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Trickle Irrigation Installation for Horticulture Crops

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Agricultural Engineering Update

Structures & Environment | Soil & Water | Energy | Safety | Crop Processing | Power & Machinery

AEU-32

Short Course

Trickle Irrigation Installation for Horticulture Crops

by

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Princeton - March 26, 1987
9 a.m. to 3 p.m. - CST

Course Outline

1. Trickle Irrigation Overview
    a. Mean monthly precipitation
    b. Mean monthly pan evaporation
    c. Monthly irrigation requirement

2. Design Planning
    a. What is needed to design a system
    b. Design planning map information
    c. Example planning map

3. Water Supply
    a. City water
    b. Other water supplies pumps, motors, and engines

4. Basic Trickle Irrigation System
    a. Control station
        (1) pump or city water connection
        (2) backflow preventor
        (3) fertilizer tank
        (4) fertilizer injector
        (5) water meter
        (6) filter(s)
        (7) pressure gauges
        (8) pressure regulators
        (9) main shutoff valve
        (10) controllers
        (11) pressure relief valves
    b. Main, submains/manifolds
    c. Laterals
        (1) strip tubing
        (2) hose with emitters
            (a) laminar flow emitter
            (b) turbulent flow emitter
            (c) vortex
            (d) pressure compensating emitter
    d. Fittings
        (1) an example for city water connection
        (2) schematic of various fittings

5. Design Drawing

6. Installation
    a. Tools required
    b. Procedure

7. Emitter Clogging Problems
    a. Needed water quality
    b. Physical, chemical, and biological clogging problems

8. Irrigation Scheduling
    a. Tensiometers
    b. Resistance blocks

1. Trickle Irrigation Overview

Climatic Conditions

	May	Jun	Jul	Aug	Sep
Bluegrass Region					
Precip.	4.11	4.19	4.66	3.43	2.95
Evapo.[1]	5.96	6.46	6.72	6.25	4.57
Western Region					
Precip.	4.43	3.95	3.79	3.33	3.19
Evap.	6.40	7.15	7.47	6.31	4.66

Irrigation Needs[2] (Hort. crops)

Soil type	precip. condition	May	Jun	Jul	Aug	Sep
loamy	normal[3]	0.00	0.36	3.23	1.81	0.00
loamy	dry[4]	0.00	0.50	3.57	2.14	0.00
loamy	very dry[5]	0.14	1.07	4.56	3.55	0.00
sandy	normal	0.00	0.44	3.44	2.32	0.00
sandy	dry	0.00	0.57	3.74	2.61	0.00
sandy	very dry	0.00	0.62	3.85	2.73	0.00

[1] pan evaporation

[2] irrigation required to increase the water holding capacity (WHC) to field capacity whenever WHC decreases to 50%

[3] normal 1 year out of 2

[4] dry 1 year out of 5

[5] very dry 1 year out of 10

Ponds and Wells

Pond Volume	
ft^3	40% x Width x Length x Depth
gal	7.48 x ft^3
ac-ft	ft^3/43,560

Advantages and Disadvantages of Trickle Irrigation

Advantages:

*reduces water volume needed
*reduces water waste (minimizes water runoff)
*water placement to roots
*reduces weed growth
*prevents soil crusting
*improves crop quality and yield, may hasten maturity
*reduces disease problems
*promotes even soil moisture (reduces tomato cracking)
*reduces root zone temperature

*no wind interference with distribution pattern
*runs on low pressure. uses smaller equipment and less energy
*easily automated. zoned
*can be permanent system for perennial crops
*can inject chemicals
*can work while watering
*between rows remains hard and dry for equipment
*seeds and transplants not washed. damaged or dislodged
*low labor requirement once installed
*variable spacing. design

Disadvantages:

*clean water needed to prevent clogging
*roots may seek emitters/holes
*initial assembly labor
*above ground line damage by equipment
*rodent damage
*dislodging supply tubes
*frequent irrigation required

2. Design Planning

a. What is needed to design a system

Area
  1) area to be irrigated
  2) Topography of area

Crop
  1) Crops to be raised_______________
  2) Field location of crops
  3) Row spacing

Water Supply
  1) Location of water supply
  2) Type of water supply_______________
  3) Pressure
  4) Flowrate

Soil
  1) Soil Series or Soil Type

b. Design Planning Map Information

1. Map scale 1'' = ___________ ft

2. Sketch boundary of farm.

3. Locate the water source

4. Locate field(s)

5. Provide elevations on the map <u>or</u> at least
   a. locate highest point in the field and elevation difference between the water supply and highest point
   b. provide estimate of field slope(s)

6. Location of rows and preferred direction

7. Spacing between rows

8. Plant spacing along rows

Refer to enclosed example

2. Design Planning

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Refer to enclosed example

3. Water Supply

a. City Water

1. Size of service line _______________ in
2. Water meter size ___________________ in
   - normally 5/8, 3/4, or 1 in
3. Static water pressure _______________ psi
   - connect a pressure gauge to a hose bib and turn water on
4. Flow rate in gallons per minute _______ GPM
   obtain from the table below:

Service[1] Line (in)	Water Meter (in)	Gallons Per Minute for Static Pressure of 30	40	50	60 (psi)
1/2	5/8	2.0	5.0	6.5	7.5
3/4	5/8	3.5	7.0	9.5	11.0
3/4	3/4	6.0	9.0	12.0	14.0
1	3/4	7.5	11.5	15.0	17.5
1	1	10.0	13.5	19.5	23.5
1 1/4	1	12.0	17.0	23.5	28.5

[1] Submatic Drop Irrigation Catalog. 1980. Submatic Irrigation Systems. Lubbock, Texas.

b. Other Water Supplies

-Pump

Pressure and flow rate depend on irrigation system requirements. A pump should be selected that achieves:

a. _______________ ft of head (H)

b. _______________ gpm

-Drive system

To determine horse power needs:

-determine water horse power from

$$WHP = \frac{H \times 8.3 \times GPM}{33,000}$$

-determine break horse power which accounts for pump efficiency being less than 100%

-obtain pump efficiency from a manufacturing pump curve

$$BHP = WHP/\text{pump efficiency}$$

-select drive system to be used and corresponding efficiency from the table below

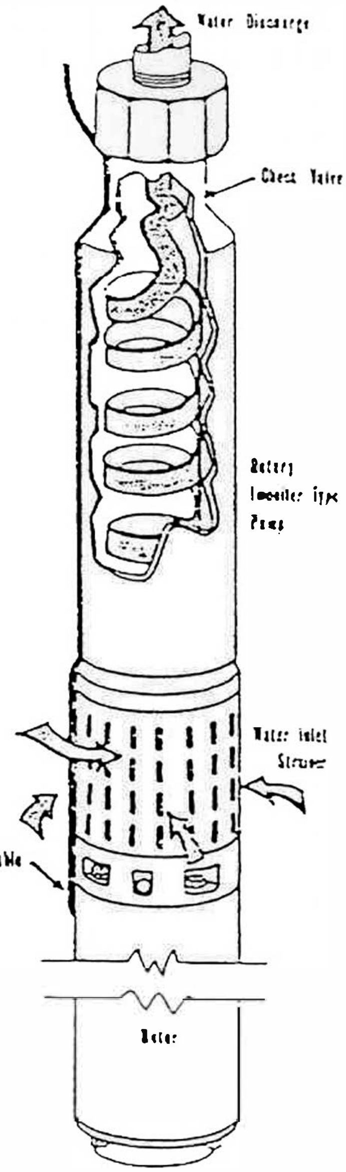
drive system	efficiency (approx.)
electric motor	90%
gas engine	25%
diesel engine	25%

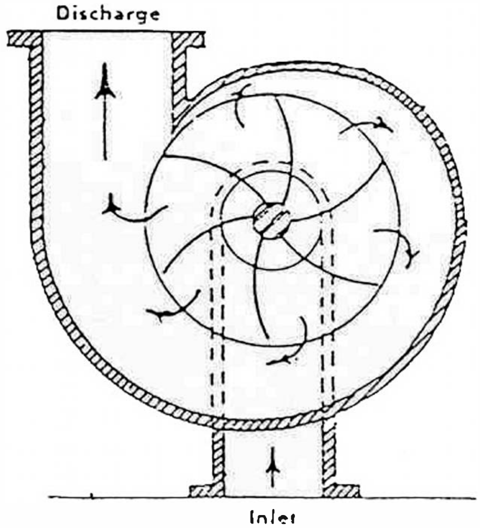
-required motor or engine horse power

Required H.P. = BHP/efficiency

-this may be further increased depending upon the connection between the drive system and pump, i.e., direct drive, belt drive, etc.

Submersible Pump





4. Basic Trickle Irrigation System

a. Control station

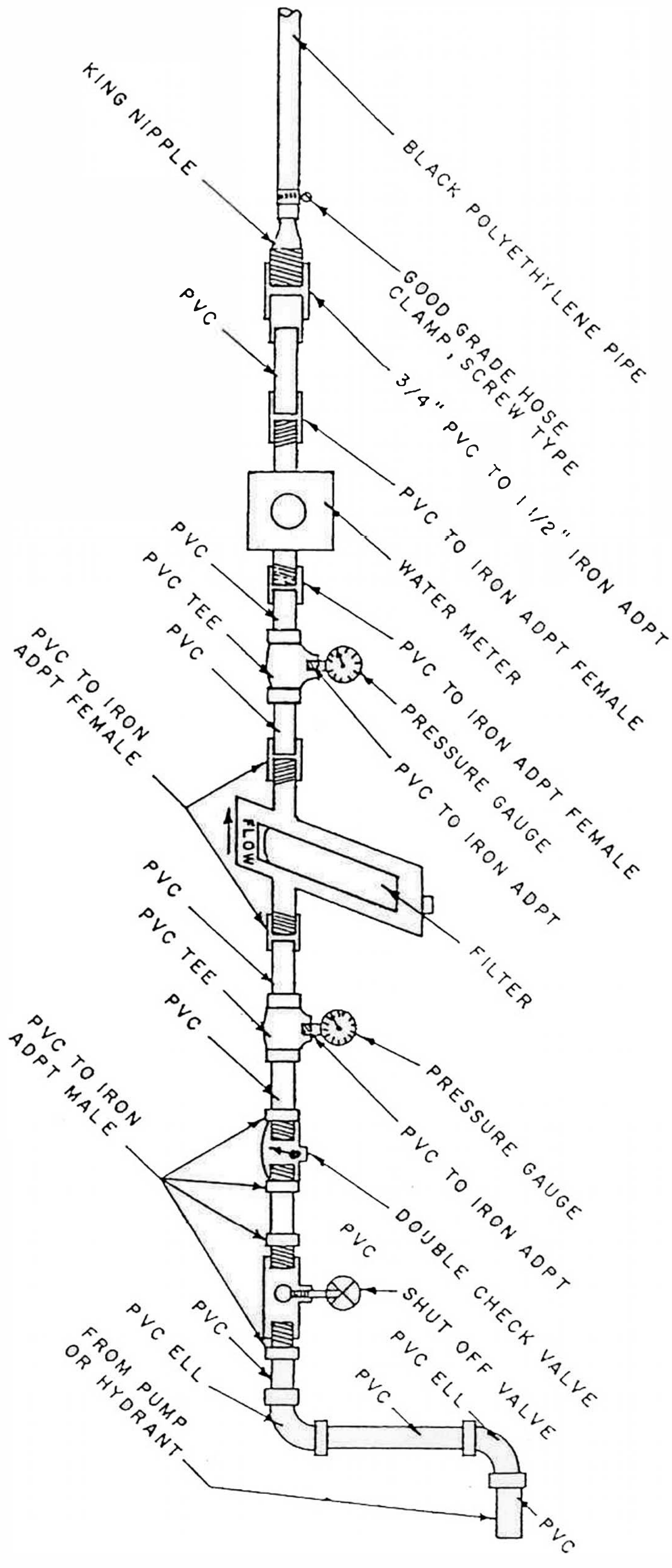
- contains all the components that link the water supply to the mainline
- the next 5 figures illustrate the various configurations of trickle irrigation systems
- components of a control station

(1) city water connection or engine or motor and pump
(2) backflow preventor (ex. check valve)
(3) fertilizer tank
(4) fertilizer injector
(5) water meter
(6) filter
(7) pressure gauges
(8) pressure regulator
(9) main shut off valve
(10) controller
(11) pressure relief valve

(2) Check VALVES
- prevents reverse flow of water
- prevents backflow from damaging pump
- prevents suction lines from being drained (prime)
- protects municipal water from contamination

(3) Fertilizer tank
- simply to hold the fertilizer

(4) Fertilizer injector
- injector pump
- venturi
- differential pressure tank
- injector pump
    - type - piston or diaphragm
    - constant concentration
    - require power source
    - more costly than venturi or differential pressure tank
    - requires more maintenance
- venturi
    - suction device
    - significant head loss
    - no power requirements
    - low cost
- differential pressure tank
    - non-uniform concentration
    - good for some chemical application
    - no power requirements


KING NIPPLE
BLACK POLYETHYLENE PIPE
GOOD GRADE HOSE CLAMP, SCREW TYPE
PVC
3/4" PVC TO 1 1/2" IRON ADPT
PVC TO IRON ADPT FEMALE
WATER METER
PVC
PVC TEE
PVC
PVC TO IRON ADPT FEMALE
PRESSURE GAUGE
PVC TO IRON ADPT
PVC TO IRON ADPT FEMALE
FLOW
FILTER
PVC
PVC TEE
PVC
PRESSURE GAUGE
PVC TO IRON ADPT
PVC TO IRON ADPT MALE
DOUBLE CHECK VALVE
PVC
SHUT OFF VALVE
PVC
PVC ELL
PVC
PVC ELL
FROM PUMP OR HYDRANT
PVC

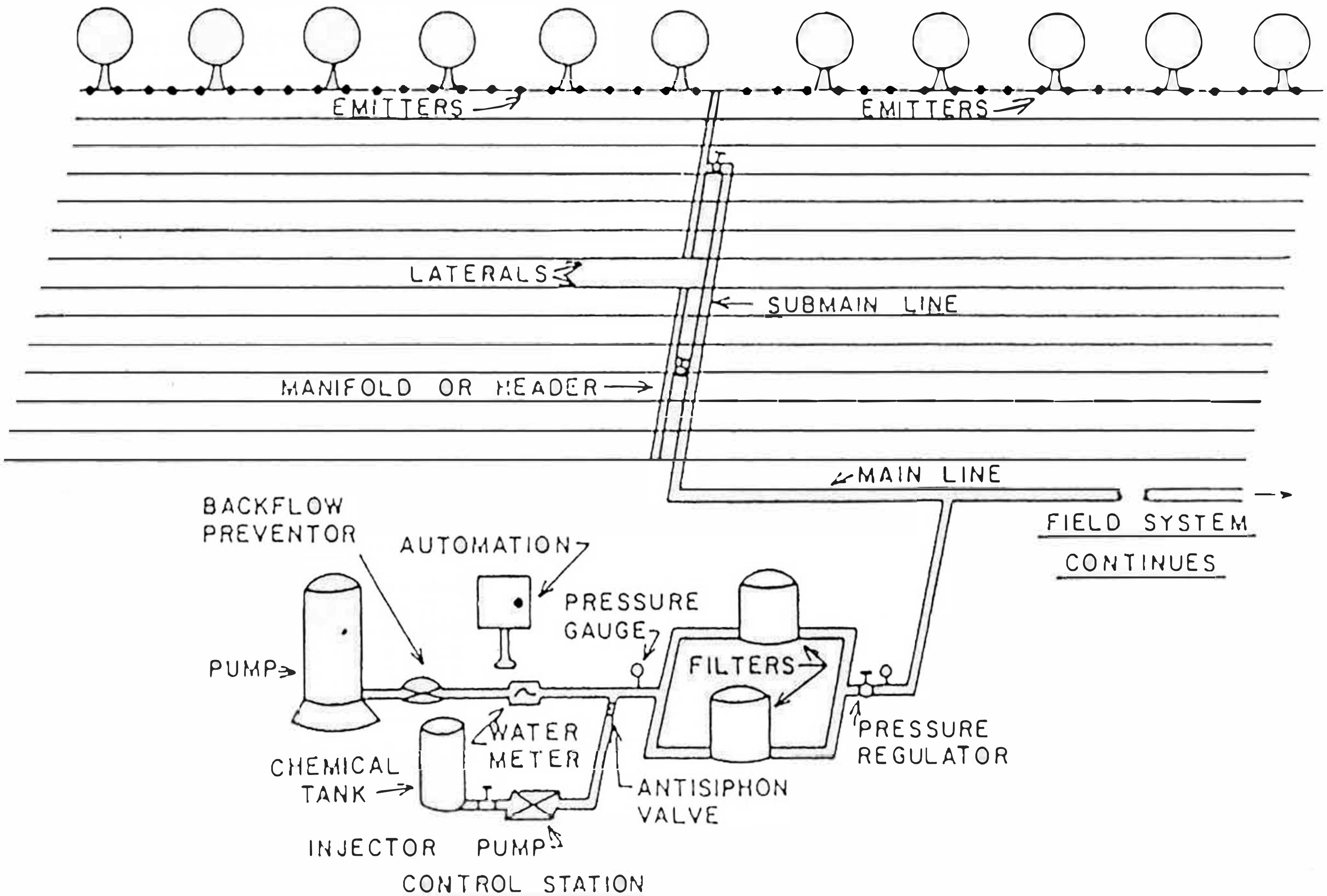


Fig. 1.1.4 An example of a basic trickle irrigation system.

