# DEVELOPMENT OF A COMPACT AIR-REGULATED SIPHON FOR USE IN STORM SEWAGE OVERFLOWS

by

CHARLES J A MILROY BSc CEng MICE MIWEM

A thesis submitted to the Council for National Academic Awards in partial fulfilment of the requirements for the degree of Master of Philosophy.

Sponsoring Establishment : Department of Civil Engineering
Sheffield City Polytechnic

Collaborating Establishment : Dumfries and Galloway Regional Council

August 1988

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## SYNOPSIS

An air regulated siphon has been developed to operate as a storm water overflow. One of the main requirements has been that a siphon of compact design can accommodate high discharges for relatively small increases in upstream level thereby preventing the possibility of surcharges in the sewer upstream of the overflow.

The s-shaped siphon was chosen for development as it has, by virtue of its natural shape, an efficient priming system. The downstream leg of the s-shaped siphon is returned beneath the crest so that a vertical wall of water formed shortly after first spill thereby effecting a seal which ensures priming.

A sectional perspex model was used to determine the effects of inlet lip length, inlet lip elevation, tailwater level, siphon width, upstream channel width, vortices at inlet and revised outlet configurations. Results were compared using a dimensionless plot of the ratio of priming head and throat depth (hi/d) against co-efficient of discharge (CD). The curves obtained for all the differenct configurations are useful as design aids for the design of a compact air regulated siphon for use in storm sewage overflows.

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ACKNOWLEDGEMENTS

The author would like to acknowledge Dr D J Balmforth for his help and guidance in producing this document. Thanks are also due to the Director of Water and Sewerage, Dumfries and Galloway Regional Council, Mr K Holliday and Miss H Jordan who assisted in various stages of this work.

# CHAPTER ONE

# INTRODUCTION

1.1 Introduction to siphons

1.2 Uses of an air regulated siphon

1.3 Air regulated siphons, advantages and disadvantages

1.4 Types of flow regime in air regulated siphons

1.5 Siphonic hunting

## 1.1 Introduction to siphons

The simplest form of siphon is the U-tube siphon (fig 1) as used by the Greeks as far back as 1500 BC. The siphon may be of iron, lead, glass or plastic tubing, generally circular in section, primed by applying suction at the downstream end. This type of siphon, once primed, transfers water from a higher level to a lower level by gravitational means. However, all the air has to be removed first and the act of removing air is termed priming.

The U-tube siphon was first used, in conjunction with aqueducts and open channels, to transfer water for domestic and irrigation purposes over long distances and difficult terrain. However, the main requirement for the development of hydraulic structures came with the Industrial Revolution. Industry required water not only for manufacturing purposes but also for canal navigation. Dams, docks and canals were built, all requiring some form of level control. At this time weirs and spillways were the main form of overflow arrangement but gradually in the latter part of the 19th Century and the beginning of the 20th Century siphons were developed as an alternative means of level control.

Initially the siphon used was the blackwater siphon and the problems experienced with some of these siphons made engineers wary of siphons in general. In broad terms the Blackwater siphon is an inverted U-tube where the saddle is

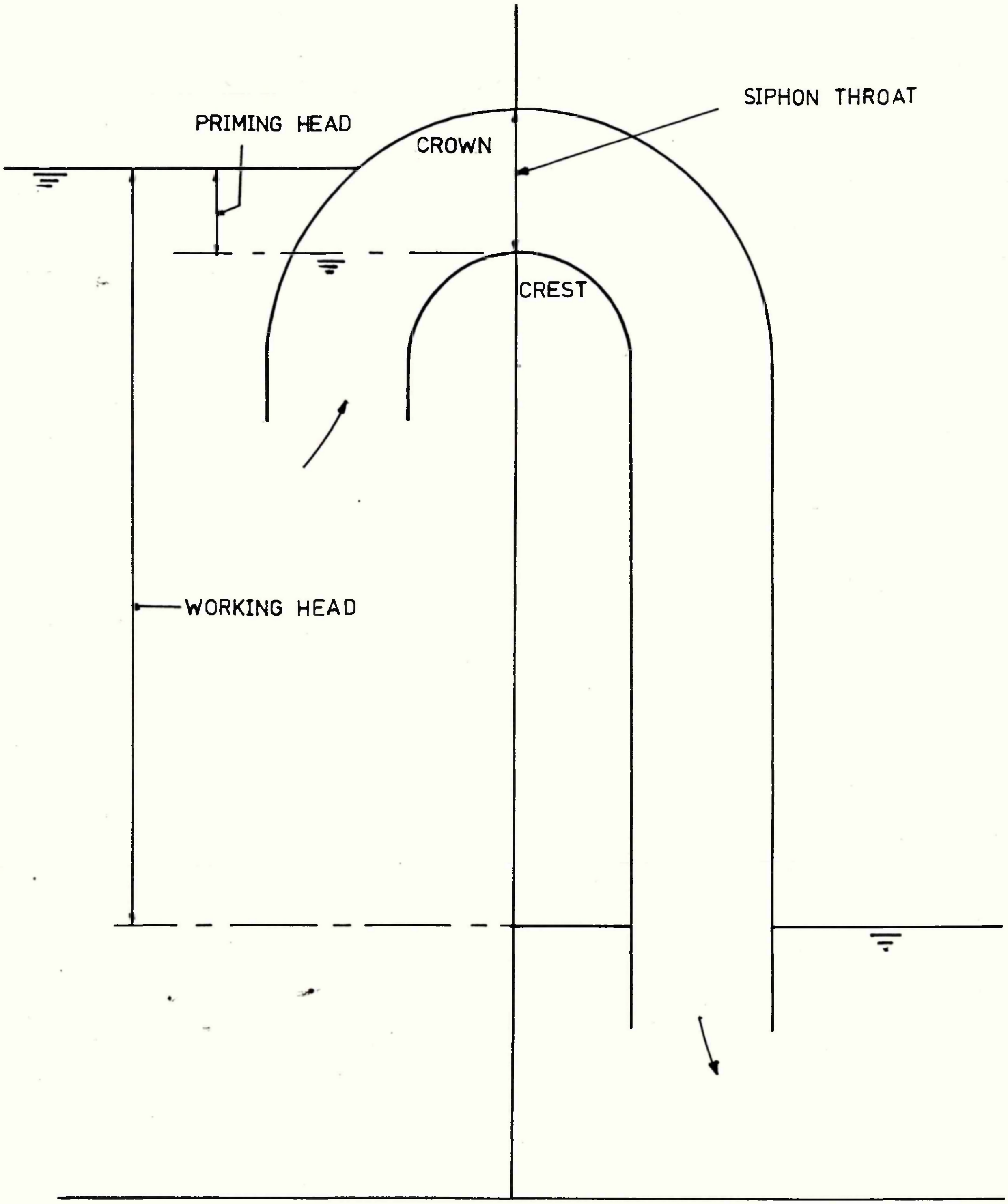


Fig1. A DIAGRAMMATIC SECTION OF A SIMPLE SIPHON TUBE

set well above the intake (fig 2a). It can be primed artificially by closing off the outlet and filling the downstream leg with water from a remote source to a level higher than saddle level, but more usually the upstream level is allowed to rise until the flow over the saddle initiates priming, whereupon full-bore discharge takes place. The flow is virtually constant, being determined by the total head across the structure and not by the inflow to the structure. Full-bore discharge continues until the upstream water level is drawn down sufficiently to admit air, which breaks the siphon column, thus causing sudden and total cessation of flow. The process repeats itself if the inflow to the inlet continues.

This mode of operation is clearly ill-suited to natural flow situations where a control structure will usually be required to accommodate a wide range of discharges. In such circumstances a blackwater siphon will tend to 'hunt' (ie alternately prime and deprime) unless there is a particularly large body of water for it to draw on immediately upstream, or unless the inflow to the siphon is more or less constant at it's design capacity, neither of which is likely in a river, canal or in a storm sewer. In fact this type of siphon is rarely used except as part of a storm-water overflow ie incorporated within bellmouth dropshaft spillways. The head-discharge relationship for a typical blackwater siphon is given in fig 2a.

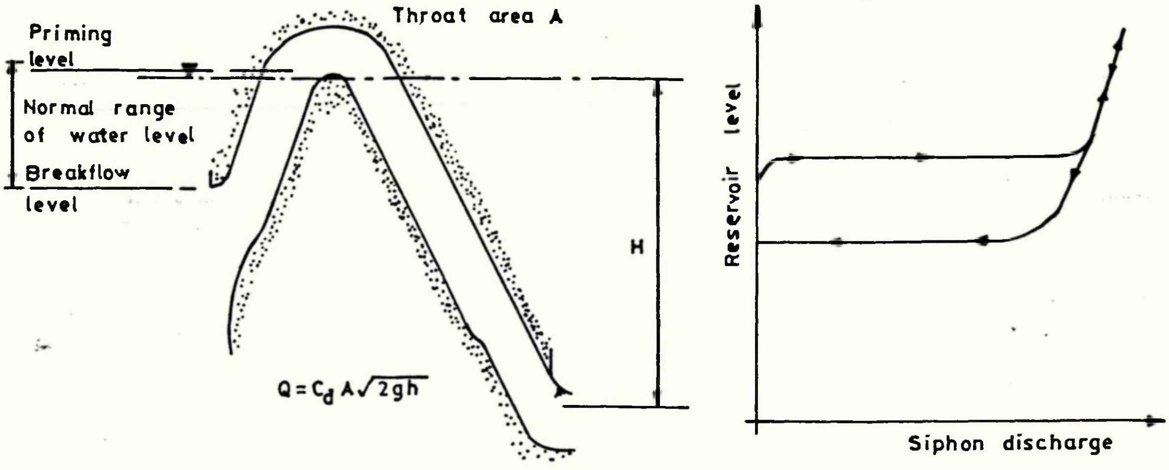


FIG 2(a) BLACKWATER SIPHON AND ITS TYPICAL HEAD/ DISCHARGE CHARACTERISTICS

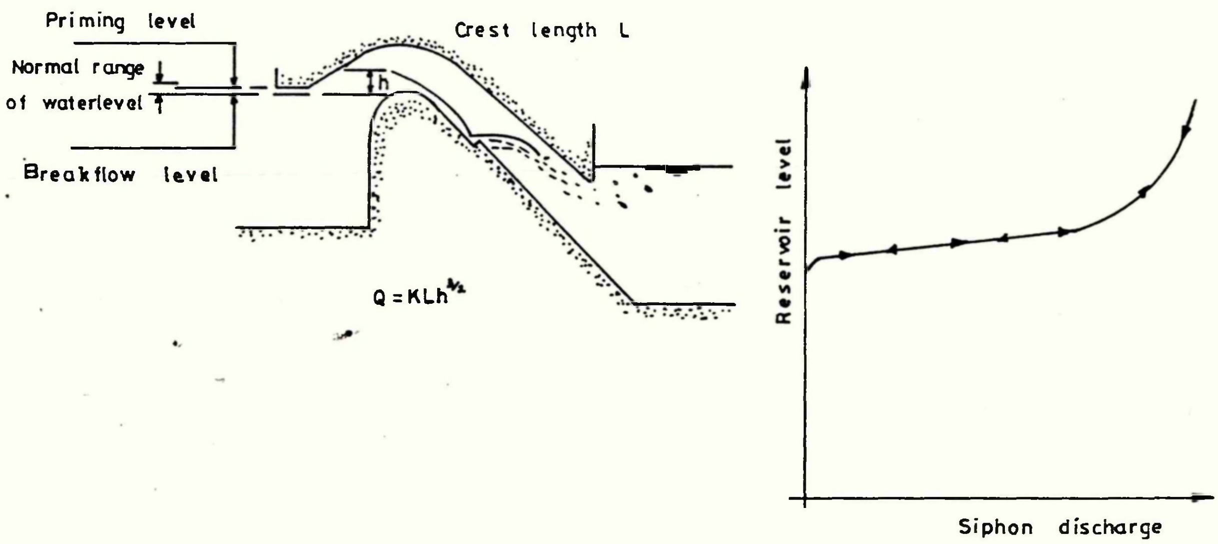


FIG 2(b) AN AIR REGULATED SIPHON AND ITS TYPICAL HEAD/DISCHARGE CHARACTERISTICS

The cycle of priming and de-priming is not satisfactory for level control and therefore an improvement to the blackwater siphon was sought. It was found that blackwater flow may be readily arrested by the admission of atmospheric air into a low-pressure region of the siphon. Kenn[1], by plotting air flow against corresponding water flows found that as the air flow is increased, by admission into the siphon hood, the discharge is reduced, initially almost linearly but finally at an increasing rate. Therefore, an effective method of control had been found where flow rate was determined by the volume of air admitted.

Two main types of air inlet were developed for use in siphons. The first, and most successful, took the form of a slot in front of the siphon hood. The size and shape of this slot has a great effect on hydraulic performance. The optimum slot configuration was found to be a shallow slot extending the full width of the siphon. This configuration produced fine control of the upstream water level with minimum flow instability. However, in the region where the air demand increased with increasing discharge, a form of inlet such that the rate of air entry was not directly dependent on the reservoir level was preferred. The provision of a lip over the slot, through which air and water could be drawn to produce a local drawdown curve, was found to be an effective solution.

The second type of air inlet arrangement, as sometimes used in sewerage overflows, introduced air, by means of a pipe, into the crown of the siphon. This method of air admittance proved unsuccessful as a method of air regulation as dispersion of air over the width and depth of flow was found to be inadequate and hunting resulted. This emphasised the importance of introducing air both near the entrance of the siphon and over its full width.

Development of siphon design continued resulting in the air-regulated siphon. The earliest recorded air-regulated siphons are believed to be the Renala siphons in India, designed by E S Crump and completed in 1922[(2)].

The traditional air regulated siphon spillway resembles a weir over which an airtight hood has been placed (fig 2b). Part of the intake is at a higher level than the saddle, or crest, thereby allowing very low discharges to be passed as normal weir flow before the siphon primes. Priming occurs gradually as the flow builds up; the rising water level seals off the hood from the atmosphere, and the internal pressure drops as entrained air is carried away at the downstream end. The internal head, and therefore discharge, increases as the hood pressure is reduced. Unlike the blackwater siphon, however, the air regulated siphon does not immediately prime to full bore flow, for as the discharge increases air is drawn in at the intake and the hood pressure is stabilised as the air entrained into the hood from inlet is equal to that taken out of the hood by the flow through the siphon. Air is either introduced by vortex induced entrainment or a form of gulping[3] under the inlet lip, both forms of entrainment draw air under the inlet lip.

The head-discharge relationship for this type of siphon is illustrated in fig 2b. From this figure it can be seen that the flow characteristics in general are smoother, resulting in a uniform increase and decrease in siphon discharges, which closely relate to the flow quantities offered to it.

There are two main types of air regulated siphon employing different methods of self-priming. The original design (fig 3a) was that of a saddle shape with a ramp or "ski-jump" deflecting water onto the outer face of the downstream leg thereby creating an effective seal. This type of siphon was mainly used for dam spillways and river regulators. For situations where space is restricted the siphon has to be as compact as possible and an S-shaped siphon was developed (fig 3b). The S-shaped siphon has built into its natural shape an efficient priming system. The downstream leg of the 'S' siphon is returned beneath the crest so that a vertical wall of water formed shortly after first spill thereby effecting a seal which ensures efficient priming.

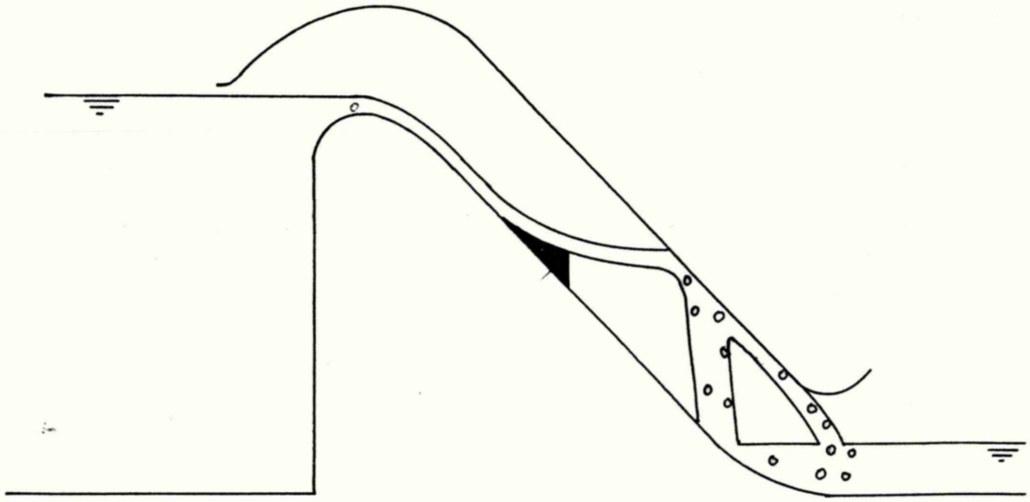

FIG 3A SKI JUMP DEFLECTOR METHOD OF AIR ENTRAINMENT

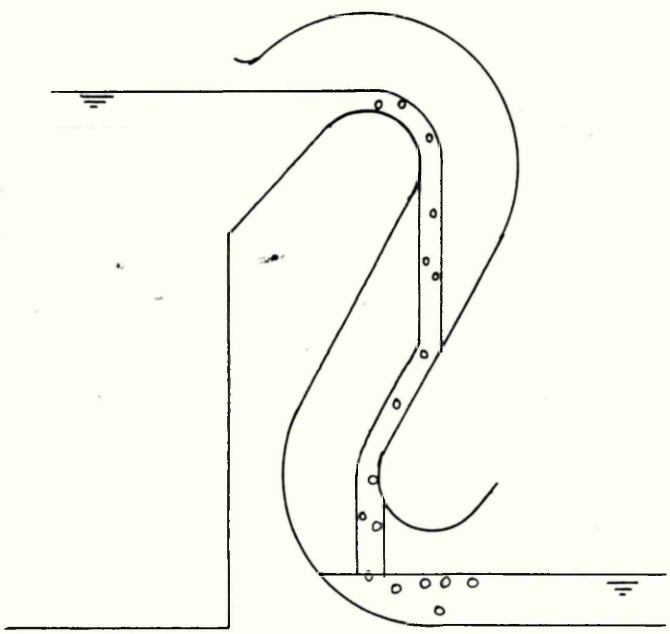

FIG 3B FALLING NAPPE METHOD OF AIR ENTRAINMENT

(a) The ski-jump method of air-entrainment

At low discharges, water passing over the crest takes off at the "ski-jump" (fig 3a) and strikes the hood near its tail, creating a turbulent region which entrains air and passes it downstream with the flow. Initially, the crest acts simply as a weir, since an ample supply of air can enter under the lip. As the discharge increases, causing the upstream level to rise, the supply of air is restricted and the entraining mechanism becomes more powerful. A partial vacuum is created, raising the internal water level and increasing the discharge through the siphon until equilibrium is again reached. At higher discharges separation occurs at the crest, and the air pocket contracts until eventually it is swept out of the siphon, the air then passing through the siphon as a chain of bubbles(4). This chain of events removes the air from the siphon, thereby priming it, allowing full bore flow. This method is usually used in the case of dam spillways where the downflow leg has to slope away from the inlet, ie down the dam face.

