Iseki Vacuum Systems

DESIGN MANUAL

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AMENDMENT RECORD

DATE	PAGES	ISSUE	COMMENTS
September 1998	2-6, 2-8, 2-9	#4	Amendments to maximum lengths of each vacuum sewer pipe diameter and amendments to gradients between certain invert lifts on vacuum sewer profile.

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PRELIMINARY INFORMATION

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General

Iseki Utility Services Ltd. is a worldwide manufacturer, designer and installer of vacuum transportation systems. Iseki's innovative technology has primarily been used to collect sewage from domestic and industrial property, but it has also been used to solve seemingly intractable problems in other situations such as roof drainage and replacement of failed sewers in inaccessible locations. Please contact Iseki in the UK for advice and assistance on these and other special applications.

Iseki vacuum interface valves are manufactured in the UK to stringently controlled standards of both construction and testing.

Plastic Pipe Selection

The material generally used for vacuum sewerage networks is polyethylene.
Detailed specifications for this material can be found in this Design Manual at Chapter 3, Sub-section 3.1.1.1 polyethylene pipe.

The principal advantages of this material are its resiliency and strength which means that ground movement, settlement, etc.,do not cause cracks or breaks in the lines. Also, the use of electro-welded couplers creates joints that have even greater strength than the pipe itself, as opposed to other jointing techniques which create joints somewhat weaker than the pipe.

As an alternative, consideration may be given to the use of uPVC pipe information on which can be found in Chapter 3, Sub-section 3.1.1.2 uPVC pipe

In this manual, reference is generally made first to polyethylene pipe in standard metric measurements followed by the equivalent uPVC pipe sizes. Please contact Iseki for any further detailed information required on this subject.

Safety

All of the following advice and requirements are based upon the assumption that the collection station will be maintained in an adequately fenced and secured condition so as to prevent unauthorized persons gaining access and interfering with or working on any plant or structure. It is also assumed that competent and suitably trained staff will perform installation and operational and maintenance duties on the Iseki System and its mechanical and electrical equipment and components.

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It is very important to note that if Iseki recommends or suggests any equipment, material, procedure, or specification or makes any other recommendation with respect to an Iseki System, Iseki considers the recommendation or suggestion to be a requirement for a successful Iseki System.

Iseki has set forth below and elsewhere in this Design Manual certain information regarding the installation, operation and maintenance of an Iseki System and its equipment and components. The list is not meant to be complete, and clients must consult with Iseki and their engineers and contractors in connection with the installation, operation, and maintenance of an Iseki System.

Vacuum Pumps

i) Adhere at all times to the current safety legislation and local laws, codes, and regulations (hereafter "Laws").

ii) Before carrying out any work on the pumps or motors, ensure the electrical supply is isolated and cannot be re-activated from any other source.

iii) Wear adequate personal protective equipment.

iv) All work on pumps or motors must be carried out only by appropriately qualified tradesmen or engineers.

v) After any work on the pumps or motors, check the correct operation of the emergency stops.

vi) Extreme care must be taken to avoid injury from attempted manual handling of inappropriate components.

Discharge Pumps

i) Adhere at all times to the current safety legislation and local Laws.

ii) Before carrying out any work on the pumps or motors, ensure the electrical supply is isolated and cannot be re-activated from any other source.

iii) If the pump is to be dismantled or removed for repairs or maintenance, steam clean the pump to remove any debris and kill any bacteria that may be present.

iv) Wear adequate personal protective equipment.

v) All work on pumps or motors must be carried out only by appropriately qualified tradesmen or engineers.

vi) Upon completion of maintenance or repair, ensure all covers are correctly refitted before activating the Iseki System. For those covers that must be left open to make adjustments, additional care must be taken while adjustments are made and upon completion of the adjustments the covers must immediately be replaced.

vii) After any work on the pumps or motors, check the correct operation of the emergency stops.

viii) Great care must be taken to avoid injury from attempted manual handling of inappropriate components.

Electrical Control Panel

These instructions, while as explicit as practicable, assume that operational and maintenance staff are competent and have expertise in the use of the applicable electrical equipment.

I) The control panel must not be altered or adapted for use other than for which it was designed.

ii) Suitable personal protective equipment must be worn wherever appropriate.

iii) Any defects in or damage to plant or equipment must be reported immediately to supervisory management.

iv) All accidents must be reported immediately and any necessary corrective action taken.

v) Before carrying out any work on the electrical panel, isolate the equipment from the supply as follows:

- Lock the isolator switch at OFF and pocket the fuses.
- Demonstrate the electrical isolation of the equipment.
- Display a warning notice.

vi) Carry out all maintenance work strictly in accordance with the requirements of local electrical safety and other Laws.

vii) When replacing a component, the replacement must havethe same rating/tolerance as the discarded item.

viii) Compressed air must not be used to clean the panel compartments, terminal boxes, other equipment, etc.

ix) On completion of a maintenance procedure, all earth connections must be checked for good contact and cleanliness and all safety devices must be tested to ensure that the equipment has been refitted correctly.

Standby Generator

i) Adhere at all times to the current safety legislation and local Laws.

ii) Suitable personal protective equipment must be worn where appropriate.

iii) Any defects or damage to plant or equipment must be reported immediately to supervisory management.

iv) Guards must not be removed until electrical isolation has been completed and proved.

Vacuum Vessel

i) Adhere at all times to the current safety legislation and local Laws.

ii) Before opening a vessel for inspection or cleaning, the vacuum must be vented from the vessel and vacuum and discharge pumps isolated. Vacuum mains into the vessel must be shut. All other appropriate safety precautions must be taken, e.g., gas detection equipment used and the vessel fully emptied.

iii) Appropriate lifting equipment must be used if the vacuum vessel is to be moved.

Confined Spaces

I) Anticipated confined spaces are interface valve chambers and the collection station building, in particular the basement area.

ii) Adhere at all times to the current safety legislation and local Laws.

iii) The following is a suggested minimum standard of care required when entering these confined spaces. Where a local Law or standard exists, that Law and standard should take precedence.

- Proper safety equipment should be used and proper protective clothing should be worn as required. For the collection chambers this would include the following:
  - Safety helmet
  - Protective overalls
  - Safety footwear
  - Gloves
  - An atmospheric monitor (capable of detecting hydrogen sulfide and lack of oxygen)
  - A first aid kit
- Local Laws regarding entry to the applicable premises must be followed prior to the commencement of work.
- No work should occur if an unsafe atmosphere is detected.

Leptospirosis

Leptospirosis is a disease that can possibly be passed to humans via rat urine. Since there is a remote possibility of this infection being present in sewers, workers should be aware of the symptoms and possible risks.

The disease can be caught by the bacteria entering the body through cuts and scratches and through the lining of the mouth, throat and eyes after contact with infected sewage. The symptoms begin with a flu-like illness with a persistent and severe headache.

As a precaution against infection, wear protective clothing and always wash hands before eating, drinking or smoking. If symptoms such as those described above occur, report to a doctor immediately and explain about the type of work carried out.

FIRST AID

A suitable first aid box and medical instruction book must be placed and maintained within the collection station building.

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NOMENCLATURE

Terms used in this manual and their meanings are set forth below.

SEWER NETWORK	
TERM	MEANING
Breather	Air vent allowing atmospheric air to be drawn from outside the valve pit into the interface valve during its operating cycle.
Crossover	3" diameter pipe connecting interface valve to the vacuum sewer.
Division valve	A valve placed at a junction or in a vacuum sewer line enabling that part of the network beyond the valve to be isolated for trouble shooting or maintenance purposes.
Gravity lateral	Pipe connecting property being served to the sump section of the valve pit.
Interface valve	Device for admitting collected sewage into the vacuum sewer network.
Lift	Rise in the vacuum sewer profile formed from 2# 45° elbows.
Sensor pipe	2" diameter pipe within the sump portion of the valve pit which acts as a pressure transferring device initiating the opening of the interface valve.
Suction pipe	3" diameter pipe within the sump portion of the valve pit connected to the interface valve. It is the conduit through which the sewage is evacuated when the interface valve operates.
Valve monitoring	A system offering the facility of monitoring each system interface valve operation. The open/closed mode of each valve can be monitored on a mimic board with the ability to register or sense an open valve caused by either an obstruction or long timing.
Valve pit	Structure housing the interface valve and also forming a sump from which collected sewage is evacuated.

COLLECTION STATION	
TERM	MEANING
Collection station	The assembly of mechanical, electrical and control equipment generating the vacuum for the sewer network and discharging the collected effluent.
Control panel	The electrical control system which operates and controls the pumps and other equipment within the collection station.
PLC	Programmable Logic Controller within the control panel carrying the operational philosophies for the equipment.
Recovery systems	Part of the control philosophies within the PLC enabling the system to recover automatically from certain fault conditions without calling out maintenance personnel.

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TERM	MEANING
Dry weather flow	The theoretical flow calculated by dividing daily water use by time. May be expressed in gallons per minute or liters per second.
Peak flow	Dry weather flow multiplied by a factor to take into consideration peaks within the daily flows, for example first part of the morning or early evening. Generally the factor used is 4 for vacuum systems, but please refer to local standards for guidance.

ABBREVIATIONS

The following abbreviations are used within this manual:

ABBREVIATION	MEANING
DWF	Dry weather flow
PF	Peak Flow
Qdp	Discharge pump flow rate
Qvp	Vacuum pump capacity
Sv	System volume
T	System pump down time
Vo	Operating volume of collection vessel
Vt	Total volume of collection vessel

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CHAPTER 1

CONCEPT

1.1 SEWAGE COLLECTION

1.1.1 Gravity Collection System

Since the time of the Romans, sewage has been collected by gravity. Indeed some Roman sewers such as the Cloaca Maxima are still in use today. Gravity sewers require pipes laid to a constant fall with the sewage discharging into either a watercourse or into a pumping station. The excavation associated with gravity sewers is often wide, deep and costly. Usually such excavations have a major environmental impact. For example, inspection manholes can be a major cause of surface water infiltration.

1.1.2 Vacuum Collection System

A vacuum collection system does not rely on gravity to transport sewage. Therefore, vacuum sewer pipes can be laid close to parallel to the ground surface. A typical vacuum system for sewage collection essentially comprises of the following:

- Gravity Collection System - a gravity sewer main serving each property designed and operated as a conventional gravity sewer.

- Vacuum Interface Valve Chambers - chambers into which the gravity sewer lines flow. Each chamber houses a vacuum interface valve and typically serves up to 4 properties. Chambers are similar to conventional sewer manholes and are generally about 2m deep.

- Vacuum Main - operates under a vacuum of about 500mm mercury and connects the interface chamber to the vacuum/pumping station. The vacuum main is usually 6 bar polyethylene electro-weld jointed pipe laid at a depth of about 1.5m in a sawtooth profile.

- Vacuum Collection Station - comprising a collection/vacuum vessel, vacuum pumps, discharge pumps and associated control gear.

In brief, vacuum sewerage systems operate as follows:

- Wastewater from each property flows by gravity into the interface chamber.
- When the wet sump in the interface chamber is full, the vacuum interface valve in the chamber automatically opens and the liquid, followed by a quantity of air, is rapidly drawn into the vacuum main.
- Each intake or slug of sewage and air is moved incrementally along the vacuum main under the momentum imparted by air and liquid admitted as the valves within interface chambers open as required throughout the system.
- When the momentum of each inrush is consumed, the sewage temporarily collects in the low points of the sawtooth profile of the vacuum main until another upstream valve fires and repeats the movement sequence.
- When the slug of liquid arrives at the vacuum/pump station, it enters the vacuum vessel where it is stored and subsequently discharged to the treatment plant.

The central element of the vacuum sewer system is the large bore (90mm) Iseki vacuum interface valve. The Iseki valve is an extremely robust and reliable component which is pneumatically controlled and actuated without the need for mechanical equipment or an electrical supply.

The Iseki valve, together with the use of comparatively small diameter UPVC and polyethylene pipes, provide a practical and cost effective alternative to the conventional gravity system.

Note: For specification details of pipes see Chapter 3, Sub-section 3.1.1.2 uPVC pipe, Chapter 3, Sub-section 3.1.1.1 Polyethylene pipe.

In vacuum sewerage systems the valve is situated in a pre-cast concrete or fibreglass sump/chamber. See Figure 1 and Figure 2.

1.2 TYPICAL VACUUM SEWAGE SYSTEM APPLICATIONS AND ADVANTAGES

1.2.1 Typical Vacuum Sewage System Applications

The vacuum sewage collection and transport systems that Iseki specialises in are being used for wider and more varied applications than those envisaged just a few years ago.

Vacuum sewage collection and transport systems have many applications in industry for collecting all forms of liquids, including rainwater (from roofs), toxic and radioactive effluent. Collection pipes may be installed above ground, overhead or in utility ducts.

The versatility of the vacuum sewer system can be employed in a variety of locations and situations such as:

- Rural community main sewerage
- Roof drainage
- Industrial redevelopments
- Camp and caravan sites
- New housing developments
- Old towns with narrow streets
- Diversion of small sea outfalls
- Hospital effluent collection
- Airports/shopping centres
- Railway services
- Replacement of failed gravity systems
- Petro-chemical industry
- Food processing plants

- Collection of toxic and radioactive waste
- Condensate collection systems
- Factory sewerage
- Leachate from landfills
- Spillage around tank farms
- Collecting used oil and fluids
- River and lakeside communities
- Quayside redevelopments
- Arctic Communities

1.2.2 Typical Vacuum Sewage System Advantages

Vacuum collection and transportation systems can provide significant capital and ongoing operating cost advantages over conventional gravity systems, particularly in flat terrain, high water table or hard rock areas. Vacuum sewer systems are installed at shallow depths, which minimises excavation, shoring, restoration requirements and hence disruption to the community. Collection pipes can be installed above ground, overhead or in utility ducts.

One of the many advantages of a vacuum system is that there is no infiltration of ground water into the system. This means that the sewage treatment works have to handle less water. Whereas flow calculations for gravity systems are based on six times the flow to allow for water infiltration, the peak flow for a Vacuum system is calculated using a smaller multiple of the dry weather flow. For this reason the cost of treatment to the raw sewage at the sewage treatment works is reduced.

Other advantages of the Iseki System are listed as follows:

- Small bore, high integrity pipelines
- Shallow, narrow trenches minimising excavation, backfill and re-instatement costs
- Minimal environmental impact
- Low maintenance costs

- High velocities generated (6 metres per second) eliminate blockages by disintegrating sewage solids
- No manholes required in vacuum network at all.
- Reduced health and safety risks to maintenance crews
- Minimised dewatering in land with high water table
- Water and sewer pipes may be laid in the same trench without risk of cross contamination
- No infiltration of ground water
- Eliminates pollution from effluent leakage
- Pipelines can be laid over, under or around unforeseen obstructions.

The alignment of vacuum mains is extremely flexible, without the need for manholes at points of change in grade or direction. Vacuum sewer mains can skip over and around other services or obstacles and can be used to achieve uphill flow. Turbulent velocities of 5 to 6 metres per second are developed as the sewage and air pass through the interface valve. This disintegrates solids and reduces the risks of sewer blockages which are unknown in a correctly designed and constructed vacuum system.

No electricity is required at the interface valve, which enables the system to be installed in virtually any location.

Fractures in gravity systems may go undetected for a long time. A leak in a vacuum main will raise an alarm within minutes of the break. The mains have to be repaired for sewage transport to continue, ensuring up to date maintenance and eliminating deterioration and infiltration. As a safety factor, storage capacity is included within the collection sumps in order to provide adequate reaction time for the maintenance crew.

Due to the shallow depth of the installation, additional connections can be quickly and simply made by a small construction crew, thus reducing the disruption and restoration work normally required for conventional gravity sewers.
The Iseki valve has been developed to withstand highly aggressive conditions, and all materials in the Iseki valve resist salt water corrosion and deterioration from a wide range of corrosive and toxic materials. A copy of an accelerated corrosion study report, which was carried out by a UK University, may be obtained from Iseki representatives.

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CHAPTER 2

DESIGN

2.1 DETERMINING THE CATCHMENT AREA

2.1.1 General.

Prior to the commencement of the detailed design process, the ultimate catchment area must be determined. In addition to the existing properties and businesses within the catchment area, an assessment must be made of probable future development. This assessment must take into account any supplemental development which could occur within the area and any possible extensions to the system which will be required beyond the present boundaries of the catchment area. Correct analysis of these factors will ensure adequate sizing of the pipework and collection station equipment for all envisaged flows.

2.2 DETERMINING FLOWS

2.2.1 Sewage Flow Calculations

Once the number of properties, businesses etc. has been assessed, a calculation must be carried out to determine the dry weather and peak flows that will be generated. This is of vital importance because the design of an Iseki System will be adequate to cope with all expected conditions only if peak flows are accurately forecast. For example, this calculation must consider the number of persons at the properties to be served by the vacuum collection system, the number of hours each business will operate, etc. A typical example of such a calculation is given in the table Typical Catchment Area. It can be seen from the example that an assessment has been made of the number of persons living in the domestic properties and the number of guests and customers visiting the businesses within the catchment area.

The flows derived from these calculations are used to determine the following:

- Pipe dimensions
- Selection of the station pumping equipment
- Vacuum vessel size

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Typical Catchment Area

Property type	No. of persons	Total flow litres per day	No. of hours per day	Average flow litres per second	Peak flow litres per second.
Residential	212x150	31800	24	0.37x 4	1.48
Coffee Shop	200x11	2120	6	0.10 ✓	0.40
Hotel and Restaurant No.1				x4	
resident staff	12	1800	24	0.02	0.08
guests	44	8800	24	0.10	0.40
restaurant	32	800	6	0.04	0.16
bar meals	200	5000	8	0.17	0.68
Hotel and Restaurant No.2					
resident staff	18	2700	24	0.03	0.12
guests	64	12800	24	0.15	0.60
restaurant	64	1600	6	0.08	0.32
bar meals	160	4000	6	0.18	0.72
Caravan Park					
domestic	8 x100	1600	24	0.02	0.08
field No.1	500	12500	24	0.15	0.60
field No.2	500	12500	24	0.15	0.60
future development	480	12000	24	0.14	0.56
Primary School	78	2730	8	0.10	0.40
Public Toilet	2000	8000	15	0.15	0.60
Totals				1.95	7.8

The total of the calculated figures in the table Typical Catchment Area have been rounded up and the flows used for that particular design are as follows:

* Average or dry weather flow 1.95 litres per second. x 4 = 7.8
* Peak flow 7.8 litres per second

2.3 DESIGN OF THE VACUUM SEWER NETWORK

2.3.1 General

The pipelines used in a vacuum sewerage system have four main purposes:

1) To provide a vacuum supply from the vacuum tank to the vacuum interface valve within the collection sumps;

2) To collect the sewage admitted to the sewers through the vacuum interface valves and transport it to the vacuum station collection vessel;

3) To recover speedily the vacuum throughout the pipework system after a vacuum interface valve has cycled; and

4) To regenerate the two-phase flow.

Various types of vacuum sewer profiles have been used historically. All have common features such as downslopes, risers, highpoints and low points.

The high and low points of the profile are important features. The high points are used as vacuum reservoirs while the low points are used as liquid reservoirs which also act as two-phase flow (see below) regenerators. Slope on the sewers is also used to control reverse flows. See Section 2.3.5. Reverse Flow Or Backsurge.

A question often asked is: "Why do we need to lay vacuum sewers to a profile?"

The answer is that if we laid vacuum sewers like a water main and followed the ground profile with a minimum depth of cover, then these pipes would rapidly fill with sewage due to the action of both forward and uncontrolled reverse flow. This means that the sewers would become waterlogged and fill all available air space. The vacuum could not then be transferred back from the vessel to the interface valves, which would cause the vacuum transport to cease.

What is meant by Two-Phase Flow?

As applied to vacuum transport of sewage, two-phase flow has been described as: "Any flow involving two states or phases of matter (i.e., gas-liquid, solid-liquid, or solid-gas). The term "two-component flow" is used to describe flows involving two separate chemical substances. For example, a steam-water flow is two-phase and not two-component, but an air-water flow is both two-phase and two-component. Therefore, if wastewater is assumed to be a single component, vacuum wastewater transport may be considered both two-phase and two-component.

In this manual the term "two-phase flow" is used to describe "two-phase, two-component flows."

Why two-phase flow?

If we introduce air at atmospheric pressure with liquid in a vacuum transport system, we reduce the specific gravity of the mass which will accelerate due to the high energy created by the atmospheric pressure air rising into the vacuum pipe. This air is trying to raise the negative pressure of the pipe to its own level of the atmosphere. Usually the interface valve, through which the air has been admitted, is sited at a considerable distance from the vacuum source. This results in the high velocity generated by the foam or two-phase flow.

By reducing the specific gravity of the mass of liquid, we can increase the static head that may be overcome in a vacuum system. The increased velocity may also assist in the efficient transportation of sewage.

Iseki Systems operate with air to liquid ratios from 6:1 up to 10:1. The air to liquid ratio may be varied for each interface valve depending on its location and topographical position. The actual ratio is dependent upon the specific installation details of each valve. The correct settings are provided as part of the Operation and Maintenance Manuals available from Iseki.

The 90mm Iseki valve relies on the shallow liquid depth in the valve sewage sump to draw a vortex and suck in air as the valve opens.

The two-phase flow is regenerated in the sewer traps, which we call two-phase flow regenerators.

2.3.2 Flow Regimes in Vacuum Sewers

The basic flow regimes that occur in vacuum liquid transport systems are as follows:

- Full bore flow
- Wavy flow
- Plug or slug flow
- Two-phase flow.

2.3.2.1 Full Bore Flow

As its name implies the pipe bore is full of liquid which is drawn through a pipe as long column by a vacuum acting on the front face and atmospheric pressure acting on the rear. In this type of flow the liquid moves slowly and most of the available head is used up in friction losses.

Disadvantages of full bore flow include short vacuum pipe lengths due to lack of available head and a risk of solids deposition. Full bore flow is difficult to achieve in practice as gases are often released from the liquid moving under the influence of negative pressure There is also the difficulty of preventing air entering the system at the time the liquid is discharged into it. Often so called full bore systems are in practice two-phase flow systems which have a very low air to liquid ratio.

