspector. It is an absolute necessity that good relations be maintained with the general public.

6. When leaving the project at night, no unnecessary obstructions to traffic should be left behind, such as earth lumps from the trench excavation or sections of pipe that encroach on the roadway.
7. The Inspector must ensure that the Contractor shall
   - Erect, provide and maintain
     - All necessary barricades for the construction and for streets close to traffic;
     - Suitable warning signs at places where surfacing ends or where it is not compacted;
     - Warning signs outside of and 150 meters from each end of the projects;
     - Warning signs 150 meters in advance of any place on the project where the operations – interfere with the use of the road by crosses or coincides with an existing road;
     - All of the above illuminated at night with lights from sunset to sunrise.
   - Provide a sufficient number of watchmen;
   - Deploy Traffic flagmen as needed. In case only alternating one-way traffic control needs to be imposed, the Contractor shall furnish flagmen to direct traffic through the section of road under one-way control.

C. SIGNS, SIGNALS AND BARRICADES

The inspector must ensure that the signs, signals and barricades are properly utilized.

1. Barricade

This is an intentionally placed obstruction to deter the passage of persons or vehicles.

a. Types:

- Permanent – A large surface area barrier at the limits of the work area.
- Temporary – Smaller barricade used for work area protection or as portable bases for temporary warning or directional signs.

b. Placement:

- Should be placed so that there is no gap large enough for a vehicle to pass.
- Should be facing traffic and must be illuminated or reflectorized at night.
- Should never be placed in a moving lane of traffic without an advance warning sign.

2. Delineators

These are markers which aid the driver in determining the locations and alignment of the traffic lane.

3. High-Level Warning Devices (Flag Standards)

These are devices, which provide advance warning of a work area. These should be at least twelve (12) feet high with three flags for daytime and three flashers for nighttime use.

4. Flagmen

Flagmen or other appropriate traffic control capabilities should be provided when operations are such that and barricades do not provide the necessary protection on or adjacent to a highway or street. A flagman/flagmen should be fielded

- Where workmen or equipment intermittently block a traffic lane;
- When one lane is used for two directions of traffic;
- Where construction warning control devices are being placed or removed.

All flagmen should be provided with red or orange jacket (or vest) and equipped with 16-inch square red or orange flags and paddles for daytime use and red flashlights for use at night or other means which will make the flagmen quickly identifiable.

References

1. American Water Works Association. (1986). *Principles and Practices of Water Supply Operations (Vol. 3): Introduction to Water Distribution.* AWWA.
2. Association of Structural Engineers of the Philippines. (1992). *National Structural Code of the Philippines* (4th ed., Vol. 1). ASEP.
3. Department of Public Works and Highways. (1991). *Water Supply Manual.* Bureau of Research and Standards, DPWH.
4. Faust, R. W. (2007). *The Hydraulic Principles of Water Supply Systems.* PDH Center.
5. Ferguson, P. M., Breen, J. E., & Jirsa, J. O. (1987). *Reinforced Concrete Fundamentals* (5th ed.). John Wiley & Sons, Inc.
6. Hardie Iplex Pipeline Systems. (1993). *uPVC Pipelines Design Textbook.* Hardie Iplex Pipeline Systems.
7. Local Water Utilities Administration. (1975). *Inspector's Construction Manual.* LWUA.
8. National Water Resources Council. (1979, March). *Rural Water Supply: Design Manual* (Vol. I). NWRC.
9. National Water Resources Council. (1980). *Rural Water Supply: Construction and Installation Manual* (Vol. II). NWRC.
10. National Water Resources Council. (1981). *Rural Water Supply: Operation and Maintenance Manual* (Vol. III). NWRC.

THE WORLD BANK OFFICE MANILA
23rd Floor, The Taipan Place
F. Ortigas Jr. Road, Ortigas Center
1605 Pasig City, Metro Manila, Philippines