(b) The falling nappe method of air entrainment

By altering the actual geometry of the siphon, without the inclusion of any ski-jump mechanism, and by sloping the downflow leg towards the inlet the fluid at weir-flow discharges falls onto the opposite wall producing the same priming effect. This priming effect is shown in fig 3b.

## 1.2 Uses of an air regulated siphon

Air regulated siphons are most commonly used in the following roles - overflows, spillways and level regulators.

### (a) Overflows

Air regulated siphons used as overflows are in essence smaller scale siphon spillways, the only difference being that they have different requirements. The type of siphon used in this situation are known as low head siphons, ie with a working head of up to 3m. This low head virtually ensures that cavitation will not occur.

The most widely used low head siphon overflow system is the storm water overflow system which determines the amount of sewage flowing into a works, the residue is passed for storage or disposal. A typical arrangement of a traditional siphon overflow on a combined sewer is shown in fig 4. Siphons have been found to be particularly suited for use on storm water overflows and all tests carried out for this report are based on a storm water overflow configuration.

The requirements of such a siphon are as follows:

(i) If overflow water is to be discharged into receiving waters then the level of the overflow should be such that sufficient dilution has been achieved. This dilution has traditionally been 6 x dry weather flow (6xDWF).

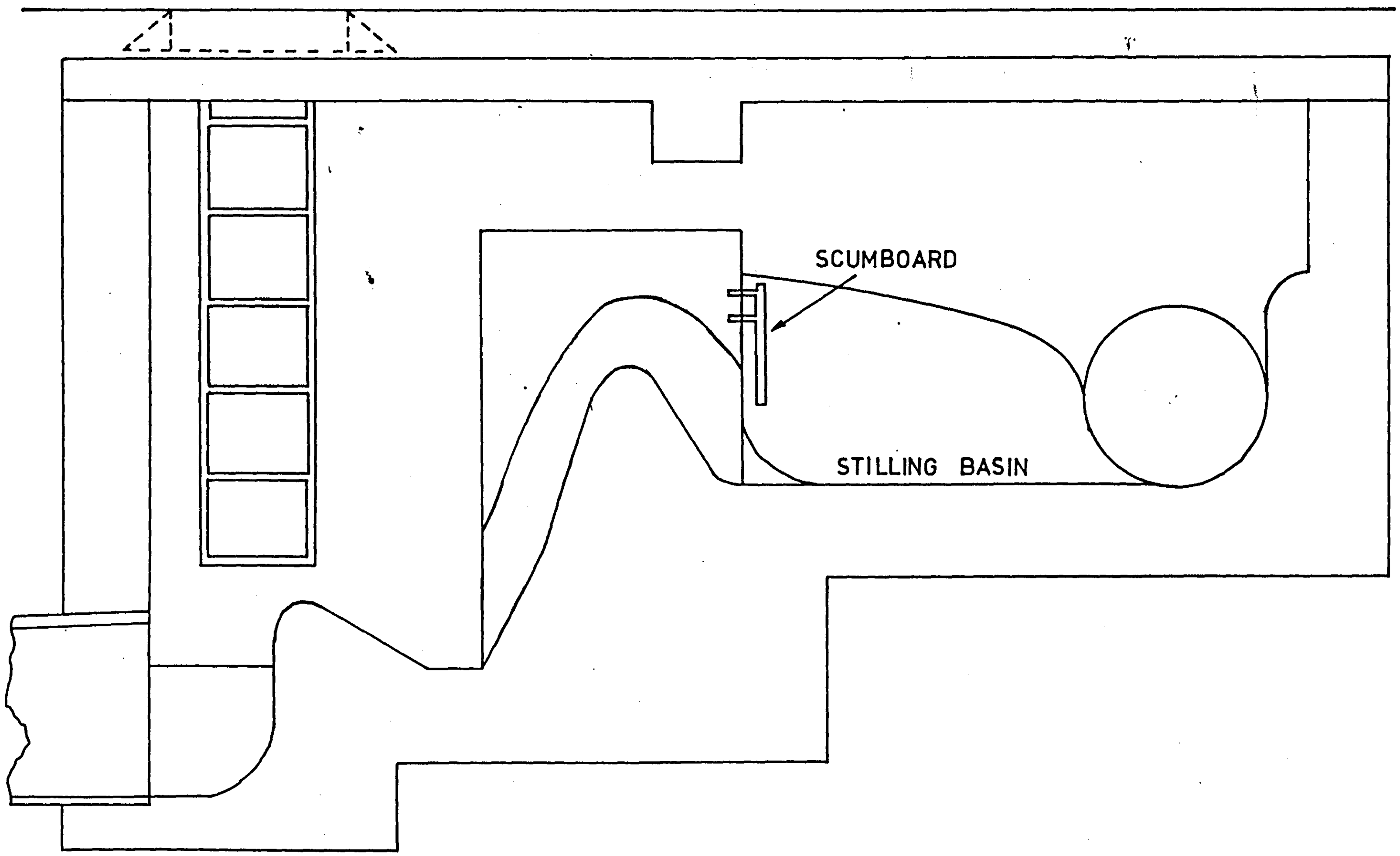


FIG 4 TYPICAL ARRANGEMENT OF AN AIR REGULATED SIPHON OVERFLOW ON A COMBINED SEWER

(ii) The overflow should operate with an efficiency such that undue surcharging of the system does not occur, nor surface flooding.

(b) Spillways

The most common type of siphon spillway is one straddling the crest of a dam, fig 5. This type of siphon is termed a "high head" siphon due to large differences in upstream and exit levels which may exceed 9m. The results of high heads are large velocities which cause low pressure especially in the crest. Because of cavitation which may cause structural damage, negative pressures must not be allowed to approach 9m. The answer to this velocity criterion is the use of some flow restrictor, the most generally used one being converging outlets. To provide an adequate seal to allow priming to occur (the exit is open to the atmosphere) a ski-jump arrangement has to be used. In some cases (Spelga Dam) a second ski-jump was proposed near the exit, the object of which was to form an additional pocket in order to increase air-pumping effects and oppose the ingress of air from downstream. Using the "two ski-jump" type of arrangement on the Spelga Dam, Northern Ireland 1975[5] they have a working head of 8.5m, the level was raised by 1m so causing a phenomenal increase in storage capacity of 22%.

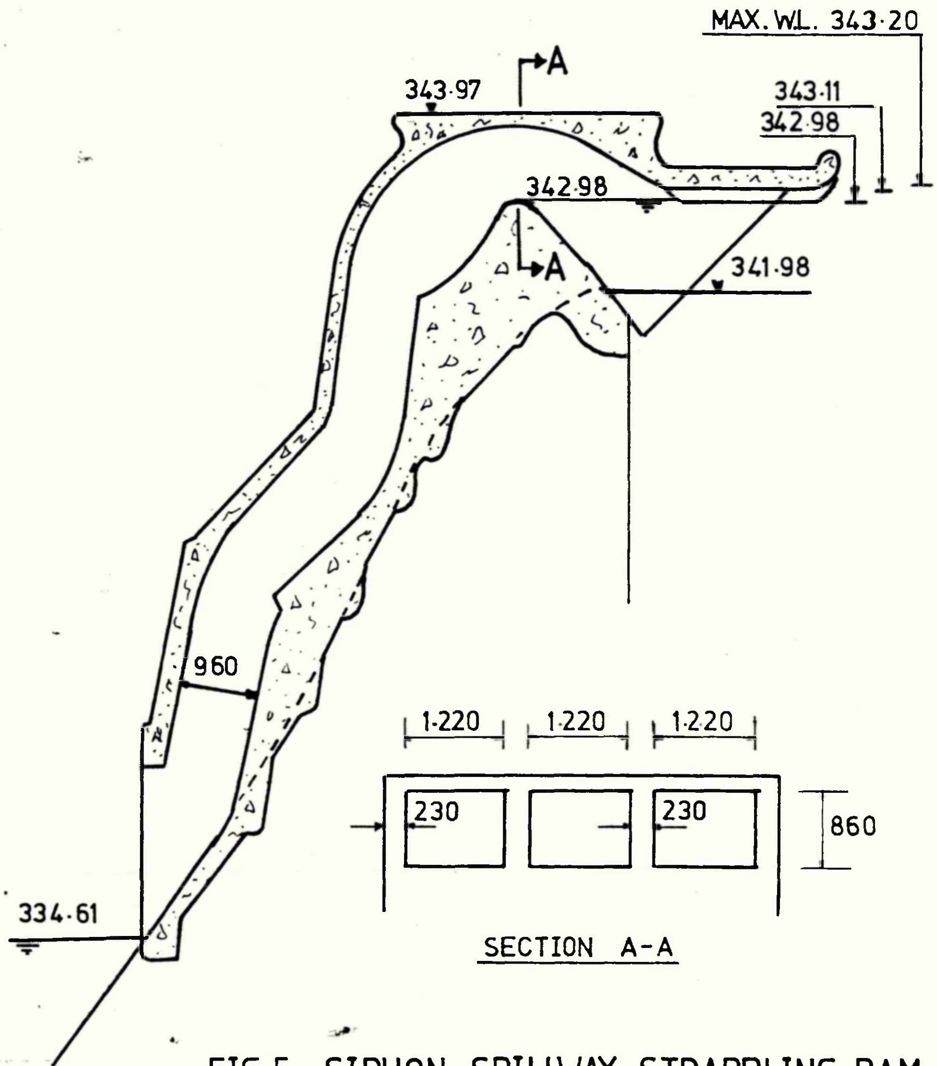


FIG 5 - SIPHON SPILLWAY STRADDLING DAM CREST
(SPELGA DAM)

POSKITT AND ELSAWY
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Another type of spillway siphon is the combined use of one or more siphons with a bellmouth dropshaft spillway. A number of siphons are arranged radially within the bellmouth spillway structure, fig 6. The siphons regulate flow into the dropshaft and supress turbulence.

(c) River and canal level regulators

Low head air regulated siphons fulfil this role and are used in cases where the maximum upstream levels are to be closely controlled such as river and canal control devices. Flood water is discharged through the siphon to keep river/canal levels below maximum values in order to prevent flooding. A typical low-head air regulated siphon acting as a river flood regulator is shown in fig 7.

## 1.3 Air regulated siphons, advantages and disadvantages

When considering other spillway or overflow devices which are usually weirs, an air regulated siphon has many advantages.

(a) Even though discharges may vary greatly, upstream levels are regulated within a very small range. Weirs require large upstream level variations for similar discharges.

(b) A siphon utilises the full working head between upstream and downstream levels whereas a weir discharge is governed by the relatively small head over its crest. Thus siphon crests can be placed higher than weir crests and still be capable of discharging

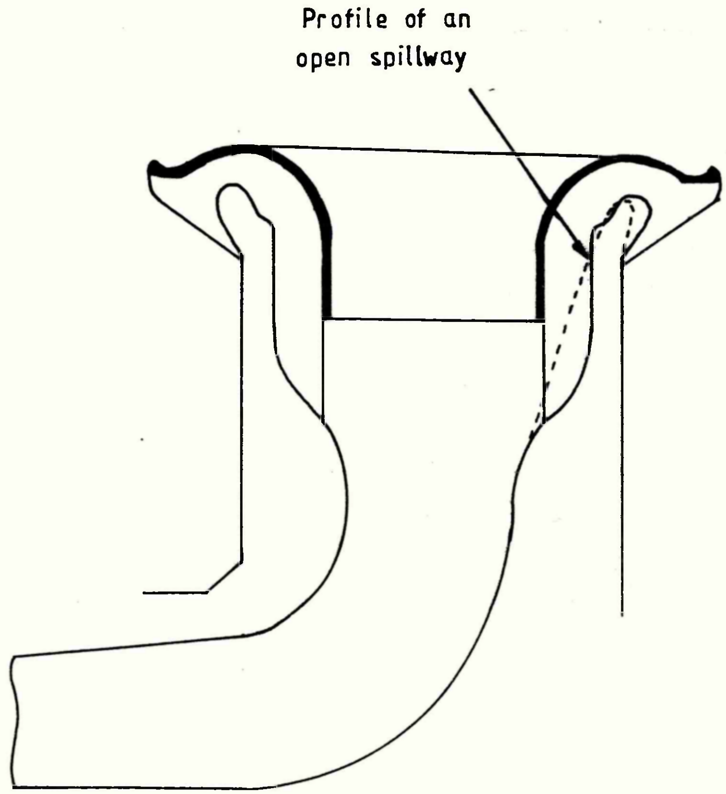


FIG 6 SIPHONS INCORPORATED INTO A

BELLMOUTH DROPSHAFT SPILLWAY

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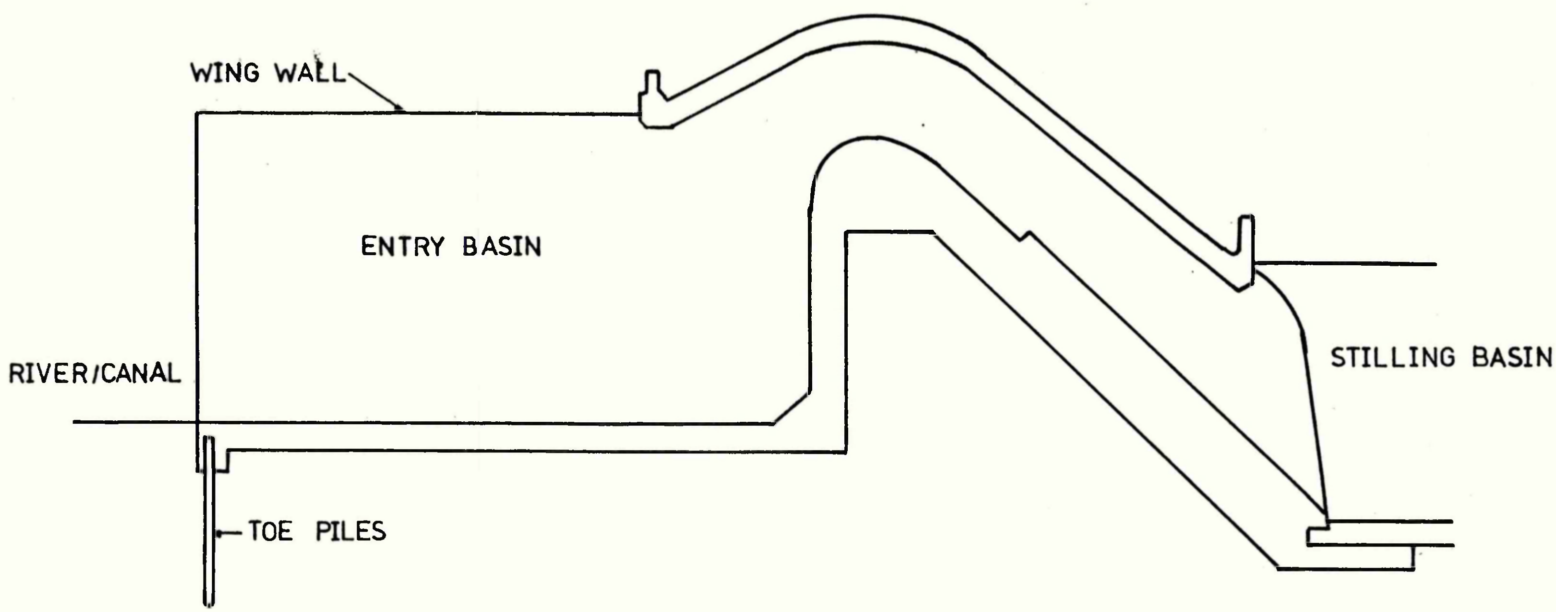



FIG 7 - A LOW HEAD AIR REGULATED SIPHON AS A RIVER/CANAL LEVEL REGULATOR equivalent flows. This is the case of reservoir overflows and will allow an extra storage capacity for a given dam height.