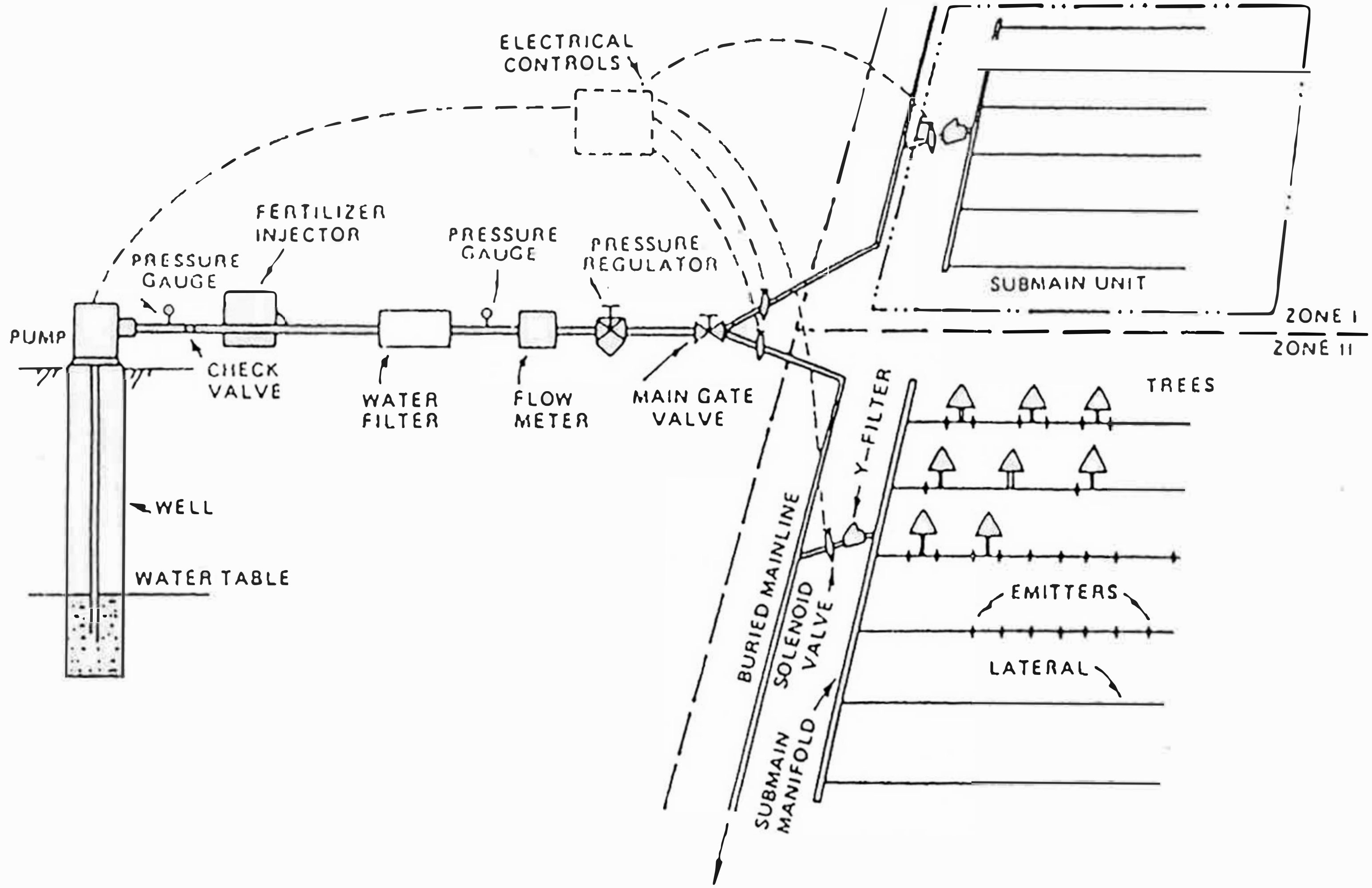


Fig. 3.4.1 Trickle irrigation system components.

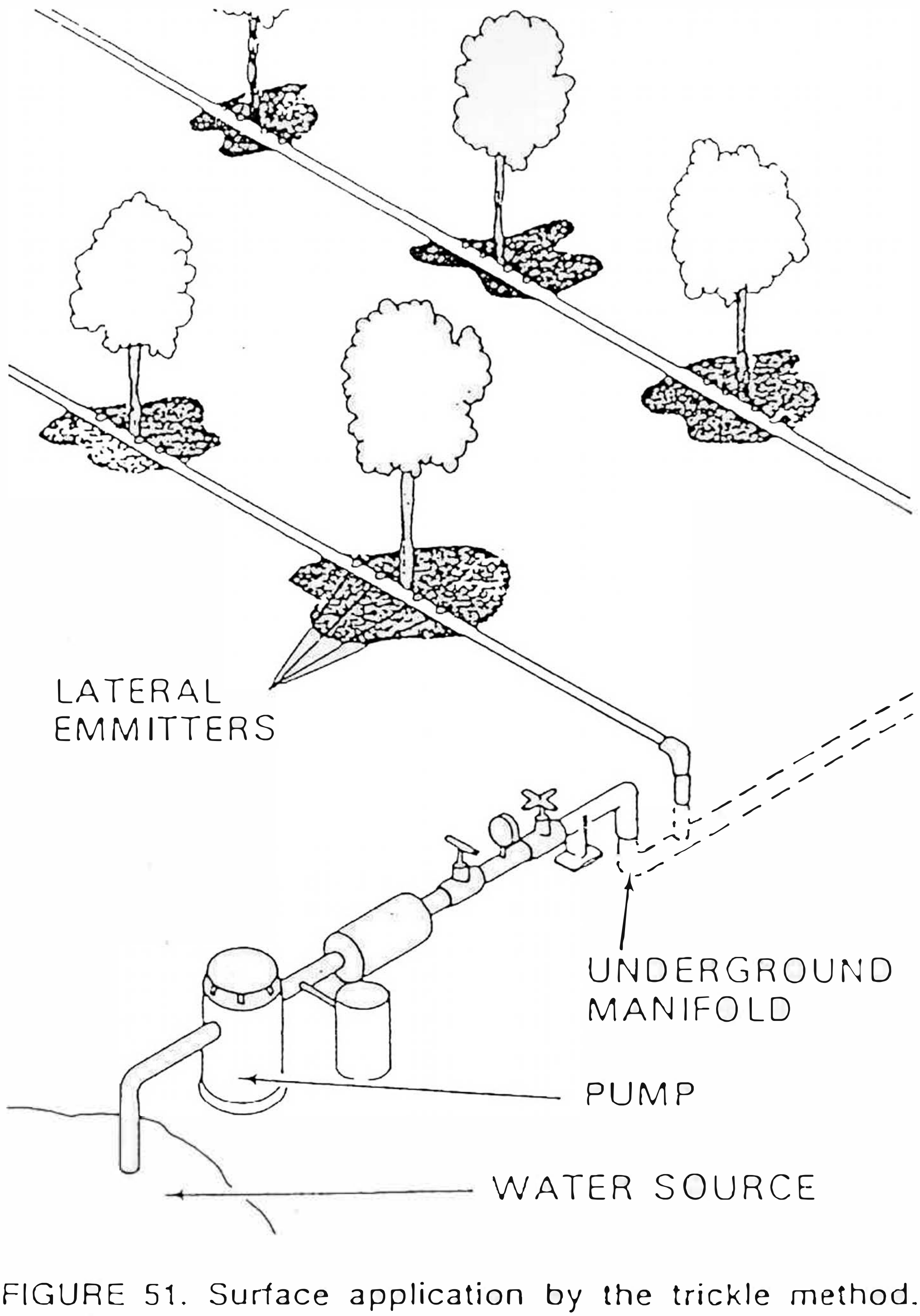


FIGURE 51. Surface application by the trickle method. Water is applied very slowly onto the surface of the soil through special outlet emitters in plastic pipe.