2.3.2.2 Wavy Flow

This type of flow occurs where small continuous flows are admitted to a vacuum sewer having a bore several times larger than the admitting valve. Transport takes place due to the initial velocity assisted by the shear force between the faster moving air above the liquid. This type of flow is often associated with marina systems where large holding tanks are pumped or sucked out using a 90mm interface valve with a sewer of a considerably larger diameter.

2.3.2.3 Plug or Slug Flow

The basic claim of the early plug flow systems was that a plug or slug of liquid moved through the pipe at high speed and rapidly disintegrated into foam. These systems normally included "plug reformers" or "transport pockets." The plug reformers or transport pockets are in fact two-phase flow regenerators.

Early plug flow patents refer to the plugs being rapidly transformed into foam (two-phase flow). Even if we consider the micro second of time when the "plug" is accelerating out of the plug reformer, by definition it is a two-phase flow system. The term plug flow was used as an easy method to explain the transport mode.

2.3.2.4 Two-phase Flow

All types of flow experienced in a vacuum sewerage system should strictly be classified as two-phase flow. However in the past the term "two-phase flow" has been applied to vacuum transport systems with air to liquid ratios higher than 2:1. In an Iseki System the air to liquid ratio varies from 6:1 in some installations to as high as 10:1 in others.

Air to liquid ratios are adjusted by varying the time the Iseki vacuum interface valve is held open. This timing adjustment is made by a needle valve built into the Iseki valve control system.

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2.3.3 Two-phase Flow Regeneration

Two-phase flow is generated initially at the vacuum interface valve and sewage sump. Visually two-phase flow appears as foam moving at velocities of up to 6 metres per second per second through the vacuum sewer. The air gradually passes through the foam, the foam reforms into liquid, and the liquid runs by gravity to one of the sewer low spots. The foam then reforms into liquid and runs by gravity to fill one of the sewer low spots.

The Iseki sewer profile is generally designed so that the liquid lying in the low spots completely fills the pipe bore. This is illustrated in Figure 3 Stage 1. These low spots are termed 'two-phase flow regenerators'.

When a ladder of several lifts is required close together on an upslope, one or more of the lifts should be constructed such that the low spot is not completely filled. This is achieved by making the fall from the top of one lift to the bottom of the next 80% of pipe outside diameter. Generally, if more than three lifts are required in a ladder, at a spacing of less than 25 metres between lifts, then each alternate lift should be designed as 'open'. Please contact Iseki if more information or assistance is required on this aspect of sewer design.

Note also that the use of both sealed and unsealed low spots enables a balance to be struck between optimizing two-phase flow regeneration (sealed low spots) and optimizing vacuum transfer (unsealed low spots). Figure 3 Stage 2 illustrates the start of a two-phase flow regeneration microseconds after an upstream vacuum interface valve has opened and admitted an air blast of atmospheric pressure. The complete two-phase flow regeneration is illustrated in Figure 3 Stage 3.

2.3.4 Vacuum Recovery

Each time a 90mm Iseki valve cycles, it admits air into the vacuum sewer. The air entering at atmospheric pressure raises the absolute pressure inside the vacuum sewer which must be quickly lowered if the remaining vacuum interface valves are to operate on demand in the rest of the system.

The factors affecting vacuum recovery times are:

1) Size of vacuum pumps
2) Size of vacuum sewers
3) Amount of water in the sewers

All these factors are taken into account when designing a system.

2.3.5 Reverse Flow Or Backsurge

It is important to understand reverse flows, which were often the cause of many early vacuum system problems. Consider the top diagram of Figure 4.1 which shows a vacuum main with a closed valve connected to it by a tee fitting. The vacuum in the three legs of the tee is in equilibrium. Figure 4.2 shows the valve open, admitting a two-phase flow foam plug.

Due to the liquid colliding with the wall of the pipe and the equal vacuum on both sides of the tee, the flow is split in approximately equal positions in either direction. Half flows towards the vacuum station with the remainder flowing backwards away from the station. Hence the term reverse flow or backsurge. The lower diagram, Figure 4.3, shows the two-phase flow being admitted through a 45 degree Y-fitting. The diagram indicates the direction of flow. The Y does not completely eliminate the reverse flow, but it does reduce it to around twenty percent of the liquid pulse. The shallow gradient in the direction of flow also contributes to minimizing the effects of the backsurge.

Reverse flows can travel considerable distances away from the sewage admission point and are the cause of many vacuum systems waterlogging. Waterlogging means that the vacuum sewer contains a high percentage of liquid rather that a high percentage of vacuum.

2.3.6 Crossover Connection Between Vacuum Valve and Sewer

The connection from the vacuum valve to the main sewer, Figure 5, is made using 90mm outside diameter PE pipe.

Note: *For specification details of pipes see Chapter 3, Sub Section 3.1.1.1 uPVC pipe, Chapter 3, Sub-Section 3.1.1.2 Polyethylene pipe.*

The connection enters the main sewer "over the top" through a 45 degree Y-fitting. See Sub Section 2.9.1 Crossovers for details of the design of crossovers.

When two or more Iseki valves are installed in one chamber, separate 90mm outside diameter PE pipe service lines from each valve should be directly connected to the vacuum main.

Iseki will provide a special sump design based upon flows and location in the pipe network for multi-valve chambers. Connections from branch sewers to the vacuum mains are made in a similar manner as those from the vacuum valves to the main.

2.3.7 Division Valves

Division valves are installed around the main sewer lines in order to isolate a particular section of the vacuum sewer network. See Figure 6.

The valves are normally covered with a surface box to allow operation with a T key. See Chapter 3 Specifications, Sub-section 3.1.4 Division Valves for details of suitable valves.

2.3.8 Clean Outs

Due to the high transportation velocities, the risk of sewer blockages occurring in a correctly designed and installed vacuum sewerage system are virtually non-existent. However in the unlikely event of a blockage, access to the vacuum sewer is made through one or more of the Iseki valve connections. Therefore the fitting of cleanouts to the sewers in an Iseki System is not required.

2.3.9 Selection of Vacuum Sewer Pipe Sizes.

Note: *For specification details of pipes* see *Chapter 3, Sub-section 3.1.1.1 uPVC pipe, Chapter 3, Sub-section 3.1.1.2 Polyethylene pipe.*

To ensure the optimum operation of the vacuum system, it is essential that the pipes be sized as indicated in the following sub-section. To select the correct vacuum sewer pipe size, the two following criteria must be taken into account:

- The maximum cumulative flow into each size of pipe used to make up the vacuum main pipe, and
- The maximum length of each size of pipe used to make up the vacuum main pipe.

An interface valve, 90mm internal diameter, is fitted in the collection sump. The connection pipe between this interface valve in the collection sump and the vacuum main is called a crossover, which is a 90mm outside diameter polyethylene pipe. Only one interface valve may be connected onto a pipe of this size and the crossover should be no more than 35 metres length before it is upsized to a main as described below.

The smallest size main used in the vacuum system is 110mm outside diameter PE pipe. This pipe runs, on a particular line, from the farthest interface valve towards the vacuum station, and it picks up additional flows from each of the interface valves it passes. The cumulative flow within the pipe must be calculated. Once it reaches a flow of 2 litres per second, the pipe diameter must then be increased to 125mm for a flow of up to 5 litres per second.

There is a second criterion that must be taken into the calculation. If the length of 110mm outside diameter PE pipe on the main pipe run reaches 500m, then the pipe diameter must be increased to 125mm, regardless of the cumulative flow.

The cumulative flow in the 125mm PE pipe must continue to be calculated. Once it reaches 5 litres per second, the pipe diameter must then be increased to 160mm external diameter PE pipe. As with the smaller diameter, there is also a length limit on the amount of 125mm PE main on a single pipe, which is 800m.

For 160mm PE the maximum cumulative flow is 10 litres per second, and the maximum single pipe run must not exceed 1500m.

The next size pipe used is 200mm outside diameter PE. For these pipes the maximum cumulative is 15 litres per second, with no maximum single pipe run length.

Should a pipe larger than this be indicated, refer to Iseki prior to design work being undertaken.

Pipe Calculations

PIPE DIAMETER	MAX. CUMULATIVE FLOW	MAX. PIPE LENGTH
90mm diameter PE	One interface valve	35m
110mm diameter PE	2 litres per second	500m
125mm diameter PE	5 litres per second	800m
160mm diameter PE	10 litres per second	1500m
200mm diameter PE	15 litres per second	Unlimited

2.3.10 Vacuum Sewer Design

Vacuum sewerage systems acquire their energy for the transportation of sewage from differential air pressures, i.e. the difference between atmospheric air pressure and the vacuum level within the sewer network. This available energy is finite, and it therefore follows that once that energy has been used, transportation of effluent within the system will cease. Clearly it is of fundamental importance for the system design that this limiting factor is understood and the limits adhered to.

The Iseki Vacuum System uses a high air:liquid ratio - typically around 6:1. This ratio produces a foamed mixture of sewage and air with a low specific gravity. Experience has shown that frictional losses within the sewers may safely be ignored provided the guidelines on pipe sizing and vacuum pump selection are followed.

The available energy within the system may be used to overcome static head changes within the sewer network. The vacuum levels generally maintained by the vacuum pumps are around -.70 bar. The interface valves themselves require a minimum vacuum level of about -0.25 bar to operate correctly, leaving 0.45 bar of differential pressure available for the transportation of the sewage. This equates to approximately 4.5 metres lift.

What this means in practice is that the static head from any one point on the vacuum sewer network back to the collection station must not exceed 4.5 metres. Nevertheless, it may be possible to generate further lift, and if you are in this situation, please consult with Iseki designers.

2.3.10.1 Sewer Profile

The following sub-section deals with the method of designing the sewer profile and determining the summation of static lift.

In general, a gradient of 1:500 (or 0.2%) or greater must be maintained within the sewer. Lifts are built into the sewer line profile to act both as two-phase flow reforming pockets and to bring the sewer back up to minimum depth of cover, thus avoiding the need for deep excavations. In general, each lift will be 300mm from invert to invert. (See Figure 7.)

For the purposes of calculating the cumulative static head on a line, each 300mm lift is counted as only 150mm. The high generated velocities within the sewer will help to carry the slug of sewage through the lift. With a 300mm lift and a 1:500 gradient, in perfectly flat ground a lift would be required every 150m.

A theoretical maximum sewer length can therefore be calculated as

$$\frac{4.5}{0.15} \times 150 = 4500\text{m}.$$

In practice however, it is most unlikely that 4500m of perfectly flat ground will ever be encountered. Any sewer profile is likely to comprise some flat ground, some downslopes and some uphill sections. Figure 8 shows a typical longitudinal section of vacuum sewer with each of these profiles.

In general, lifts should not be closer than 6m from one another and lifts larger than 300mm should be avoided where possible. If a lift of more than 300mm is required, then the contribution toward the total static head on that line will be the actual lift measurement. It is always preferable to use several smaller lifts than to install a single large lift.

Note: If a single lift in excess of 1500mm is indicated, assistance and advice should be sought from Iseki before starting a design.

2.4 DESIGN OF THE COLLECTION STATION EQUIPMENT

2.4.1 General

Vacuum stations can be sized to suit most flows.

Vacuum station capacity is not the controlling factor in the design of a vacuum sewerage system. The total static head loss in any single sewer controls the limits of a service area.

Due to the static head limitations of the sewer, more than one vacuum station may be required to serve the catchment area. Where multiple stations are required, the size of collection vessels and machines will be standard as far as practicable.

Vacuum stations should, where possible, be located to:

- Give equal flows in the sewers
- Equalize lift losses in each sewer
- Keep sewer lengths to a minimum

2.4.2 Station Main Components

The main components of the station are:

- Vacuum Sewage Collection Vessel

  This vessel is usually made of steel or fibreglass.

  Connections are provided on the vessel for the following: sewage discharge pumps, vacuum supply, vacuum switches, level probes, pump prime lines, manhole and the incoming vacuum sewers. The latter have a ninety degree bend inside the tank, which we recommend be turned through a 45 degree angle to the horizontal and pointed away from the sewage pump suction connections.

- Vacuum Reservoir Vessel:

  This additional vessel is required only where mechanical vane vacuum pumps are selected. If used, it will require connections for vacuum pumps, sewage vessel, drain line and man access. See Figure 10.

  A typical volume for such a vessel would be 1000 litres, which may be deducted from the calculated total volume as calculated in the vessel volume formula in Sub-section 2.4.3.1 Design of Vacuum Sewage Collection/ Reservoir Vessel. The vacuum reservoir vessel is not required if liquid ring pumps are specified.

- Vacuum Pumps:

  These are liquid ring or, alternatively, mechanical sliding vane.

- Sewage Pumps:

  Non-clog sewage pumps that will pass spheres of around 70mm are normally used.

- Non-return Valves

  The non-return valves fitted to the sewage pumps are cast iron with stainless steel shafts and shall be complete with an external level and weight. The tongue is fitted with a soft elastomer seat. Ball type non return valves are fitted on the vacuum pipework between the vessel and vacuum pumps.

- Vacuum Pump Check Valves

  Vacuum Pump Check Valves are cast iron or plastic and fitted with an elastomer seat.

- Station Stop Valves

  Station Stop Valves have resilient vacuum tight seats and are capable of fast opening and closing with glands specified for vacuum service.

- Equalizing Lines.

  The sewage pumps in an Iseki System have vacuum constantly applied to them through their suction connection to the vacuum vessel. Pumps are designed for positive not negative pressure in their casings. Thus, when the pumps are on standby, there is a risk of air leaking into the pumps causing a loss of prime. The purpose of the equalizing line is to evacuate any air that may leak into the pump and prevent loss of prime.

  The use of equalizing lines may be avoided by correct pump selection and installing a soft seat non return valve in the pump suction line.

- Vacuum Chart Recorder.

  We recommend that a twenty-eight day circular vacuum chart recorder be fitted in the station. This chart indicates the number of starts and stops of the vacuum pumps as well as showing when the peak and low flow periods occur. It is a valuable diagnostic tool. Iseki also offers an optional digital self-recording device. Further data recording equipment is available to monitor all aspects of the station performance. Please contact Iseki for information about this equipment.

A typical vacuum station layout is shown in Figure 9. This shows the vacuum collection vessel and sewage pumps at basement level with the vacuum pumps and controls at ground level. It would be constructed on site from a package of equipment designed by Iseki for installation within the applicable building.

With small installations it is possible for the mechanical package of equipment to be assembled on a skid unit. See Figure 11. The unit is then shipped to site, lowered into a previously constructed basement, and then the building is completed. This reduces site labor costs and speeds up installation work.

2.4.3 Design of Components

The following sub-sections detail designs of the components within the vacuum station.

2.4.3.1 Design of Vacuum Sewage Collection/ Reservoir Vessel

The vacuum sewage collection/reservoir vessel performs two functions.

1) As a wet well, as in a conventional pumping station, it is a tank which holds the sewage until the level is sufficient to initiate the discharge pumps.

2) As a reservoir of vacuum, it helps to minimize the number of starts per hour for the vacuum pumps.

In general, the following formula may be used to calculate the operating volume of the collection vessel:

$$Vo = \frac{15 \times 60 \times DWF}{1000}$$ = .9 x DWF

where DWF is dry weather flow in litres per second. This formula gives a volume equal to 15 minutes of dry weather flow.

The total volume of the collection vessel will generally be 3 times the operating volume.

$$Vt = 3 \times Vo$$ = 2.7 x DWF ✓ Approx = Vol Wash Flow

For example, consider a system with a dry weather flow of 3 litres per second:

$$Vo = \frac{15\ 60 \times 3}{1000} = 2.7 \text{ cubic metres}$$

$$Vt = 3 \times 2.7 = 8.1 \text{ cubic metres}$$

This formula will cover the majority of system designs. However, on projects where the volume of the sewer network is large in relation to the peak flow, the vacuum reservoir function of the vessel becomes less important and the proportion of the vessel that may be used to hold sewage can increase. However, this proportion should not exceed 50% of Vt.

Note: Please contact Iseki for guidance on this aspect of vessel design.

2.4.3.2 Design of Vacuum Reservoir Vessel

This additional vessel is used primarily as protection against moisture carryover to the vacuum pumps. This is vital where mechanical vane pumps are used because this type of pump is easily damaged by such an event. We recommend liquid ring type pumps, which are less prone to this damage. If they are used, this additional vessel is not required.

2.4.3.3 Design of Vacuum Pumps

Iseki generally recommends the use of liquid ring vacuum pumps. These pumps, although somewhat less efficient than sliding vane vacuum pumps, are preferred for the following reasons:

- Their purchase price is less.
- The use of a second vacuum vessel for moisture removal from the airflow is not required.
- They are less prone to damage if a foreign object is drawn through them. Sliding vane pumps may be partially destroyed by such an event.
- They have fewer moving parts and therefore lower maintenance costs.
- They do not require lubricants.

The only exception to the above recommendations is when ambient temperatures are very high (over 35°c). In such a situation the service water for the liquid ring pump becomes too hot and the efficiency of the pump drops away. Sliding vane vacuum pumps are preferred in hotter climates.

The selection of the appropriate size of vacuum pump is determined by the following three factors:

1) The peak flow of sewage to be collected

2) The length of the longest single vacuum sewer line on the sewer network

3) The overall volume of the pipework within the network.

The calculation to determine the vacuum pump capacity is as follows:

$$Qv = 3.6 \times Qp \times 1.5 \times R$$

Where Qv is in cubic metres per hour and Qp is litres per second.

R is a factor determined by the length of the longest single sewer line.
For a length between less than 1500m., R=6
For a length between 1500m and 2000m., R=7
For a length between 2000m and 3000m., R=8
For a length between 3000m and 3600m., R=9

Note: For sewers over this length, please refer to Iseki for detailed assistance.

Example:

A system with a peak flow of 10 litres per second and with a longest sewer length of 1750m

$$Qv = 3.6 \times 10 \times 7 \times 1.5 = 378 \text{ cubic metres per hour.}$$

The next model of vacuum pump up from this calculated requirement should usually be selected. Generally, two vacuum pumps will be required, each capable of the calculated duty.

For most systems, the vacuum pump downtime to the systems operating level (around -0.7 bar mercury) should be less than 5 minutes.

Note: *This calculation should be made assuming that all vacuum pumps are running. The calculated time is important to determine recovery of the vacuum system, e.g., following a power failure or system shutdown.*

$$T = \frac{Sv}{Qvp} \times 0.7$$

where Sv is capacity of the mains in cubic metres, Qvp is in cubic metres per minute, all pumps are running, and T is in minutes.

On systems where there is a relatively small peak flow but a very large volume of pipework, the requirement calculated may be larger when derived from the pump downtime rather than the peak flow alone.

In such a circumstance, three vacuum pumps may be selected each with a capacity of 50% of the calculated capacity.

During normal operation, a single vacuum pump will have sufficient capacity to run the system. However, if the system requires regeneration of vacuum from atmospheric pressure back to operating vacuum, all three pumps will start to recover the system within the calculated time period.

Note: *For further details of the operating logic of the vacuum pumps see Chapter 2, Section 2.5 PLC Control Philosophy*

2.4.3.4 Design of Sewage Discharge Pumps

Two sewage discharge pumps are recommended for use in an Iseki vacuum station. Each pump would be sized to discharge the calculated peak flow. Checks should be made to ascertain whether local laws, regulations, or custom require additional safety factors.

Pumps and motors are selected using similar calculation and sizing procedures employed for a conventional pumped main from a wet well. In addition, account must be taken of the vacuum head against which the sewage pumps must draw the sewage from the collection vessel. This additional head will amount to approximately 7m on the suction side of the pump.

A typical pump and piping arrangement for a vacuum system is illustrated in Appendix A Illustrations, Figure 12. The equalizing lines are 25mm diameter clear tubing. Their main purpose is to equalize pressure on either side of the pump impeller thereby reducing the load which the motor has to overcome to start the pump.

The use of horizontal screw impeller pumps rather than the conventional vertical pumps with open impellers may cancel the need for the equalizing lines.

Note: *Great care must be taken in the selection of pumps. We strongly recommend that close liaison between system designer and pump manufacturer be established to determine the correct pump model.*

2.5 PLC CONTROL PHILOSOPHY

2.5.1 General

The collection station mechanical and electrical equipment are controlled by the PLC unit within the electrical control panel.

2.5.1.1 Discharge Pumps

The discharge pumps operate on a duty/standby basis. The duty is selected/rotated automatically within the PLC logic.

When the sewage level within the collection vessel reaches the duty level, the selected duty pump will start and will continue to run until the stop level is reached. If the standby level is reached, the duty pump will stop and the standby pump will start and will continue to run until the stop level is reached. If the standby pump fails, the PLC will reinstate the duty pump run signal.

On resumption of the power supply after a power failure, the discharge pump being called to run will be delayed for thirty seconds.

If the High Level is reached within the holding vessel, Recovery System No. 1 will be brought into operation. See Chapter 4 Operation, Sub-section 4.2.3 Recovery System No. 1.

2.5.1.2 Vacuum Pumps

The vacuum pumps operate on a duty/assist basis. The duty is selected/rotated automatically within the PLC logic.

On initial start up of the system both vacuum pumps will be brought into operation, with the minimum recommended delay between the starting of each pump. On reaching the normal vacuum operating level, both pumps will stop. On falling vacuum, the pumps will be brought into operation via the appropriate vacuum/pressure switch.

When both vacuum pumps are called to run, Recovery System No. 2 will be brought into operation. See Chapter 4 Operation, Sub-section 4.2.2 Recovery System No. 2.

When High Vacuum is detected, both vacuum pumps will be locked out of operation until manually reset via the Fault Reset button on the control section door.

2.6 INSTALLATION TECHNIQUES AND PROCEDURES

2.6.1 General

Like conventional sewerage systems, the vacuum system must be installed in accordance with the engineer's design. A common misconception by construction personnel is that the invert lift sewer profile and connections entering over the top are unimportant since the system works by vacuum.

Prior to construction it is advisable to hold a meeting of all site staff to explain the method of system operation and construction details. The importance of the correct invert lift profile and connection methods should be stressed. Electro-fusion welded joints, if used, should only be made by qualified operators.

Correct bedding and backfilling of the plastic pipes are important to prevent damage from traffic loads and to maintain pipe alignment.