(c) A siphon can prime quickly to full capacity without large increases in upstream level.

(d) Because of their relatively small size, compared to equivalent crest lengths of weirs, siphons may be accommodated within smaller confines where other devices may not even be contemplated.

Conduits are more liable to blockage than most open structures but this can be avoided by the provision of grilles and screen arrangements in front of the siphon entrance. Where consequences of total blockage are unacceptable an emergency weir spillway may be provided at a higher level to avert this danger.

The cost of construction of siphons would be significantly reduced if they became more commonplace structures. This would be especially the case if, for the common roles, siphon requirements could be standardised and a range of such siphons detailed. However due to their versatility some air regulated siphons will always need to be designed specifically and therefore will always be relatively expensive items. Nevertheless, the ability of air regulated siphons to exactly suit the requirements should compensate for the extra expense. The close constructional tolerances which they impose require accurate and expensive construction and considerable falsework for relatively small quantities of materials. They do however, appear to offer a means of economically increasing storage in many existing reservoirs which have weir type overflow structures[5]. Another point to consider is that design costs are generally small compared to constructional costs.

## 1.4 Types of flow regime in air regulated siphons

Fig 8 compares the typical Head/discharge relationship for an air regulated siphon with those of a conduit and a weir. The terms $h_1$ and H are defined as follows:

$h_1$ (priming head) = reservoir level (above crest level)

H (working head) = difference between inlet tank level and outlet tank level

There are four clearly defined flow regimes for an air regulated siphon, weir flow, sub-atmospheric weir flow, air partialised flow and blackwater flow, represented by 0-A, A-B, B-C and C-D in fig 8.

### (a) 0-A, Weir flow (fig 9a)

In this phase the siphon acts as a normal rectangular weir. The upstream level is below the inlet lip and the air above the crest is at atmospheric pressure, as there is an air passage under the inlet hood. The siphon is only open to the atmosphere via the inlet as the nappe falling on the far wall

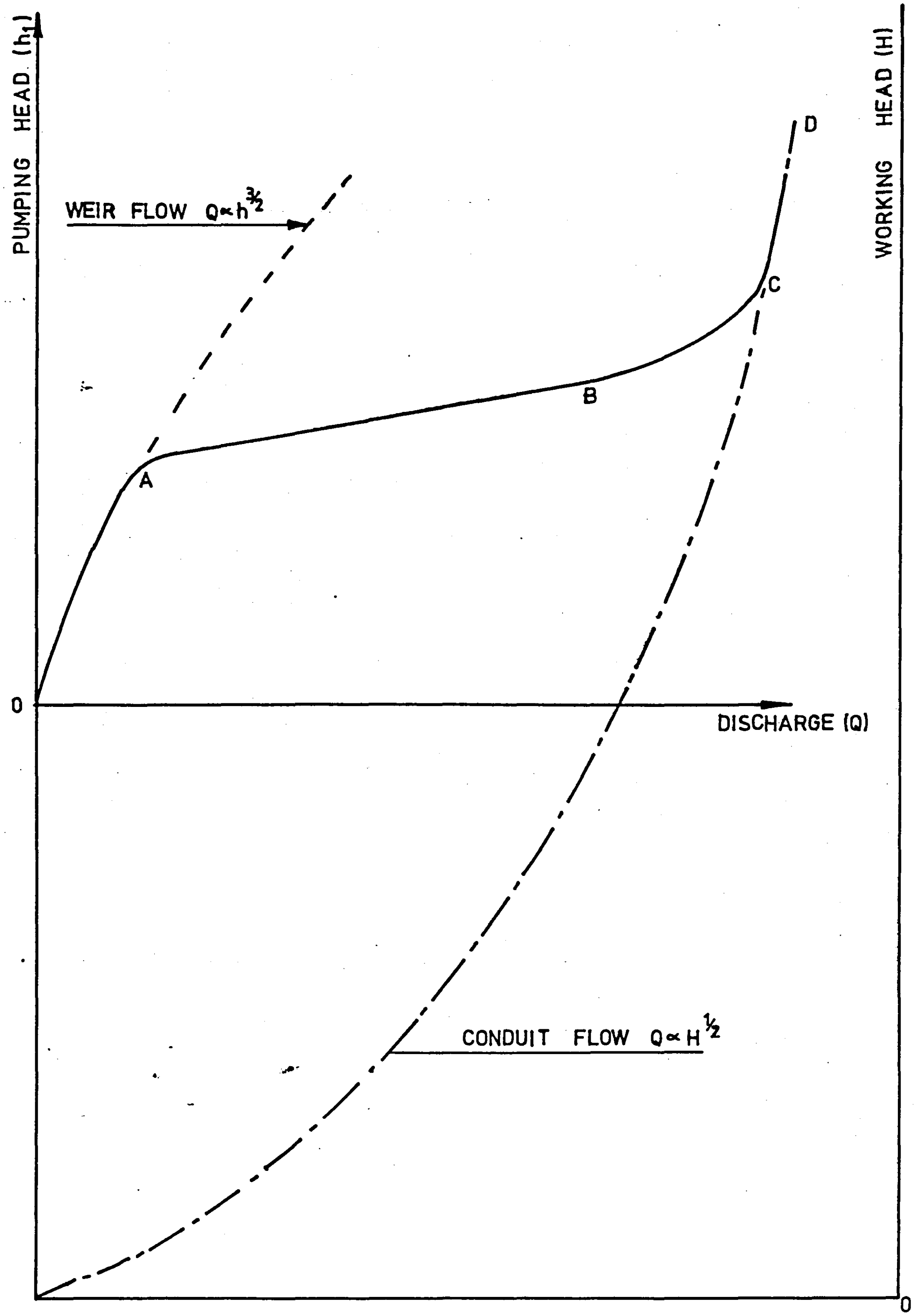



FIG 8 - TYPICAL HEAD/DISCHARGE RELATIONSHIP FOR AN AIR REGULATED SIPHON

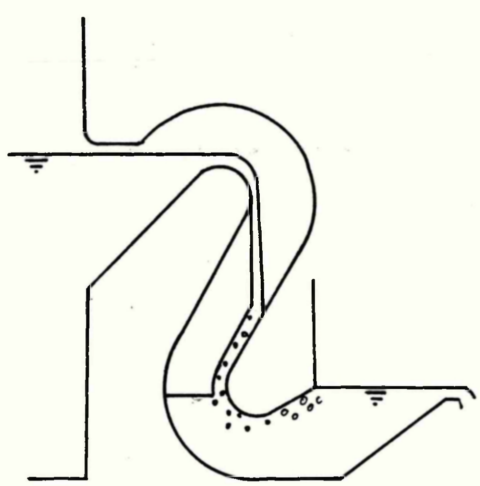


FIG 9A-WEIR FLOW

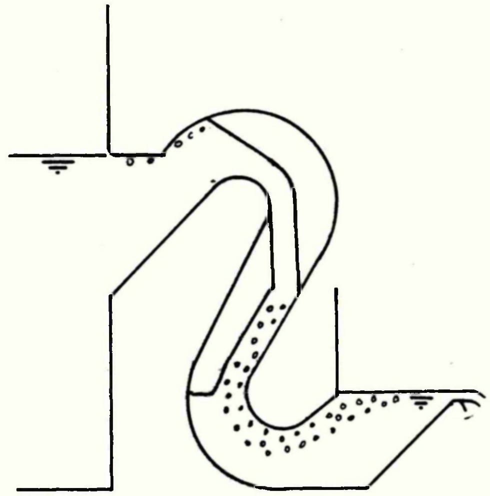


FIG 9B-SUB ATMOSPHERIC WEIR FLOW

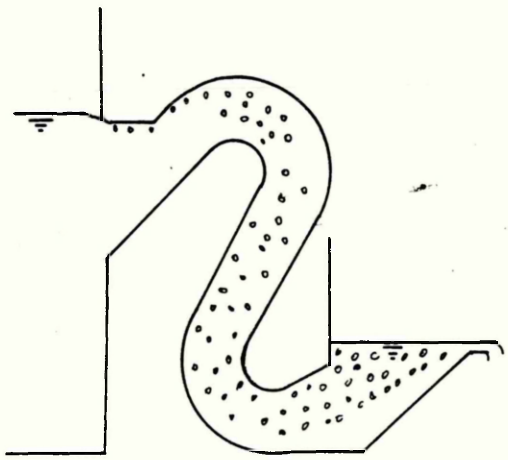


FIG 9C-AIR PARTIALISED FLOW

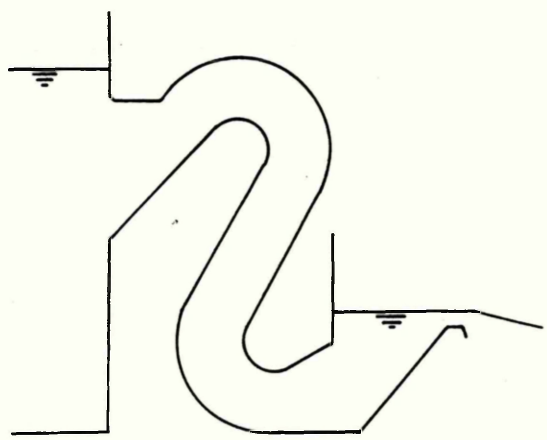


FIG 9D-BLACKWATER FLOW

FIG 9 - TYPES OF FLOW REGIME IN AIR REGULATED SIPHONS

seals the outlet. In this flow regime air-entrainment has no effect. The flow follows the weir equation $Q \propto h^{3/2}$.
The siphon has been shown to pass a very small proportion, perhaps 5% of its total flow in this way before moving onto the next flow regime[2].

(b) A-B, Sub-atmospheric weir flow (fig 9b)

With a flow increase the air space in the siphon becomes sealed off as the reservoir level has risen to a level above that of the inlet. The flow entrains air from this air space causing a partial vacuum. This vacuum has the effect of water being drawn up into the siphon so increasing the flow. But to compensate for this air-entrainment, air is drawn under the inlet lip to maintain the air at a constant pressure, even though it is below atmospheric pressure. Head[2] termed this flow regime induced weir flow under sub-atmospheric pressure, however sub-atmospheric weir flow appears to be a more compact phrase retaining the accuracy of meaning.

(c) B-C, Air partialised flow (fig 9c)

As the inflow into the reservoir increases and the reservoir level rises, the flow in the siphon also increases and the air space is reduced until it is removed altogether at the commencement of air-partialised flow. This means that there is a full-depth flow at the weir crest. Air is still drawn under the lip either by a gulping effect or by vortex induced air entrainment. This represents the largest and most useful flow regime of the air regulated siphon and for a well designed air regulated siphon this phase will be extensive ie covering a large range of flows. Air partialised flow produces a mixture of water and air bubbles distributed throughout the siphon with no large stationary pockets[4].

(d) C-D, Blackwater flow (fig 9d)

When the inlet lip is totally immersed and no air is admitted to the siphon (by gulping or vortex action), the siphon will be running full bore without air bubbles being passed through the siphon. The siphon in this stage is acknowledged, by all sources of information, as being fully primed. This can only be achieved by raising the water level by increased flow. As opposed to air partialised flow, the blackwater flow regime produces relatively small flow increases for increases in upstream levels. The discharge relationship for a siphon running under blackwater flow conditions is the same as that of a closed conduit where $Q \propto h^{1/2}$.

From this information it is possible to see the transition in flow type. Sub-atmospheric weir, air partialised and blackwater flows as being analagous to weir flow transforming to conduit flows. When looking at the head-discharge curves the transition should be smooth for a well designed siphon.

## 1.5 Siphonic hunting

Siphonic hunting (sometimes termed overrun) occurs generally at low inflow rates into the upstream reservoir which cause priming to commence but it is insufficient to build up and maintain blackwater flow. But Harrison[4] had the following to say on hunting with respect to his research work. If the water level in the upstream reservoir is well below the siphon crest when a flood occurs (flow increasing into the reservoir) it is possible that the water level could be approaching its lip level as the flood inflow reaches its peak. When the upstream level rises rapidly and hunting occurs, ie the water level rises above its equilibrium level for the given inflow discharge in the time that the siphons take to prime. The siphon then discharges more than the inflow discharge until the upstream level has been drawn down to its equilibrium position. This additional discharge is temporary blackwater flow and when the upstream level reaches its former equilibrium level, air is admitted breaking siphonic flow. The cycle of priming and depriming recommences with the upstream level oscillating and surges and lulls in discharge.

CHAPTER TWO

# STATE OF THE ART REVIEW

2.1 Siphon shapes

2.2 Inlet configuration

2.3 Outlet configuration

2.4 Vortices at inlet

2.5 Siphon materials

## 2.1 Siphon shapes

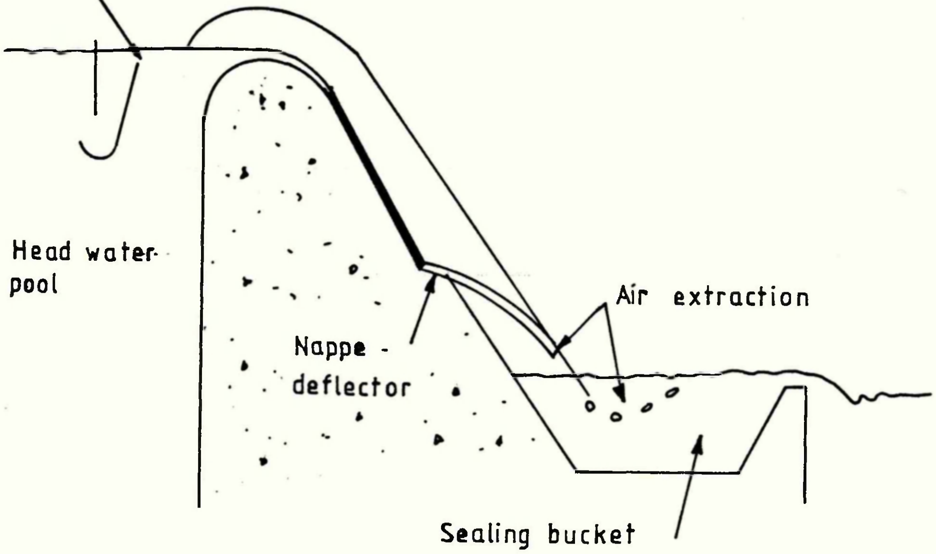
Setting aside the primitive yet practical U-tube type siphon as shown in fig 1, two siphon shapes have dominated publications. The "saddle" shaped siphon which is mainly used for dam spillways and river level regulators and the "S" shaped siphon which is generally applied to situations where space is restricted and the shape has to to be kept as compact as possible

Design of the "S" siphon depends mainly on the radius of curvature of the crest and the lower bend to ensure that separation immediately after the crest does not occur. Modification and optimisation of this curvature significantly improves the discharge capacity of the siphon. The saddle shaped siphon requires an artificial aid to complete this seal as there is no natural seal formed by the water in the downstream leg as is apparent in an "S" shaped siphon. Designers and researchers have included deflectors, which deflect the flow on the downstream leg of the siphon onto the upper surface so achieving this seal. Ackers and Thomas[6] described the problems of priming in saddle siphons and methods required to ensure that efficient priming may occur. Their conception of the problem and how to achieve a solution is laid out as follows.

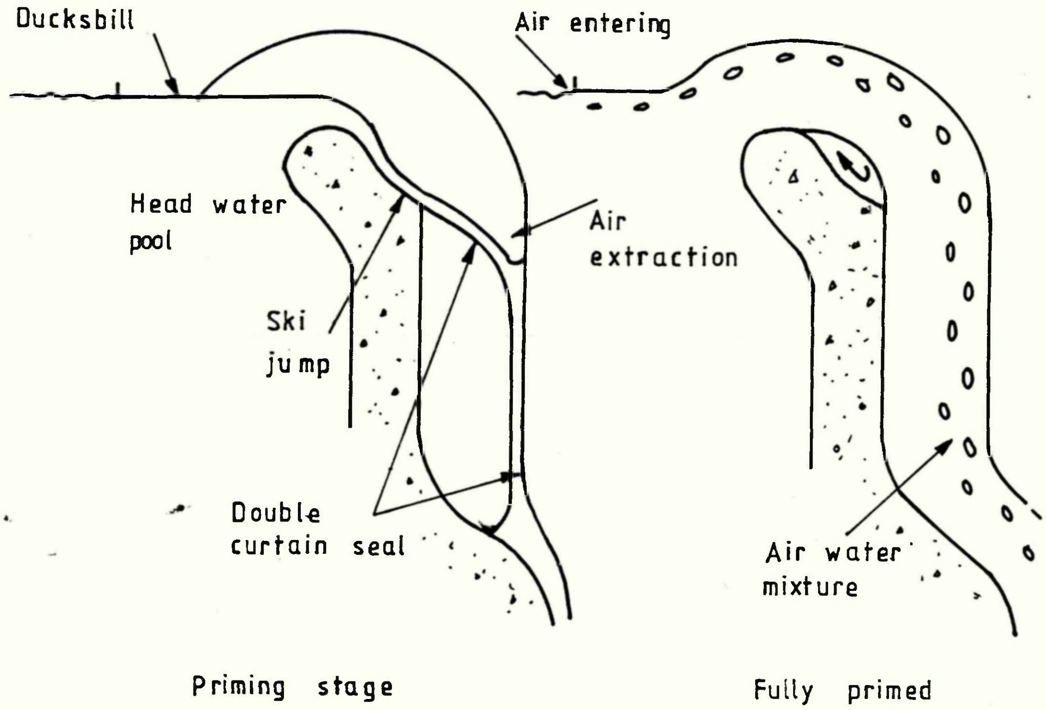
Except for the air intake, the design of an air regulated siphon is generally similar to that of a blackwater siphon. The essentials are that in the priming stage it must be capable of exhausting the air from the crown, by entrainment, so that the siphon may flow full, the difference being that after priming whereas a blackwater siphon will flow full of water, an air regulated siphon will carry an air-water mixture. The aim is generally to achieve priming with a smooth transition, at the minimum possible depth, the priming depth being measured as the height of mean upstream head above siphon crest level when the siphon first becomes capable of extracting enough air to flow continuously with an air-water mixture.