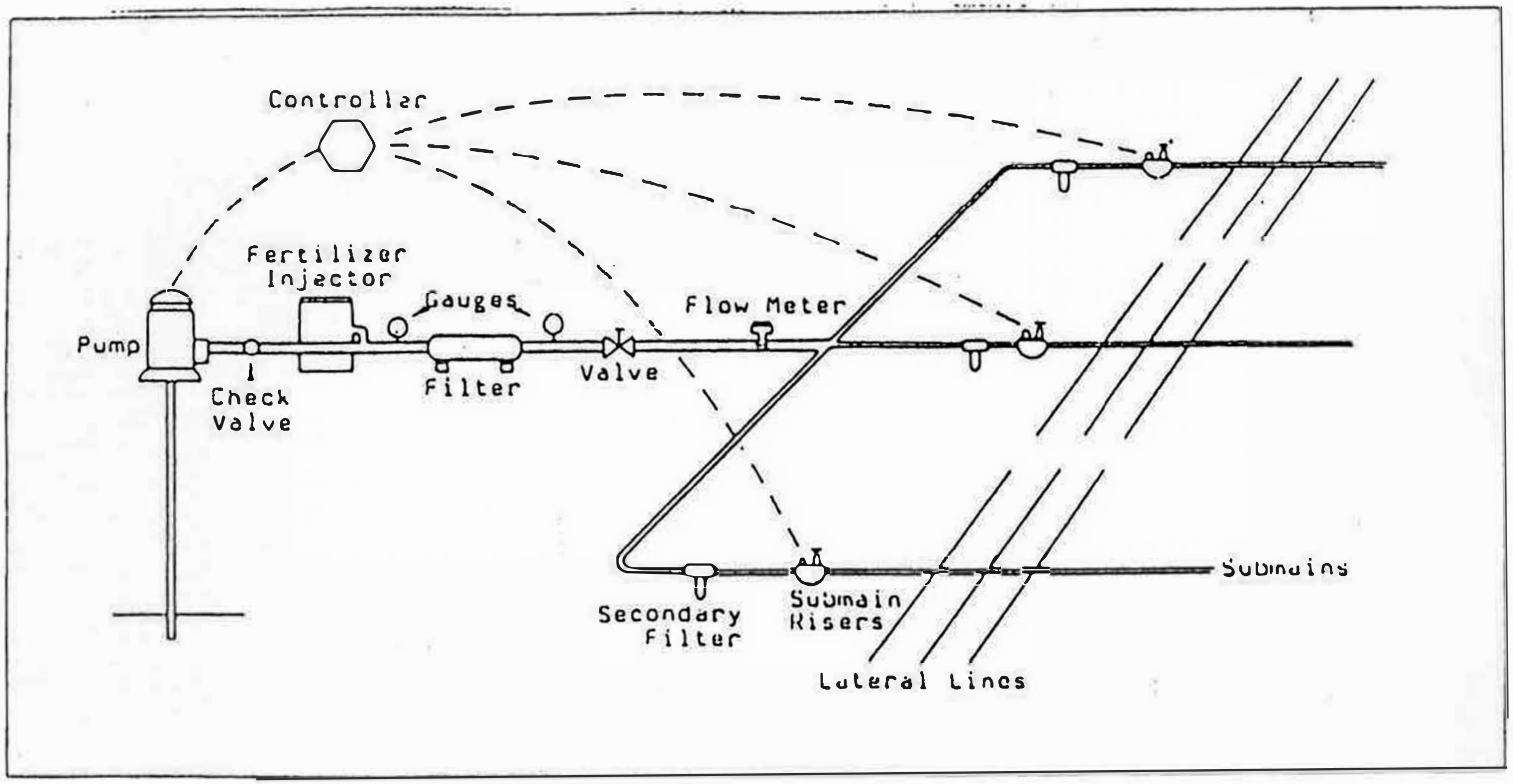


FIGURE 10-1: COMPONENTS OF A TYPICAL MICRO-IRRIGATION SYSTEM

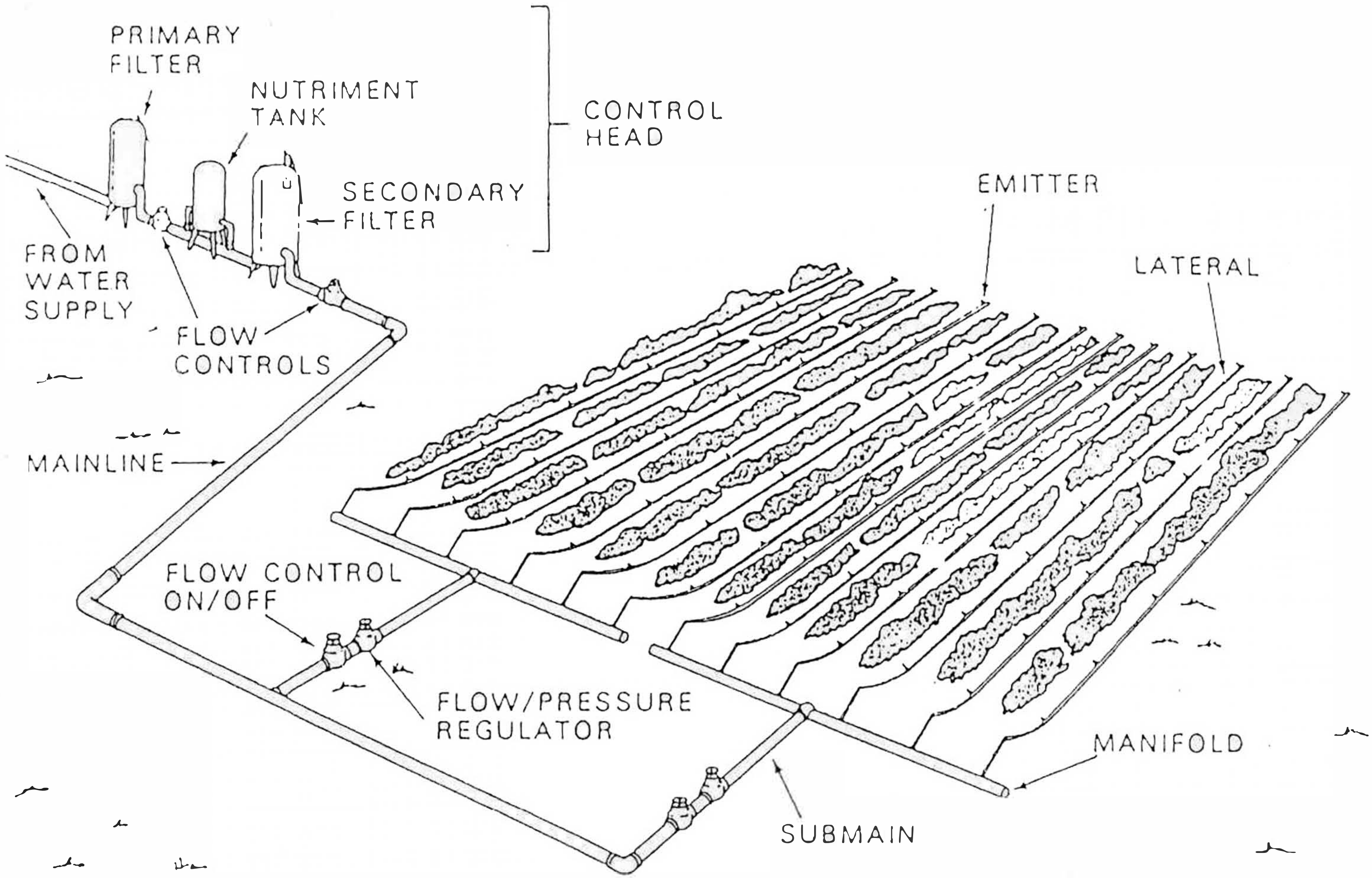


FIGURE 152. Basic units of a trickle irrigation system.

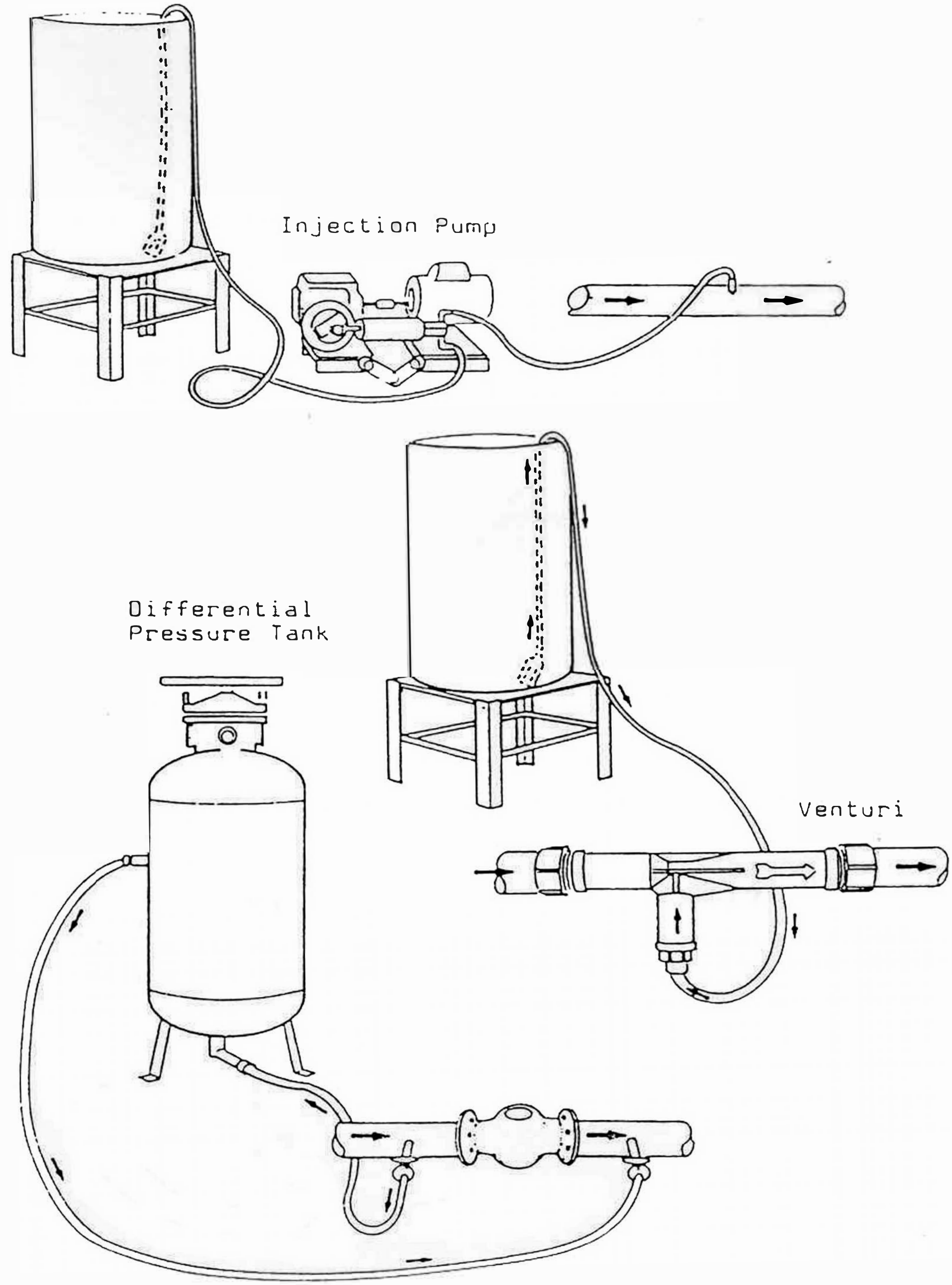


FIGURE 5-1: CHEMICAL INJECTION DEVICES

(5) Water Meters
- determines the rate water is being applied
- determine the quantity of water used
- monitors continuing performance of the irrigation system
- assist in irrigation scheduling and cost analysis

(6) Filters
- selection based on:
  - flow rate (GPM)
  - contaminate (types, site, concentration)
  - required quality
- types of filters
  - screen filter
  - centrifugal separators
  - media filters

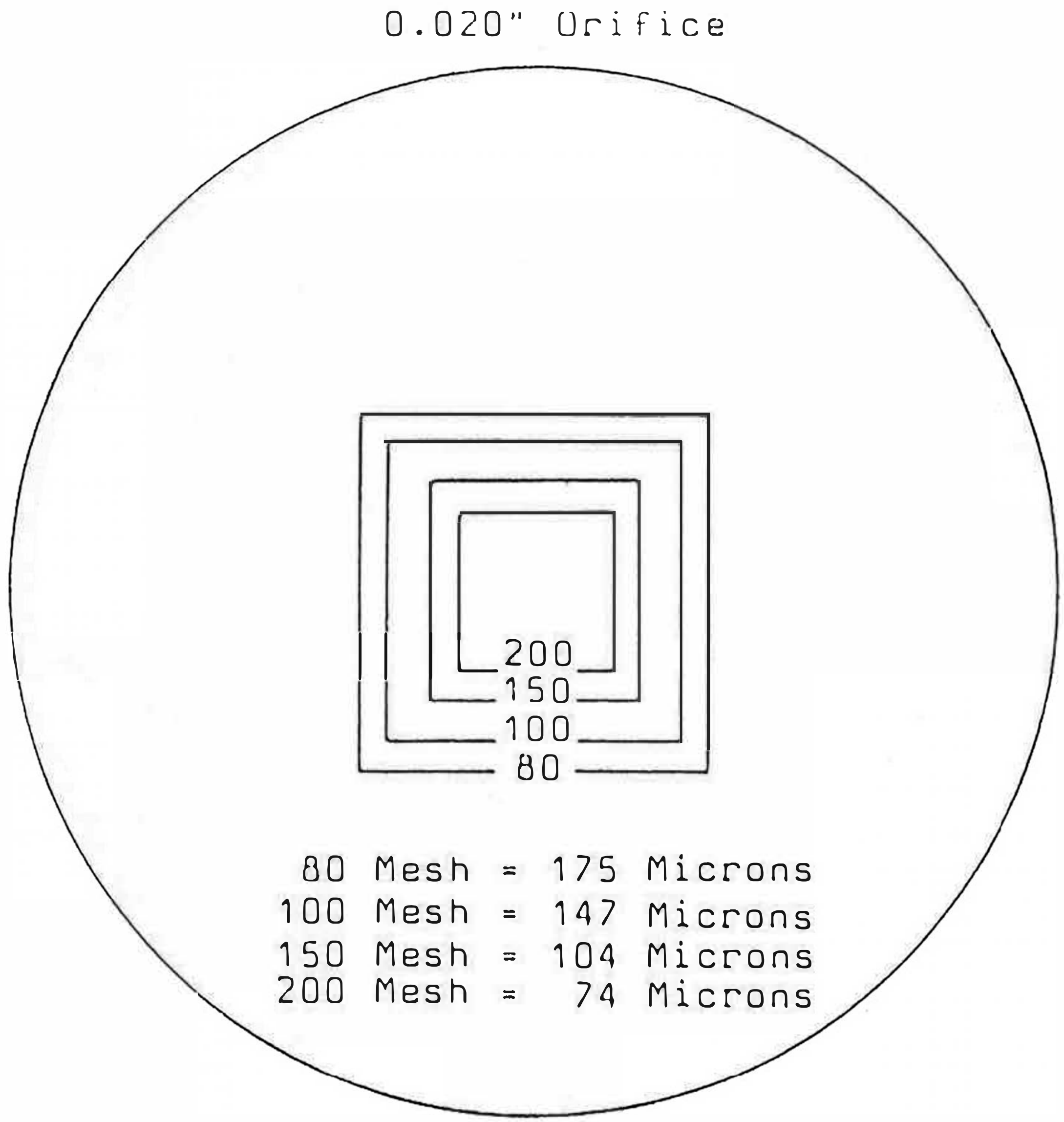
Screen Filters
- fine mesh screen enclosed within a cased housing
- primarily for filtering water containing inorganic materials i.e. sand, silt, scale
- remove small amounts of organic contaminants
- cannot trap and hold large amounts of organic material without restricting the flow

Centrifugal Sand Separators
- remove sand, scale and other particles that are heavier than water
- often installed on suction side of pump
- self cleaning
- require minimum maintenance
- must be sized correctly

Media Filters
- filters water containing either organic or inorganic contaminants
- ability to hold and entrap large quantities of contaminants
- water is filtered through sand
  - *Selection of sand type
    - too coarse sand will lead to poor filtration and system clogging
    - too fine sand will cause unnecessary and excessive backwashing ofo the filter
    - depends on type of emitters or strip tubing used in the system
- must be cleaned by backwashing or reversing the direction of water flow through the bed

(7) Pressure Gauges
- used to measure pressure at critical locations, i.e. entrance of mains and submains
- may indicate pressure loss due to clogging before and after a filter
- may indicate leakage, line breaks, etc.

(8) Pressure Regulators



JRE 4-1: SCREEN MESH SIZES COMPARED TO 0.020-INCH ORIFICE

TABLE 3.2.1

Classification of screens and particle sizes.

Screen mesh no.	Equivalent diameter (micrometer)	Particle designation	Equivalent diameter (micrometer)
16	1180	Coarse sand	>1000
20	850	Medium sand	250-500
30	600	Very fine sand	50-250
40	425	Silt	2-50
100	150	Clay	<2
140	106	Bacteria	0.4-2
170	90	Virus	<0.4
200	75		
270	53		
400	38		

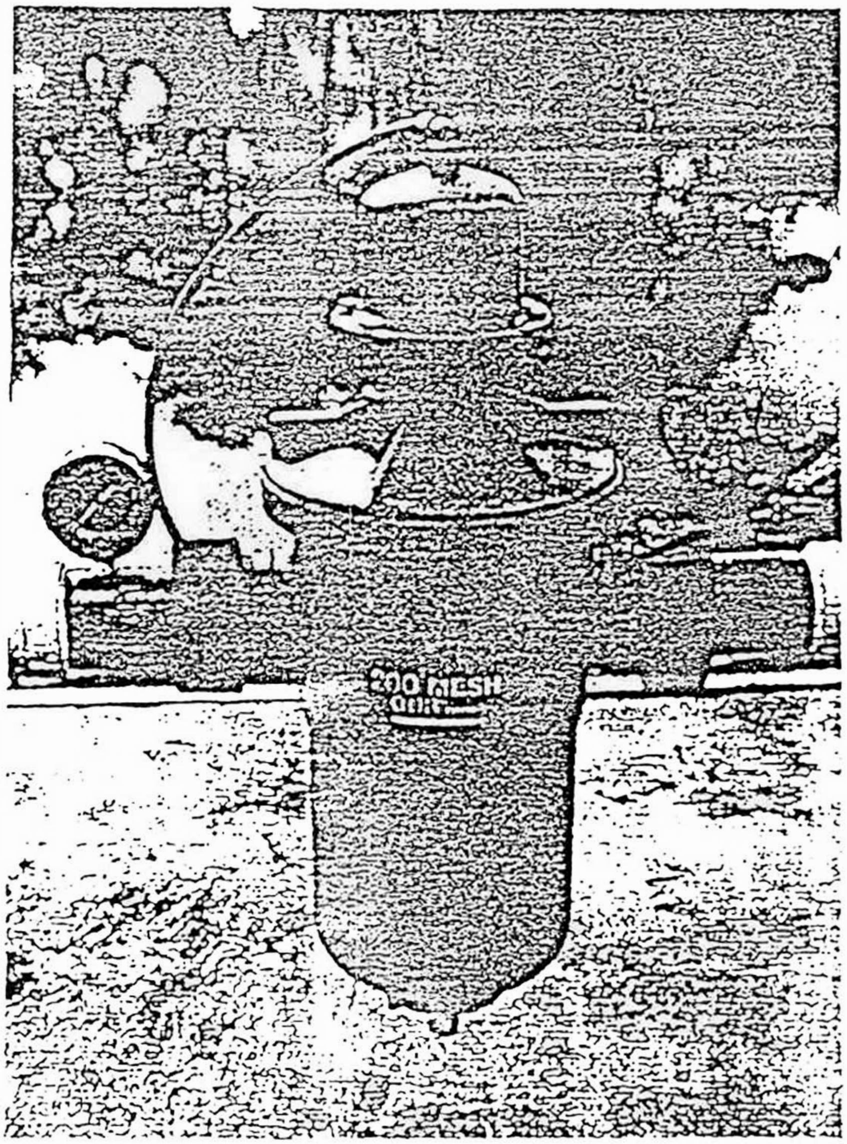
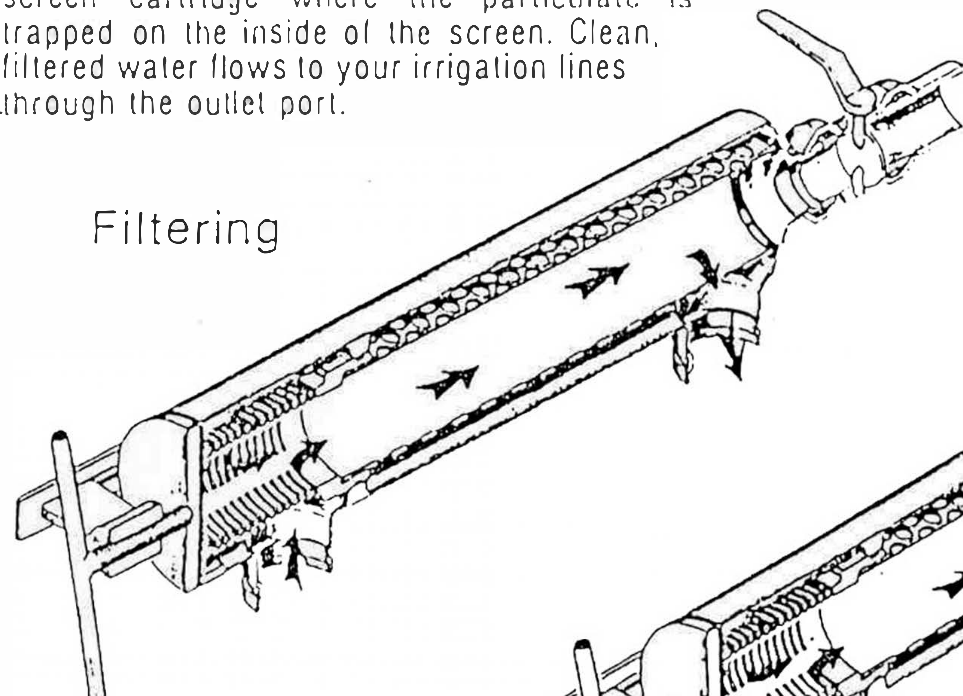