Vacuum system designs are flexible. It is generally possible to reroute sewers around, over, or under unforeseen obstacles that maybe found during the installation phase. However, such design changes should not be made without consultation with the Iseki System design engineer.

Before the final 500mm of backfill is placed, it is advisable to lay a metal coated plastic tracer/warning tape. This will allow the route of the sewer to be traced at a later date using a magnetic location device. The tape will also act as a warning if excavation is carried out at a later date without the route of the sewer being established.

2.6.2 Valve Pit Installation

A typical concrete Iseki valve pit installation is shown in Figure 13. Other types of valve chambers maybe used to suit local practices and codes.

A selection of valve pit designs are described in Chapter 3 Specifications, Sub-section 3.1.5 Valve Pit/Collection Sump to Sub-section 3.1.5.5 Dual In-situ Concrete Chambers.

The small sump in the bottom of the valve chamber must be designed to initiate vacuum interface valve operation when 40 litres of sewage have accumulated. To achieve valve initiation, the open end of the 50mm sensor pipe must be 175mm below the 40 litre capacity sewage line.

Design engineers should ensure the completed chamber will have sufficient weight to prevent floatation and strength parameters to prevent implosion of the empty unit in ground with a high water table.

Final valve timing will be set when all vacuum interface valves have been installed and the sewage is flowing.

The completed valve chamber installation should be checked for any groundwater infiltration.

2.6.3 Gravity Lines And Sump Venting

Valve chambers and their integral sumps are fitted with a floor/roof arrangement (see Figure 1), which prevents air being drawn into the sump when the Iseki valve cycles.

Venting of the sumps is usually through the gravity inlets and the house plumbing vents. These 100mm vents should be positioned downstream of all house connections to eliminate any risk of plumbing traps being sucked dry when the vacuum interface valve cycles.

Venting of sumps by this method reduces the risk of blockages in the gravity lines. The rush of air through the pipes each time the Iseki valve cycles scours any debris from the gravity lines into the sump.

Should a blockage occur in a gravity line as the valve is cycling, there is a risk of thin wall gravity pipes collapsing. To avoid this situation, system designers should specify pressure pipe for all new gravity connections connected to the Iseki valve sump.

Where existing house plumbing vents prove inadequate in size, a new vent connected in the gravity line to the Iseki valve sump will be required.

In climates where freezing temperatures are experienced, this auxiliary vent should be placed as far away from the sump as practical. In any event, it should not be closer than 6 metres to the sump. This will warm the cold air as it moves through the gravity line and prevent freezing of the Iseki valve.

In some instances the new vent will be placed outside the house served by the gravity lines with the new 100mm vent terminating 1-1.5m above ground level.

When a vacuum sewerage system is installed, Iseki recommends that new gravity lines be laid from the home to the sump. All existing gravity lines should be abandoned. Existing septic tanks should be filled in and must not be used as sumps for the Iseki valve installation without the prior written approval of Iseki.

It is important that new gravity pipe connections to the sump be thoroughly cleaned to ensure they are free from all construction debris, shingle and crushed rock before the valve installation is commissioned.

2.6.4 Elimination of Infiltration to the Gravity Lines

Vacuum sewers are designed to eliminate infiltration. This reduces collection and treatment costs. Therefore it is important that all forms of infiltration to the gravity lines connected to the sump also be eliminated.

The importance of correct material, joint selection, installation and removal of debris from house gravity connections cannot be too highly stressed.

2.6.5 Vacuum Station

Vacuum stations are either assembled at the final location from a package of equipment or delivered to site as a skid mounted unit. In both instances, the building should be prepared in advance by the civil engineering contractor.

Skid mounted vacuum stations have all their pumps and controls mounted with the vacuum vessel on a skid. The unit is pre-piped, wired, and tested prior to leaving the factory. The unit is delivered to site, moved onto prepared foundations, connected up, and re-tested.

Larger vacuum stations are assembled on site from an equipment package. Installation of this equipment follows the same practice as for a lift or pumping station.

2.7 TESTING PROCEDURES

2.7.1 Vacuum Testing Of Sewers

Two-phases of vacuum testing are recommended:

1) On a daily basis; and

2) When all vacuum sewers and the vacuum station are complete.

2.7.2 Daily Testing (Duration of test, 1 hour)

The daily vacuum test should be carried out on all pipework laid during the day. All open ends of the sewers should be capped and a vacuum pressure of -0.8 bar applied. The vacuum in the pipe should be allowed to stabilize for 10 to 15 minutes, after which time the vacuum should not drop more than 1% per hour for each hour of the test.

Daily testing should be carried out prior to the trenches being backfilled. If a leak is detected, it may be located using an ultrasonic type leak detector or pressurizing the pipe with low pressure air and checking each joint with a commercial leak detector. After all the leaks have been repaired, the pipe should be re-tested.

2.7.3 Final System Test (Duration of test 4 hours)

The final test should be carried out prior to the fitting of any Iseki vacuum interface valve. For the purpose of this test the complete system is defined as running from the stub on the Iseki valve inside the chamber through all the vacuum sewers to the vacuum vessel. The vacuum pressure of -0.8 bar is applied using the station vacuum pumps.

A vacuum chart recorder should be used to record the system vacuum. The system vacuum should be allowed to stabilize before the test is commenced. The system vacuum should not drop more than 1% per hour for each hour of the test.

During the vacuum testing, air temperature and barometric pressure may vary. This could affect the results. Changes in both temperature and atmospheric pressure should be considered when analyzing results.

2.8 DETAIL DESIGN OF PARTICULAR ELEMENTS

2.8.1 Crossovers

Crossovers are the connections between the vacuum interface valves and the vacuum sewer. They are constructed from 90mm outside diameter PE pipe and fittings. Often it is not possible to complete the detailed design of each and every crossover since the precise location of the valve chambers may be subject to on site verification and change during construction.

Therefore, it is important to define certain rules that will enable the on site engineering staff to install the crossovers correctly without the necessity of referring back to the system designer on every occasion. The rules are as follows:

Rule 1 The junction of a crossover with a main should be formed with a 45° 'Y' branch fitting. Wherever possible this branch should be vertically fitted so that the crossover connection enters the main from above. In no circumstances should the 'Y' branch be canted at an angle of more than 45° from the vertical. See Figure 14.

Rule 2 There should be a minimum of 50mm fall or 0.2% gradient from the back of an interface valve to the 'Y' branch connection. Use whichever figure gives the larger fall. See Figure 15.1.

Rule 3 If a single invert lift is required in the crossover, it should be no closer than 1 metre to the interface valve. There should be a minimum of 50mm fall between the back of the interface valve and the bottom of the invert lift. See Figure 15.2.

Rule 4 If several invert lifts are required to bring the crossover up to and into the main, the lifts should be spaced no closer than 3 metres apart with a minimum fall of 50mm between the top of one lift and the bottom of the next lift.

NOTE: This spacing of lifts may necessitate running the crossover parallel to the main for some distance. See Figure 15.3.

Rule 5 If a crossover connection is required close to an invert lift on the main, this junction should not be made within 3 metres from the top of the lift or within 6 metres from the bottom of the lift.

Rule 6 Any crossover in excess of 6 metres in length should be fully designed by the system design engineer in advance, rather than on site, in accordance with rules No.1 to No.5. Longer crossovers should be treated as branch lines, from the design point of view.

2.8.2 Junctions

The branch line (i.e., the sewer line with the lesser flow), must be joined into the main line (i.e., the sewer with the greater flow) using a vertically installed 'Y' branch

Junctions should be avoided within 3 metres of the top of a lift or 6 metres from the bottom of a lift.

Some examples of junction arrangements are shown in Figure 16.

2.8.3 Breathers

The breather pipe is a critical component part of the vacuum sewerage system. It is the breather that provides air to the interface valve to enable its correct operation See Figure 17, General Arrangement Drawing.

The breather pipe is generally formed from 18mm outside diameter ABS pipe. It is essential that there is a gradient from the bottom of the vertical section of the breather pipe back toward the interface valve in its chamber.

Certain rules should also be applied to the installation of these breathers. The rules are as follows:

Rule 1 For a breather pipe of up to 6 metres in length, use an 18mm outside diameter ABS pipe. For a longer breather pipe, use an18mm pipe for the first 6 metres from the valve, then step the size up to 25mm outside diameter ABS pipe.

Rule 2 For a breather pipe of up to 6 metres in length, install the breather pipe with a 300mm fall measured from the base of the vertical section to the interface valve chamber.

Rule 3 Under no circumstances should a breather pipe be laid with a back fall or a flat section. This is of critical importance because an incorrect profile may lead to the pipe becoming blocked with condensate water causing the interface valve to become inoperative due to lack of air through the breather.

2.9 DESIGN EXAMPLES

2.9.1 General

Iseki Utility Services Ltd. is at the forefront of the push to develop and improve Iseki's THE VACUUM WAY™ System, which is a sewage and effluent vacuum collection system with a growing world-wide potential.

Applications of the Iseki System are available upon request from Iseki representatives. This sub-section has a selection of brief descriptions of some of the Iseki System applications and why THE VACUUM WAY™ System was the most suitable solution.

2.9.2 First Time Sewerage of Rural Communities (Example: Wrangle Village, UK; Paty Village, Hungary)

These projects involve rural communities with well-spaced homes, often spread out along one or two main roads in typical ribbon development style. In these applications the land was flat and with high water table and unstable soil. The main reason for using a vacuum system for these developments was the reduction in construction and operating costs over a conventional system.

- Wrangle Village UK

Wrangle illustrates the traditional use of a vacuum sewerage system in an area with flat topography, a high water table, and widespread housing. In this installation a cost saving of 40% was achieved when compared to traditional drainage technology.

The very difficult ground conditions, the long ribbon development, and the flat topography meant the council drainage engineers were faced with a difficult sewerage project.

The most efficient and cost effective gravity pumped sewerage system required several pumping stations and deep sewers.

The potential of THE VACUUM WAY™ System was assessed and found to be the most suitable. Using THE VACUUM WAY™ System meant that the village could be served by only a single vacuum station and shallow sewers, giving an overall cost saving of some 40%. Installation of the vacuum system was carried out efficiently and quickly, with narrow trenches excavated using a trenching machine.

The existing Council estates were serviced by the installation of dual interface valve chambers which intercepted the gravity pipes running from the estates towards the redundant sewage treatment works, which was to be demolished.

- Pilis Village Hungary

Each property was originally served only by septic tanks. The Mayor decided to modernize the sewerage system by installing mains drainage and a new treatment plant. A conventional system proved unsuitable, difficult and costly for several reasons - a requirement for deep river crossings, a main international trunk road running through the village with strict regulation regarding excavations, sprawling housing developments, and the remote location of the treatment plant.

Pilis Village also required an environmentally friendly and non-intrusive system, including the collection station building. Consequently, an architecturally sympathetic design was selected such that the buildings blended with the local architecture.

2.9.3 Industrial Developments (Example: Addcap Offshore Base, Abu Dhabi, UAE)

This is a large industrial development where all services had to be in place to allow the developer to sell plots. Consequently, the vacuum sewers and the vacuum station were installed before the plots were offered for sale. Once a plot was sold and industrial construction commenced, a sewerage connection fee was charged and the vacuum valve and its chamber were then installed.

THE VACUUM WAY™ System proved the ideal solution. Pipes were installed at shallow depths, largely above the sea water table, and the inherent flexibility of the system in terms of future development was greatly appreciated by the client.

This method of installation considerably reduced the developer's initial cash outflows and, combined with the construction cost savings on often marginal land, made THE VACUUM WAY™ System a sound solution to the problem of sewering the new developments.

Although it was not done for this Abu Dhabi location, note that it is possible to lay both the water mains and vacuum sewer in the same trench, which results in reduced cash outflows for the developer.

2.9.4 Above Ground Structure (Examples: All England Lawn Tennis Club, Wimbledon, UK and Ceuta, Lake Maracabo, Venezuela)

These projects involve sewering of above ground structures which would be difficult and costly to achieve with conventional systems.

- All England Lawn Tennis Club - Rain Water Collection

This project illustrates Iseki's original design approach to problem solving and the adaptability of THE VACUUM WAY™ System to different applications. The roof had the difficult geometry of the gutter being some feet below the crown of the roof, which was where the main drainage pipes had to run for aesthetic reasons. This meant that a powered system of some kind had to be used and Iseki were able to offer the most cost effective and efficient solution.

THE VACUUM WAY™ System proved an ideal choice because it was the most cost effective and efficient solution. The interface valves were located high in the roof space, draining both the inner and the outer gutters via dual ring mains back to a single collection station.

- The Maracaibo Project

This project involved the sewering of a village built on piles above a lake. All the houses were connected by wooden walkways one meter above the lake water level. The sanitation was left to nature and the effluent dumped directly into the lake below.

Iseki offered a solution with its vacuum technology.

The vacuum pipework was unobtrusively slung beneath the pedestrian walkways and as such was protected from local fishing boats without creating any access problems for the householders.

The collection sumps were also slung beneath the walkways, where they were visually unobtrusive but accessible for maintenance purposes.

This unique application in Latin America illustrates the flexibility of THE VACUUM WAY™ System in terms of its ability to solve otherwise intractable problems of access.

2.9.5 Stadium Drainage (Example: Zayed Sports Stadium, Abu Dhabi)

This project illustrates the adaptability of THE VACUUM WAY™ System to solve unusual and difficult drainage problems.

The stadium was built in an area with saline ground water, the level of which had risen since construction. The aggressive conditions had damaged the sewers below the stadium to such an extent that replacement was vital. The prospects of re-laying the sewer in such ground conditions and with such poor access was daunting.

A suggested alternative to reline the damaged pipe was also very difficult primarily due to severe access problems.

THE VACUUM WAY™ System was able to intercept the incoming gravity flows above ground in collection sumps and, via a vacuum interface valve and ring main, collect the sewage in a steel vessel located in the vacuum station cleverly positioned beneath the seating.

This project demonstrates the unique versatility and engineering flexibility of THE VACUUM WAY™ System to provide solutions in cases of difficult FLUID HANDLING PROBLEMS.

Careful design ensured comprehensive operation of the System both under maximum design conditions of 70,000 spectators attending the Arab Gulf Football Tournament and normal day to day attendance with the very small flows generated by the employees at the complex.

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CHAPTER 3

SPECIFICATION

3.1 SPECIFICATIONS FOR FIELD EQUIPMENT

3.1.1 Pipe for Vacuum Sewers

The preferred material for vacuum sewers is polyethylene. An acceptable alternative is solvent jointed uPVC. Iseki does, however, strongly recommend that consideration be given to the use of polyethylene pipe and fittings. The principal advantage of this material is its great resilient strength, which means that ground movement, settlement etc. do not cause cracks or breaks in the lines. Also, the use of electro-welded couplers creates joints that have even greater strength than pipe itself, as opposed to the situation with other jointing techniques which create a joint somewhat weaker than the pipe.

3.1.1.1 Polyethylene pipe

For temperate climates, the recommended Polyethylene pipe, all sizes, is 6 bar rated PE80 DR17.6 with electro fusion couplers at joints.

Pipe fittings should be PE80 SDR17.6 or SDR11.

This description has superseded the older Modified Density Polyethylene (MDPE) and High Density Polyethylene (HDPE) classifications.

For normal highway loading the use of SDR11 (10 bar rated) pipe is not necessary.

However, in climates with extreme heat conditions, consideration must be given to the use of a more highly rated pipe to counteract the effects of de-rating due to temperature. In these instances, SDR11, 10 bar PE80 should be used.

3.1.1.2 uPVC pipe

The recommended 3" uPVC pipe is Schedule 40 with all solvent welded joints. All 4"and larger sizes should be SDR21 with gasketed joints for pipe solvent welds for fittings.

Pipe fittings should be Schedule 40 DWV, ASTM D2665; solvent cement D2564.

Any manufacturer must certify that the gasket joint has been tested in accordance with ASTM D3139, Section 6.1.2, and the assembled joint must be able to withstand a vacuum of 24" mercury for four hours with less than 1% per hour leakage while in the axially deflected position as in 6.1.1.

Note: If solvent jointed uPVC pipes are used, the installer should closely follow the manufacturers specification.

In large bore pipework we strongly advise the use of polyethylene.

3.1.2 Marker Tape.

To facilitate the tracing of a sewer line and to act as a warning to a future excavator, the use of a traceable marker tape is required. This should be a 150mm wide polyethylene dual layer tape with a stainless steel tracer wire encapsulated between the two layers.

The wire should be in sinusoidal wave form, which allows up to 25% stretch deformation of the tape without damage to the tracer wire. The tape should be printed with a descriptive warning of the pipework below.

3.1.3 Pipe Fittings

Pipe fittings selected should be appropriate to the pipe material specified. For polyethylene pipe, the use of PE80, SDR11 fittings is recommended (see Sub-section 3.1.1.1 Polythene pipe). Electro-fusion couplers are preferred to butt welded joints.

If uPVC pipe is specified, the fittings used should be Drain Waste and Vent type. All joints should be Solvent welded.

3.1.4 Pipe for Gravity Sewers

As mentioned in Chapter 2, Section 2.6.3 Gravity Lines And Sump Venting, para. 4, it is a requirement that lines leading to vacuum interface valve chambers be constructed from pressure pipe. This is due to the possibility of low pressure within the lateral connections which could cause the collapse of a pipe. Therefore the material used should be uPVC Schedule 40 (see Sub-section 3.1.1.2 uPVC pipe) or, if preferred, vitrified clay.

3.1.5 Division Valves

Division valves enable each vacuum sewer to be individually isolated either as a whole using the station valves or in sections using the valves within the sewer network itself.

The preferred valves are resilient seated gate. Resilient seated gate valves should be capable of withstanding a vacuum of -0.8 bar and passing a hard solid sphere with a diameter equal to 100% of the nominal bore of the valve. The body, bonnet, gate and bridge should be fabricated from ductile or cast iron. The stem should be stainless steel, and the gate should be encapsulated with EPDM.
As an alternative, eccentric plug valves may be used. They should be capable of withstanding a vacuum of -0.8 bar and passing a hard solid sphere with a diameter equal to 85% of the valve diameter. The body, bonnet and plug should be fabricated from ductile or cast iron. The closing face should be 90% nickel.

Valves of either type should be fitted with a cap on the spindle suitable for operation with an extended Tee key. Gate valves of all sizes should be direct operation, plug valves of over 100mm nominal bore and will require a geared actuator to overcome vacuum effects in opening the valve.

3.1.6 Valve Pit/Collection Sump

Many configurations and materials are successfully used worldwide for the valve pit/collection sump. For example, the two sections may be mounted vertically one on top of the other or the two sections may be separated by some distance. The sections may be made from pre-cast concrete units or from fiberglass or from polypropylene. The diameter of the sections for standard chambers may be as small as 900mm or as large as 1500mm. All these and other variants have been successfully employed in Iseki Systems.

Once the basic requirements of the components are understood, the most suitable variant for a particular project may be determined by the engineer. Certainly there are no rigid standards relating to material, shape or size that cannot be adapted to best suit each project. For example:

- If access to a site is restricted and very difficult then fiberglass units could be used, which are easy to handle manually,.
- For an area with very bad ground conditions and restricted access for machinery, then side-by-side valve chambers and sumps may be used because of their suitability for hand installation.
- Industrial sites with very heavy wheel loading may suggest the use of pre-cast concrete units. Pre-cast concrete units require less skilled labor to install adequately when compared with fiberglass. Also the depth of pre-cast concrete sumps may be adjusted for lateral connections.

Each project should be judged on its own merits and a decision made on the basis of cost, ease of installation, suitability for a particular application, and satisfaction of Iseki's recommendations and minimum requirements.

3.1.6.1 The collection sump

The collection sump must prevent ingress of water from outside and prevent leaks of the collected sewage into the surrounding ground. The collection sump must also be sealed around penetrations through the chamber wall. It must be capable of withstanding the loads imposed upon it from ground and hydrostatic pressure and both static and dynamic road loading.

The bottom of the sump must be shaped to ensure the operation of the interface valve. Emptying the sump removes all solids, thereby rendering the sump self-cleansing. The sump must be made of material of sufficient strength as well as strong enough to resist any corrosive actions of the collected effluent.

3.1.6.2 The valve chamber

The valve chamber houses the interface valve. It must prevent ingress and egress of water. The valve chamber must also be sealed around penetrations through the chamber wall . It must be capable of withstanding the loads imposed upon it from ground, hydrostatic pressure, and both static and dynamic road loading. The valve chamber must be large enough to house the interface valve itself and allow access for a maintenance worker.

3.1.6.3 Pre-cast concrete units

Typically the pre-cast concrete units should be 1050mm or 1200mm in diameter.

The units themselves must be of sufficient weight to require no anti-floatation measures - a considerable advantage in an area with a high water table.

Units are made watertight by the use of hydrophilic rubber or other approved jointing materials, at the joints of the unit and grommets at the pipe penetrations. The units should be capable of withstanding compression and easily able to withstand all imposed loads.

The collection sump requires a conical benching section and ideally a 400mm diameter bottom, which is the optimum size for the scouring action of the sewage as it enters the suction pipe to clear.

The benching should have a minimum angle of 45° from the horizontal which should ensure no hang up of solids, resulting in a clean and relatively odor free environment. The sump wall should be capable of being drilled to take lateral connections at any radial position required.

Step irons should be provided in the valve chamber to enable safe and easy access.

The floor slab of the valve chamber should have an access way to the collection sump section, complete with a loosely fitted cover. The use of correctly sealed joints between the units and a well fitted manhole cover will ensure no water ingress into the chambers.

3.1.6.4 Fiberglass units

This material has been widely used in the United States. These units are typically 1 metre in diameter and lightweight and therefore easily handled.

A concrete base may be required as an anti-floatation measure.

The collection sump section should be shaped to form self-cleansing benching. The sump wall must be capable of being drilled to take lateral connections at any radial position required and to be sealed using grommets.

The valve chamber must be sealed to prevent any moisture entering the collection sump.

3.1.6.5 Alternative fiberglass units

An alternative fiberglass unit of 1200mm diameter, with protection against harsh, corrosive saline ground water and high temperatures, has been used in desert climates.