Before the air in the crown can be evacuated, the waterway of the siphon must be sealed upstream and downstream so that the pressure drop in the crown can be maintained. The upstream seal results from the submergence of the air intake by the rising head water. The downstream seal may be provided either by submerging the outlet in the tailwater as in fig 10a or by deflecting the flow in the form of a detached nappe to form the other as in fig 10b.

Submergence of the outlet below lowest tailwater level is generally completely effective and if necessary the tailwater level can be maintained by providing a tail weir or a bucket as in fig 10a. In some cases this is not feasible, and




10(a) SIPHON WITH SEALING BUCKET




10(b) SIPHON WITH DUCKSBILL, SKI JUMP PRIMING & FREE OUTLET

FIG 10 METHOD OF SUBMERGING SIPHON OUTLET

ACKERS & THOMAS

reliance must be placed on the deflected nappe. A single seal at the outlet may then not be perfect and it is desirable to provide a second seal higher in the downstream leg by deflecting the flow from the inner to the outer wall as in fig 10b.

In the Plover Cove siphon[4] submergence of the outlet was by using an outlet bucket as the dam's siphons would not be drowned at any stage of priming and a divergent outlet could not be used to increase the discharge. A second ski-jump was proposed near the exit of each siphon as shown previously in fig 5 the object of which was to form an additional pocket in order to increase air pumping effects and oppose the ingress of air from downstream.

## 2.2 Inlet configurations

Charlton and Perkins[7] defined two parameters whose relative values affect the priming and performance of a siphon based on earlier work by Crump and Ackers[8].

The two parameters are as follows:

a = height of air inlet above the crest

p = equivalent head of water above the crest required to provide a discharge at which the rate of air entrainment is just sufficient to evacuate the air from beneath the hood and cause priming.

The evacuation of the air inlet may be selected while the priming level is dependent upon the efficiency of the air entrainment system within the siphon, and on the efficiency and type of outlet seal.

When $a < p$, at the level of potential priming the air inlet is submerged and thus sealed. Air may be entrained and removed causing the siphon to prime. The reservoir level is then drawn down below priming level to permit air to enter. This is an unstable condition and the siphon may de-prime particularly if appreciable drawdown occurs. When the reservoir has a large surface area this is less likely and stable performance could result. However in a storm water overflow de-priming is likely to occur.

When $a > p$, at the potential priming level the air inlet is open, and priming may be delayed. As the discharge and upstream water level increase more air is evacuated and more is drawn through the air inlet which is ultimately throttled as the water level continues to rise. Sub-atmospheric weir flow develops which gradually changes to air partialised flow with little instability. Avoiding a sudden change from one mode of flow to another reduces the possibility of drawdown which, were it to occur, could be tolerated since the pre-priming conditions are stable.

Elsawy and Ervine[9] realised not only the importance of inlet lip elevation but also inlet lip length and inlet depth. They recognised that short lip lengths require larger upstream heads for a required discharge, compared to a lower head for longer lip lengths required for same discharge. They attributed this to a function of the specific energy at a section just at the upstream end of the inlet lip. The variation of flow through the siphon at each lip length used by Elsawy and Ervine is shown in fig 11. The lower portion of the graphs refers to the sub-atmospheric weir flow phase, and the upper portion to the air partialised flow phase. The longest lip length has a very small air flow at the onset of priming, resulting in instability and hunting. With regard to inlet lip elevation fig 12 shows the effect of each lip elevation on the priming characteristics of the siphon. The lowest lip elevation produced the steepest priming curve and the highest lip elevation produced the shallowest. Hunting was found to be greatly reduced at the highest lip elevation.

## 2.3 Outlet configurations

Various authors have covered the effects of different outlet configurations. Charlton and Perkins[7] found that outlet conditions affect the priming, air entrainment and the stability of the siphon. The most effective seal occurs when the outlet is submerged. Providing a basin at the outlet, however, may be inadequate if the basin is so shaped to permit the water to pass smoothly through it before shooting

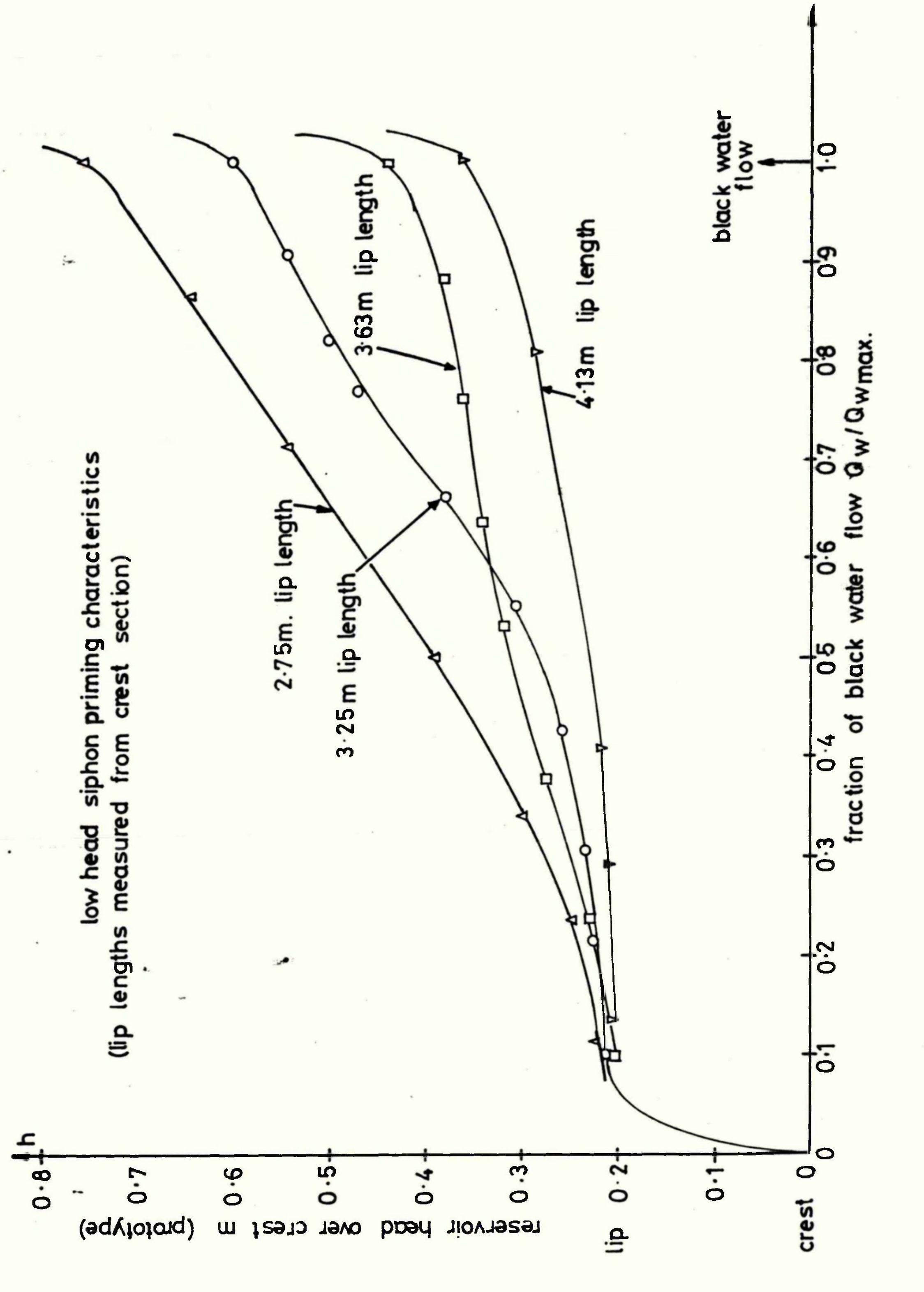



Fig 11 - Effect of lip length on the low head priming characteristic

ELSAWY AND ERVINE

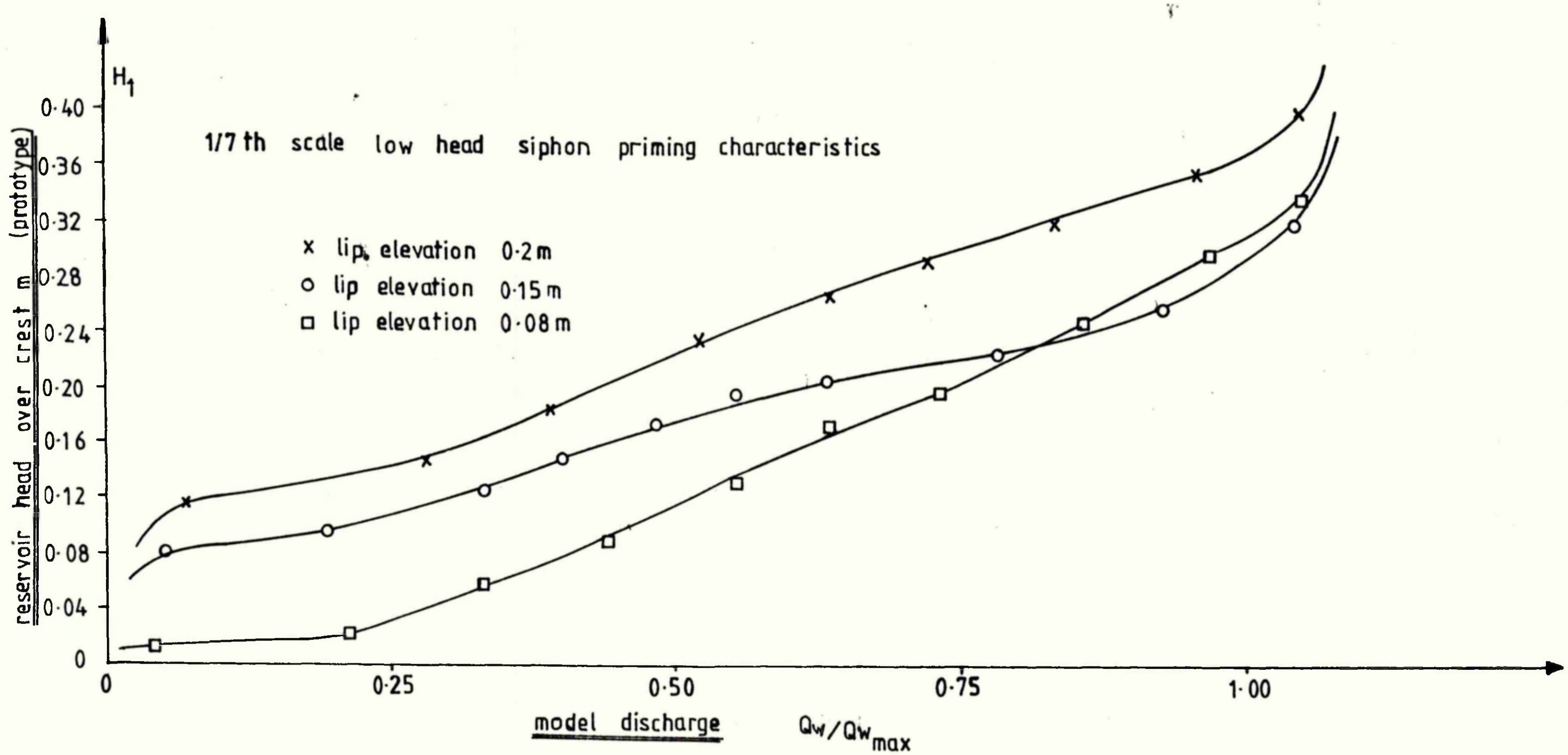



Fig 12 Effects of lip elevation on the priming characteristics of the low head siphon

clear of the structure. The water level must back up within the basin and cover the lip of the outlet, preventing the entry of air. Under such circumstances a small step in the outlet leg, to provide a temporary curtain seal and entrain air at the lower stages of flow, is required. This has the advantage of interfering little with the flow at higher stages, and having only a slight effect on the coefficient of discharge.

Elsawy and Ervine went one stage further. They showed the effect on the priming characteristics for differing tailwater levels to be quite pronounced (fig 13). At higher tailwater levels the initial stages of the priming characteristic are largely unaffected, but near full flow the head/discharge curve becomes much steeper and gives a lower maximum flow as expected due to the reduced head. For higher tailwater levels an increased tailwater level on the siphon produces a marked drop in air flow but at the expense of poor control at certain flows. It is clearly an advantage having a decreased air flow at higher tailwater levels, provided the air control and regulation is not seriously affected.

## 2.4 Vortices at inlet

Reddy and Pickford[10] described the factors affecting the production of vortices at inlet and their physical effects on hydraulic machinery. This is of great importance to the siphon designers when considering inlet conditions. Vortex

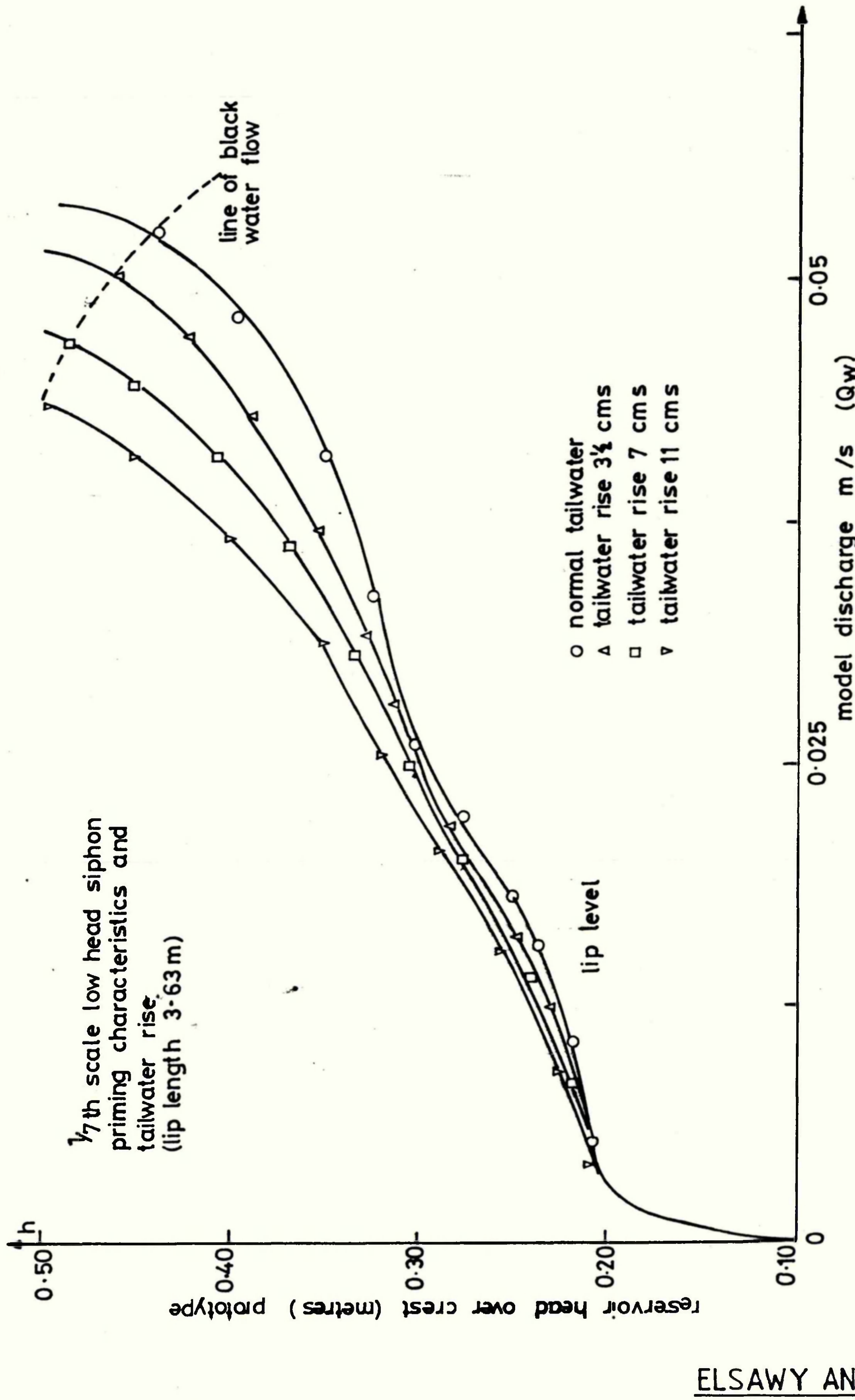



Fig 13 - Effect of tailwater level on priming characteristics.

ELSAWY AND ERVINE

induced air entrainment is considered a disadvantage as the vortices tend to make the siphon flow unsteady therefore producing a varying upstream level.