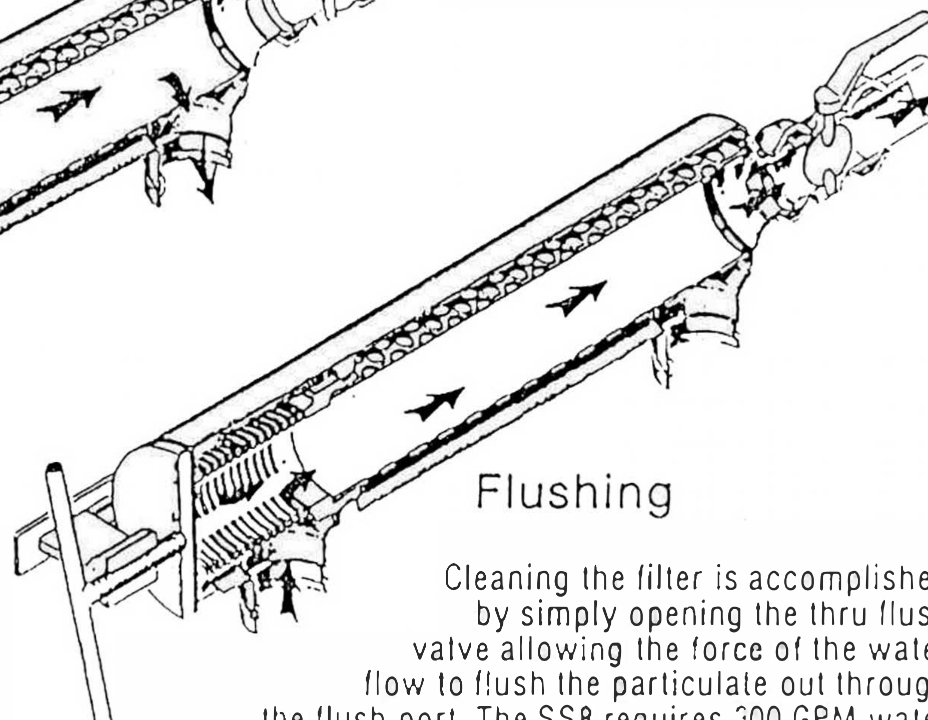
FIGURE 160. Filter commonly used in trickle irrigation.

The "Thru Flush" System

During the filtering mode, source water enters the filter through the inlet port and then through the screen cartridge where the particulate is trapped on the inside of the screen. Clean, filtered water flows to your irrigation lines through the outlet port.

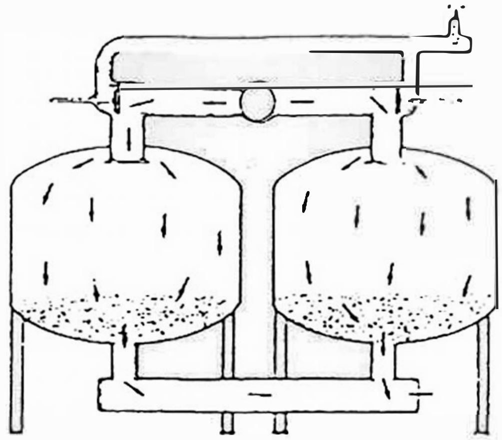


Filtering

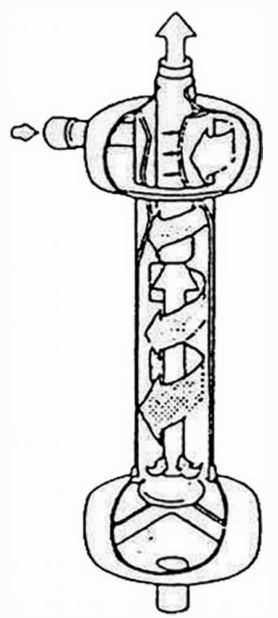


Flushing

Cleaning the filter is accomplished by simply opening the thru flush valve allowing the force of the water flow to flush the particulate out through the flush port. The SS8 requires 300 GPM water available to provide the thru-flushing cleaning action. The SS6 requires 150 GPM water available to provide thru-flush cleaning action.



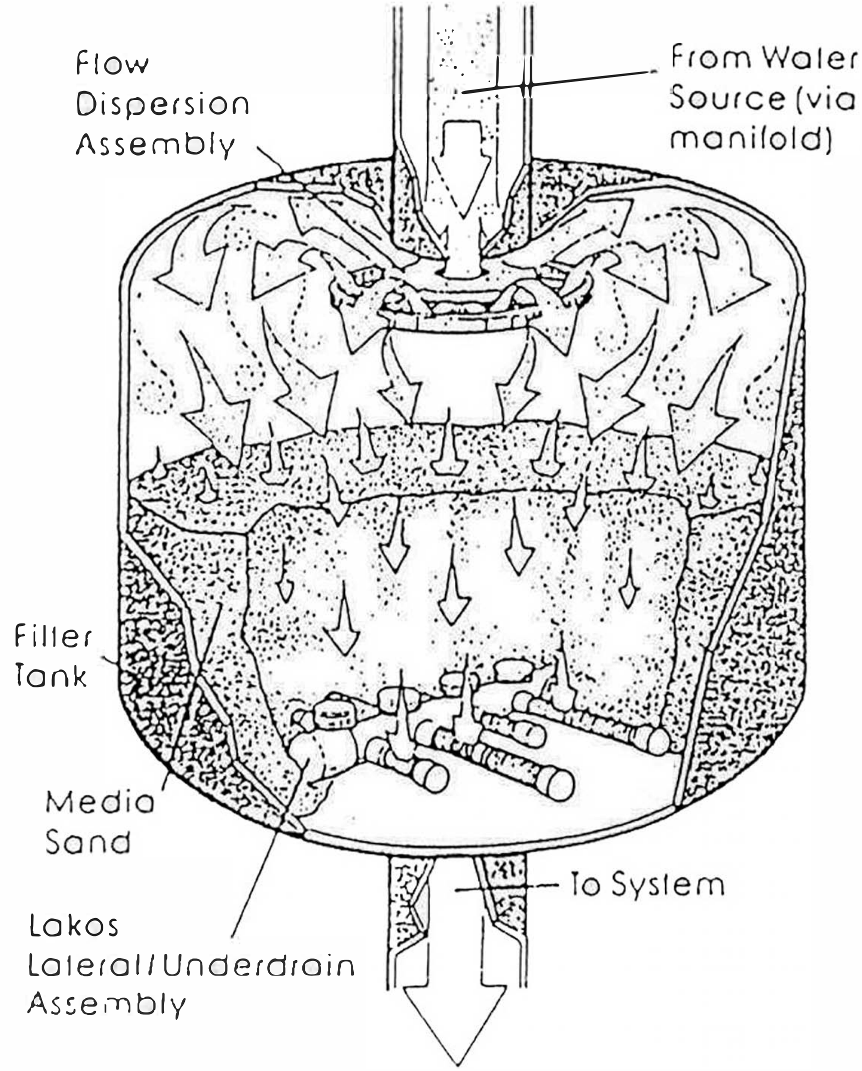
Media Filter

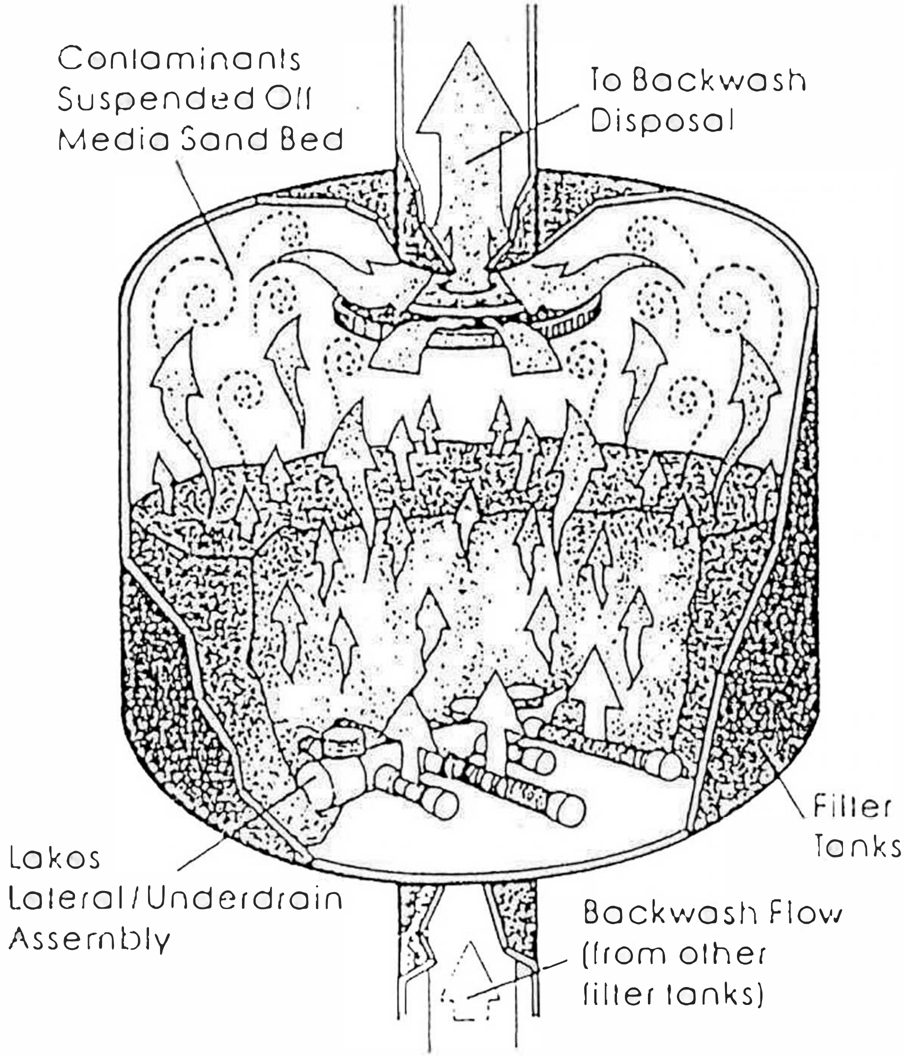


Centrifugal
Separator

FIGURE 4-2: COMMON TYPES OF FILTRATION EQUIPMENT

Lakos Filtering Process





Lakos Backwash Process

(9) Shutoff Valves
- use to shut water flow off completely
- placed in control station unit and at the head of submains

(10) Controllers
- time clock that will operate over a two week period and will turn on and off automatic valves for a given period of time each day or every other day
- subunits can automatically be irrigated in sequence thus saving time and labor

(11) Pressure Relief Valves
- installed to prevent high pressures
    1) Sudden opening or closing of a valve
    2) Starting or stopping of a pump
    3) Pressure regulating valve failure
    4) Slamming shut of a check valve
    5) Failure to evaluate static as well as dynamic pressure conditions for a pipeline
- hydraulic or electric valves
- automatic unlimited number of cycles
- order of operation can be changed
- operating time and quantity of water can be changed

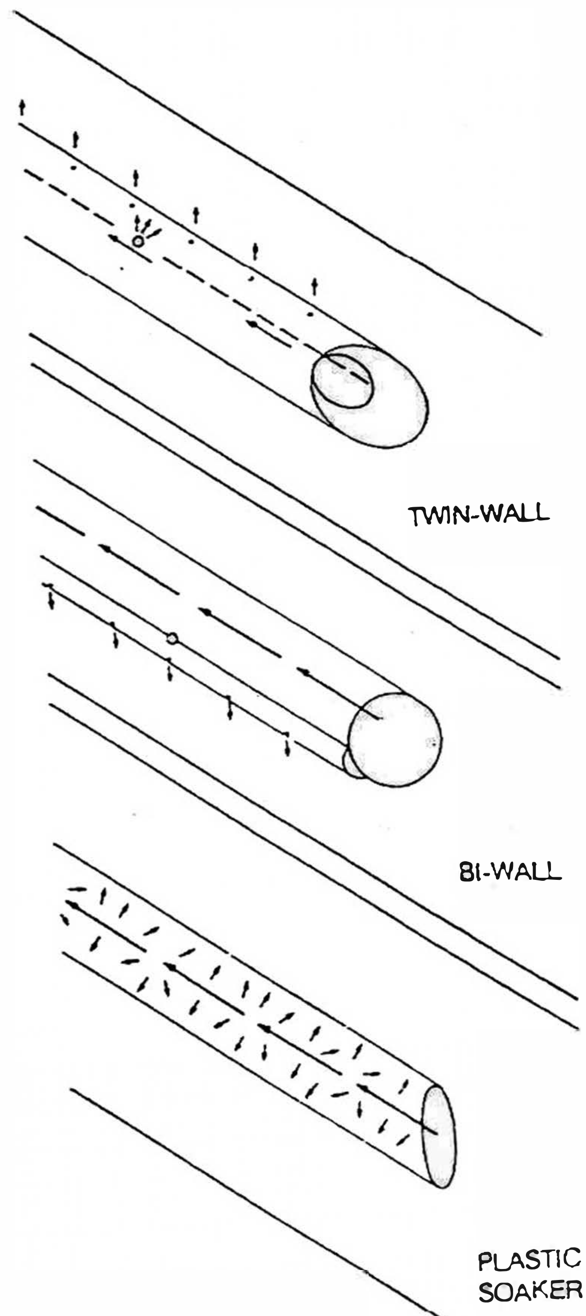
b. Main, Submains, and/or Manifolds
- transports water from source to submain lines