3.1.6.6 Dual In-situ Concrete Chambers

These may be suitable for use in very restricted areas where a variety of shapes and sizes of sumps are needed to fit among existing services and obstructions.

These examples of valve pit/collection sumps as listed above give an indication of the range of acceptable designs. Iseki will be pleased to advise on alternative proposals and to help with overcoming particular problems of access, space availability, materials etc.

3.2 SPECIFICATIONS FOR VACUUM STATION EQUIPMENT

3.2.1 Vacuum Station Pipework and Valves

Generally, pipework within the collection station may be divided between the sewage discharge segment, which is formed from ductile iron elements, and the vacuum segment, which is formed from plastic elements.

The discharge segment includes the pipework between:

- The collection vessel and discharge pumps, and
- The discharge pumps and the outside of the vacuum station building.

The ductile iron pipe should be extended to 500mm beyond the vacuum station wall from where it will be changed to the selected pumped vacuum main material. Pipework and fittings should be jointed with standard flanges with plated bolt sets. EPDM rubber gaskets should be used between all flanges.

All pipework should be adequately supported by bracketry or concrete stools.

Stop valves must be as described in Chapter 3, Section 3.1.4 Division Valves. Non-return valves must be resilient seated flap valves with external weighted lever to assist closure or ball type.

Figure 18 shows typical piping arrangement for the ductile iron section.

The plastic piping in the station includes the following:

- The vacuum takeoff from the vessel to the vacuum pumps;
- The air exhaust from the vacuum pumps to atmosphere;
- The plumbing arrangement around the vacuum pumps; and
- The auxiliary suction pipe used for emptying the drainage sump in the station building.

The pipework should be either Schedule 80 uPVC or ABS. Ball stop valves and ball type check valves must be used in the vacuum pipework. All pipework should be adequately supported with appropriate bracketry.

The auxiliary suction pipe is used to permit draining of the drainage sump within the station building. The drainage sump is 400mm x 400mm x 300mm deep. It is not normally necessary to install an interface valve in the drainage sump. A manually operated valve is adequate, which should be a ball stop valve placed in a position to be easily accessible for operation.

3.2.2 Vacuum Gauges and Chart Recorder

Vacuum gauges must be fitted to the collection vessel and each incoming vacuum main. These gauges should be 150mm diameter and placed so that they can be read while operating the valves on the incoming vacuum sewer lines.

Figure 19 shows a typical arrangement of a vacuum vessel, incoming sewer lines, isolating valves, and vacuum gauges. The gauges are mounted on the side of the isolating valves away from the vacuum vessel. This enables each line to be individually closed and the vacuum level within that line observed. This is a useful diagnostic feature during commissioning and trouble shooting procedures.

3.2.3 Vacuum Pumps

Iseki recommends the use of liquid ring type vacuum pumps, but as an alternative sliding vane pumps can also be used.

3.2.3.1 Liquid Ring Type Vacuum Pump

These pumps are capable of continuous operation and have an ultimate vacuum capability of -0.92 bar absolute.

The liquid ring type vacuum pump or compressor needs only one moving part because the functions of mechanical pistons or vanes are performed by a rotating ring of liquid compressant.

A balanced rotor, consisting of a series of equally spaced blades on a central hub and supported at one end by a shroud, is used to rotate the ring of liquid in a cylindrical body casing.

The pump body is offset from the rotor axis so that the rotating liquid almost fills then partly empties each rotor chamber once each revolution. Air or gas is ported into the sector of the rotor chamber where the liquid compressant starts to recede.

As rotation continues past the end of the inlet port, the compression begins. The liquid progressively re-enters the rotor chamber until the discharge port is reached. At this point the air or gas rushes out of the rotor chamber with some of the liquid compressant, then the cycle recommences.

The liquid ring acts not only as a piston to compress the gas but also to absorb the heat produced from the compression and friction and any latent heat occurring from vapor condensation.

At the discharge port, liquid and gas can be easily separated with suitable accessories which can be provided as standard equipment. The discharged liquid may be replaced by once through make-up, or cooled through a heat exchanger and then recirculated.

By using the liquid ring vacuum pump process, vapors can be condensed and subsequently recovered if required. Furthermore, vapor condensation reduces the volume to be handled which effectively enhances the pump capacity. The liquid compressant also cushions the impact of any liquid or soft solids that may be entrained in the inlet air or gas. Slugs of liquid can be tolerated as they should cause no damage.

This principle of operation offers a pumping action without pulsation or vibration. The moderate rotational speeds required ensure a quiet operation with minimal maintenance .

The pump should be constructed with a cast iron body and a spheroid graphite iron rotor. Pumps should be fitted with a single mechanical seal.

3.2.3.2 Sliding Vane Vacuum Pump

Sliding vane vacuum pumps produce air pressure or vacuum at considerab pressure differences.

The compressor consists essentially of a rotor mounted eccentrically inside cylinder. Loose vanes are arranged to slide in slots in the rotor. As the roto revolves the vanes are flung by centrifugal force against the cylinders wall to form a series of cells of varying volume. On one side the increase in volum creates a vacuum while on the other side the reduction in volume produce compression of the entrained air.

3.2.4 Vacuum Vessels

The sewage collection vessel within the collection station should be manufactured from either welded steel or fiberglass.

A steel vessel must be designed to the following criteria:

• Design pressure	Full vacuum
• Working pressure	-0.8 bar
• Hydraulically tested to	1.5 bar G
• Design temperature	0°C to 50°C
• Corrosion allowance	1mm
• Minimum Protective Finish	Grit blast inside and outside One coat primer inside and outside

NOTE: Local codes for sewage containment may require additional internal protection.

Figure 20 shows the nozzles and other equipment and fittings required for a typical vessel.

If a fiberglass tank is selected, the performance specification should be the same as for the steel vessel, but no grit blasting/painting is required.

3.2.5 Discharge Pumps

Two identical sewage discharge pumps are required. Each must be capable of discharging the calculated peak flow of sewage against the head created by the suction and pumping main conditions.

Recommended pumps are vertically mounted, combined, submersible dry well models. After manufacture and testing, each pump should be primer undercoated and painted with a final coat of chlorinated rubber gloss paint or equivalent, as approved by the applicable engineer. Pumps should be fitted with either roller or ball bearings housed within a cast iron casing. These bearings must be designed to carry all axial and radial thrust loads across the pump operating range.

The impeller is normally cast iron, non-clogging, statically and dynamically balanced and capable of passing a 75mm sphere at a minimum. The impeller should be attached to a high tensile steel drive shaft fitted with a renewable hardened steel sleeve.

The pump should be fitted with back to back oil seals with a backing washer fitted both at the front and the back of the glands.

The impeller housing should be manufactured from cast iron and incorporate a covered hand hole for clearing the pump. The pumps should have cast iron extensions to carry direct mounted motors on fabricated steel stools.

The motor size should be selected by the pump supplier, taking into account all head conditions. Great care must be taken in pump selection to ensure suitability for the required duty of pumping against vacuum. The manufacturer should give a suitable warranty of performance.

Horizontally mounted pump units are acceptable.

3.2.6 Control Panel

The pumping equipment within the collection station is controlled by the electrical control panel. This is a custom made item and must comply generally with the local and national codes regarding construction and component standards. The operating philosophy of the station equipment, which will enable the panel supplier to design the wiring and PLC programming, is described in Chapter 4 Operation, Section 4.2 Operating Philosophy of the Station Equipment.

3.3 PACKAGE STATIONS

For smaller sewerage systems of up to around 10 litres per second peak flow may, if required, be served by a skid mounted pre-fabricated collection station.

For such an arrangement the vacuum vessel, vacuum pumps, sewage discharge pumps and control panel, together with all piping and wiring, are assembled and tested prior to being delivered to the site, where the skid is placed within a building erected on site. Once vacuum sewer, electrical, and any other service requirements are made, the station can then be brought into operation. Figure 11 shows a typical package vacuum station.

Please contact Iseki for further details of package stations.

3.4 STANDBY POWER GENERATOR

In some situations a standby generator may be recommended. This will be the case particularly in remote locations where power outages are a regular possibility, e.g where the power lines to the station are above ground and winter storms bring down supporting poles. The designer must assess, in conjunction with the operating authority, the necessity for the standby generator.

3.5 VALVE MONITORING SYSTEM

The valve monitoring system comprises a number of sections, all of which are supplied by Iseki:

Magnetic reed switch/signal transmitter	
Fabrication	Grade 316 stainless steel
Water resistance	Sealed to impermeability at 4m water depth
Corrosion resistance	Sewage environment resistant

Connection box from switch to main cable	
Fabrication	Resin filled
Water resistance	Sealed to impermeability at 4m water depth
Corrosion resistance	Sewage environment resistant

Valve Monitoring System Cabling	
Type	1.5mm^2 single twisted pair
Armoured	Steel wire
Screened	Not necessary

Signal Generator And Display Array

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CHAPTER 4

OPERATION

4.1 GENERAL

The vacuum sewerage system comprises three main elements:

- Vacuum interface valve
- Vacuum mains
- Collection station.

4.1.1 Vacuum Interface Valve

The vacuum interface valve is installed within a chamber, in many cases combined with the collection sump. The sewage is discharged into the collection sump through the gravity connections. These lead from conventional sanitary equipment fitted within the properties, businesses, etc.

As the level of sewage within the sump rises, air is trapped in the sensor pipe, thus causing an increase in air pressure. Eventually this pressure becomes great enough to operate a switch within the control mechanism, allowing the vacuum on the downstream side of the valve to pull the air from the bonnet of the valve and lifting the plunger from its seat. Atmospheric air pressure within the chamber then rushes towards the negative pressure within the vacuum main carrying the sewage with it. As the sewage level drops within the sump, air pressure in the sensor pipe falls and the valve closing cycle starts.

An adjustable volume of air is allowed to enter the vacuum sewer after the sewage. This air generates the energy to transport the sewage. The valve, now closed, has completed one full cycle and the process begins again.

4.1.2 Vacuum Mains

The sewage is now within the second element of the system - the vacuum mains.

Initially the sewage will move at a velocity of up to 6 metres per second, as a foaming mixture of sewage and air. The velocity gradually declines as the sewage moves along the main.

The air overtakes the sewage and carries on back towards the collection vessel within the collection station. The sewage eventually settles out in the low points of the profile. The next time a valve fires, the air rushing through the sewer picks up the previous "slug" of sewage from the low points and transports it onwards.

4.1.3 Collection Station

Finally the sewage reaches the collection station, which is the third element of the Iseki System.

The equipment within the collection station is as follows:

- Vacuum vessel
- Vacuum pumps
- Discharge pumps
- Electrical control panel.

The vacuum within the vacuum vessel and the vacuum mains are maintained by the vacuum pumps and are controlled by the pressure switches inside the vacuum vessel.

Sewage enters the vacuum vessel from the vacuum sewer. The vacuum vessel contains a number of level controls which, as the liquid level rises, switch on the duty sewage pump. Sewage is discharged through the pumping main until the level in the vacuum vessel drops to the low level control which stops the pump. If the sewage inflow is greater than the duty pump capacity or if the duty pump fails, another level control will operate the standby sewage pump.

If both sewage pumps fail, a high level control will switch off both sewage pumps in the automatic mode and both vacuum pumps in the manual and automatic mode. At the same time an alarm will be transmitted to the duty operator by telephone or radio. Switching off the vacuum pumps will prevent sewage being drawn into them causing their failure.

In some countries the Laws require the installation of a standby generator designed to automatically take over in the event of a main power failure. This generator should be sized at a minimum to start and run one vacuum and one sewage pump plus all station lights and control circuits.

Rising sewage levels within the vessel are detected by probes which call in the discharge pumps as required. The sewage is discharged from the vacuum station into the primary settlement tanks within the sewage treatment works.

4.2 OPERATING PHILOSOPHY OF THE COLLECTION STATION EQUIPMENT

This Section describes the operation of the station equipment.

4.2.1 Vacuum pumps

The vacuum pumps operate on a duty/assist basis. The duty is selected/rotated automatically within the PLC logic.

On initial start up of the vacuum system, both vacuum pumps will be brought into operation. On reaching the standby vacuum level, the standby pump will stop. The duty pump will continue to run until the duty vacuum level is reached. Upon reaching the duty vacuum level the duty vacuum pump will also stop.

Due to the demand for vacuum by the vacuum interface valves connected to the system's network of pipes, the vacuum level within the vacuum collection vessel will drop.

When the vacuum level drops to the pressure at which the Duty vacuum pressure switch is set, the duty vacuum pump will start.

When the duty vacuum pump brings the system vacuum pressure up to the duty vacuum pressure, the duty vacuum pump will stop. This process is repeated during normal operation of the system.

The vacuum pressure range between the level at which the duty vacuum pump starts and stops is known as the duty vacuum range.

Typical values for starting and stopping vacuum pumps are given in Chapter 2 Design, Section 2.5 Control Philosophy.

If the duty vacuum pump does not produce sufficient vacuum to satisfy the demand from the system and the Vacuum level in the system drops to that at which the standby vacuum pressure switch is set, the standby vacuum pump will be brought into operation. When both of the vacuum pumps are called to run in this situation, Recovery System No. 2 will be brought into operation by the PLC.

If the duty vacuum pump fails to run when called for, the standby vacuum pump will be brought into operation and a "vacuum pump failed" signal will be made available at the no Volt telemetry rail within the motor control center.

If the vacuum level reaches that at which the high level vacuum switch is set, both vacuum pumps will be locked out of operation and a high vacuum level alarm will be made available at the telemetry rail within the control panel.

To bring the vacuum pumps back to automatic operation, the manual reset button on the control section door of the motor control center must be pressed.

If the Recovery System No. 2 does come into operation and the vacuum level within the system goes as low as that at which the low vacuum pressure switch is set, a low vacuum alarm will be made available at the telemetry rail within the motor control center.

The duty vacuum pump is rotated automatically by the PLC after every run period or every 24 hours.

4.2.2 Recovery System No. 2

This system comes into operation when both vacuum pumps are called to run. Its function is to attempt to recover normal operation following a valve failing in an open position.

Full details of this auto recovery system may be obtained by contacting Iseki in the UK or its local agent.

4.2.3 Sewage Discharge Pumps.

The discharge pumps operate on a duty/standby basis. The duty pump is selected within the PLC logic.

The discharge pumps are controlled by the PLC unit within the electrical control panel, which receives its signals from level control probes within the collection vessel.

When the sewage level within the collection vessel reaches the duty level, the selected duty pump will start and will continue to run until the stop level is reached. If the standby level is reached the duty pump will stop and the standby pump will start and will continue to run until the stop level is reached. If the standby pump fails, the PLC will reinstate the duty pump run signal.

On resumption of the power supply after a power failure, the selected discharge pump will be delayed for thirty seconds.

4.2.4 Recovery System No. 1

If the high level is reached within the holding vessel, Recovery System No. 1 will be brought into operation.

To eliminate false readings, the high level must be maintained for 5 seconds before Recovery System No. 1 is brought into operation. This system will attempt to clear a high level of sewage in the vessel prior to issuing an alarm call to the telemetry system.

Full details of this system may be obtained by contacting Iseki in the UK or its local agent.

4.2.5 Level Probes

This sub-section describes the operation of each of the level probes.

4.2.5.1 Common Earth Level Probe

This probe is the common earth return and is common to all other level probes.

4.2.5.2 Common Stop Level Probe

This probe is set at 200 - 300mm from the bottom of the collection vessel and restricts the operation of the pumps when it is fully exposed (out of the liquid).

4.2.5.3 Duty Level Probe

The duty level probe is set at the level at which the Duty Discharge Pump is required to operate (normally one third of the diameter of the Collection Vessel).

4.2.5.4 Standby Level Probe

The standby level probe is normally set at about half way up the diameter of the collection vessel. If the duty discharge pump fails for some reason and the level in the collection vessel reaches this probe before the duty is rotated, the standby discharge pump will be brought into operation.

4.2.5.5 High Level Probe

This probe is normally set at 3/4 of the diameter up from the bottom of the collection vessel. Its function is to prevent the liquid level within the collection vessel reaching the vacuum take off from the collection vessel to the vacuum pumps. If this level is reached and detected by the PLC, the operation of the vacuum pumps will be inhibited until the discharge pumps evacuate the liquid from the collection vessel, which will expose the common stop level probe. With the stop probe exposed the vacuum pumps become available and will operate on automatic.

The high level probe is linked to a timer which is located on the front of the control section door of the motor control center. Its function is to eliminate any false signals that may be received by the PLC due to wave action within the collection vessel. The high level probe has to be submerged for 5 seconds before the vacuum pumps operation is inhibited.

4.3 STATION TELEMETRY

This section describes the station telemetry. It is recommended that the control panel include a telemetry section with volt free contacts for each condition/alarm of the station equipment.

4.3.1 List of Telemetry Signals

List of signals made available at the telemetry rail:

DESCRIPTION	INPUT/OUTPUT
Site power	OK/Failed
Vacuum pump 1 power	Isolated/OK
Vacuum pump 2 power	Isolated/OK
Discharge pump 1 power	Isolated/OK
Discharge pump 2 power	Isolated/OK
Vacuum pump 1 running	Running/Not running
Vacuum pump 2 running	Running/Not running
Discharge pump 1 running	Running/Not running
Discharge pump 2 running	Running/Not running
Vacuum pump 1 overload	Tripped/OK
Vacuum pump 2 overload	Tripped/OK
Discharge pump 1 overload	Tripped/OK
Discharge pump 2 overload	Tripped/OK
Vacuum level	Low/OK
Vacuum level	High/OK
Sewage level	High/OK

Other items such as intruder alarms, fire alarms, standby generators, valve monitoring equipment, etc., may also be wired to the telemetry rail if required.

It is not essential that all the above conditions be transmitted back to the operations or control office. What information is essential should be determined based on the requirements and circumstances applicable to your project.. As a minimum, the low level alarm should be connected to telemetry because, eventually, any equipment failure will lead to a low vacuum alarm.

The actual selection of the telemetry equipment, (such as manufacturer, radio or land line, etc.) will the client's choice.

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CHAPTER 5

SERVICES

5.1 DESK TOP STUDY

In the past, most users considered vacuum sewerage systems for their lower capital when compared to conventional systems. Today more and more clients are looking at the operational advantages and O & M cost savings as well as initial capital costs.

When a client is considering a vacuum sewerage system, an Iseki distributor can take maps of the area and ascertain if an Iseki System is feasible. If it is, Iseki will prepare outline construction and O & M costs.

Iseki's proposal will include size and location of vacuum sewers, number of interface valves, and location and size of vacuum station together with estimated electricity and maintenance costs.

5.2 DETAILED DESIGN

Once a decision has been taken to proceed with a vacuum sewerage project using the Iseki System, the client's engineer will produce a detailed design including drawings and specifications.

The level of support and assistance he will receive from Iseki will depend upon his experience in vacuum-system design. Iseki offers a complete range of design services from full production of drawings/specifications to a simple checking procedure.

5.3 CONSTRUCTION

Generally, construction will be undertaken by a Civil Engineering Contractor and a Mechanical and Electrical Contractor engaged by the client.

If requested, Iseki technicians will visit the site to advise on installation, testing, commissioning etc. The level of assistance required will depend upon the experience of both the contractors and the supervisory engineering staff.

5.4 TRAINING

Iseki offers training services for operating staff. Training will usually cover routine maintenance, trouble shooting, and operational adjustments.

Training will be both practical and theoretical and tailored specifically to the skill levels and experience of the staff.

Fully detailed operation and maintenance manuals will be provided for client review.

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CHAPTER 6

DESIGN EXAMPLE

INTRODUCTION

This chapter illustrates a typical sewage design project, using the equations described in the foregoing chapters.

An imaginary village is illustrated in figure 21 and the necessary design criteria are given below to identify the required materials and equipment.

6.1 DESIGN CRITERIA

Approximate Population	= 500 persons
Approximate No. of Properties	= 150 No.
Flow per person	= 250 litres per head per day

6.2 FLOW CALCULATIONS

Dry Weather Flow.

$$\frac{500 \times 250}{24 \times 60 \times 60} = 1.45 \text{ litres per second}$$ ✓ (Refer to 2.2.1)

Peak Flow

4×1.45 = 5.8 litres per second

6.3 PIPELINE

Total length of sewage pipework assumed to be 4500 meters.

Calculate flow per house

$$\frac{5.8}{150} = 0.039 \text{ litres per second/house}$$

From pipe calculations table on page 2-9

$\frac{\text{2 litres per second}}{0.039}$ = 51 properties can be served in 110mm diameter pipework (for this example say 3000m of the assumed tota pipe length)

$\frac{\text{5 litres per second}}{0.039}$ = 128 properties can be served in 125mm diameter pipework (say 1000m of the assumed total length)

$\frac{\text{10 litres per second}}{0.039}$ = 256 properties can be served in 160mm diameter pipework (say 500m of the assumed total length)

Note:
The furthest 51 properties on the mainline from the station and branches with no more than 51 properties can be served by 110mm pipework.

At the point where the 52nd property meets the mainline (or a branch containing enough properties to make the total amount of properties greater than 52 at the connecting junction with the mainline), the pipe is upsized to 125mm pipework.

Once the total number of properties on a line has reached 128, the pipe diameter is increased to 160mm.

6.4 VACUUM PUMPS

Assume longest line is 2000m, therefore R value is 7

$$Qv = 3.6 \times Qp \times R \times 1.5$$
$$= 3.6 \times 5.8 \times 7 \times 1.5$$
$$= 219 \text{ cubic metres / hour}$$

(Refer to 2.4.3.3)

Select the model vacuum pump offering capacity equal or greater to Qv. Two such pumps should be provided.

Vacuum Pump Down Time

$$T = \frac{Sv}{Qvp} \times 0.7$$ (Refer to 2.4.3.3)

where Sv equals the volume of the proposed pipework.
And Qvp is the combined capacity of the vacuum pumps

Note: 3000 metres of 110mm outside diameter pipework
1000 metres of 125mm outside diameter pipework
500 metres of 160mm outside diameter pipework

$$T = \frac{(\pi(3000 \times 0.05^2)+(1000 \times 0.06^2)+(500 \times 0.075^2))}{2 \times 219} \times 0.7$$

T = approx. 4.2 mins; < 5 mins so pump size OK

6.5
COLLECTION VESSEL

Vo = 15 x 60 x DWF (Refer to 2.4.3.1)

= 15 x 60 x 1.45

= 1.305 cubic metres

Vt = 3 x 1.305

= 3.915 cubic metres

6.6
DISCHARGE PUMPS

Two (2) Discharge Pumps each allowing for the peak flow of 5.8 litres per second.