If the depth of water above an intake is low, air entraining vortices develop and these adversely affect the efficiency of the hydraulic machinery by reducing flow rate and by giving extra swirl to the fluid, in addition to causing vibration and noise. In shallow reservoirs wave action develops an unstable boundary layer (depending on the wave length to celerity) and this is generally responsible for the change in vorticity which leads to formation of air entraining vortices.

Their main recommendation is to try and still the wave formation around the inlet by use of (several) baffle boards.

## 2.5 Siphon materials

Kelly(11) suggested that there may be a relationship between tube material and bubble emergence and to confirm his suspicions carried out various tests on the following materials: mild steel, polyethelene (high density), copper, perspex and glass. He also proposed that it is the number, size and shape of "pores" or traps in the surface of the material that enables bubbles to form. No satisfactory explanation of the mechanism of origination of gas or vapour bubbles in a liquid has yet been found. Any bubbles that appear spontaneously will again vanish immediately unless considerable heating or high tensional stresses occur or unless the liquid is highly supersaturated with gas.

However, the pores provide bubble "factories" that can continue to obtain gas by diffusion from the liquid and release streams of bubbles. These factories only operate for particular bubble sizes, which means that as the pressure decreases at higher elevations within the siphon different size bubbles will emerge. Kelly concluded that the material's surface roughness determines the bubble formation. Even the comparison of slightly rusted steel with new steel is radical and the comparison of steel with perspex is startling. No bubbles formed in the fluid, all bubbles formed on the material surfaces during these tests. Thus siphon performances cannot be modelled in one material to forecast results on a project using a different material.

Kelly's conclusions do not apply to all stages of siphon discharge as it can be readily appreciated that air entrainment in the air partialised flow regime would completely swamp the processes described above.

# CHAPTER THREE

## THE THEORY AND DESIGN OF AIR REGULATED SIPHONS INCLUDING THE SIPHON MODEL

## 3.1 Dimensional analysis

To enable meaningfull comparisons of results a dimensional analysis of the terms affecting siphon discharge is required. The analysis applies to the siphon running full and therefore relates to the air partialised and blackwater flow phases. With reference to fig 14, which is a cross section of the siphon model, it can be seen that the discharge of a siphon running full is dependant on the following variables:

$$Q = f\{b, H, h_1, h_2, R_2, L, L_T, g, \rho, d, \sigma, \mu, V_a\}$$

where Q = Volume discharge rate

H = Working head

$h_1$ = Priming head

$h_2$ = Elevation of underside of inlet lip above siphon crest

$R_2$ = Outside radius of upper bend

L = Inlet lip length, measured from siphon crest

$L_T$ = Siphon length, measured along centre line of siphon section

g = Acceleration due to gravity

$\rho$ = Density of fluid

d = Siphon throat depth

$\sigma$ = Surface tension

$\mu$ = Dynamic viscosity

$V_a$ = Velocity of approach to siphon inlet

and $f\{\ \}$ = Function of

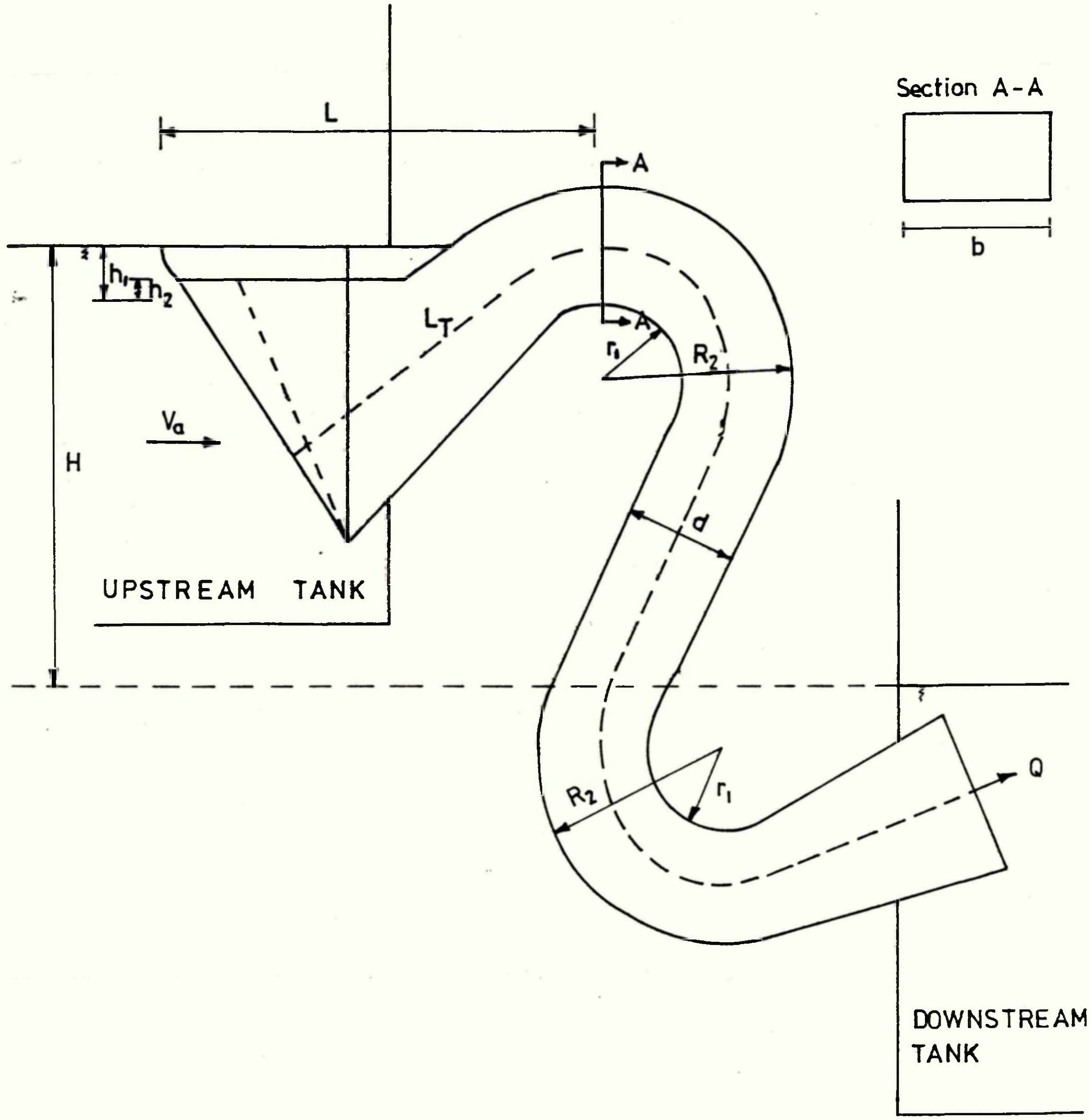



FIG 14 DIAGRAM SHOWING INLET GEOMETRY OF SIPHON

Taking the repeating variable $\rho$, g and d.

$\pi_1$ term

$$\pi_1 = \rho^a \, g^b \, d^c \, b$$

$$= (mL^{-3})^a \, (L_T^{-2})^b \, (L)^c \, L$$

for m : $0 = a$

T : $0 = -2b \quad \therefore b = 0$

L : $0 = -3a + b + c + 1$

$= 0 + 0 + c + 1 \quad \therefore c = -1$

$$\therefore \quad {}_1 = d^{-1} \times b$$

$$ {}_1 = \frac{b}{d}$$

and as dimensions of b, H, $h_1$, $h_2$, $R_2$, L, and $L_T$ are the same we can write

$$\pi_2 = \frac{H}{d}$$

$$\pi_3 = \frac{h_1}{d}$$

$$\pi_4 = \frac{h_2}{d}$$

$$\pi_5 = \frac{R_2}{d}$$

$$\pi_6 = \frac{L}{d}$$

$$\pi_7 = \frac{L_T}{d}$$

$\pi_8$ term

$$\pi_8 = \rho^a \, g^b \, d^c \, Q$$

$$(mL^{-3})^a \, (LT^{-2})^b \, (L)^c \, (L^3T^{-1})$$

for m : $0 = a$

L : $0 = -3a + b + c + 3$

$\therefore 0 = 0 + b + c + 3$

T : $0 = -2b - 1 \quad \therefore \quad b = -\frac{1}{2}$

Substitute in L equation

$$0 = 0 + (-\tfrac{1}{2}) + c + 3$$

$$\therefore \quad c = -2\tfrac{1}{2} = -\frac{5}{2}$$

$$\therefore \pi_8 = g^{-1/2} \; d^{-\frac{5}{2}} \, Q$$

$$\pi_8 = \frac{Q}{d^2 \sqrt{dg}}$$

$\pi_9$ term

$$\pi_9 = \rho^a \, g^b \, d^c \, \sigma$$

$$= (mL^{-3})^a \, (LT^{-2})^b \, (L)^c \, (mT^{-2})$$

for m : $0 = a + 1 \quad \therefore \quad a = -1$

L : $0 = -3a + b + c = 3 + b + c$

T : $0 = -2b - 2 \quad \therefore \quad b = -1$

$\therefore \quad c = -2 \qquad \therefore \quad \pi_9 = \dfrac{\sigma}{\rho d^2 g}$

$\pi_{10}$ term

$$\pi_{10} = \rho^a \, g^b \, d^c \mu$$

$$= (mL^{-3})^a \, (LT^{-2})^b \, (L)^c \, (mL^{-1}T^{-1})$$

for m : 0 = a + 1 $\therefore$ a = -1

L : 0 = -3a + b + c - 1

= 2 + b + c

T : 0 = -2b - 1 $\therefore$ $b = -\frac{1}{2}$

also 0 = 2 + b + c

$= 2 - \frac{1}{2} + c$ $\therefore$ $c = -\frac{3}{2}$

$$\therefore \pi_{10} = \rho^{-1}\, g^{-1/2}\, d^{-3/2}$$

$$= \frac{\mu}{d^{3/2}\rho\sqrt{g}} = \frac{d\sqrt{gd}}{\nu}$$

<u>$\pi_{11}$ term</u>

$$\pi_{11} = \rho^a\, g^b\, d^c\, V_a$$

$$= (mL^{-3})^a\, (LT^{-2})^b\, (L)^c\, (LT^{-1})$$

for m : 0 = a

L : 0 = -3a + b + c + 1

= 0 + b + c + 1

T : 0 = -2b - 1 $\therefore$ $b = -\frac{1}{2}$

$\therefore$ $c = -\frac{1}{2}$

$$\pi_{11} = \frac{V_a}{\sqrt{gd}} = \frac{V}{\sqrt{gd}}$$

$\therefore$ from original expression

$$\frac{Q}{d^2\sqrt{gd}} = f\left\{\frac{b}{d}, \frac{H}{d}, \frac{h_1}{d}, \frac{h_2}{d}, \frac{R_2}{d}, \frac{L}{d}, \frac{L_T}{d}, \frac{\sigma}{gd^2\rho}, \frac{\mu}{d^{3/2}\rho\sqrt{g}}, \frac{V}{\sqrt{gd}}\right\}$$

We now need to derive alternative forms of the Froude number, Reynolds' number and the Weber number using this analysis.

$\pi_8$ may be re-written by combining with $^b/_d$ and $\sqrt{^H/_d}$ to give

$$\frac{Q}{d\, b \sqrt{g\, H}}$$

since $\frac{Q}{db} = V_t$ (Where $V_t$ = mean velocity through the siphon)

$\pi_8$ becomes $\frac{V_t}{\sqrt{gH}}$ thus $\pi_8$ becomes a form of the Froude number

Similarly $\pi_{10} = \frac{d\sqrt{gd}}{\nu}$ and is a form of the Reynolds' number

and $\pi_9 = \frac{\sigma}{\rho\, g\, d^2}$ which may be inverted to

$\frac{\rho\, g\, d^2}{\sigma}$ which is a form of the Weber number

$\therefore$ the result of this analysis may be more meaningfully written as:

<u>Equation 3.1</u>

$$\underbrace{\frac{Q}{bd\sqrt{(gH)}}}_{\text{Froude number}} = f\left\{\frac{b}{d}, \frac{H}{d}, \frac{h_1}{d}, \frac{h_2}{d}, \frac{R_2}{d}, \frac{L}{d}, \frac{L_T}{d}, \underbrace{\frac{d\sqrt{gh}}{\nu}}_{\text{Reynolds' number}}, \underbrace{\frac{\rho gd^2}{\sigma}}_{\text{Weber number}}, \frac{V_a}{\sqrt{gd}}\right.$$

The variables which are being studied are contained in equation 3.1 and are H, $h_1$, $h_2$, b and L.

From equation 3.1 there are two $\pi$ terms which can be combined to yield $^{H}/h_1$

ie $\quad ^{H}/_{d} \div {}^{h_1}/_{d} = {}^{H}/_{h_1}$ <u>Equation 3.2</u>

For the purpose of our testing work we can assume that $V_a$ is small and therefore $V_a^2$ becomes negligible. This assumption allows us to ignore the effects of upstream velocity. It would not be possible to make this assumption if the siphon was fed by a narrow, shallow channel of similar dimensions to the siphon.

Comparing equation 3.1 and 3.2 with $Q = C_D\, bd \sqrt{2gH}$ (where $C_D$ is the coefficient of discharge) it can be seen that

<u>Equation 3.3</u>

$$C_D = \phi \left\{ \frac{b}{d}, \frac{h_1}{d}, \frac{H}{h_1}, \frac{h_2}{d}, \frac{R_2}{d}, \frac{L}{d}, \frac{L_T}{d}, \frac{d\sqrt{gh}}{\nu}, \frac{\rho g d^2}{\sigma} \right\}$$

Therefore meaningful study may be made by comparing the following:

$$C_D, \quad \frac{d\sqrt{gH}}{\nu}, \quad \frac{\rho g H^2}{\sigma}, \quad \frac{H}{d}, \quad \frac{h_1}{d} \quad \& \quad \frac{H}{h_1}$$

Thus dimensionless graphs may be plotted as follows:

$R_e$, $W$, $\frac{H}{d}$, $\frac{h_1}{d}$ & $\frac{H}{h_1}$ against $C_D$

where $R_e$ = Reynolds' number

and $W$ = Weber number

## 3.2 Siphonic discharge theory

The flow regime in the upper bend (Section A - A, fig 14) in the siphon is approximately that of a free vortex. This flow regime is apparent where the velocity (V) is inversely proportional to the radius (R) ie

$$V \propto \frac{1}{R}$$

Thus, the smaller the radii the faster the velocity. The region of maximum velocity and hence the region of lowest pressure occurs to the flow passing round the crest. Also the product of the velocity and the radius is constant.

ie

$$k = VR \quad \text{where } k = \text{constant}$$

$$\therefore \quad V = \frac{k}{R}$$

The working head H, may be considered to be the sum of the velocity head losses for various parts of the siphon as well as including the head loss due to the conversion of velocity. Knowing these factors it therefore is possible to derive an expression for the discharge of the siphon. The total head loss in the siphon $h_t$ may consist of:-

$$h_t = h_v + h_1 + h_2 + h_3 + h_4 + h_5$$

which since the total head is expended in producing velocity of flows and overcoming these resistances ($h_v$, 1-5) then $h_t$ = the working head H where

H = working head

$h_t$ = total head loss in siphon

$h_v$ = head loss due to conversion of velocity

$h_1$ = head loss at entry

$h_2$ = head loss due to top bend

$h_3$ = head loss due to friction

$h_4$ = head loss due to bottom bend

$h_5$ = head loss due to kinematic head at outlet

Assuming that each of these losses is proportional to the square of the velocity of flow V at the throat then expressing in terms of velocity heads:

Equation 3.4

$$H = \frac{V_t^2}{2g} (k_v + k_1 + k_2 + k_3 + k_4 + k_5)$$

$$= \frac{V_t^2}{2g} ( \Sigma k_{(v,1-5)})$$

where:

$V_t$ = mean velocity at throat

$k_{(v,1-5)}$ = empirical coefficients covering the various energy head losses

Rearranging equation 3.4

$$V_t = \frac{\sqrt{2gH}}{(\Sigma K_{(v,1-5)})^{\frac{1}{2}}}$$

The discharge through the siphon:

$Q = A_t V_t$

where $A_t$ = constant cross-sectional area of siphon along length except for entry and exit sections.

Thus:

$$Q = \frac{A_t \sqrt{2gH}}{(\Sigma K_{(v,1-5)})^{\frac{1}{2}}}$$ Equation 3.5

or $Q = C_D A_t \sqrt{2gH}$ Equation 3.6

where

$C_D = \frac{1}{(\Sigma K_{(v,1-5)})^{\frac{1}{2}}}$ = coefficient of discharge for the siphon running full and can be determined directly if k coefficients are known.

For a newly designed siphon it is unlikely that these k coefficients will be known due to the complexity of flow and to the very wide variations in velocity and pressure across various sections, thus making coefficients based on more conventional types of flow incompatible. Therefore a practical solution must be found to overcome this problem. A method of taking a series of calibration runs on the siphon measuring working heads for a series of discharges will give an accurate solution to this problem, but the discharge expression equation 3.5 will only determine the overall coefficient of discharge, $C_D$ and not the individual empirical coefficients.

The coefficient of discharge $C_D$ will be found to vary greatly with flow rates up to air partialised flow. This is because the discharge equation and the coefficient calculated is derived from a blackwater flow condition and calculations should be restricted to flows above sub-atmospheric weir flow.

From equation 3.6 ie $Q = C_D A_t \sqrt{2gH}$, it is apparent that a siphon has similar discharge characteristics to those of a sluice gate. A sluice gate utilises a similar working head to a siphon and its discharge expression is of the same format.