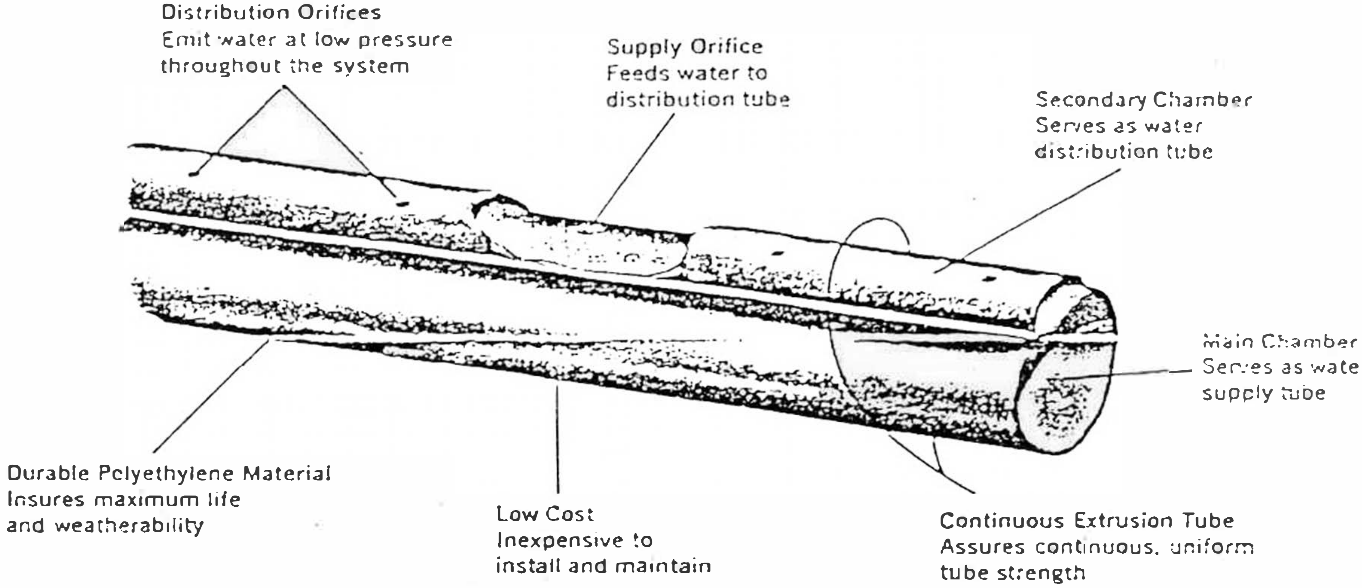
Submain (Manifolds)
- transports water from mainlines to laterals

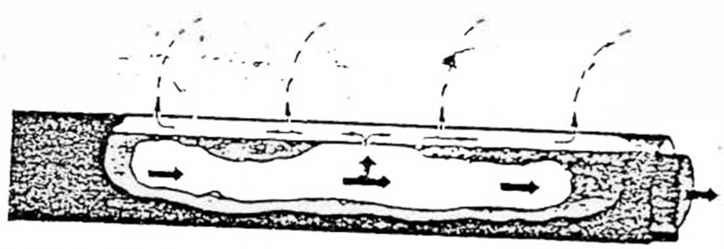
Supply or Feeder Tubes
- supply water from the submain to the drip line
- allows for correct pressure into the drip line

c. Lateral Line
- strip tubing
- hose with emitters

(1) Strip tubing
Types
- Twin wall
    - essentially a tube within a tube
    - water discharged from the supply tube enters the inside tube moves through the length of the row
    - water moves out through interior holes into the outer tube
    - outer tube has perforations every 'x' inches through which water seeps into the soil
- Bi-wall
    - consists of main chamber which water flows until pressure is same throughout the line
    - water flows into a secondary chamber on top of the main chamber and is distributed through holes along the entire chamber


TWIN-WALL
BI-WALL
PLASTIC
SOAKER


Distribution Orifices
Emit water at low pressure
throughout the system
Supply Orifice
Feeds water to
distribution tube
Secondary Chamber
Serves as water
distribution tube
Main Chamber
Serves as water
supply tube
Durable Polyethylene Material
Insures maximum life
and weatherability
Low Cost
Inexpensive to
install and maintain
Continuous Extrusion Tube
Assures continuous, uniform
tube strength



(2) Emitters

-Deliver water from laterals to soil at a specific point

-4 types of emitters

(a) Laminar flow

-smooth fluid flow at low velocities

-simple, reliable, inexpensive

-flow varies significantly with pressure

-susceptible to clogging

Ex) Microtubes, capillary tubes, spiral path

(b) Turbulent flow emitters

-fluid particles move rapidly in irregular, random motions

-resistant to clogging

-less sensitive to pressure variations

(c) Vortex emitters

-less pressure sensitive than turbulent emitter

-water passages are very small

-easily clogged by soil particles

-require high quality filtering system

-requires attentive management

Ex) Orific vortex emitter

(d) Pressure compensating emitters

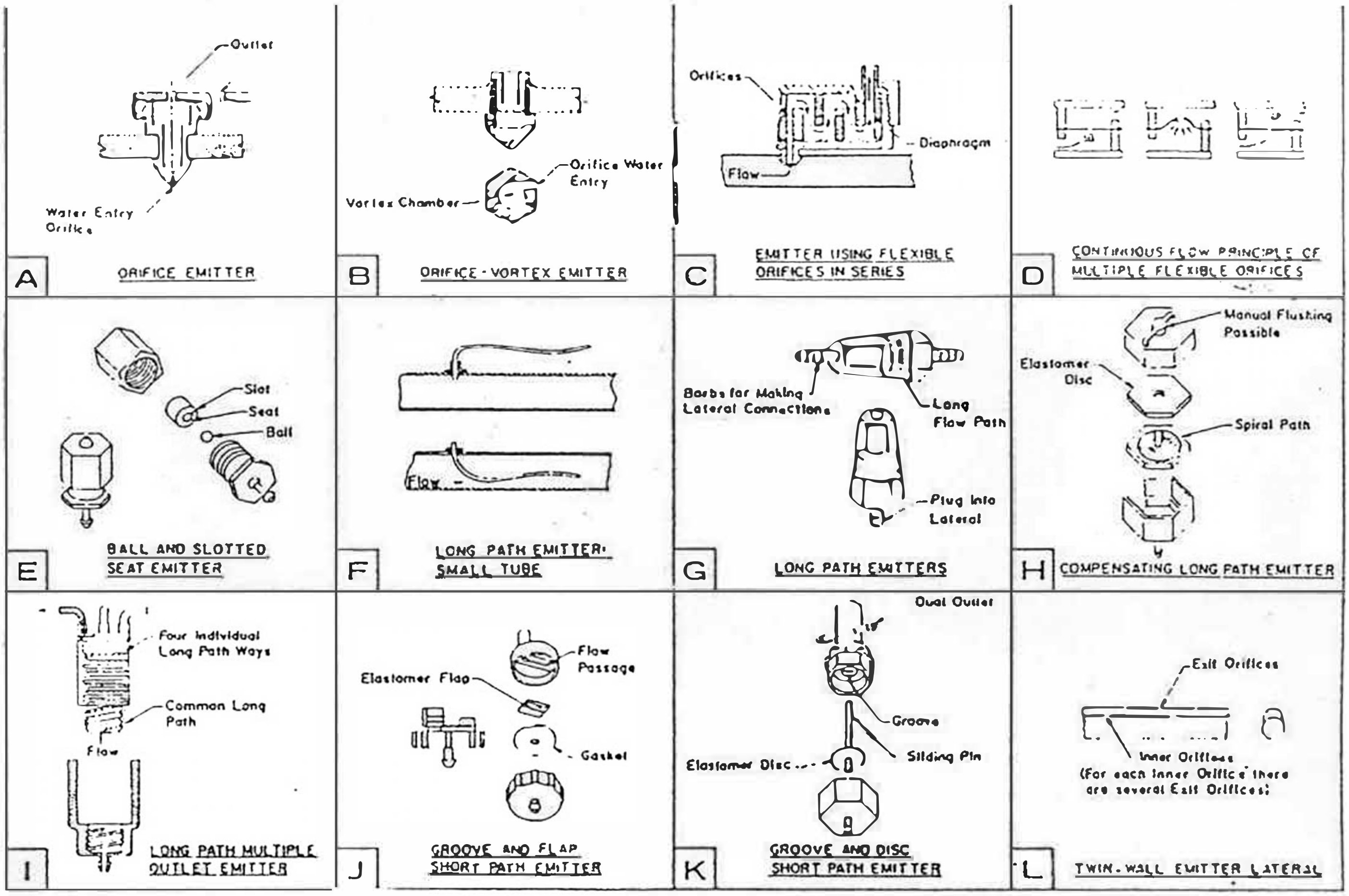
-may be laminar or turbulent

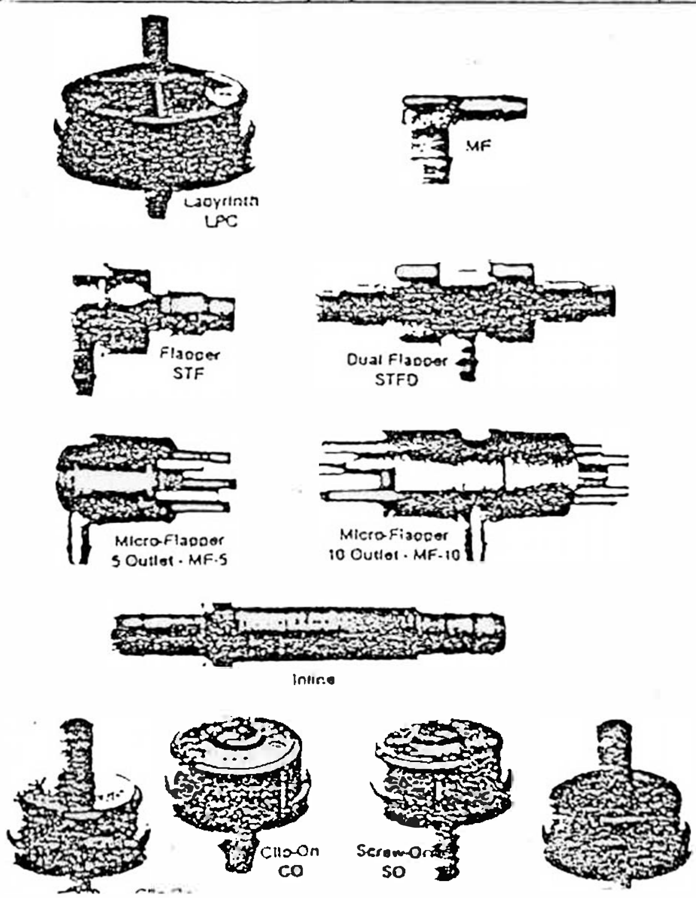
-delivers correct flow rate over a range of inlet pressures

-flow is relatively constant

-flow path is modified by elastomeric disc, diaphragm or changing water passage

-may be used on steep or undulating terrain


Outlet
Water Entry Orifice
A
ORIFICE EMITTER
Orifice Water Entry
Vortex Chamber
B
ORIFICE - VORTEX EMITTER
Orifices
Diaphragm
Flow
C
EMITTER USING FLEXIBLE ORIFICES IN SERIES
D
CONTINUOUS FLOW PRINCIPLE OF MULTIPLE FLEXIBLE ORIFICES
Slot
Seat
Ball
E
BALL AND SLOTTED SEAT EMITTER
Flow
F
LONG PATH EMITTER: SMALL TUBE
Barbs for Making Lateral Connections
Long Flow Path
Plug Into Lateral
G
LONG PATH EMITTERS
Manual Flushing Possible
Elastomer Disc
Spiral Path
H
COMPENSATING LONG PATH EMITTER
Four Individual Long Path Ways
Common Long Path
Flow
I
LONG PATH MULTIPLE OUTLET EMITTER
Flow Passage
Elastomer Flap
Gasket
J
GROOVE AND FLAP SHORT PATH EMITTER
Dual Outlet
Groove
Sliding Pin
Elastomer Disc
K
GROOVE AND DISC SHORT PATH EMITTER
Exit Orifices
Inner Orifices
(For each Inner Orifice there are several Exit Orifices)
L
TWIN-WALL EMITTER LATERAL


Labyrinth
LPC
MF
Flapper
STF
Dual Flapper
STFD
Micro-Flapper
5 Outlet - MF-5
Micro-Flapper
10 Outlet - MF-10
Inline
Clip-On
CO
Screw-On
SO