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ISEKI UTILITY SERVICES LTD
DESIGN MANUAL

APPENDIX A

ILLUSTRATIONS

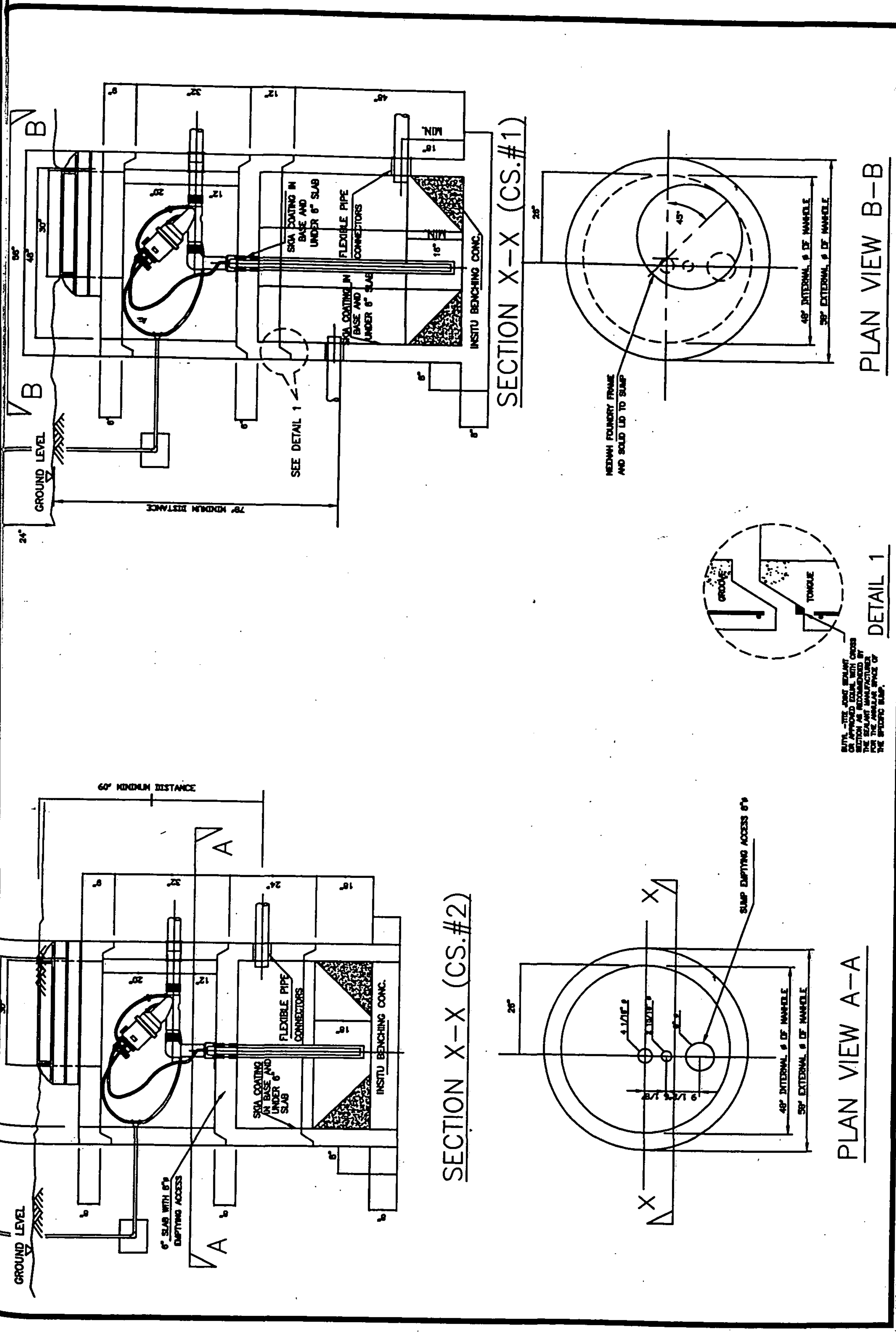


FIG 1 PRE CAST CONCRETE COLLECTION SUMP

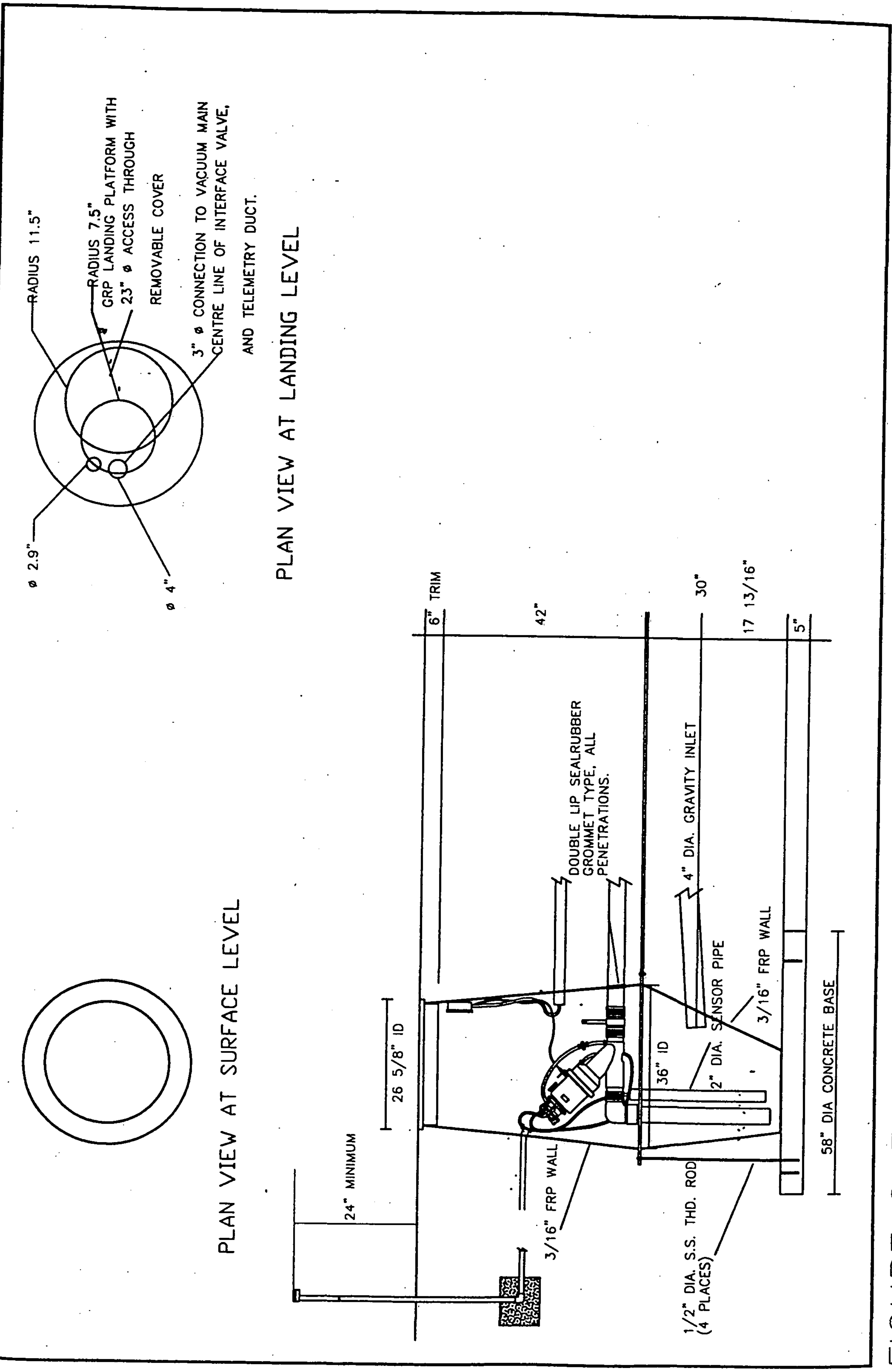


FIGURE 2 FIBERGLASS CHAMBER TO HOUSE INTERFACE VALVE

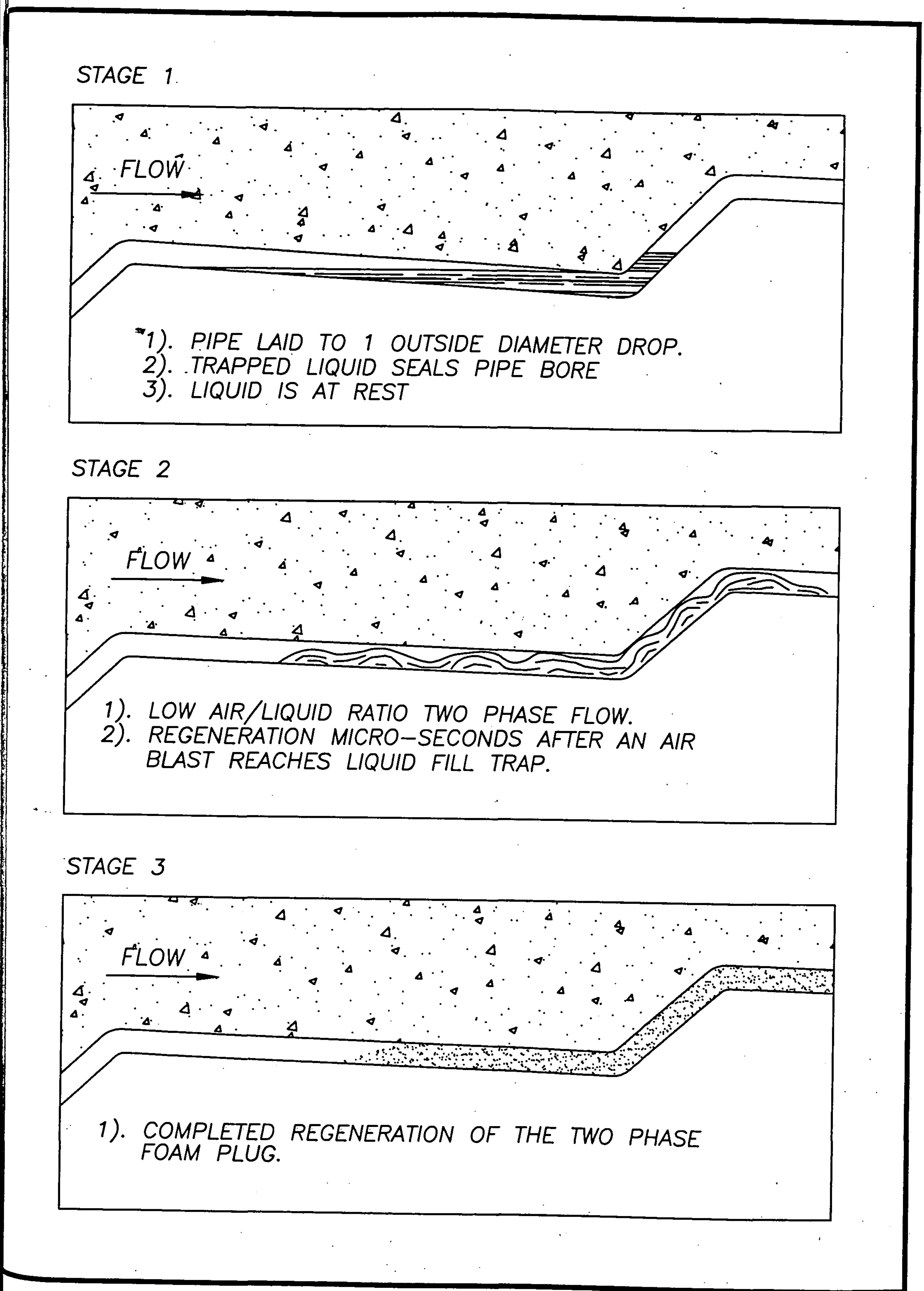
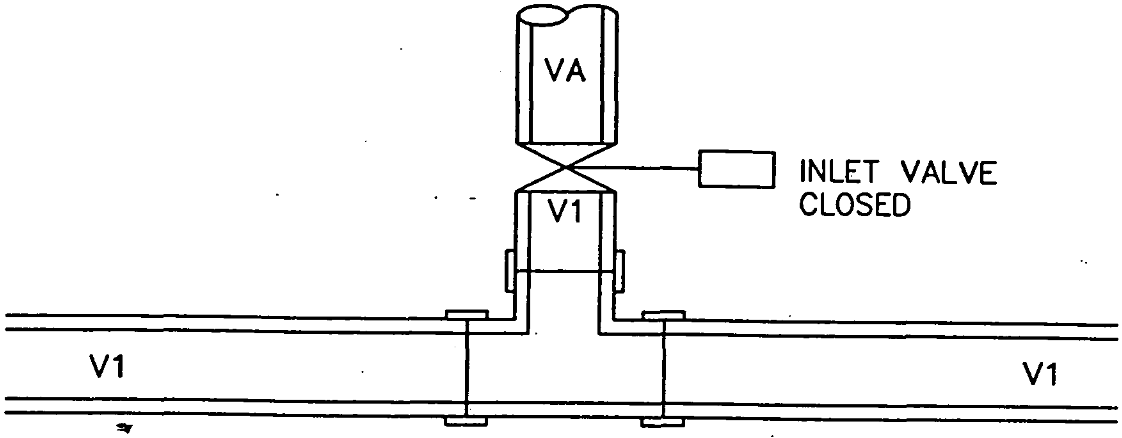
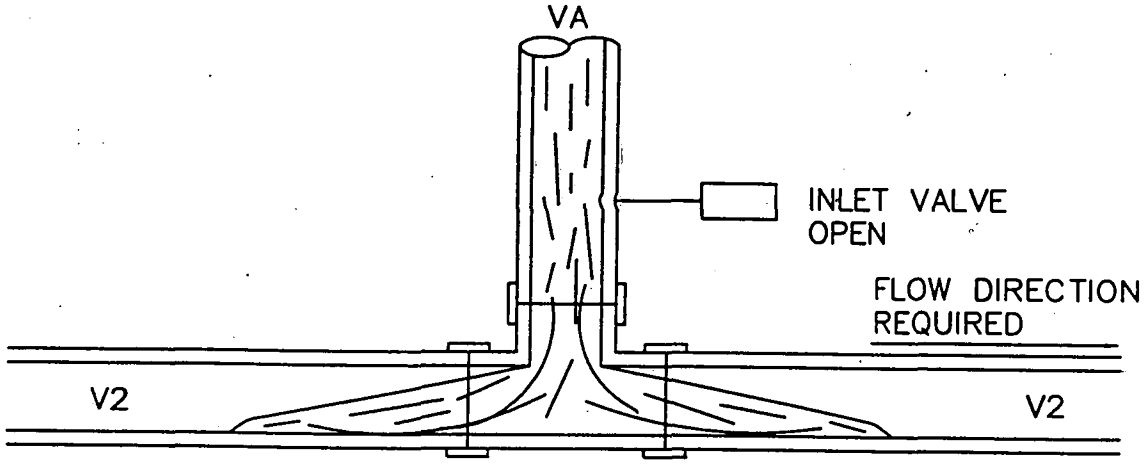


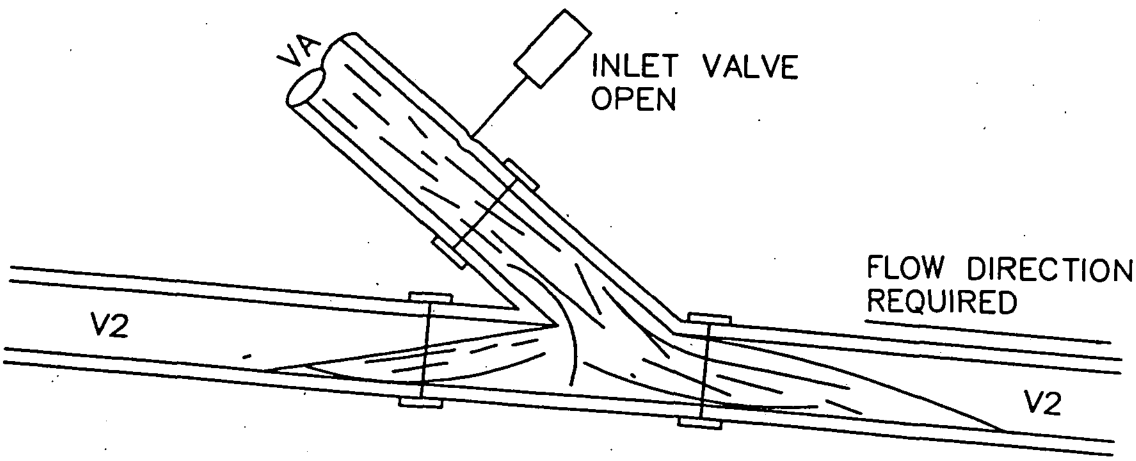
FIGURE 3 TWO PHASE FLOW REGENERATION



INLET VALVE CLOSED—VACUUM IN EQUILIBRIUM AROUND TEE CONNECTION



INLET VALVE OPENS. LIQUID AND ATMOSPHERIC PRESSURE FLOW INTO SYSTEM AT HIGH VELOCITY. LIQUID AND AIR FLOW IN BOTH DIRECTIONS IN EQUAL PROPORTIONS.



PIPE SLOPED AT 0.2% AND 45° Y FITTING USED TO MAKE CONNECTION. THIS REDUCES REVERSE FLOW TO AROUND 20% OF TOTAL OF TWO PHASE AIR/LIQUID PULSE.

FIG 4 BACKSURGE DIAGRAMS

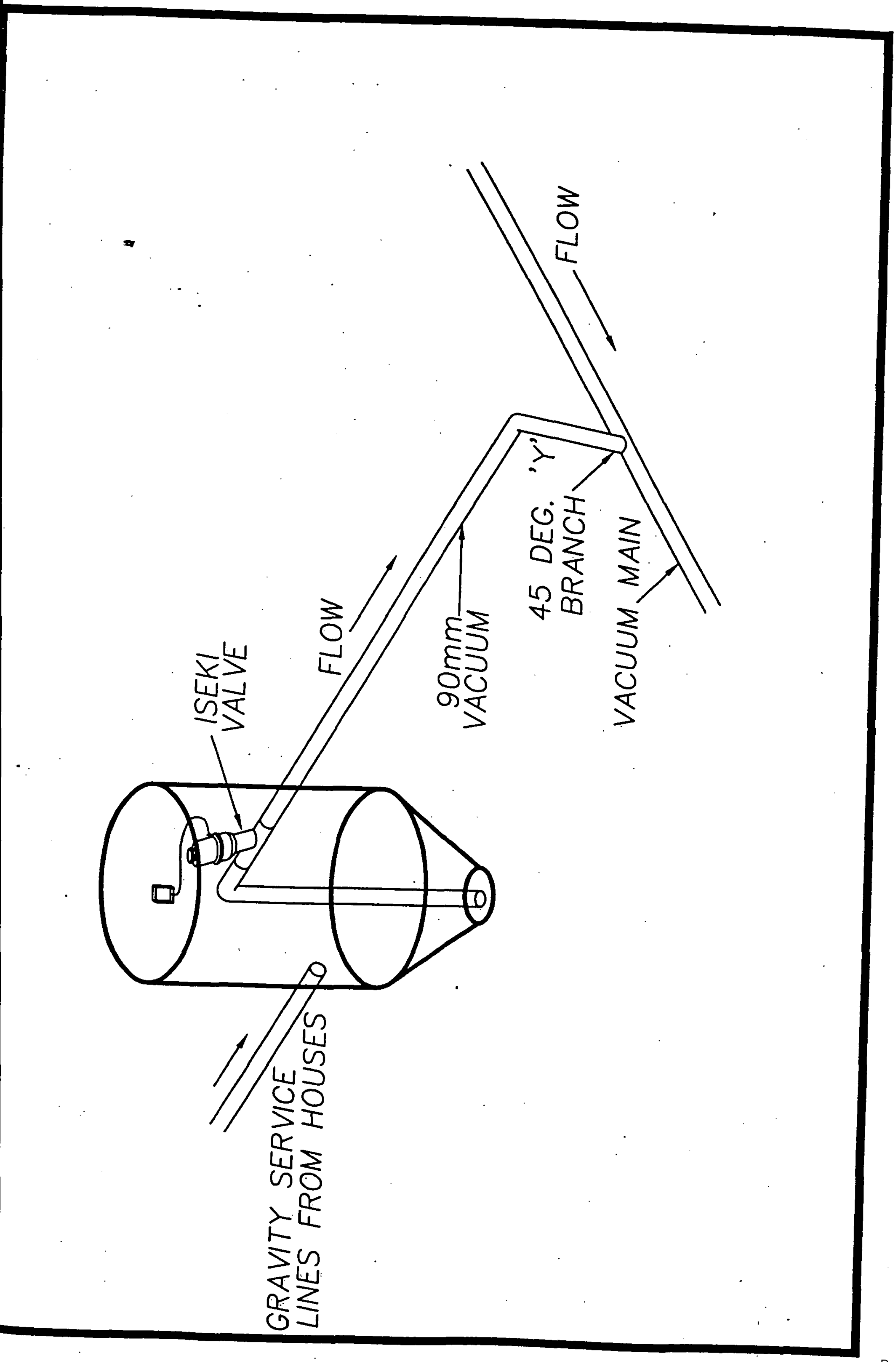
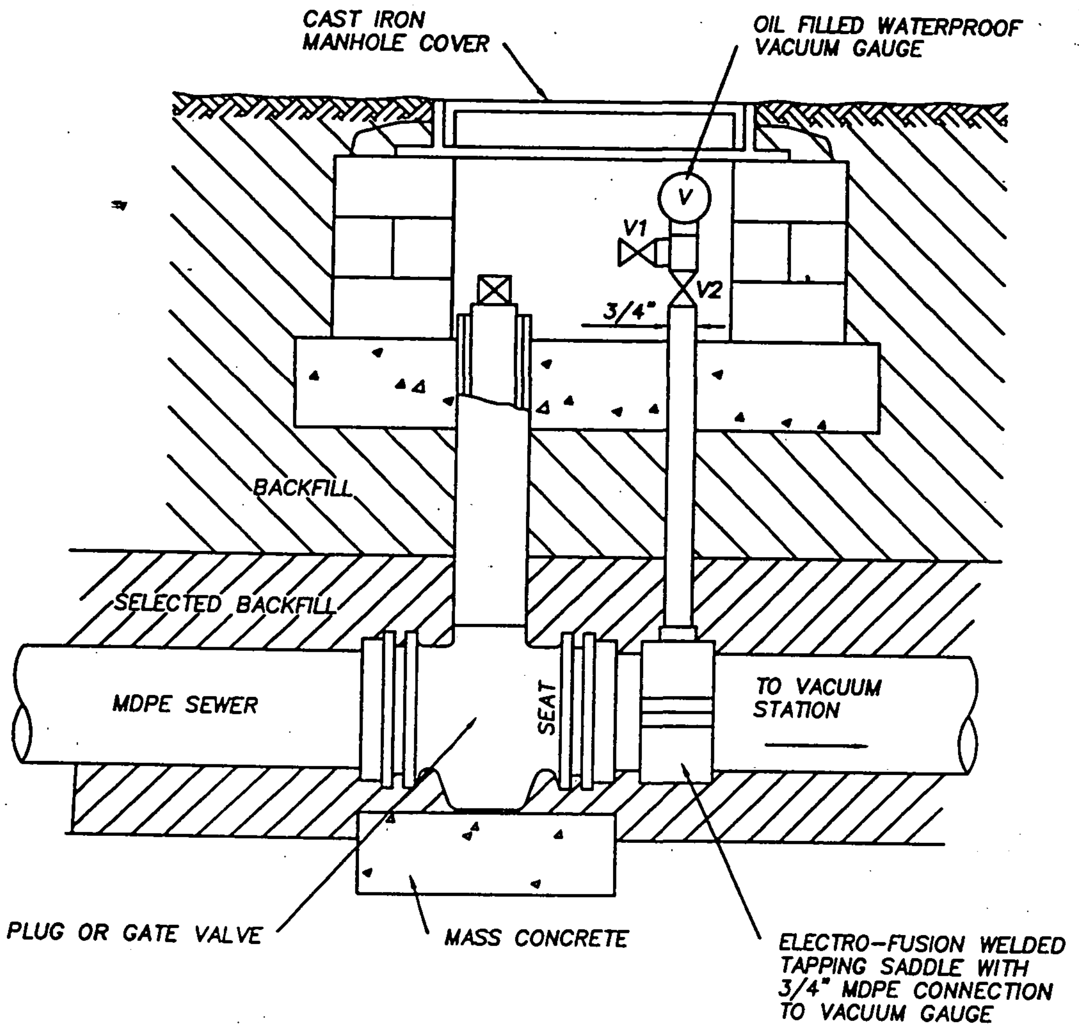