## 3.3 Low head air regulated siphon design

At this date the most logical sequence of design devised has been by Elsawy and Ervine[9] and Charlton[12]. This technique makes use of the initial requirements to determine the basic siphon dimensions and then refine such geometric features such as the inlet and outlet configurations as well as the upper and lower bends.

The known factors, initially, are the maximum discharge required and the available working head. An approximate determination can be made of the mean velocity at maximum (blackwater) flow, by assuming a typical value of the coefficient of discharge $C_D$ and using a modification of equation 3.6 ie $V = C_D \sqrt{2gH}$ as $V = Q/A$. By reducing this velocity by between 10% and 15% blackwater flow will be avoided and the resultant velocity used to determine the required cross-sectional area of the siphon. This procedure determined the following, maximum flow and corresponding velocity, working head and cross-sectional area.

The next stage in design now centred on the upper bend, determining the values of the two radii $R_1$ and $R_2$, the throat depth d and width b. Charlton showed:

Equation 3.7 where k = constant of free vortex flow.

i) $$k = R_1 R_2 \sqrt{\frac{2g}{R_1 + R_2}}$$

Equation 3.8

ii) $$R_1 = V_2 \sqrt{\frac{R_1 + R_2}{2g}}$$

Equation 3.9

$$R_2 = V_1 \sqrt{\frac{R_1 + R_2}{2g}}$$

Equation 3.10

iii) $$V_t = \frac{V_1 + V_2}{2}$$

This expression provides an approximate value of mean velocity $V_t$.

But these expressions are based on the assumption of free vortex flow in the throat and a required neutral pressure gradient between the crest and the crown to assist mixing of air and water.

Although not critical Ervine[13] recommended that the ratio of width/throat depth should be in the region of 1:5. Bearing in mind the required cross-sectional area and the $^b/_d$ ratio a trial procedure using equations 3.7 - 3.10, may be used to achieve satisfactory values of $R_1$, $R_2$, d and b. The bottom bend may be taken as the same configuration as that of the top bend but washout could occur at higher flow rates and so impede the required higher discharge, therefore, care should be taken to ensure that it is not too rounded ie of too large a radius. Washout is a term used for a case where the flow tends to cling to the lower surface as a high speed jet, which in this situation may even empty the lower sealing pool. The problem could be overcome by the use of 2 adjacent siphons (especially applicable in a bellmouth dropshaft) and arrange them so that their discharges are directed against each other. However this would result in a reduction of downstream velocities and the siphons will surcharge. Charlton[14] suggests making the lower bend of an angular design to eliminate this problem.

The inlet configuration of an air regulated siphon is of critical importance as it effects the entire range of flow characteristics. The inlet geometry forms the most delicate design area. Model tests are required on which to form a design basis and it is this which forms the substance of this report. There are three variables in inlet geometry:

(i) Inlet lip elevation above the crest, which determines the initial priming head and hence the nappe thickness for air entrainment.

(ii) Inlet lip length, which affects the characteristics of air-regulation and the head discharge relationship in the air partialised flow regime.

(iii) Aspect ratio - ratio $^{b}/_{d}$.

## 3.4 Modelling Technique

If the results obtained from a model are to be transferable to the prototype it is necessary for the two flow systems to be hydraulically similar. This entails (a) geometric, (b) kinematic and (c) dynamic similarity.

### (a) Geometric similarity

This basically is similarity of shape. The ratio of any two dimensions in the model is the same as the corresponding ratio in the prototype, or

$$\frac{(L_1)m}{(L_2)m} = \frac{(L_1)p}{(L_2)p} \qquad m = \text{model} \qquad p = \text{prototype} \qquad L = \text{length}$$

Thus if the linear scale of the model is 1:x the scalar relationship for area is $1:x^2$ and for volume $1:x^3$.

### (b) Kinematic similarity

This is the similarity of motion, thereby introducing the vector quantity and time factor. The latter is of importance in problems involving unsteady flow. The velocities (and accelerations) at homologous points and at homologous times in the two systems have the same ratio to each other. Also the corresponding directions of motion are the same. Thus

$$\frac{(V_1)m}{(V_2)m} = \frac{(V_1)p}{(V_2)p} \quad \text{and} \quad \frac{(a_1)m}{(a_2)m} = \frac{(a_1)p}{(a_2)p} \qquad V = \text{velocity}, \quad a = \text{acceleration}$$

(c) Dynamic similarity

This is the similarity of forces at homologous points in the two systems which have the same ratio to each other and act in the same direction. Thus

$$\frac{(F_1)m}{(F_2)m} = \frac{(F_1)p}{(F_2)p}$$

The component forces acting on any element of incompressible fluid may be due to pressure, gravity, viscosity or surface tension. The conditions for dynamic similarity can thus be expressed algebraically as

$$\frac{(F_p)p}{(F_p)m} = \frac{(F_G)p}{(F_G)m} = \frac{(F_V)p}{(F_V)m} = \frac{(F_{ST})p}{(F_{ST})m}$$

When considering these forces with respect to a model accurately scaled to a prototype, geometric and kinematic similarities are both achieved, true dynamic similarity is impossible to attain.

To illustrate this phenomenon let us consider the Froude and Reynolds' laws.

(a) Froude law

Gravity is the predominant factor influencing fluid motion wherever a free surface gradient is present. The Froude number represents the ratio of inertia to gravity forces, and is given by

$$F = \frac{V}{\sqrt{(gL)}}$$

where

F = Froude number  g = acceleration due to gravity

V = mean velocity  L = length, taken to be the depth of flow

For compliance with the Froude law of scaling, the corresponding velocities must be so related that

$$\frac{V_p}{V_m} = \frac{(g\ L_p)^{1/2}}{(g\ L_m)^{1/2}} = x^{1/2}$$

$V_p$ = mean velocity of prototype

$V_m$ = mean velocity of model

$L_p$ = depth of flow, prototype

$L_m$ = depth of flow, model

x = geometric scale factor between model and prototype

(b) Reynolds' law

All real fluids possess viscosity and the possibility viscous shear drag requires consideration in the planning stage of every type of fluid model investigation. The Reynolds' number represents the ratio of inertia to viscous force, and is given by $R = VL/\nu$ where

R = Reynolds' number  L = length, taken to be the depth of flow

V = mean velocity  $\nu$ = viscosity

For compliance with Reynolds' law of scaling the corresponding velocities must be so related that:

$$\left(\frac{VL}{\nu}\right)_m = \left(\frac{VL}{\nu}\right)_p$$

$$\therefore \frac{V_p}{V_m} = \frac{\nu_p}{\nu_m} \times \frac{L_m}{L_p} = \frac{1}{X}\ \frac{\nu_p}{\nu_m}$$

$$\frac{1}{X} \cdot \frac{\nu_p}{\nu_m} = \frac{1}{X}$$ when water is used in model and prototype.

From these analyses it can be seen that the velocity cannot satisfy $^1/_X$ and $X^{1/2}$ and in the same model ie full dynamic similarity is physically impossible

For a siphon, the most significant forces results from gravitational and inertial effects. The model is therefore based on similarity of these forces. The forces are due to the transference of water from a higher level to a lower level (gravity effect) and the fairly high velocities together with considerable changes in the direction of flow (inertia effect). Therefore, a Froudian model is most suitable and would accurately simulate the flow dynamics for gravity and inertia. The scale ratios for the Froude law of scaling are shown in table 3.1

Table 3.1 Scale ratios for Froude law of scaling (after Weber[17])

| Quantity | Dimensions | Froude law natural (scale 1:x) |
|---|---|---|
| Geometric | | |
| Length | $L$ | $x$ |
| Area | $L^2$ | $x^2$ |
| Volume | $L^3$ | $x^3$ |
| Kinematic | | |
| Time | $T$ | $x^{1/2}$ |
| Velocity | $L/T$ | $x^{1/2}$ |
| Acceleration | $L/T^2$ | $1$ |
| Discharge | $L^3/T$ | $x^{5/2}$ |
| Dynamic | | |
| Pressure | $M/LT^2$ | $\rho rx$ |
| Force | $ML/T^2$ | $\rho rx^3$ |
| Energy | $ML^2/T^2$ | $\rho rx^4$ |
| Power | $ML^2/T^3$ | $\rho rx^{7/2}$ |

## 3.5 Aspects of similarity and scale effects

Model/prototype conformity is good for the full discharge condition, but it is not possible to reproduce correctly the priming and de-priming processes, which are complicated by virtue of air entrainment. The priming action demands an absolute velocity sufficient to entrain and transport air bubbles and therefore does not lend itself to scale reduction. Consequently, priming in the model will occur at a relatively late stage and higher upstream level than in the prototype.

The functioning of a siphon necessarily depends on the existence of sub-atmospheric pressures, and under these conditions great care in measurement and interpretation of model pressures is required. For instance it would be quite conceivable for a model siphon to continue to operate whereas the prototype would have ceased to do so.

During priming the bubbles of air which are entrained are approximately the same size (5mm diameter) in the model as in the prototype. This non-scaling of bubble sizes and bubble rise velocities gives rise to the non-scaling of the rate of evacuation from a siphon model. Models involving velocities in the range of the bubble rise velocity may not be capable of removing entrained air from the siphon barrel.

Other scale effects include the non-scaling of surface tension forces at the siphon hood inlet, often resulting in a restriction of air inflow in the smaller models, and the greater expansion of air within the full-scale siphon often producing a larger ratio of air to water.

Also another surface tension effect occurs at the lip of the siphon, where in the model the size and frequency of the air bubbles entering the siphon are determined by the rate of making and breaking of the surface tension film between the water surface and the lip. This effect will be no greater in the prototype where, consequently, a steadier stream of smaller bubbles is to be expected. This suggests that the fluctuating forces imposed on the hood may be less severe than the model indicates, but their frequency will be greater.

Ali and Pateman(15) tested 8 models of a siphon, all built to the same design, at scales ranging from $^1/_{10}$ to $^1/_{240}$. They determined that the smallest model ($^1/_{240}$th scale) was dominated by surface tension forces. The larger scale models ($^1/_{30}$, $^1/_{17.6}$ and $^1/_{10}$) exhibit the conventional form of head-discharge curve for an air regulated siphon. The $^1/_{64.9}$ scale shows different behaviour (the $^1/_{78.9}$, $^1/_{100}$ and $^1/_{133.3}$ scale models were similar) but Ali and Pateman merely state that small-scale models do not work correctly . They also tested models of Ervine's siphon at scales of $^1/_{10}$, $^1/_{25}$ and $^1/_{50}$ and found that the two smaller models displayed the anomalous behaviour already mentioned; the largest model behaved conventionally(16).

From work carried out on several different scale models Gibson(18) concluded that the viscous effects became negligible when the product of the mean throat velocity $V_t$

and the throat, d, exceeded $0.167 m^2/s$. A tentative choice of scale of $^1/_4$ full size, yields a model throat depth of 75mm. Thus the required velocity to avoid viscous effects =

$$V_t = \frac{0.167}{0.075} = 2.39 \text{ m/s}$$

Hence a required flow rate in the model,

$$Q = V_t \, A_t$$
$$= 2.39 \times 0.075^2 \times 10^3$$
$$= 13.44 \text{ L/s}$$

From previous work carried out by Smith(19) it was known that discharges of up to 15 L/s would be encountered, hence a scale of $^1/_4$ would not incur viscosity scaling effects of the flow. Using the scale 1:4 and the table 3.2 we can draw the conclusions:

Table 3.2 Table of scalar relationships for models

| Parameter | Model | Prototype |
|---|---|---|
| Length | 1 | 4 |
| Area | 1 | 16 |
| Volume | 1 | 64 |
| Velocity | 1 | 2 |
| Discharge | 1 | 32 |
| Time | 1 | 2 |

# CHAPTER FOUR

## THE AIMS AND PROCEDURES OF EXPERIMENTATION

## 4.1 Objectives of experimentation

Because of restrictions on space in prototype installations, and the need to keep excavation to a minimum, the siphon geometry was kept as compact as possible. An S-shaped siphon was chosen with a rectangular section, not unlike the earlier types of blackwater siphon. The downstream leg of the siphon was returned beneath the crest so that a vertical wall of water formed shortly after first spill, which effected a seal and ensured efficient priming. The radius of curvature of the crest and lower bend was increased from that of earlier designs which suffered from severe separation immediately after the crest. This modification significantly improved the discharge capacity of the siphon. Particular attention was paid observing the effects of varying the following parameters (fig 15) on the siphon's performance:

(a) Inlet lip elevation over the crest ($h_2$)

(b) Inlet lip length (L)

(c) Tailwater level (ie working head H)

(d) Siphon width (b)

The aim was to produce an optimum inlet geometry configuration together with the most effective working head to provide the siphon with the required characteristics peculiar to a stormwater overflow.

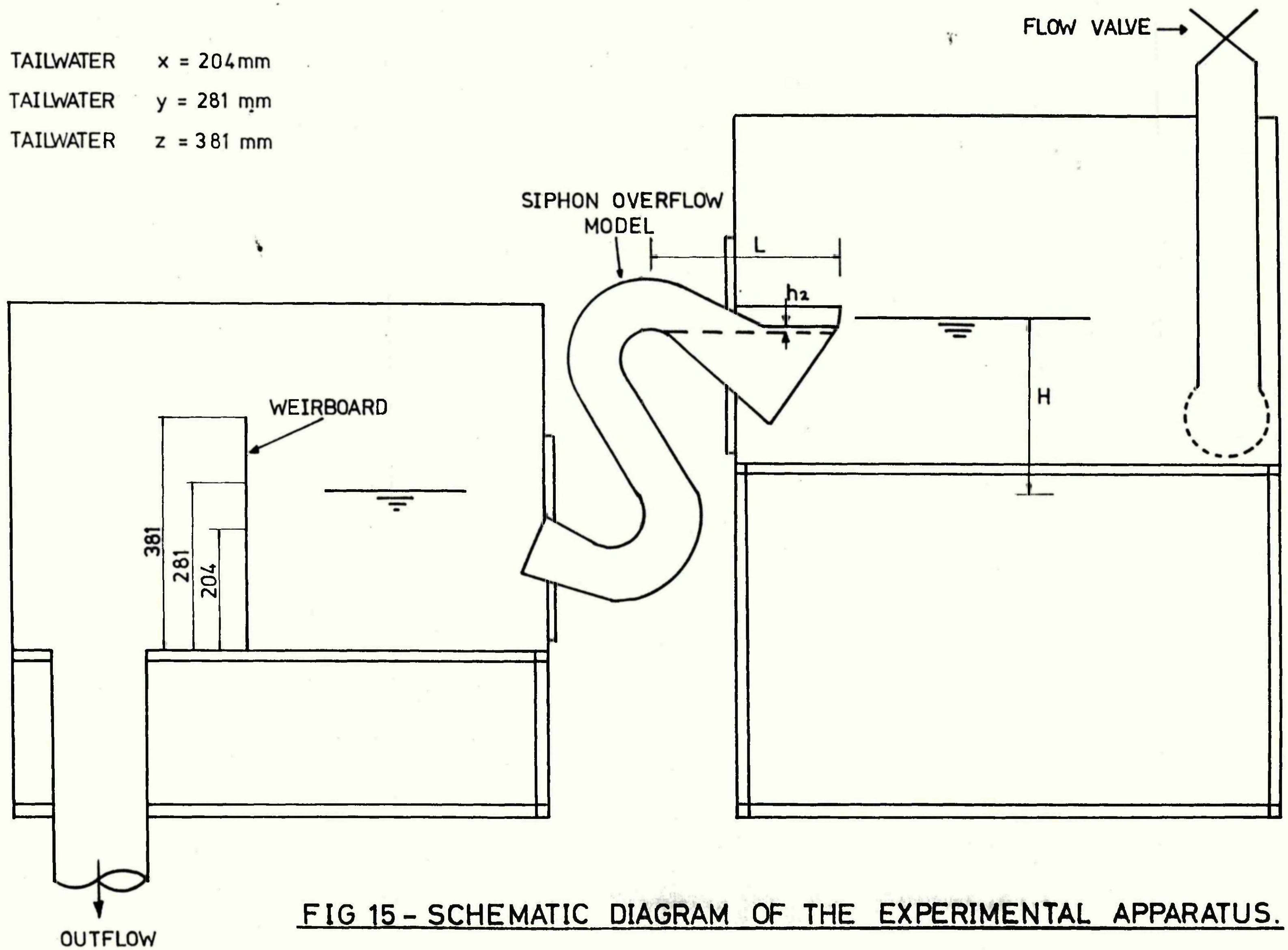



FIG 15 - SCHEMATIC DIAGRAM OF THE EXPERIMENTAL APPARATUS.

The effect of variations of the above parameters were analysed by consideration and comparison of the different head/discharge relationships of those parameters shown to be of importance in dimensional analysis.

Another important part of this work was to determine the effect of air entrainment on the values of $C_D$ and $^{h_1}/_d$.

## 4.2 The experimental apparatus

The major components of the rig were two galvanised steel tanks at different levels (higher tank for inflow and lower for outflow) which were connected by the model siphon, fig 15.

Water was delivered by a centrifugal pump through a 100mm diameter PVC pipe from an underfloor sump tank via a control valve to a diffuser in the bottom of the inlet tank and the opposite end to the siphon inlet feed. This provided a 'uniform' flow across the tank through the siphon. To vary the outlet water level three weir boards 'x', 'y' and 'z' were placed in the centre of the downstream tank. The flow was returned to the underfloor reservoir by a 300mm PVC pipe flange bolted to the tank base downstream of the weirboards.