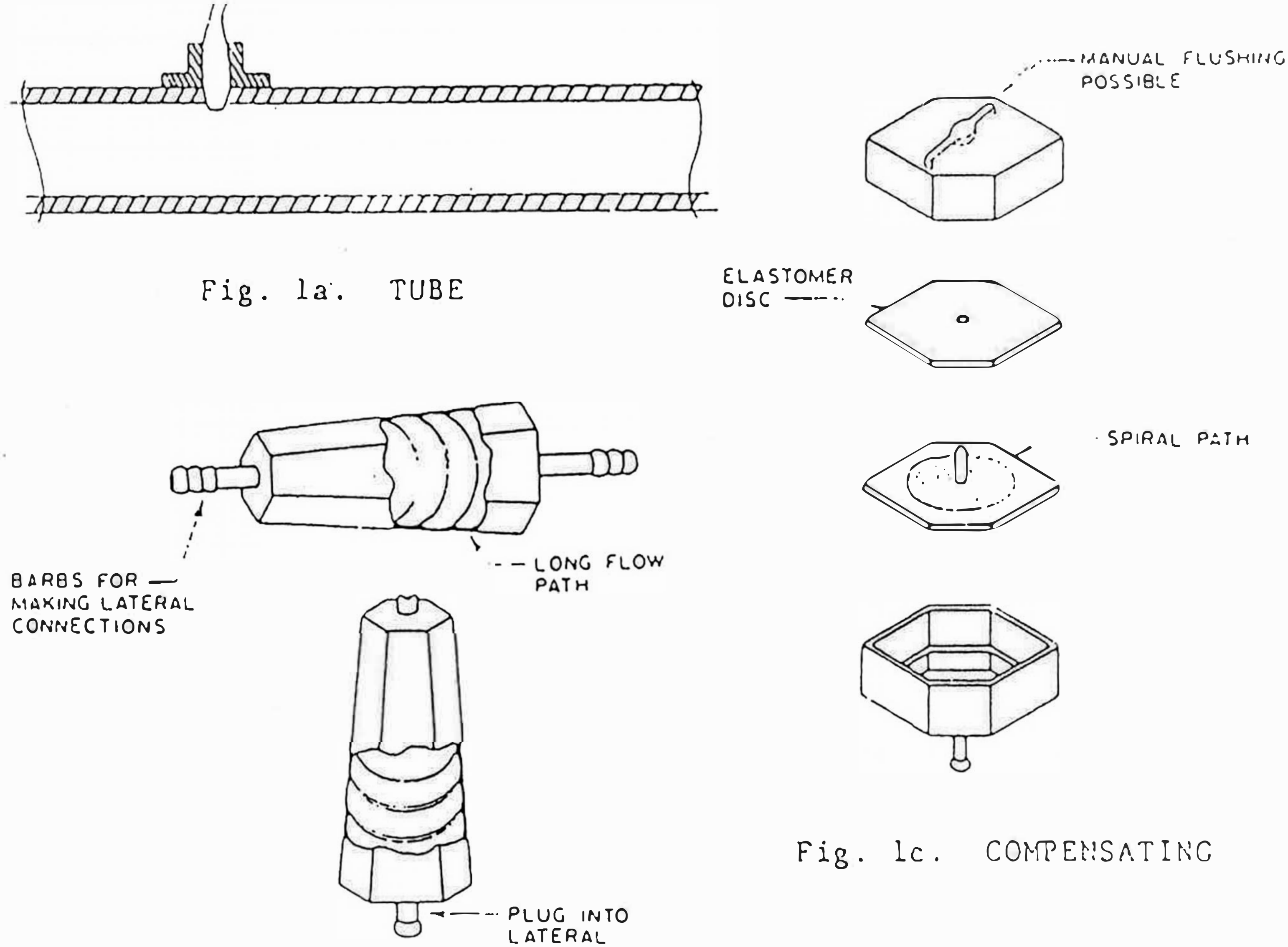


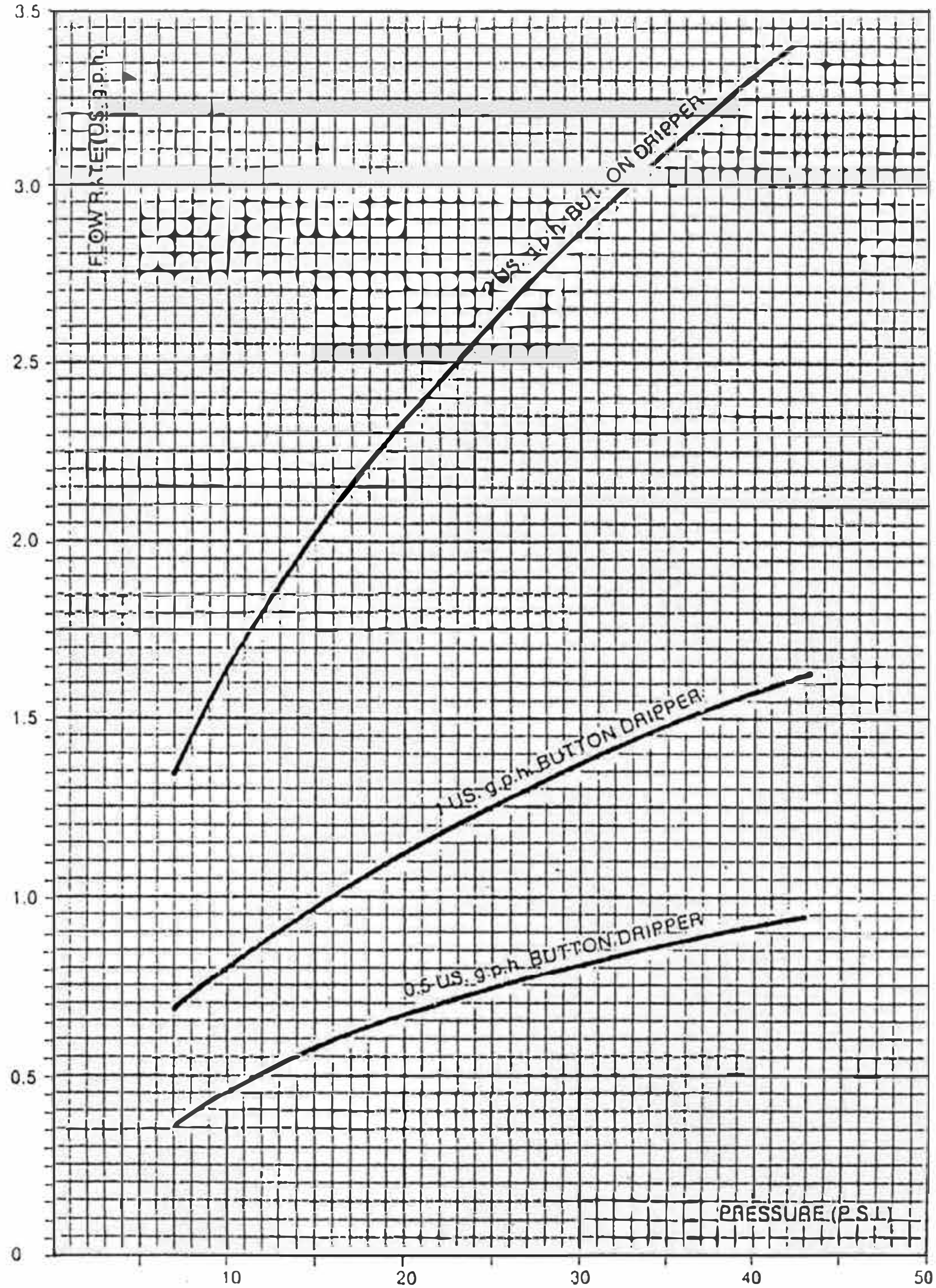
Fig. 1a. TUBE

Fig. 1b. SPIRAL

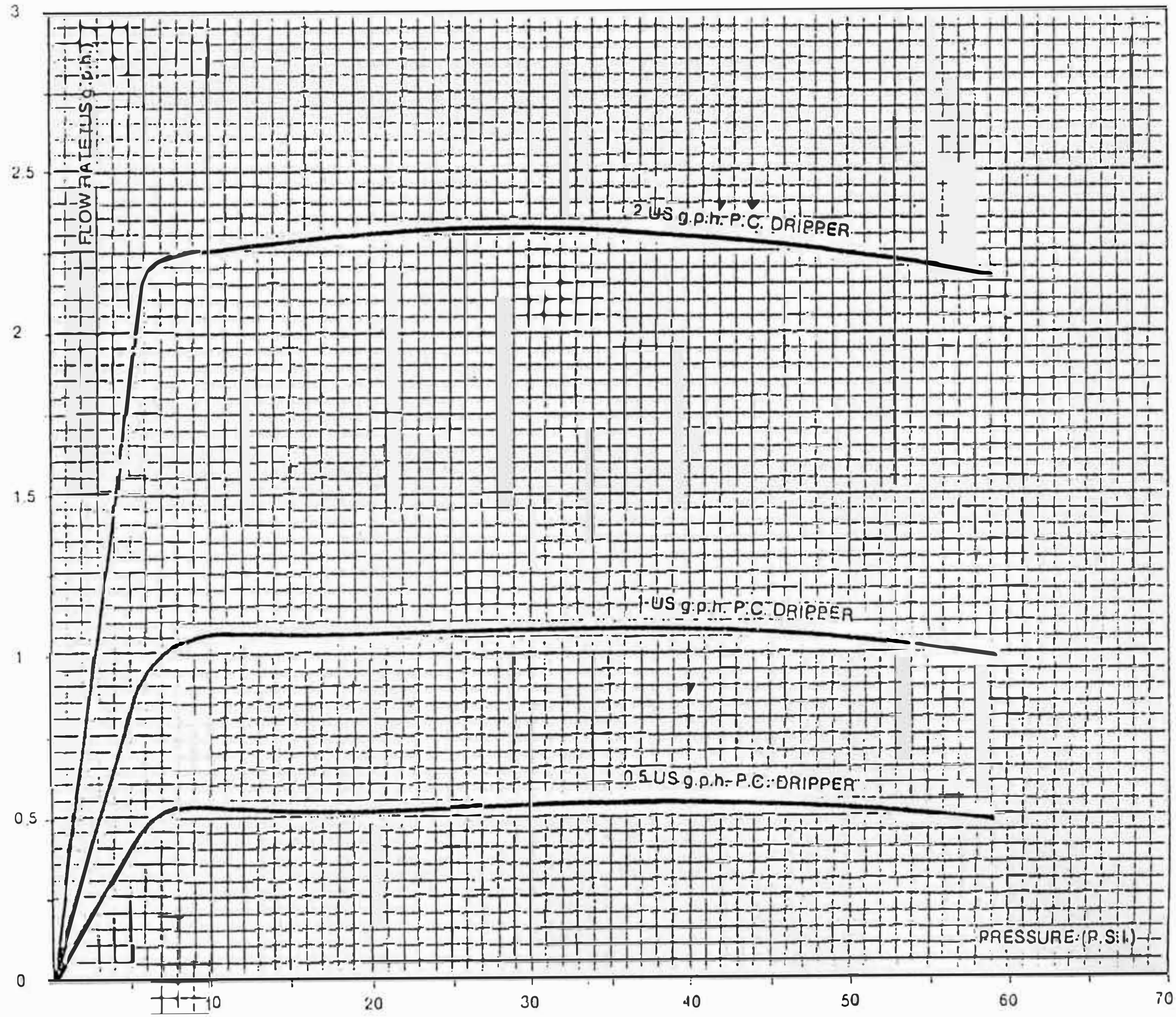
Fig. 1c. COMPENSATING

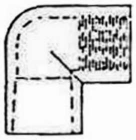
Fig. 2.1.1 Laminar (long path) emitters.
1a. Tube type laminar emitter.
1b. Spiral long path emitter.
1c. Compensating spiral laminar emitter.

BUTTON DRIPPERS
PRESSURE VS. FLOW RATE

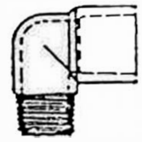


PRESSURE COMPENSATED DRIPPERS
FLOW RATE VS. PRESSURE CHART

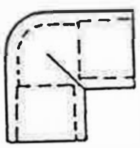




REDUCING ELL
(Slip x Fipt)



90° STREET ELL
(Slip x Mipt)



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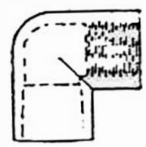

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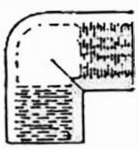
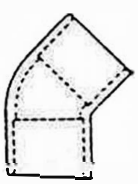


THREADED ELL
(Fipt x Fipt)

STREET ELL
(Fipt x Mipt)



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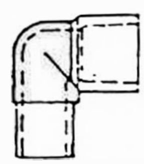
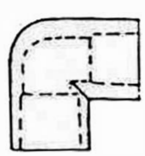
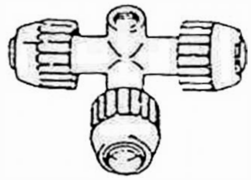


90° STREET ELL
(Slip x Slip)

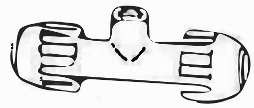


REDUCING ELL
(Slip x Slip)

TEES SIDE OUTLET
(Insert x Fipt)

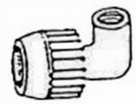


TEES COMBINATION
(Insert x Fipt)

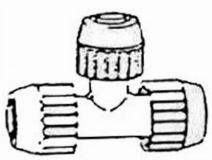


ELBOWS, ADAPTERS
(Insert x Mipt)

ELBOWS COMBINATION
(Insert x Fipt)

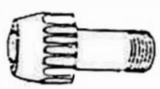


TEES
(Insert)



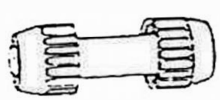
ELBOWS, CORNER
(Insert x Fipt)

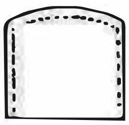
ADAPTERS
(Insert x Mipt)



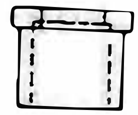
ELBOWS
(Insert)

COUPLINGS
(Insert)

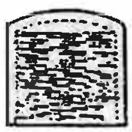




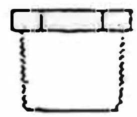
CAP
(Slip)



PLUG
(Spigot)

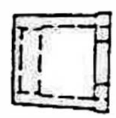


CAP
(Fipt)



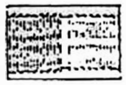
PLUG
(Mipt)

REDUCER BUSHING
(Spigot x Fipt)

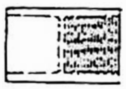


REDUCER BUSHING
(Spigot x Slip)

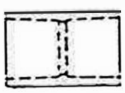
THREADED BUSHING
(Mipt x Fipt)



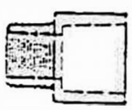
COUPLING (Threaded)
(Flpt x Flpt)



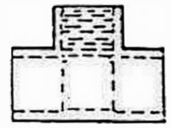
FEMALE ADAPTER
(Slip x Flpt)



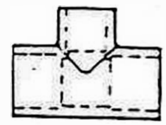
COUPLING
(Slip x Slip)



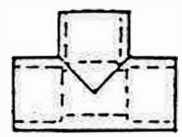
MALE ADAPTER
(Mlpt x Slip)



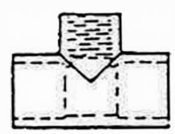
TEE
(Slip x Slip x Flpt)



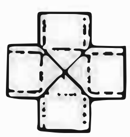
REDUCING TEE
(Slip x Slip x Slip)



TEE
(Slip x Slip x Slip)

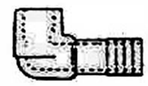


REDUCING TEE
(Slip x Slip x Flpt)

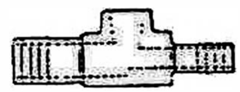


CROSS
(Slip)

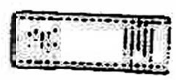
COMBINATION
AND REDUCING
ELL
(Insert x Fipt)



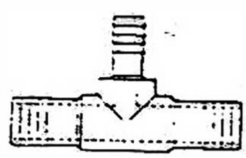
COMBINATION
AND REDUCING
TEE
(Insert x Insert x Fipt)



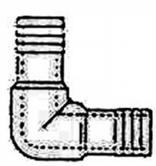
INSERT
COUPLING



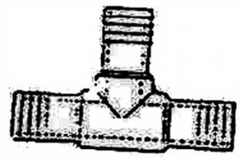
INSERT
REDUCING
TEE



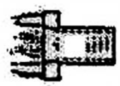
INSERT
ELL



INSERT
TEE



REDUCING
MALE ADAPTER
(Fipt x Insert)