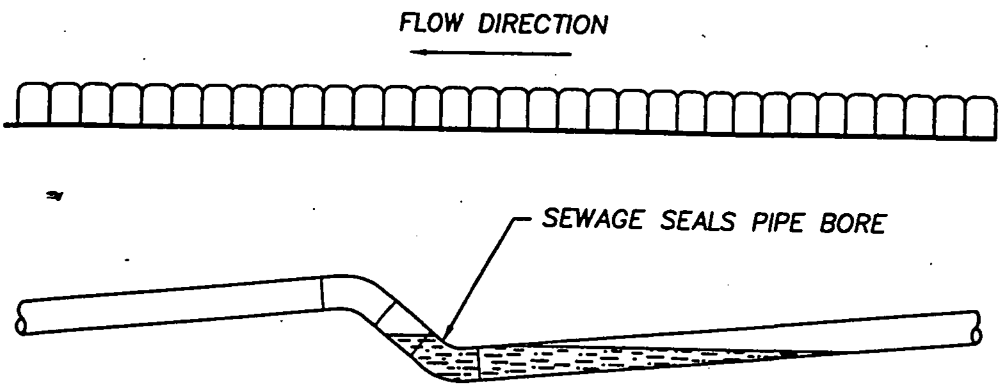
FIGURE 5 CONNECTING PIPEWORK BETWEEN ISEKI VALVE AND VACUUM MAIN



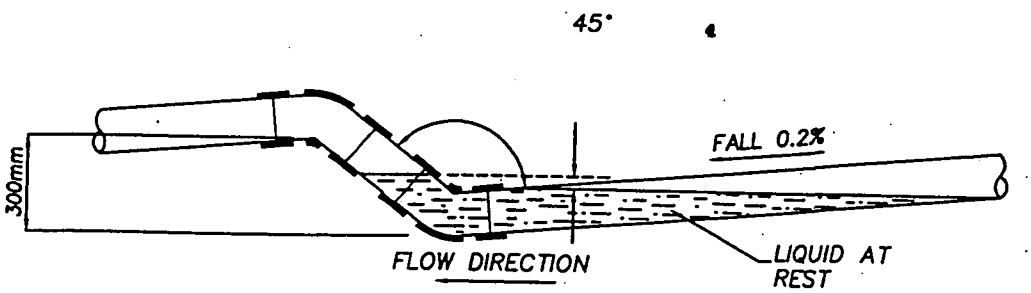
NOTES

1. SEAT END OF PLUG VALVE MUST BE TOWARDS VACUUM STATION.
2. VALVE 'V2' IS NORMALLY OPEN.
3. VALVE 'V1' IS NORMALLY CLOSED BUT IS OPENED ONCE A YEAR FOR 10 SECONDS TO KEEP 3/4" PIPE FREE FROM DEBRIS.
4. OTHER TYPES OF CHAMBERS MAYBE USED TO SUIT LOCAL CODES.

RE 6 DIVISION VALVE CHAMBER FITTED WITH VACUUM GAUGE



LIERNUR INVERT LIFT PROFILE



VACUUM SEWER IS CONSTRUCTED USING MDPE PIPE. LIFTS ARE MADE USING MOULDED ELBOWS AND PVC OR POLYETHYLENE COUPLINGS. LIFTS MAY ALSO BE PERFORMED IN ONE PIECE USING POLYETHYLENE PIPE.