To measure the discharge a venturi meter was incorporated into the 100mm delivery pipe. The venturi pressure differential was measured using two types of manometer and the discharge was found using a calibration curve. A water manometer was used to measure flow rates up to 3.1 L/sec and a water over mercury manometer for flow rates between 3.1 L/sec and 15.5 L/sec, which corresponded to the manometer's maximum reading.

By taking tappings from the base of each tank and connecting them via two plastic tubes to a multitude manometer, the upstream and downstream levels were determined. Fourteen of the sixteen pressure tapping points were also connected to this manometer, the other two tappings were connected to a U-tube water manometer and connected to each as required. A separate U-tube manometer was used as the pressure tappings in the crown of the siphon were often subjected to sub-atmospheric pressures in the air space. Because air was likely to enter the tube and result in inaccurate readings the tappings were unsuitable for use with a continuous water manometer.

## 4.3 Experimental procedure

Three siphons were used in the tests, each of identical through section but with different widths. Siphon No1 was of 0.75mm in width, siphon No2 125mm and siphon No3 100mm. The siphons were constructed so that different inlet insert pieces could be interchanged easily to facilitate changes in inlet geometry. Wooden inlet insert pieces of various thicknesses were made, initially to the longest required for testing (5d), and then cut down in length as the testing proceeded. The variation of inlet lip elevation was achieved by varying the thickness of the insert piece.

The inlet configurations tested for siphon 2 were:

(a) Inlet lip lengths, lengths of 5d, 4d, 3d, 2.4d (where d is the throat depth).

(b) Inlet lip elevations above the crest, $h_2$ of 30, 20 and 10mm for most lip lengths in (a).

A series of three tests were carried out for each inlet configuration and by alteration of the tailwater level using different height weirboards the working head was altered for each run. A test run consisted of 14 or 15 increments in flow rate from zero to the maximum possible. For each increment in flow, manometer readings were recorded to determine the siphon discharge and by use of the multitube manometer the upstream and downstream levels were recorded to determine the working and priming heads. The flow regime and any physical factors noted were recorded in a comments section.

The results obtained from siphon 2 were used to determine the optimum lip length and the above procedure was repeated for 3d and 2.4d on siphon 1.

Having completed these tests, further work was carried out on optimising the inlet geometry of siphon No2 and the following inlet configurations were used to achieve this aim.

(a) Inlet lip lengths, lengths of 4.2d, 4.0d and 3.8d (d = throat depth)

(b) Inlet lip elevation above the crest, $h_2$ of 15mm, 10mm and 5mm for all inlet lip lengths in (a) above.

Siphon No3 was then tested to investigate the effect of siphon width more thoroughly.

Finally tests were carried out on a revised outlet configuration (fig 16) and the results compared to the straightforward downstream weir at outlet. This revised configuration incorporated a side exit from the stilling basin instead of an outlet exit over tailwater weirs. The downstream wall of this revised chamber was removeable and several positions at right angles to the direction of flow were tested.

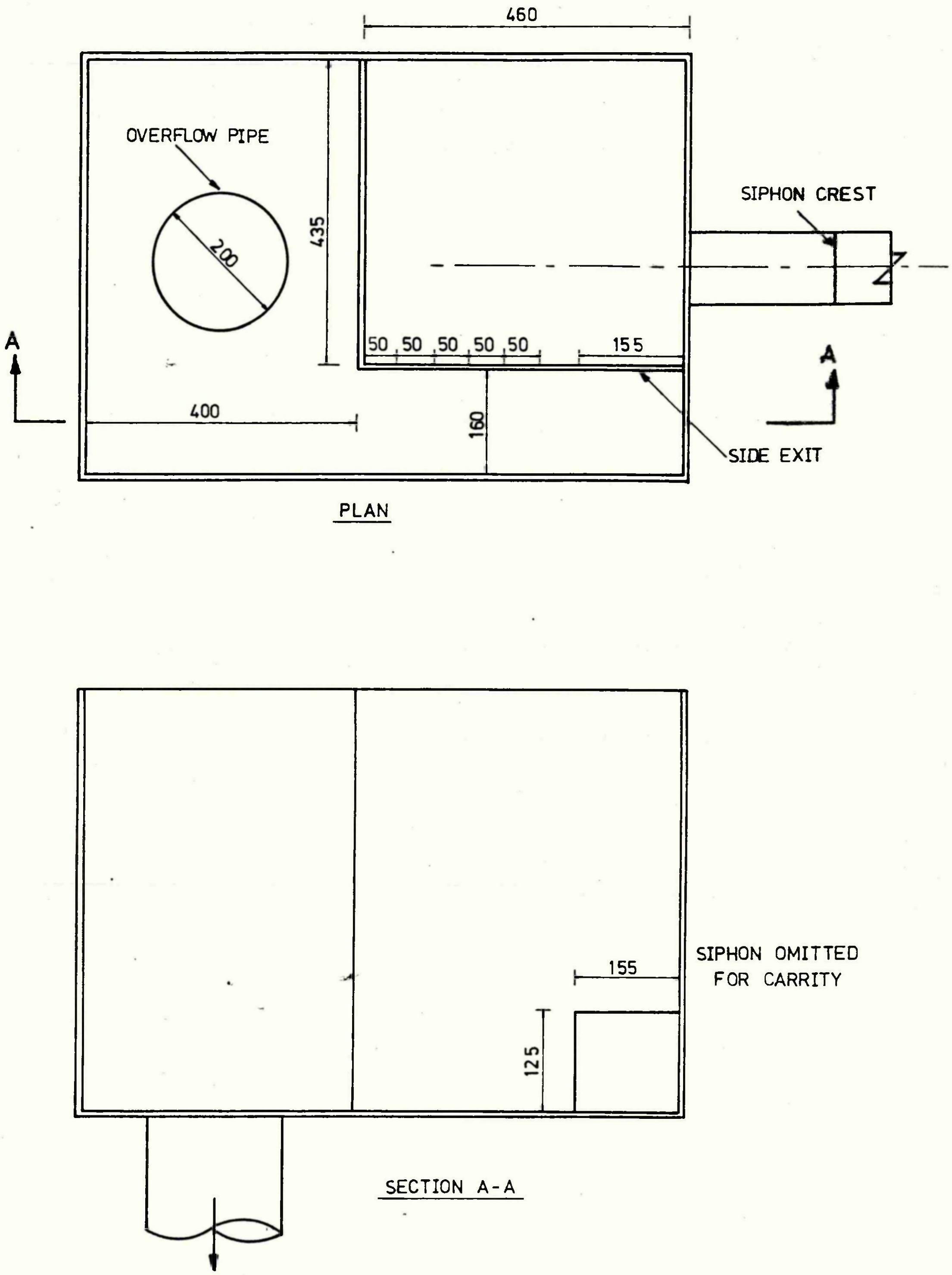



FIG 16 - SIDE EXIT TYPE STILLING BASIN-PLAN & SECTION

# CHAPTER FIVE

# DISCUSSION OF RESULTS

5.1 Order of analysis

5.2 Effects of inlet lip elevation

5.3 Effects of inlet lip length

5.4 Effects of tailwater level

5.5 Effects of siphon width

5.6 Effects of upstream channel width

5.7 Effects of vortices at inlet

5.8 Effects of revised outlet configuration

5.9 Dimensional analysis of the optimum siphon configuration

## 5.1 Order of analysis

The effects of tailwater level, lip length and lip elevation were initially investigated using siphon No2. Comparisons were later made with siphon Nos 1 and 3 which were used for investigations of upstream channel width (siphon No1) and outlet configuration (siphon No3).

(a) Using siphon No2 investigation into the effect of lip elevation was carried out using a lip length of 2.4d and elevations of 10mm, 20mm and 30mm above crest level. Although all tests were carried out using different tailwater levels, tailwater level 'Y' (281mm) was used for analysis and was considered as giving the optimum seal at this stage. From analysis of the results the optimum inlet lip elevation was determined.

(b) Using this optimum lip elevation sections of differing length were used: 2.4d, 3d, 4d and 5d - the 4d inlet lip length was found to give the best performance, as discussed later.

(c) Having determined two criteria in (a) and (b) the variation of tailwater level was thoroughly investigated and the most effective level determined.

(d) Having determined generally the optimum inlet lip length and elevation further work was carried out to determine those parameters more precisely. As in (a) and (b) above tailwater level 'Y' was used for the following configurations.

| Inlet Lip Length | Inlet Lip Elevation |
|---|---|
| 3.8d | 5mm |
| 3.8d | 10mm |
| 3.8d | 15mm |
| 4.0d | 5mm |
| 4.0d | 10mm |
| 4.0d | 15mm |
| 4.2d | 5mm |
| 4.2d | 10mm |
| 4.2d | 15mm |

During the above tests all inlet inserts were tested using side plates to avoid the effects of side vortices and to represent prototype installation details more accurately (see section 5.7).

(e) To complete testing and to determine the effect of siphon width, further tests were carried out on siphon No3 (100mm width) using the same configurations as in (d) above with tailwater level 'Y' (281mm).

To demonstrate the effects of different inlet configurations five basic graphs have been plotted.

I Working head (H) Vs discharge (Q)

II Priming head ($h_1$) Vs discharge (Q)

III Coefficient of discharge ($C_D$) Vs discharge (Q)

IV Ratio of working head/throat depth ($^H/_d$) Vs coefficient of discharge ($C_D$)

V Ratio of priming head/throat depth ($^{h1}/_d$) Vs coefficient of discharge ($C_D$)

Note: IV and V have dimensionless axes.

However, for accurate investigation into optimum inlet configurations, effects of side plates etc only graph V was used as this graph is indicative of the siphon's performance and is easily interpreted. Further to these graphs three other dimensionless graphs are to be considered.

(1) Ratio of working head/priming head ($^H/h_1$) Vs coefficient of discharge ($C_D$)

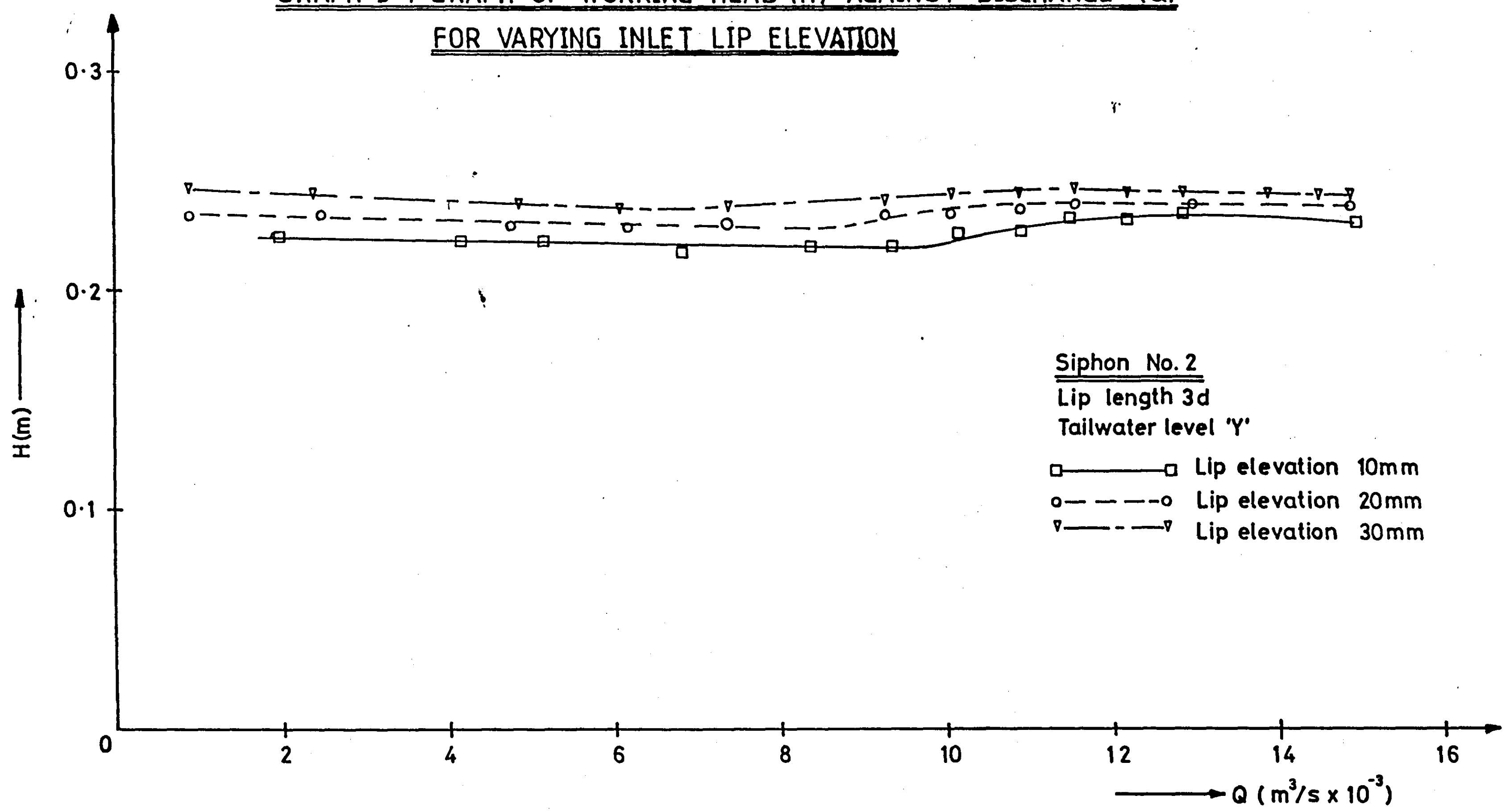
(2) Reynolds' number ($R_e$) Vs coefficient of discharge ($C_D$)

(3) Weber number (W) Vs coefficient of discharge ($C_D$)

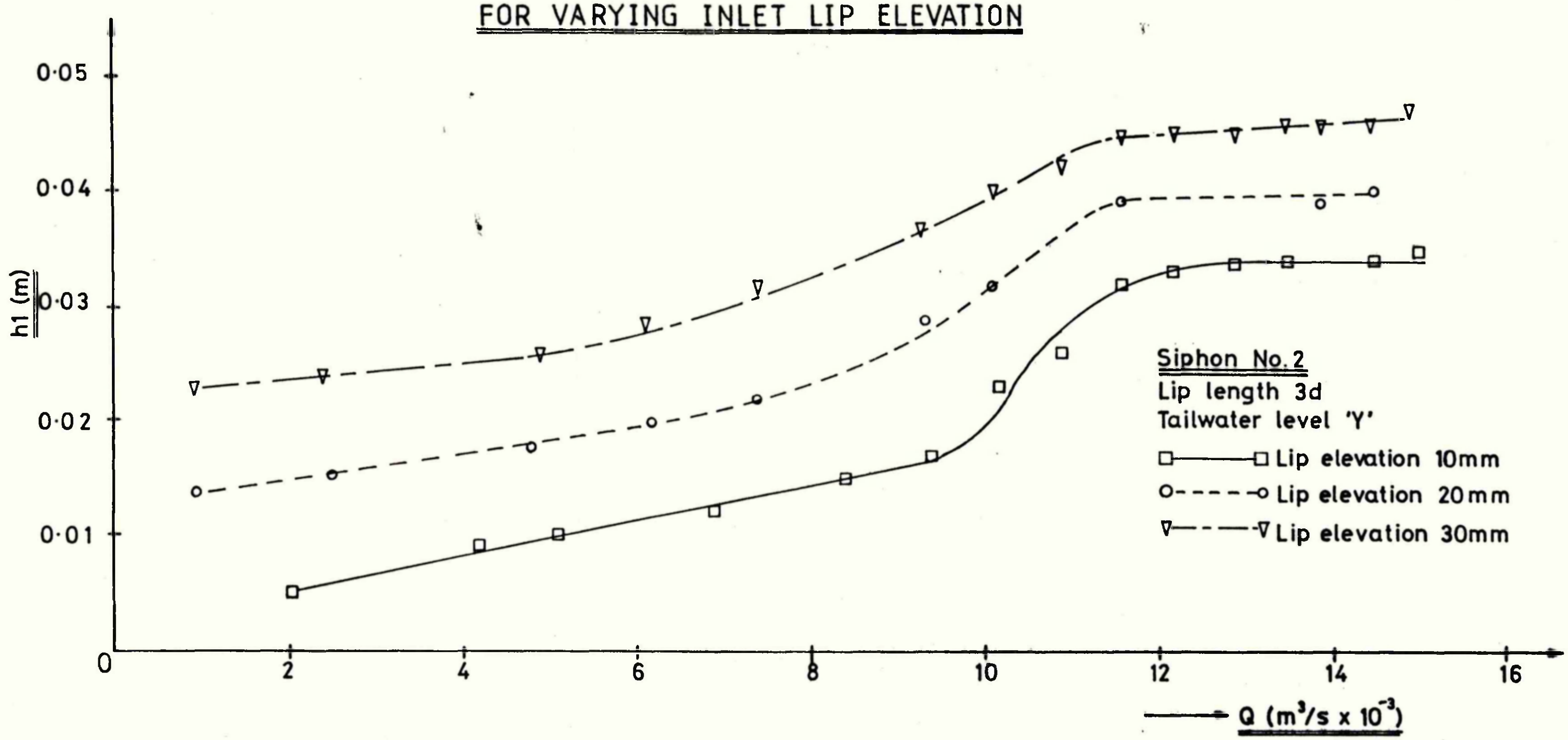
5.2 Effects of inlet lip elevation (graphs 5.1 - 5.9 refers)