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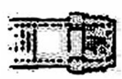
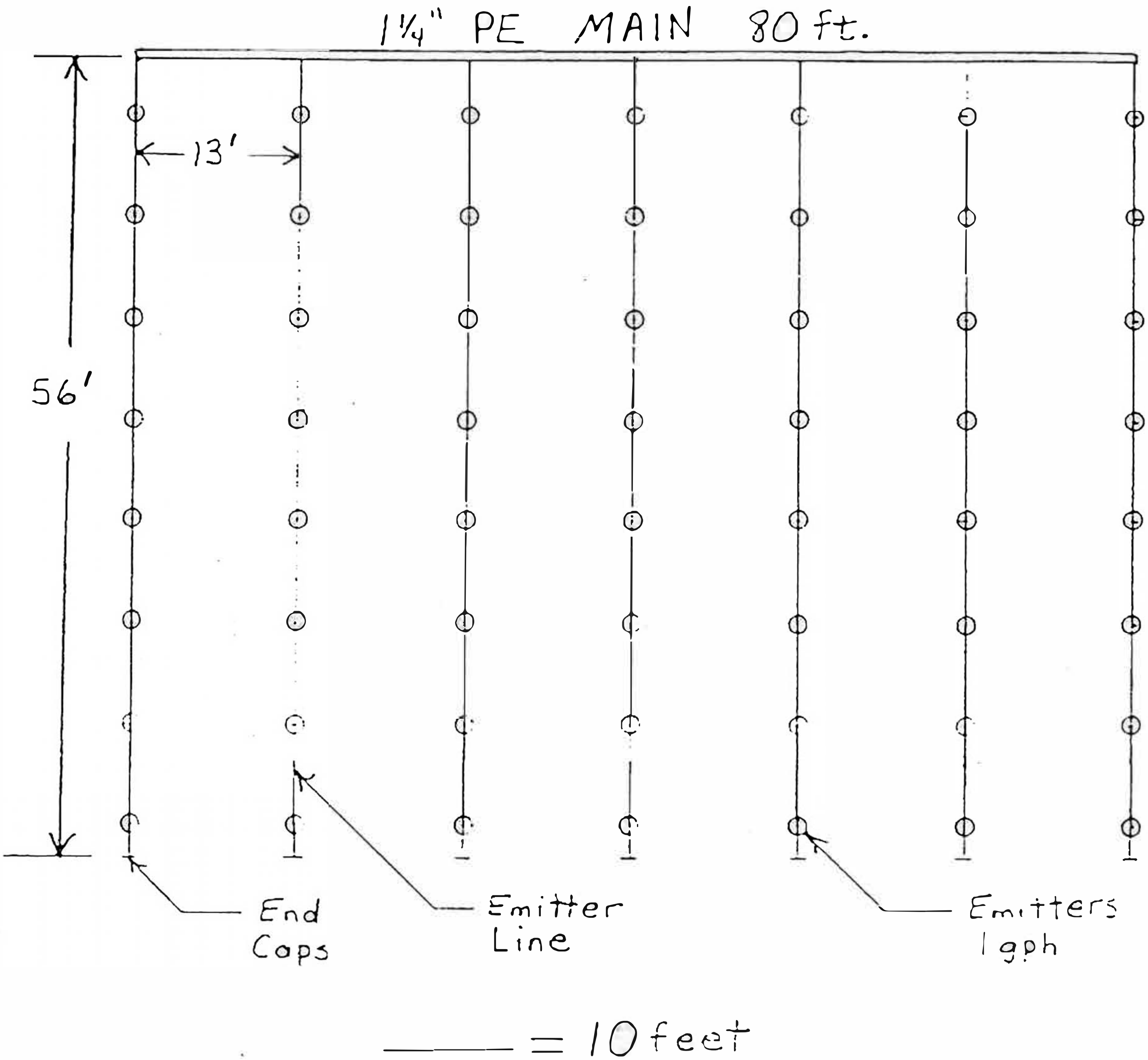
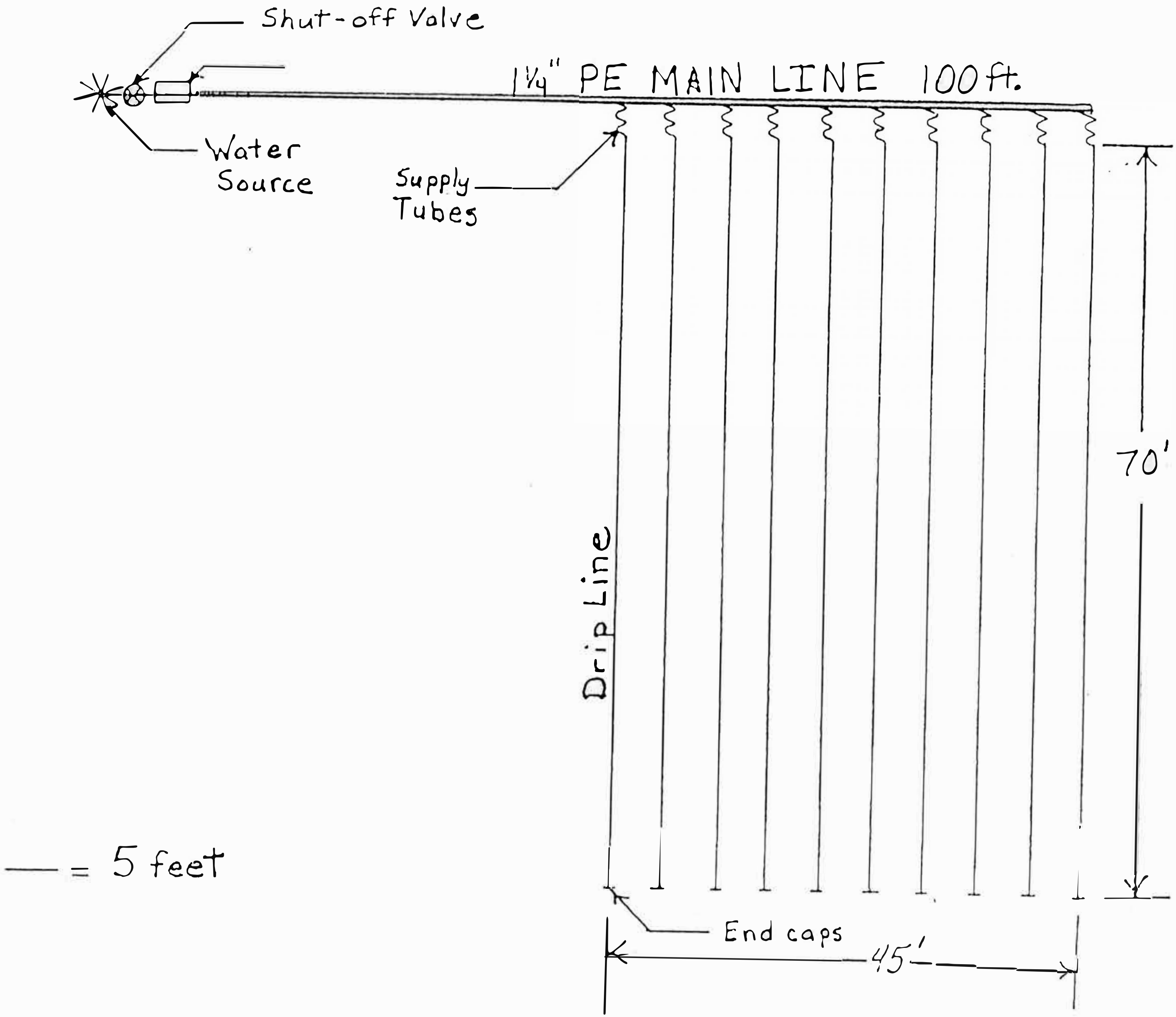
MALE ADAPTER



INSERT
REDUCING
COUPLING


1¼" PE MAIN 80 ft.
56'
13'
End Caps
Emitter Line
Emitters 1 gph
= 10 feet



Shut-off Valve
1¼" PE MAIN LINE 100ft.
Water Source
Supply Tubes
70'
Drip Line
= 5 feet
End caps
45'

6. Installation

a. Tools required

*pipe wrench

*hand saws

*PVC pipe cutter

*hacksaw

*screwdriver

*files

*crowbar

*rags

*PVC cleaner

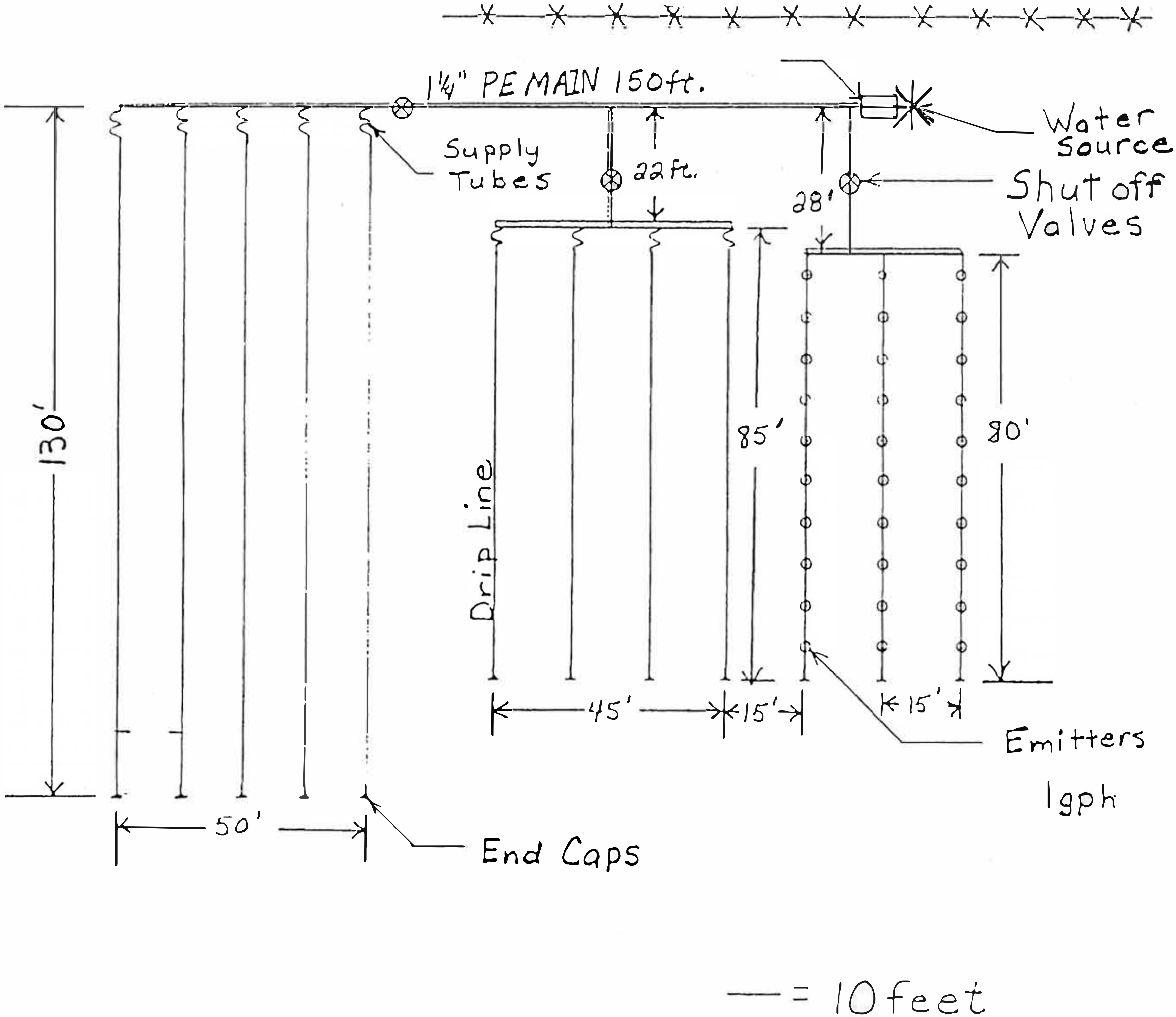
*PVC glue

*teflon tape

*emitter punch tools

*submain punch tools

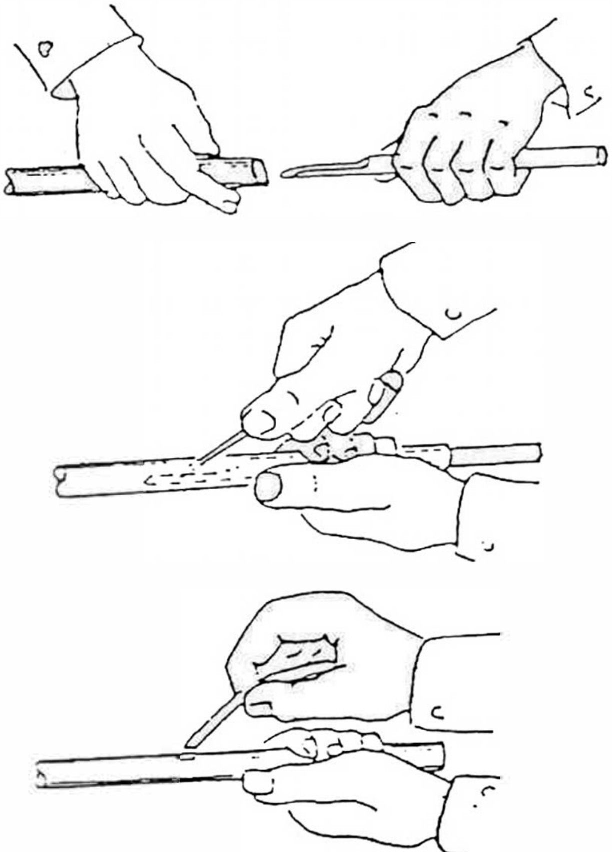
*drill with bits


1¼" PE MAIN 150ft.
Water Source
Supply Tubes
22ft.
28'
Shutoff Valves
130'
Drip Line
85'
80'
45'
15'
15'
50'
Emitters 1gph
End Caps
— = 10 feet

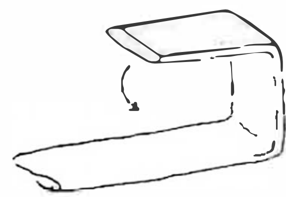
HOOK - UP TECHNIQUE

Guide

Awl

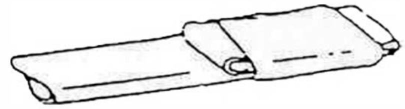


Guide used to prevent puncturing both walls

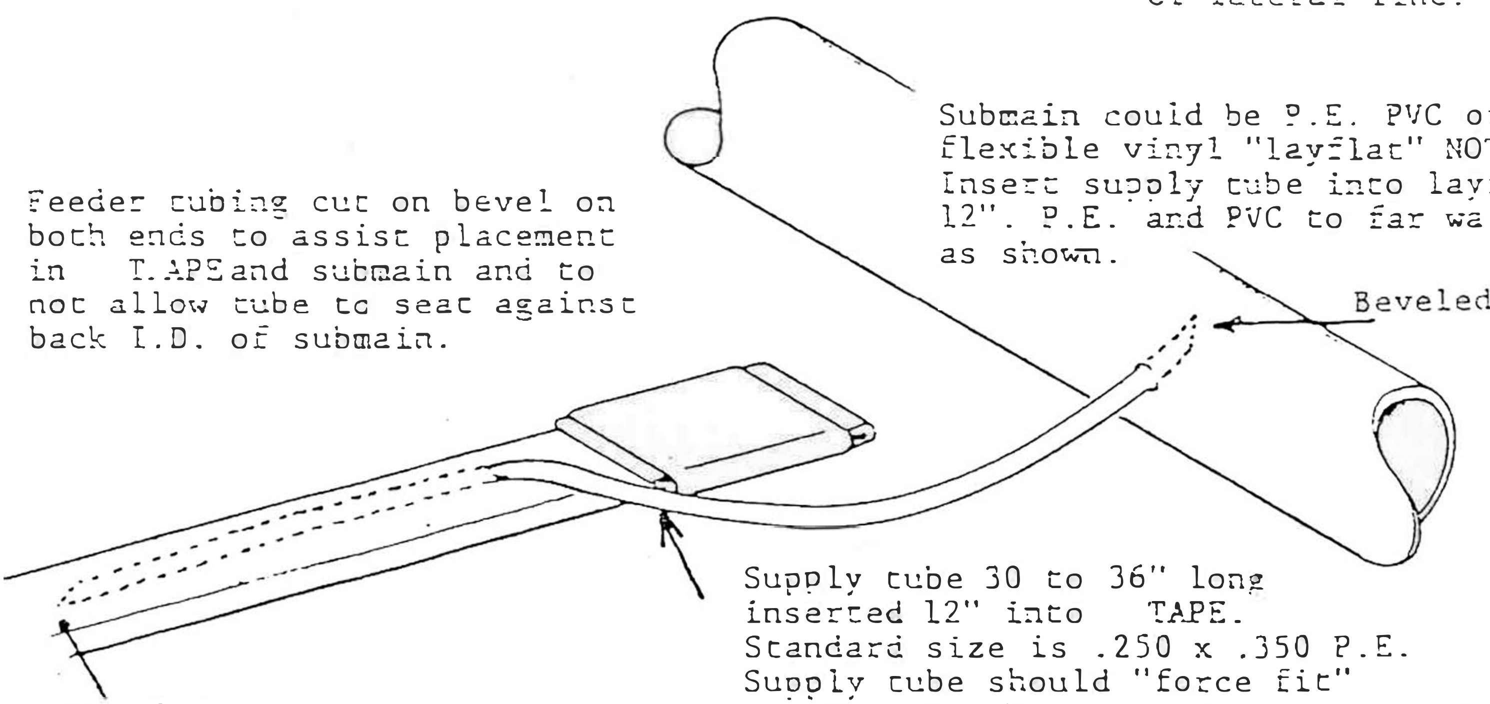


dou
over twice
(4 thickness)

2" long
sleeve



Sleeve can be remove
for periodic flushin
of lateral line.