FIGURE 7 ISEKI INVERT LIFT DETAIL

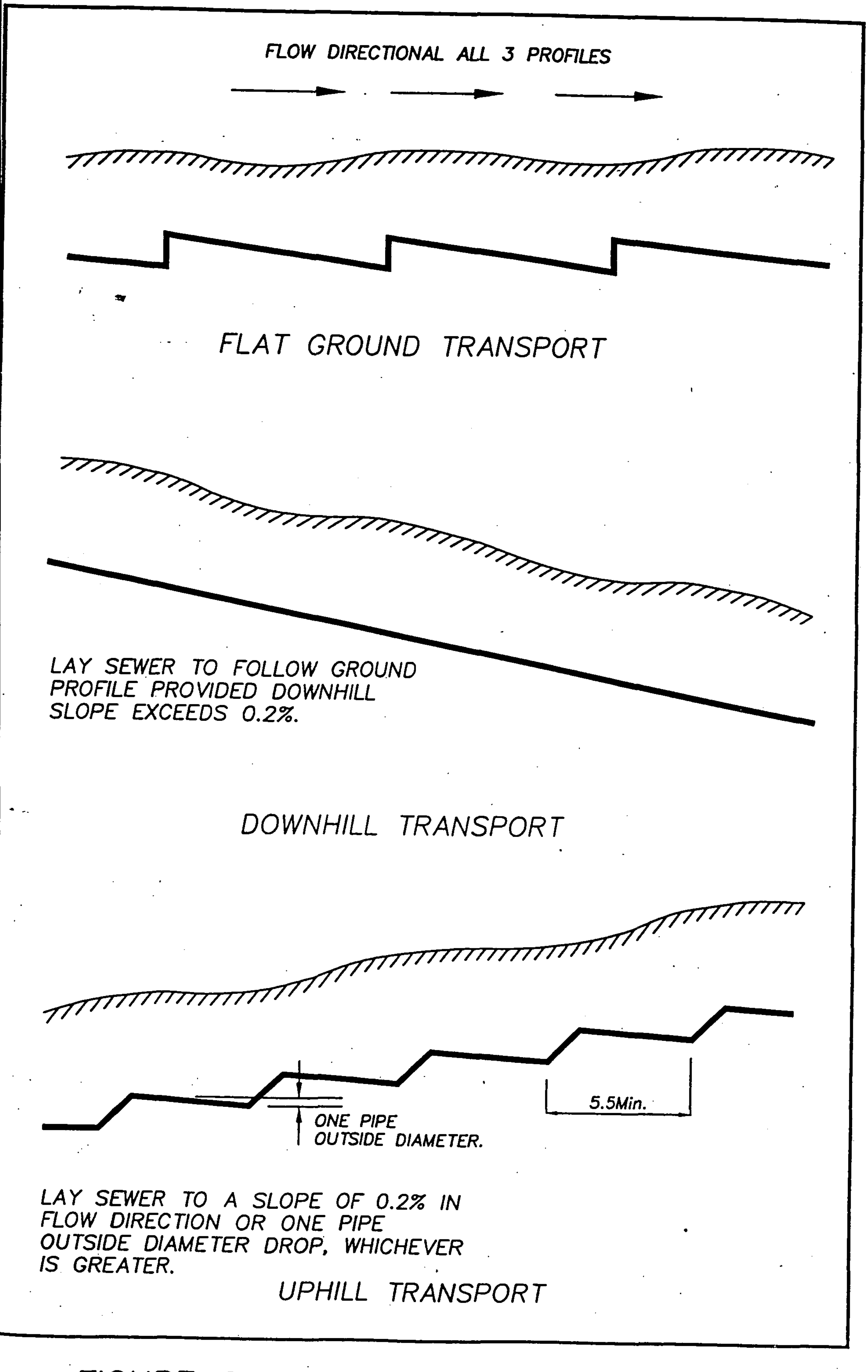


FIGURE 8 ISEKI INVERT LIFT PROFILES

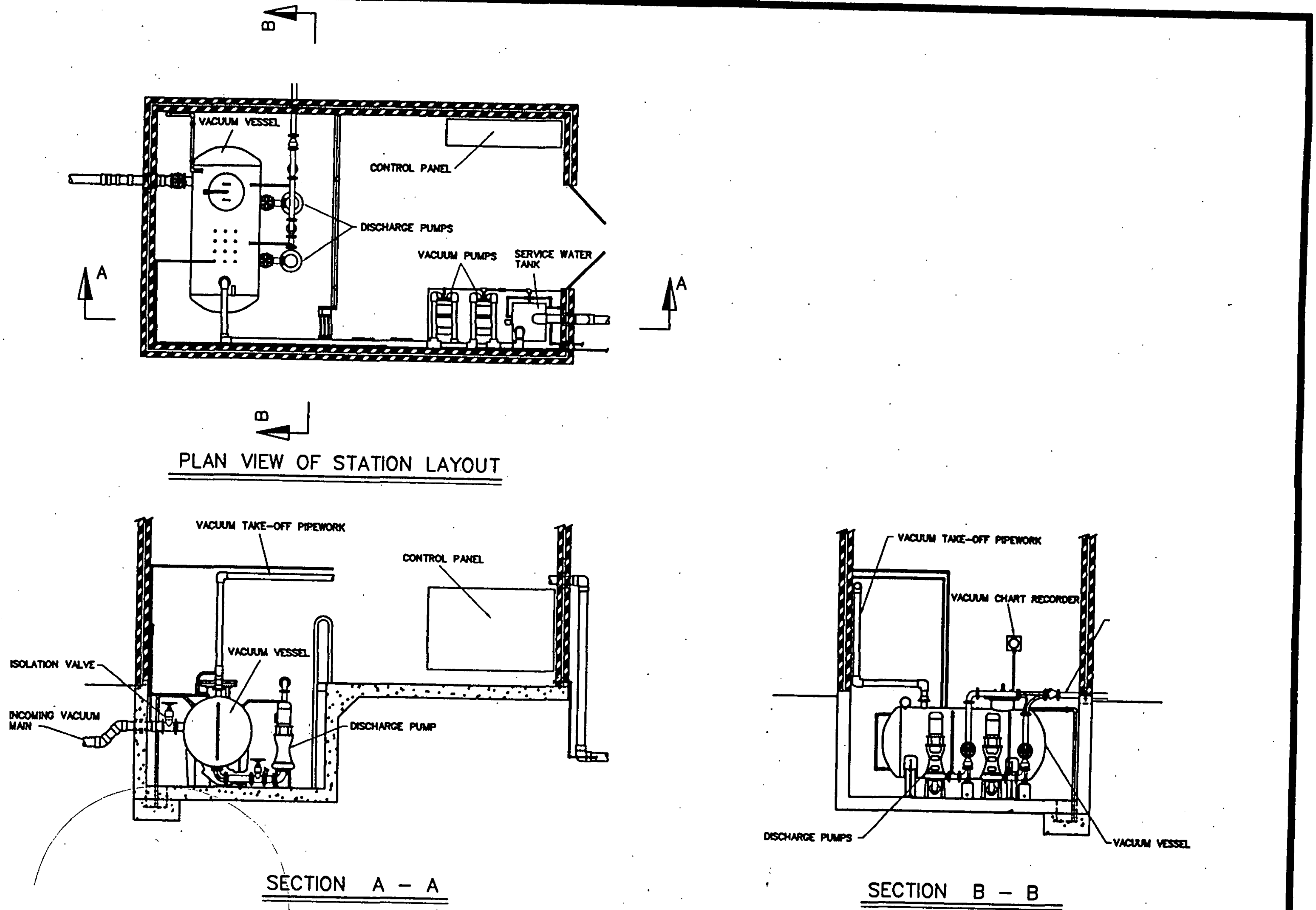


FIGURE 9 A TYPICAL VACUUM STATION

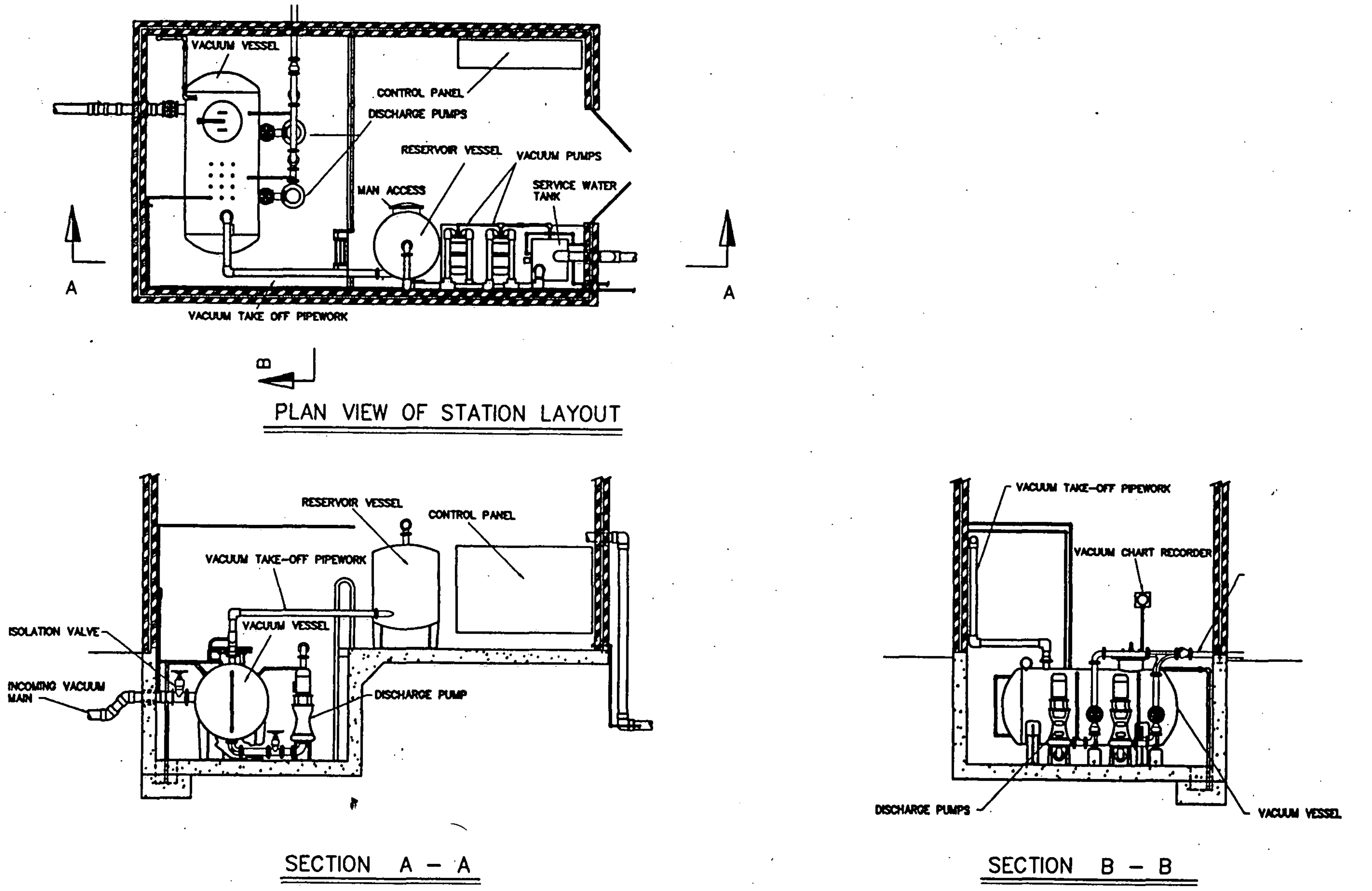


FIGURE 10 VACUUM STATION WITH RESERVOIR VESSEL

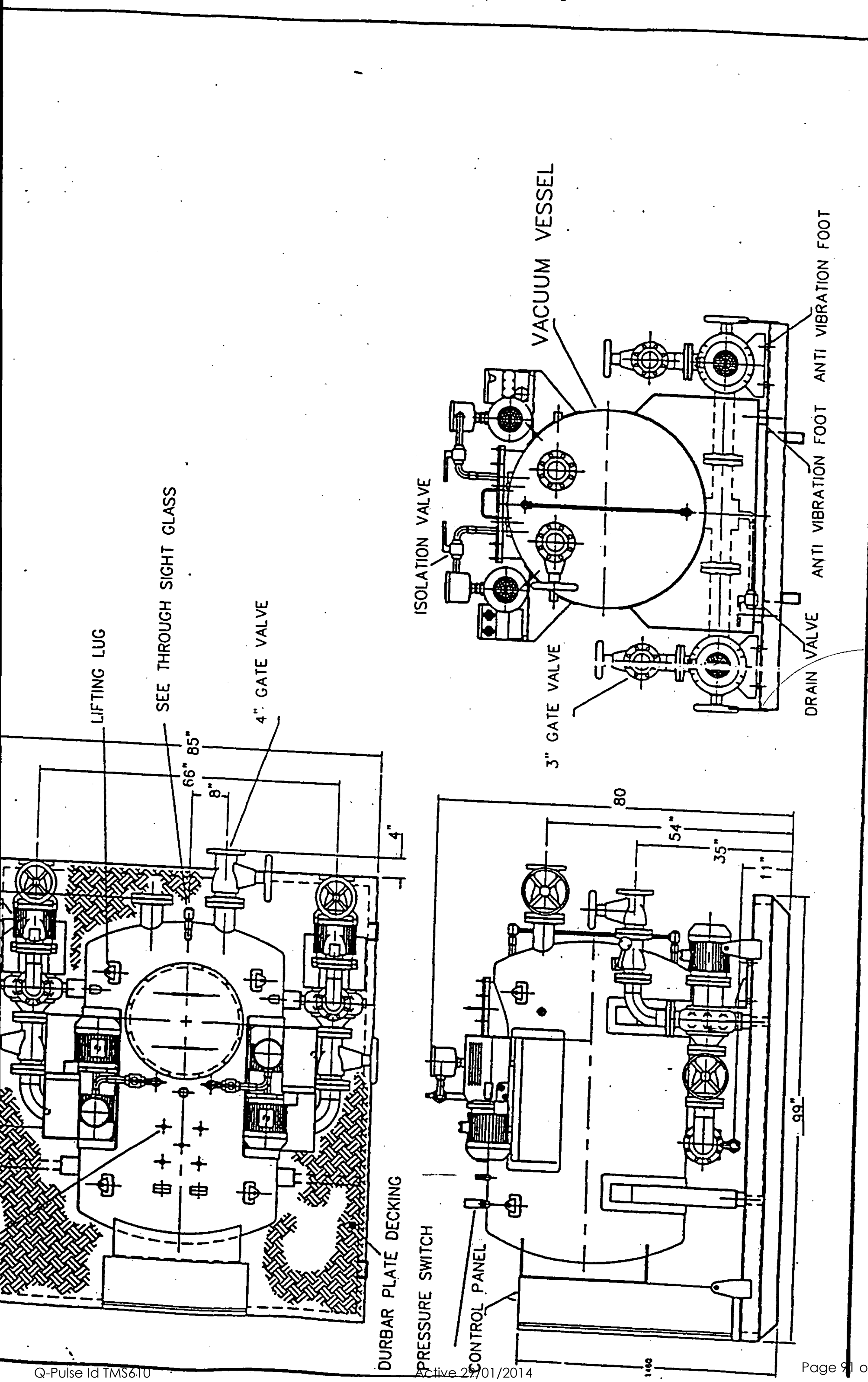


FIG 11 SKID MOUNTED VACUUM STATION

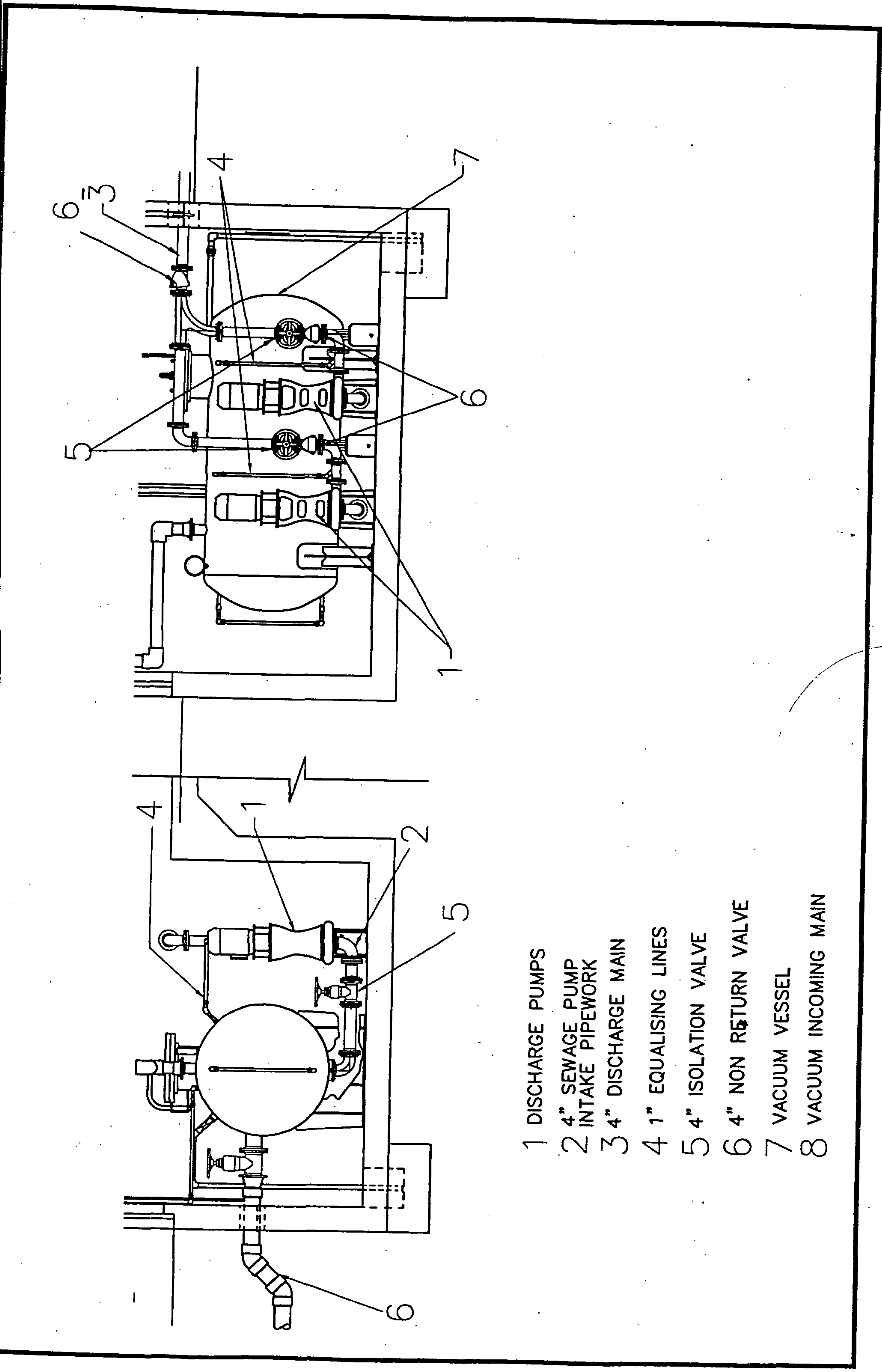


FIGURE 12 DISCHARGE PUMPS WITH TYPICAL PIPING ARRANGEMENT.

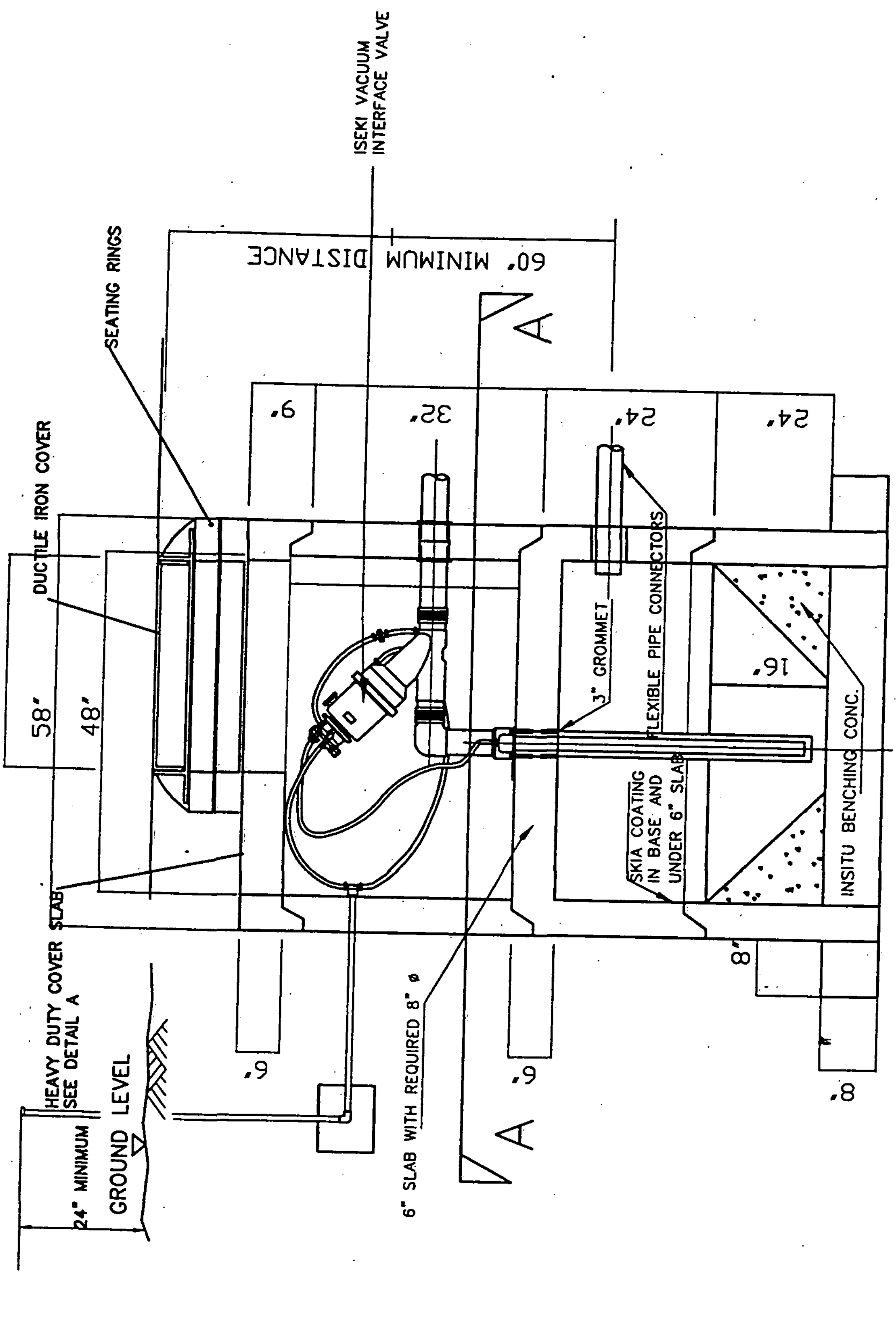


FIG 13 ISEKI VALVE PIT INSTALLATION

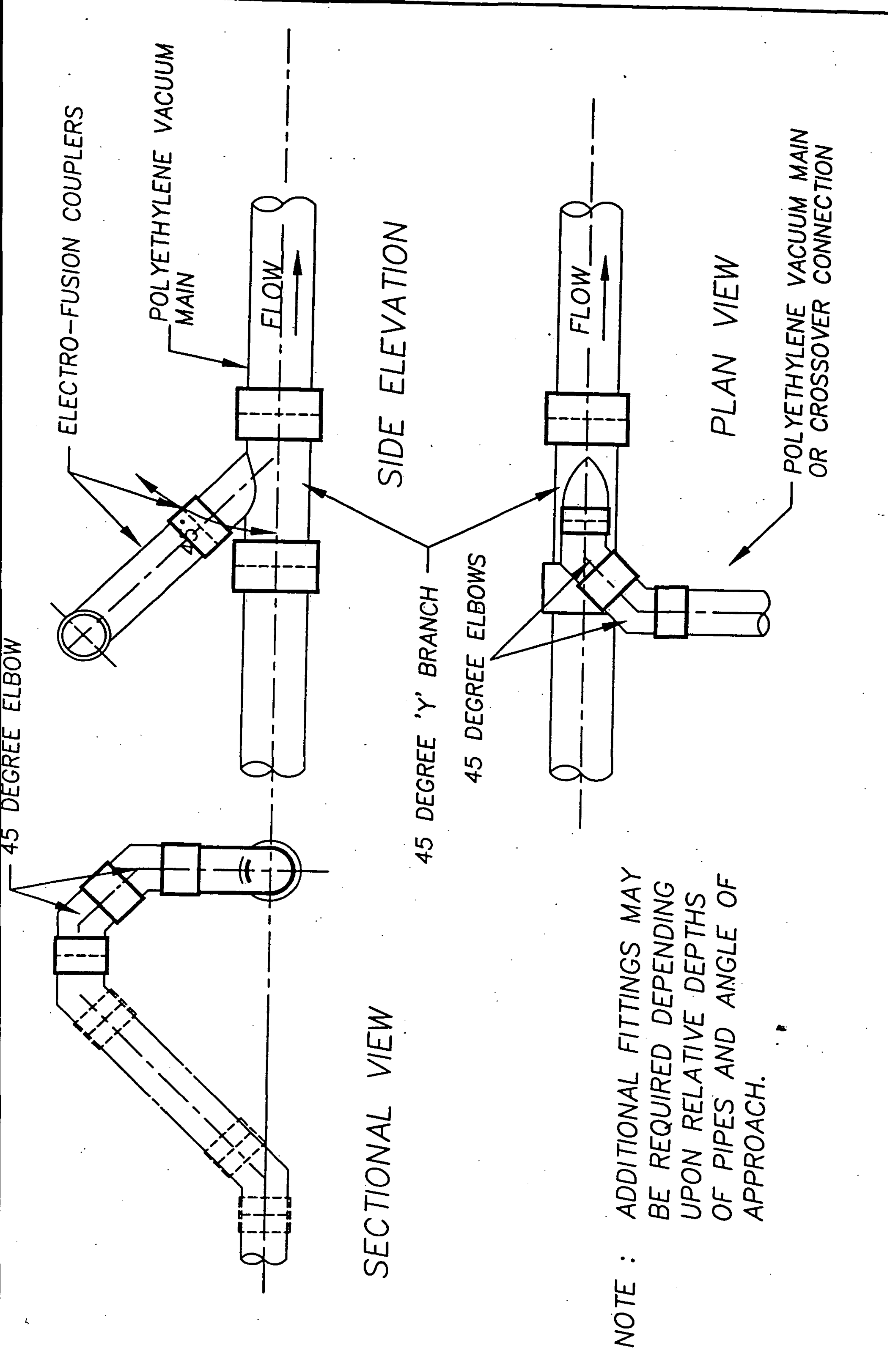
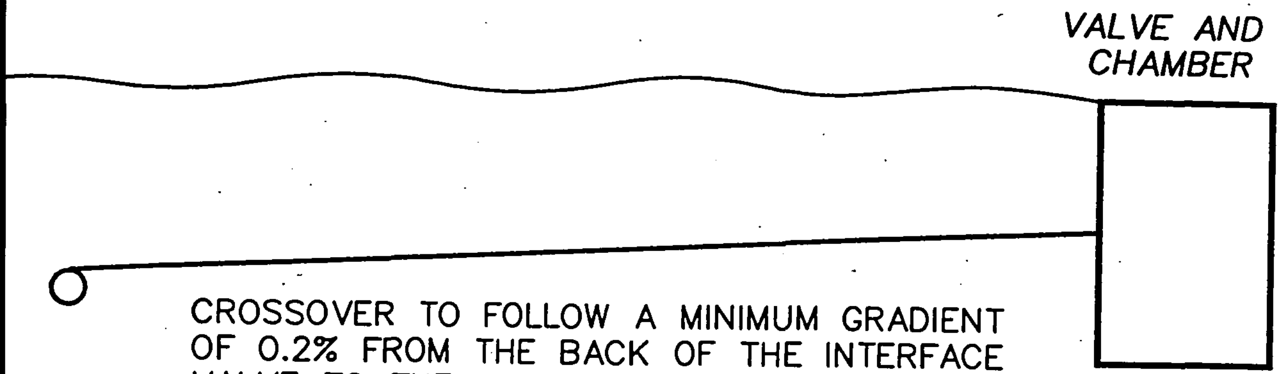
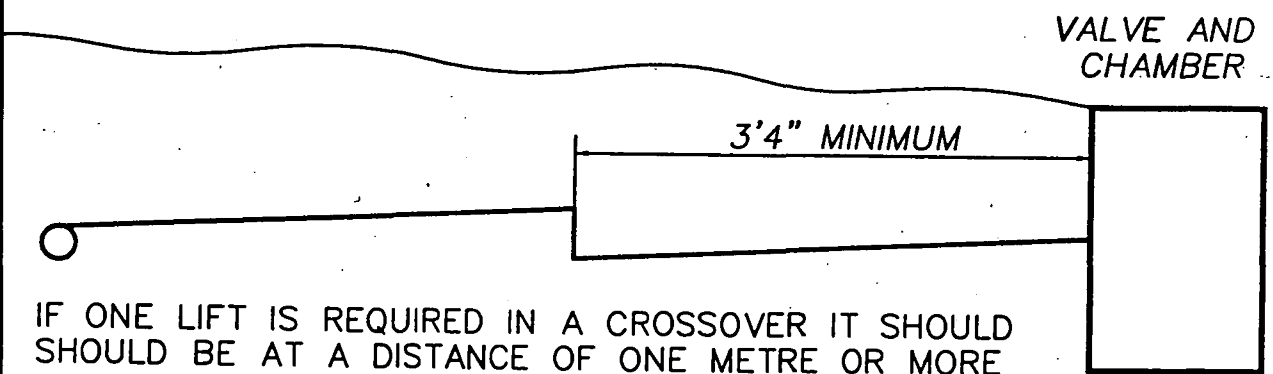


FIG 14 TYPICAL 'Y' BRANCH CONNECTION



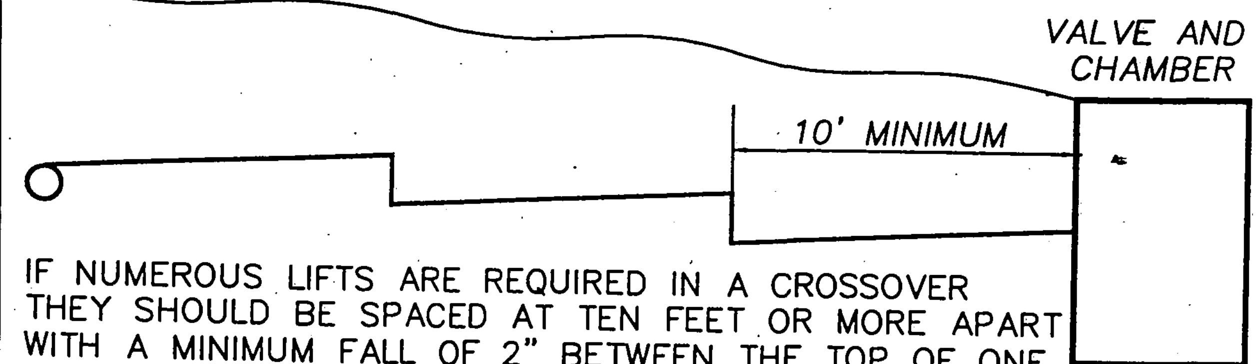
CROSSOVER TO FOLLOW A MINIMUM GRADIENT OF 0.2% FROM THE BACK OF THE INTERFACE VALVE TO THE Y BRANCH CONNECTION

15.1 ;CROSSOVER CONNECTION REQUIRING NO LIFTS



IF ONE LIFT IS REQUIRED IN A CROSSOVER IT SHOULD SHOULD BE AT A DISTANCE OF ONE METRE OR MORE FROM THE INTERFACE VALVE WITH A MINIMUM FALL OF 2" BETWEEN THE BACK OF THE INTERFACE VALVE AND BOTTOM OF THE INVERT LIFT.

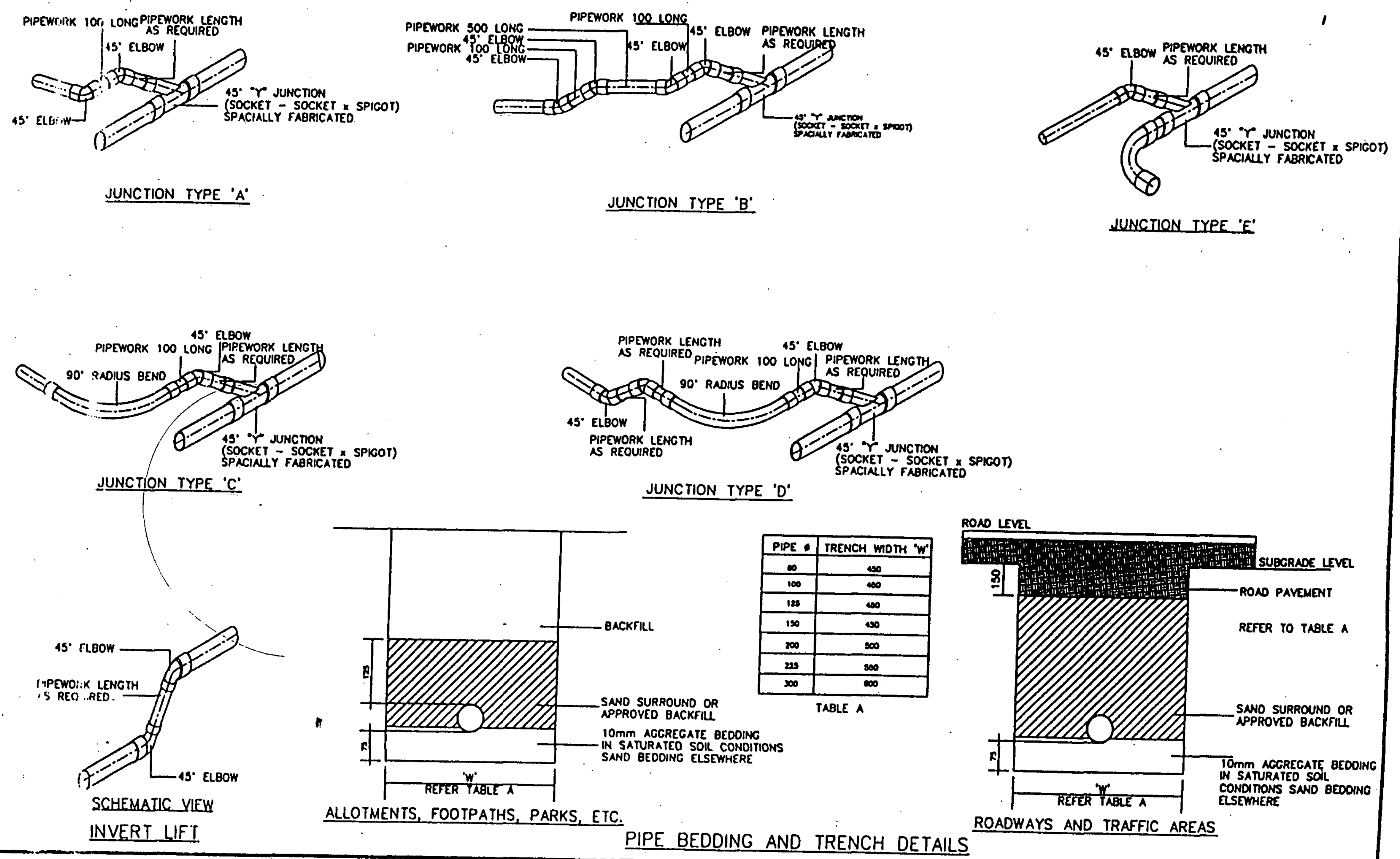
5.2 ;CROSSOVER CONNECTION REQUIRING ONE LIFT



IF NUMEROUS LIFTS ARE REQUIRED IN A CROSSOVER THEY SHOULD BE SPACED AT TEN FEET OR MORE APART WITH A MINIMUM FALL OF 2" BETWEEN THE TOP OF ONE LIFT AND THE BOTTOM OF THE NEXT LIFT.