Submain could be P.E. PVC or flexible vinyl "layflat" NOTE: Insert supply tube into layfla 12". P.E. and PVC to far wall as shown.

Feeder tubing cut on bevel on both ends to assist placement in T.APE and submain and to not allow tube to seat against back I.D. of submain.

Supply tube 30 to 36" long inserted 12" into TAPE.
Standard size is .250 x .350 P.E.
Supply tube should "force fit" TAPE and submain to insure leak-free hook-up.

b. Installation procedures

*pipe for mailines and submains is laid out

*assemble mainline and submains

*clean pipe before glueing

*make sure correct glue is being used with PVC pipe
there are different type glues for different size pipes

*in cool weather allow additional time for glue joints
to cure

*PVC pipe should be cut square

*lateral lines are installed in the field but not yet
connected to submains
care should be taken that lateral lines are not
plugged with soil, etc. Keep ends closed

*close all submain control valves

*fill mainlines with mainline valves open to flush
foreign material out of mainlines

*assemble manifold lines, leaving ends open

*punch or drill holes into manifold lines for dripline
supply tubes and emitter lines

*flush manifold lines of any foreign debris

*connect drip line and emitter line

*check system for leaks

*repair any leaks

TABLE 3.1.1

Tentative water quality criteria for indicating emitter clogging hazards (after Bucks and Nakayama, 1980).

Type of problem	Minor	Moderate	Severe
Physical			
Suspended solids[a]	50	50-100	>100
Chemical			
pH	7.0	7.0-8.0	>8.0
Dissolved solids[a]	500	500-2,000	>2,000
Manganese[a]	0.1	0.1-1.5	>1.5
Total iron[a]	0.2	0.2-1.5	>1.5
Hydrogen sulfide[a]	0.2	0.2-2.0	>2.0
Biological			
Bacterial population[b]	10,000	10,000-50,000	>50,000

TABLE 3.1.2

Principal physical, chemical and biological contributors to clogging of trickle systems (after Bucks et al., 1979).

Physical (suspended solids)	Chemical (precipitation)	Biological (bacteria and algae)
Inorganic particles:	Calcium or magnesium carbonate	Filaments
Sand		
Silt		Slimes
Clay	Calcium sulfate	
Plastic		Microbial decomposition:
	Heavy metal hydroxides, carbonates, silicates, and sulfides	Iron
Organic particles:		Sulfur
Aquatic plants (phytoplankton/algae)		Manganese
Aquatic animals (zooplankton)	Oil or other lubricants	
Bacteria		
	Fertilizers:	
	Phosphate	
	Aqueous ammonia	
	Iron, copper, zinc, manganese	

TABLE 3.1.3

Causes of clogging or flow reduction and relative percent occurrenc in trickle irrigation emitters at Yuma, Arizona (after Gilbert et al. 1981)[a].

Causes of clogging	Percent of occurrence Individual	Total
Physical factors		
Sand grain	17	
Plastic particles	26	
Sediment	2	
Body parts of insects and animals	3	
Deformed septa[b]	7	55
Biological factors		
Microbial slime	11	
Plant roots and algal mats	3	14
Chemical factors		
Carbonate precipitates	2	
Iron-manganese precipitates	0	2
Combined factors[c]		
Physical/biological	8	
Physical/chemical	2	
Chemical/biological	6	
Physical/biological/chemical	2	18
Nondetectable (probably physical)		

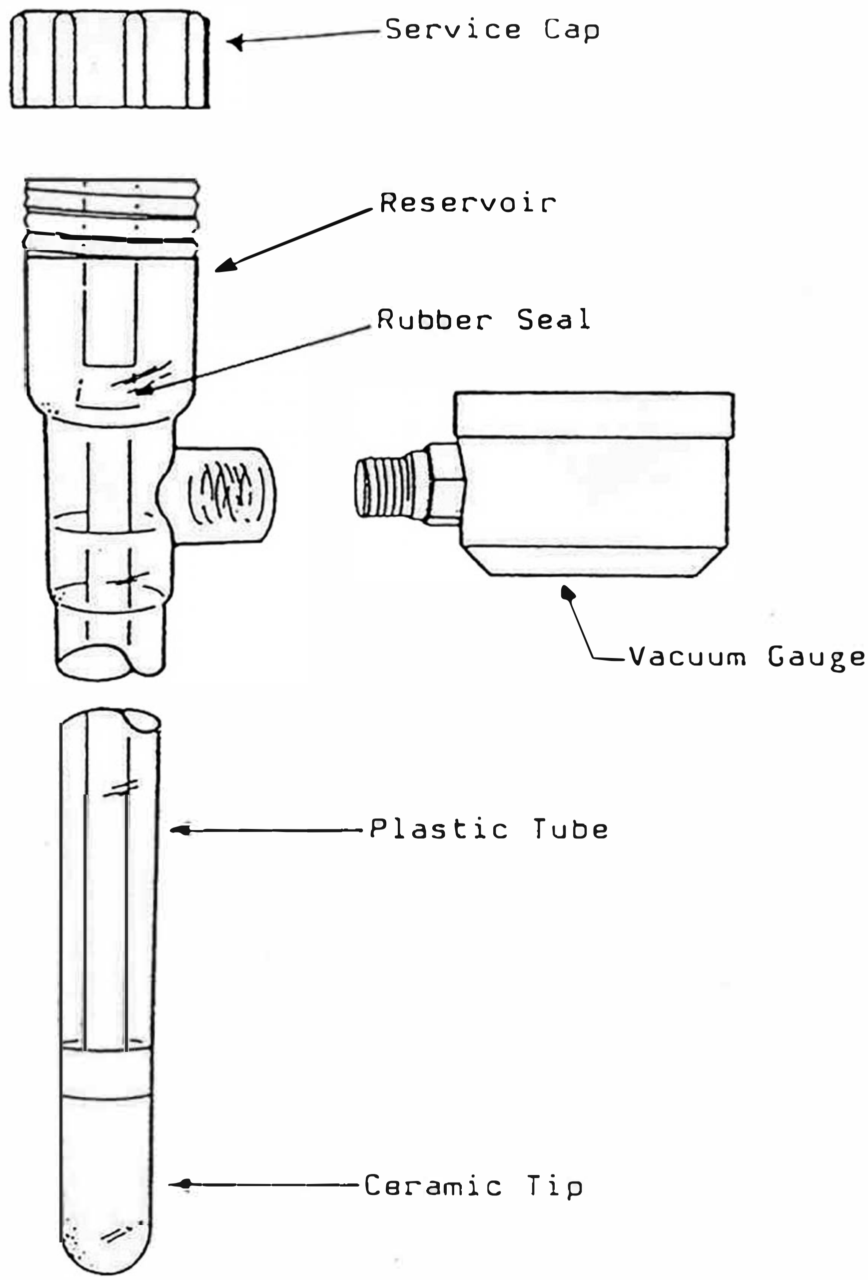


FIGURE 13-2: TENSIOMETER COMPONENTS

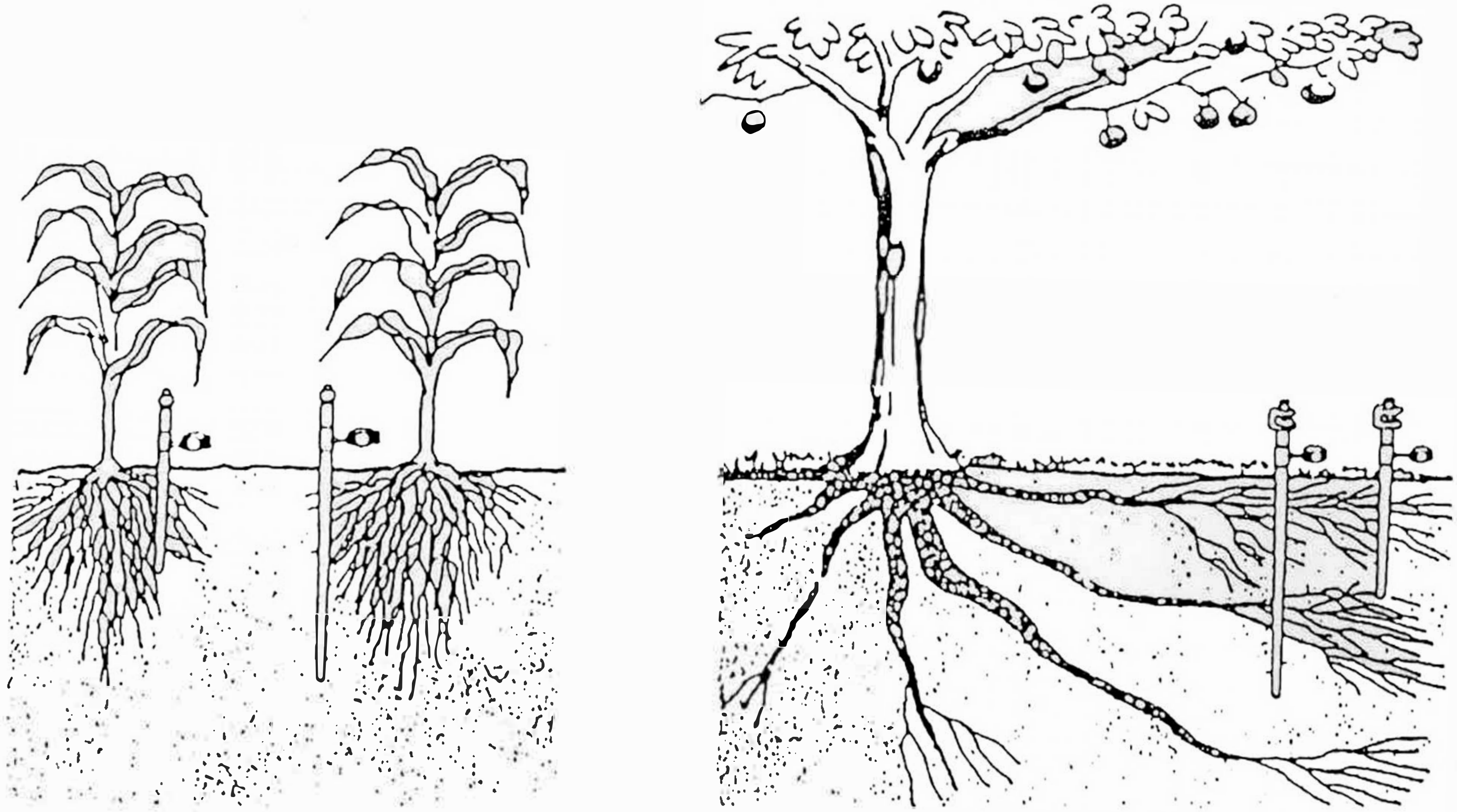


Figure 6. ---Tensiometers used to measure soil moisture.

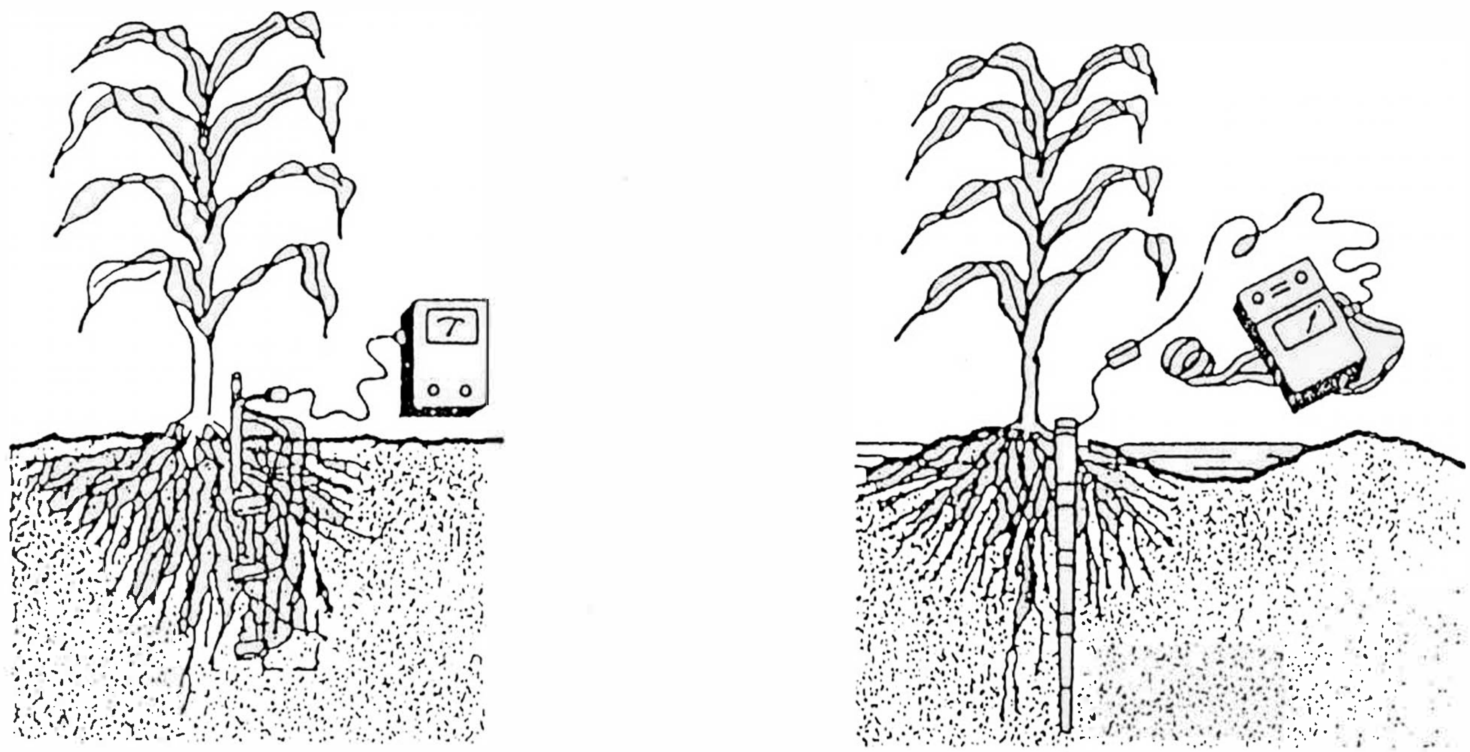


Figure 7, --Electrical-resistance soil-moisture meters.