G 15.3 ;CROSSOVER CONNECTION REQUIRING NUMEROUS LIFTS

FIGURE 15 CROSSOVER PROFILES



PIPE ø	TRENCH WIDTH 'W'
80	450
100	460
125	480
150	450
200	500
225	550
300	600

TABLE A

FIG 16 JUNCTION EXAMPLES

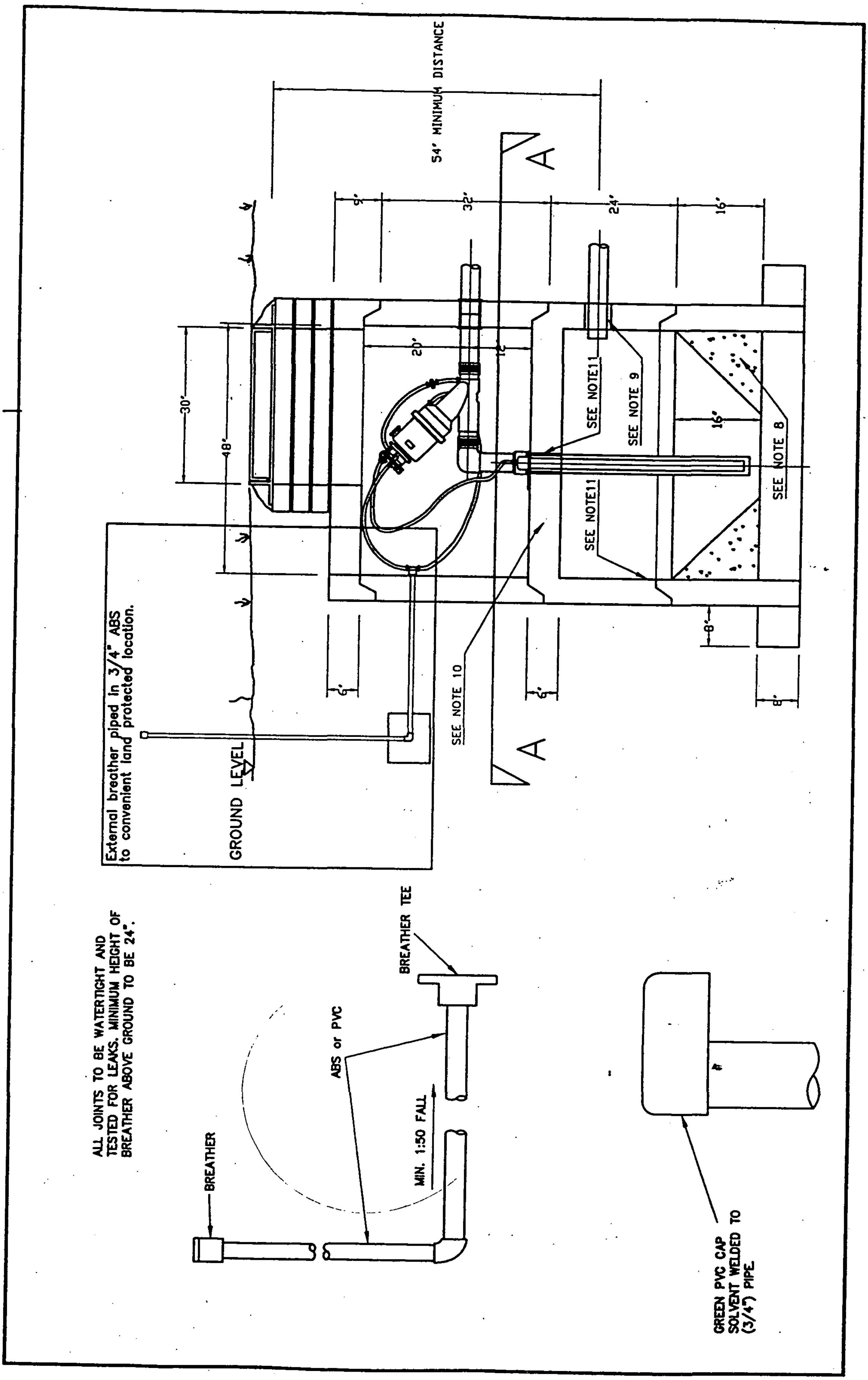
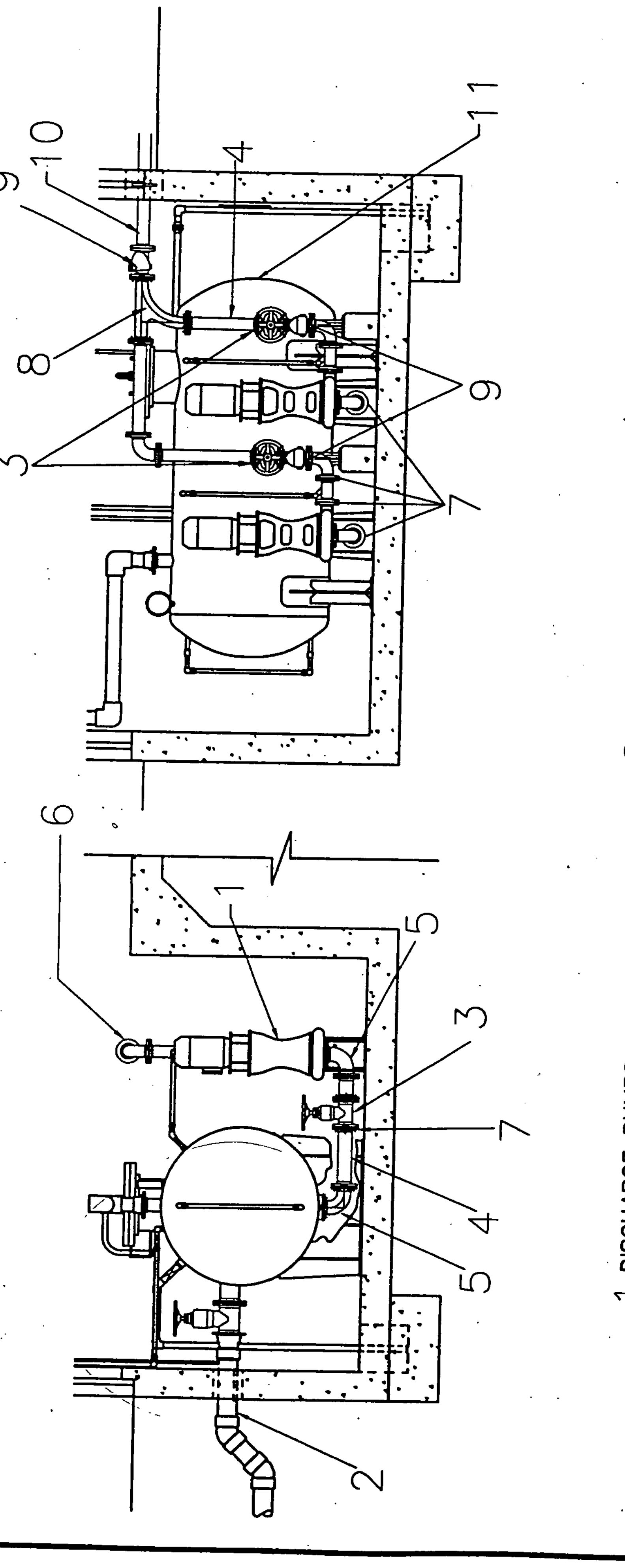


FIG 17 BREATHER PIPE ARRANGEMENT



1 DISCHARGE PUMPS
2 4" POLYETHYLENE SEWAGE VACUUM INCOMER
3 4" IRON STOP VALVE
4 4" IRON STRAIGHT CONNECTORS
5 4" IRON 90° BEND
6 EXITING DISCHARGE PIPEWORK
7 4" IRON PIPE FLANGE CONNECTIONS
8 4" IRON TEE
9 4" IRON NON RETURN VALVE ON DISCHARGE PIEWORK
10 4" IRON STRAIGHT CONNECTOR EXTENDING 18" BEYOND WALL OF VACUUM STATION
11 VACUUM VESSEL

FIGURE 18 DUCTILE PIPEWORK ARRANGEMENT IN VACUUM STATION.

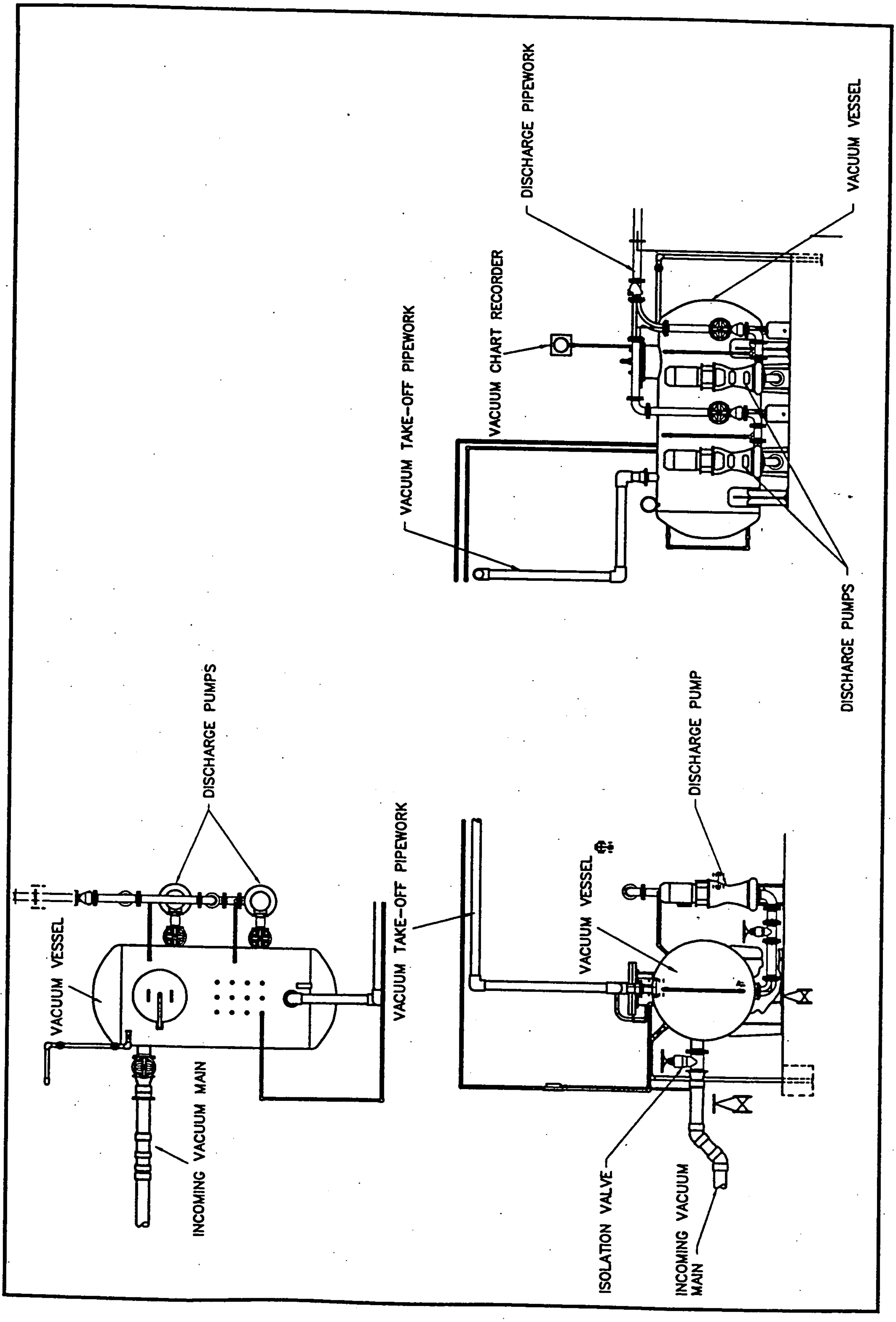


FIGURE 19 VACUUM VESSEL AND ASSOCIATED PIPEWORK

NA - MANHOLE ACCESS
NB - VACUUM INCOMER
NC - VACUUM TAKE OFF
ND - VESSEL DISCHARGE
NE - AUXILLARY SUCTION
NF - EUALISER LINE CONNECTION
NG - VESSEL VACUUM GAUGE
NH - SIGHT GLASS HIGH/LOW LEVEL CONNECTIONS

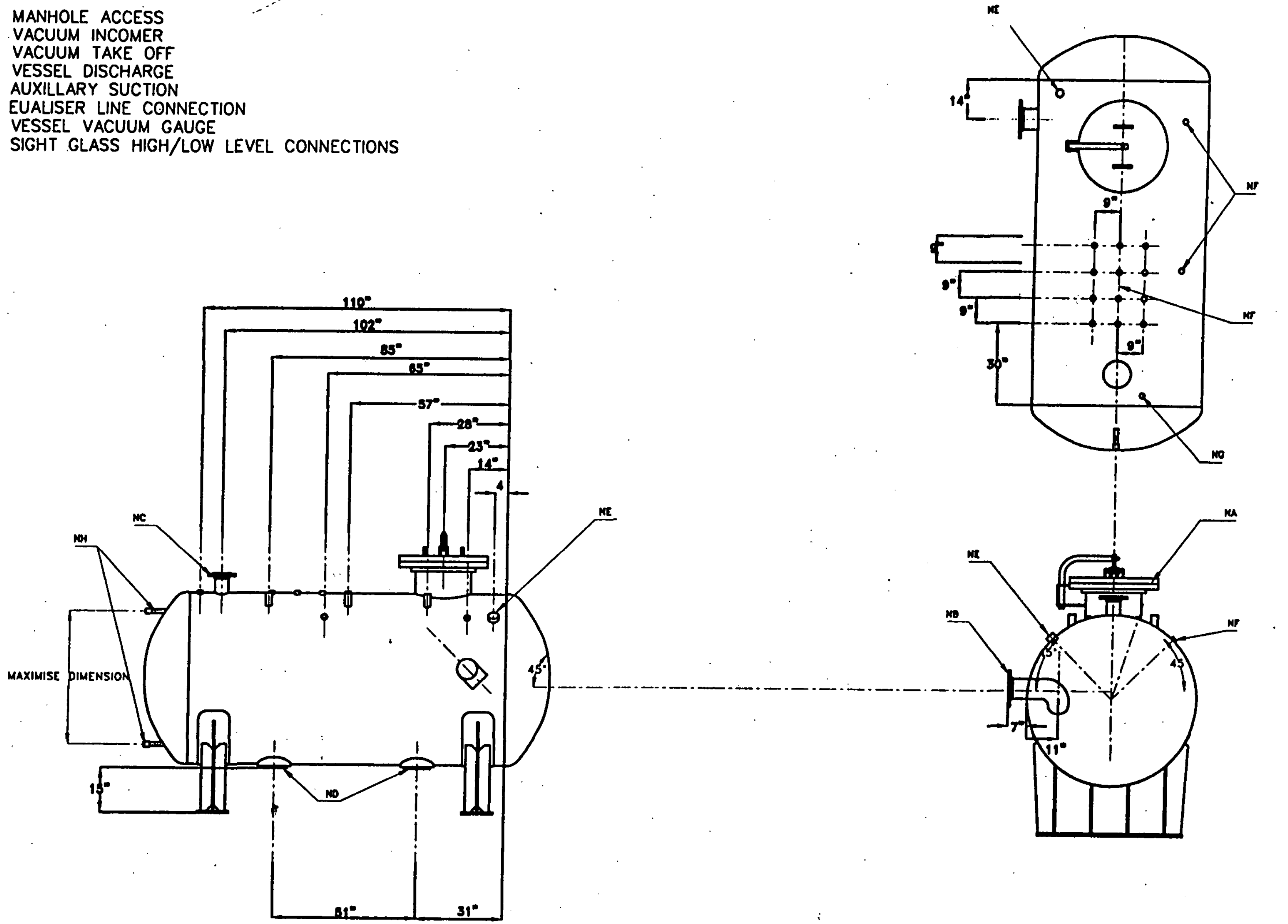


FIG 20 A TYPICAL VACUUM VESSEL

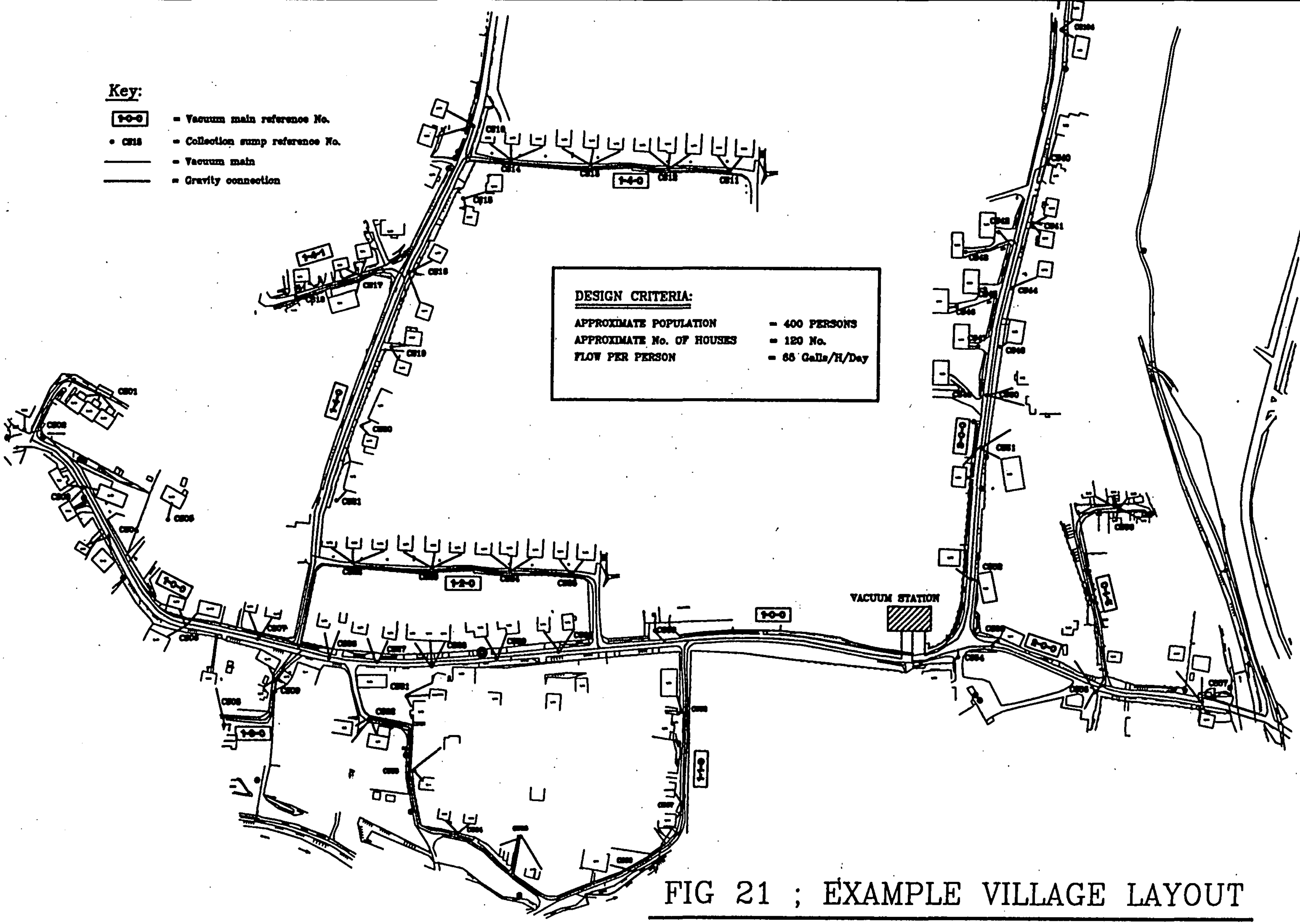


FIG 21 ; EXAMPLE VILLAGE LAYOUT

(NOT TO SCALE).

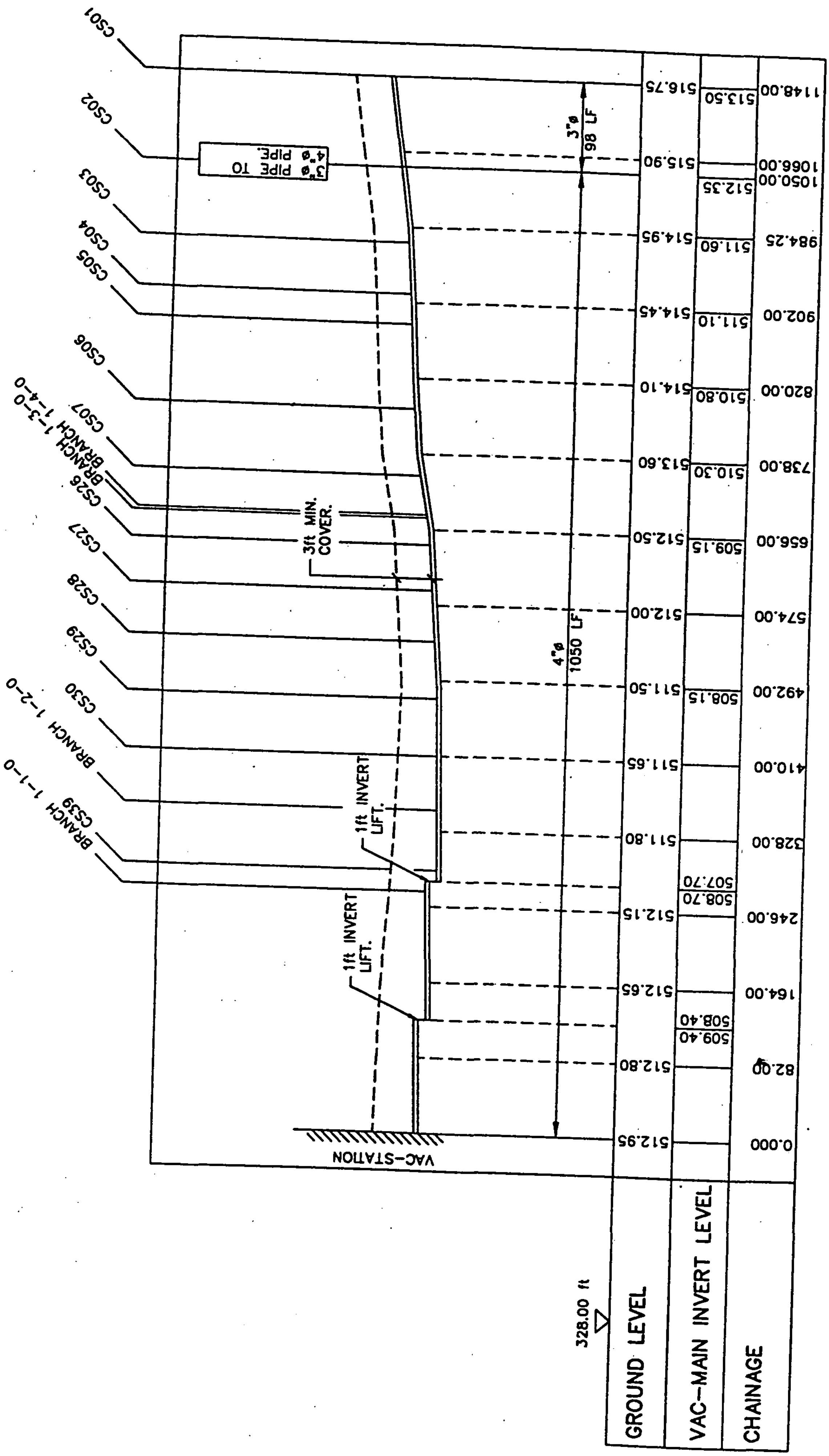


FIG 22 ; EXAMPLE SEWER PROFILE

Longitudinal Section :- Example village layout, Vac-Main 1-0-0
Scale 1:100 vertical, 1:1250 Horizontal.

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