Air partialised flow is the flow phase the siphon is required to operate in. It can be seen from graphs 5.1 - 5.3 that during air partialised flow, the higher inlet elevations (ie

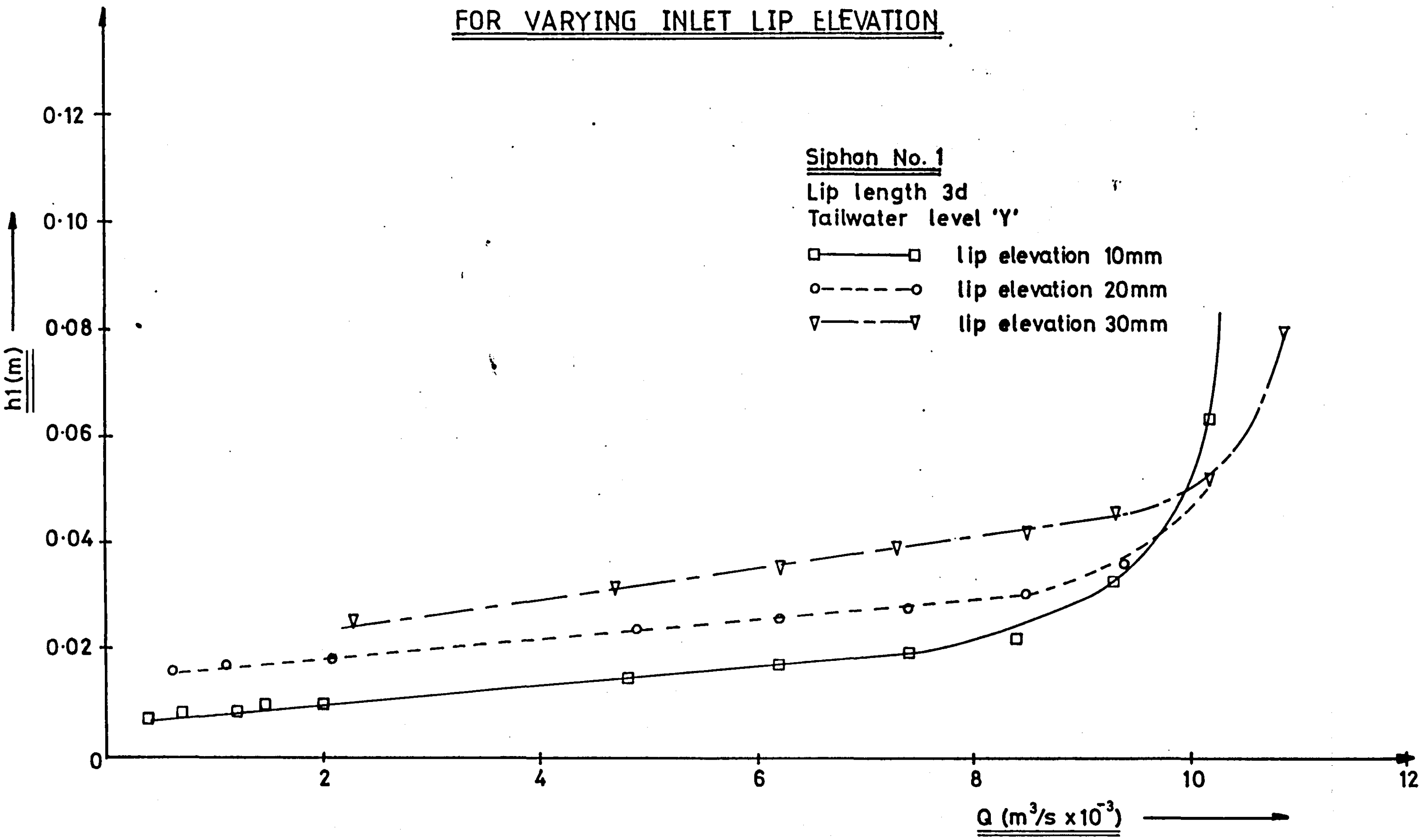
GRAPH-5·1 GRAPH OF WORKING HEAD (H) AGAINST DISCHARGE (Q) FOR VARYING INLET LIP ELEVATION



GRAPH 5·2-GRAPH OF PRIMG HEAD (h1) AGAINST DISCHARGE (Q) FOR VARYING INLET LIP ELEVATION



GRAPH 5·3 - GRAPH OF PRIMING HEAD AGAINST DISCHARGE (Q) FOR VARYING INLET LIP ELEVATION



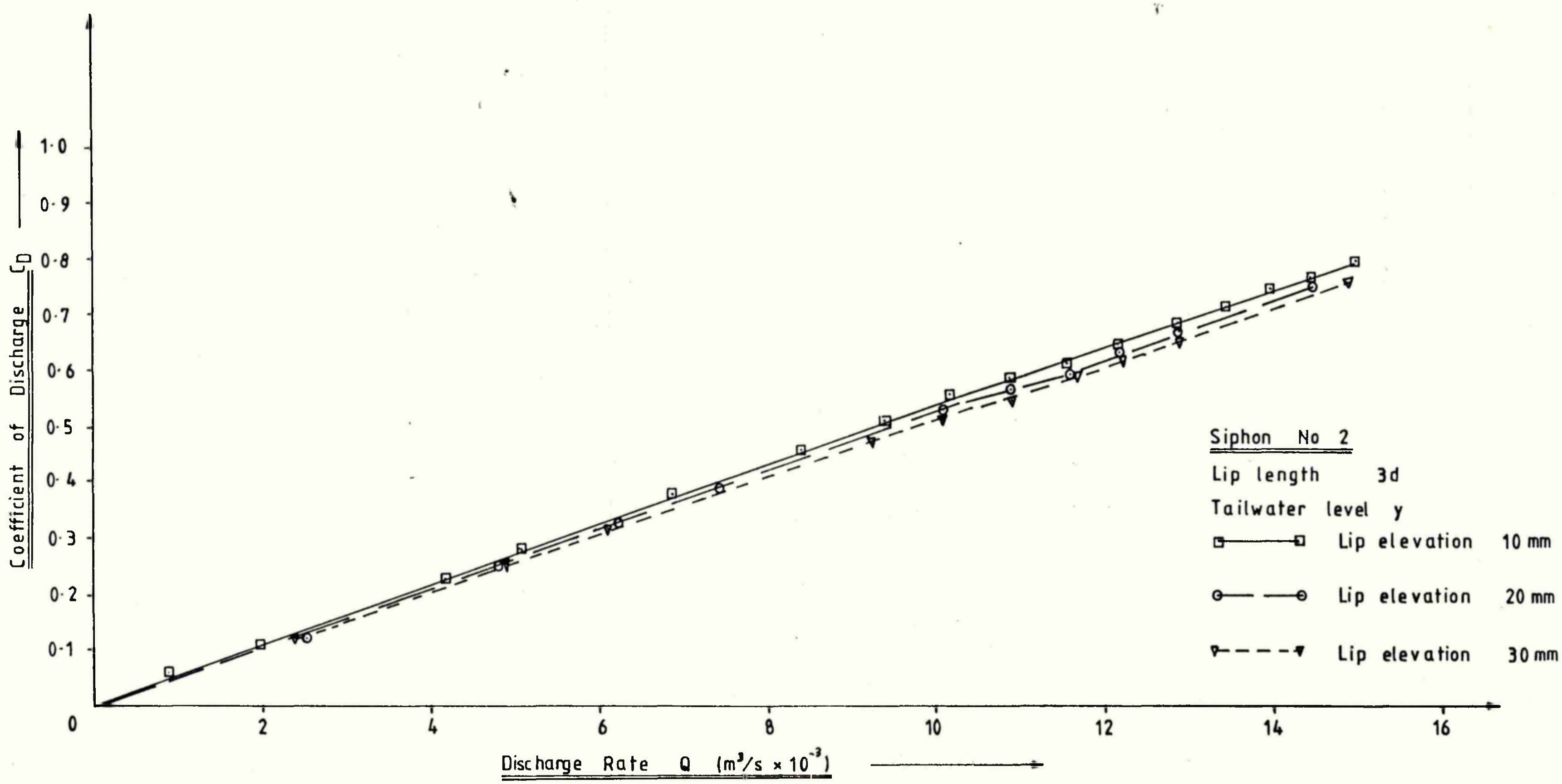
the higher the underside of the inlet lip insert compared to the siphon crest) require greater working and priming heads to produce equivalent discharges. However, at the onset of blackwater flow the priming head/upstream ratio is almost the same for all inlet lip elevations (graph 5.3). It can also be seen that the start of blackwater flow occurs at a lower discharge (and therefore head) for a lower inlet lip elevation.

From graph 5.2 a transition or 'humped' zone can be seen between 9.0 and 11.5 $m^3/s \times 10^{-3}$. This is probably due to vortex action at inlet and this phenomena is explained more fully in chapter 6 with specific reference to fig 17.

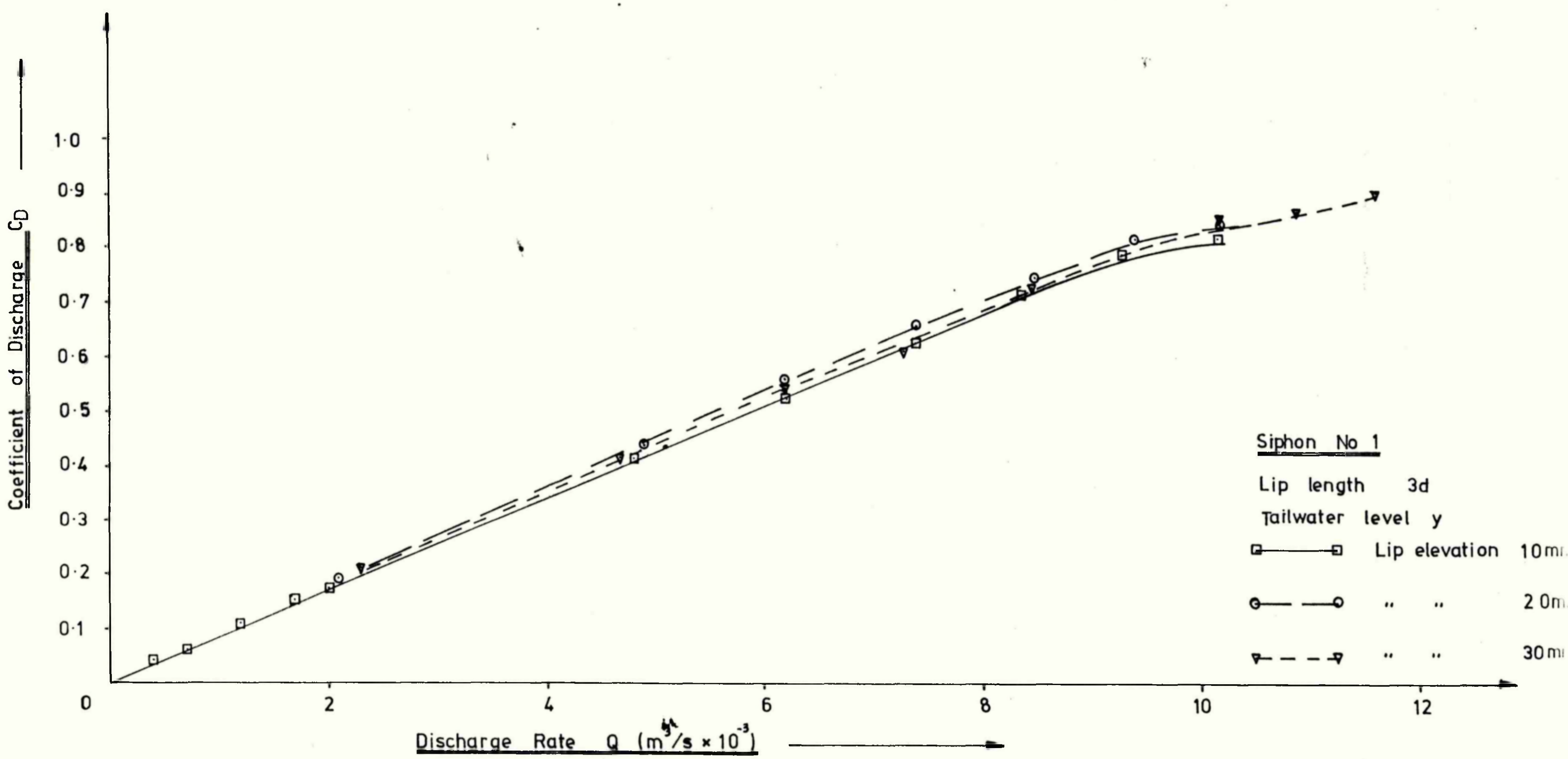
Graphs 5.4 and 5.5 plot coefficient of discharge ($C_D$) against discharge (Q). The coefficient of discharge is greater for a given discharge as the inlet lip elevation decreases. As blackwater flow increases the coefficients of discharge rapidly level off to constant values as discharge increases. The highest lip elevation gives the highest coefficient of discharge for this flow phase, probably due to less contraction at inlet. Graphs 5.6 - 5.8 illustrates the same characteristics as above.

Graph 5.9 confirms that the above results are not particular to any one inlet lip length and it would appear from this graph that an inlet lip elevation of 5mm would be the optimum. However, an inlet lip elevation of 10mm is considered the

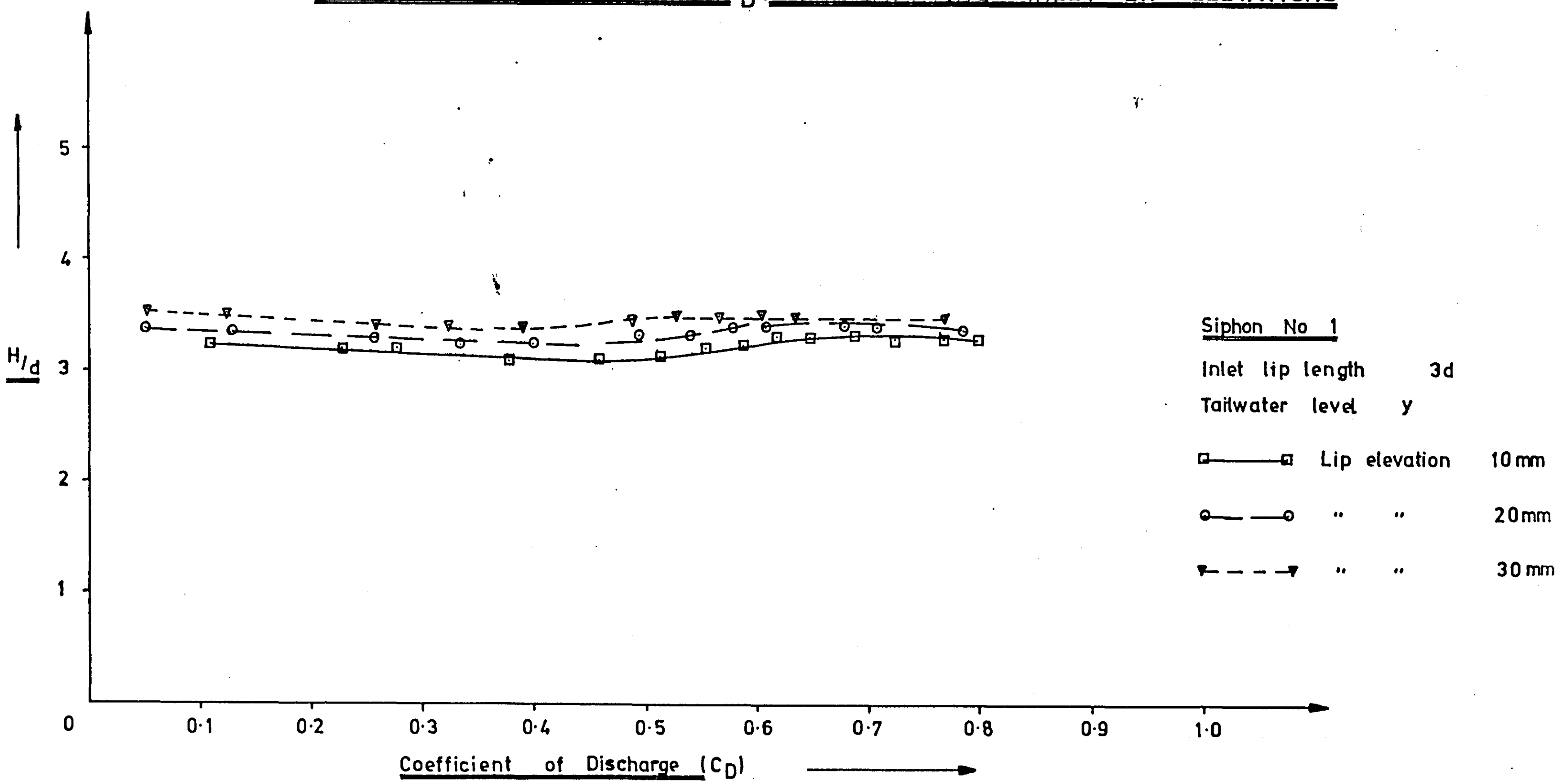
GRAPH 5·4 - GRAPH OF COEFFICIENT OF DISCHARGE ($C_D$) AGAINST DISCHARGE (Q) FOR VARYING INLET LIP ELEVATIONS



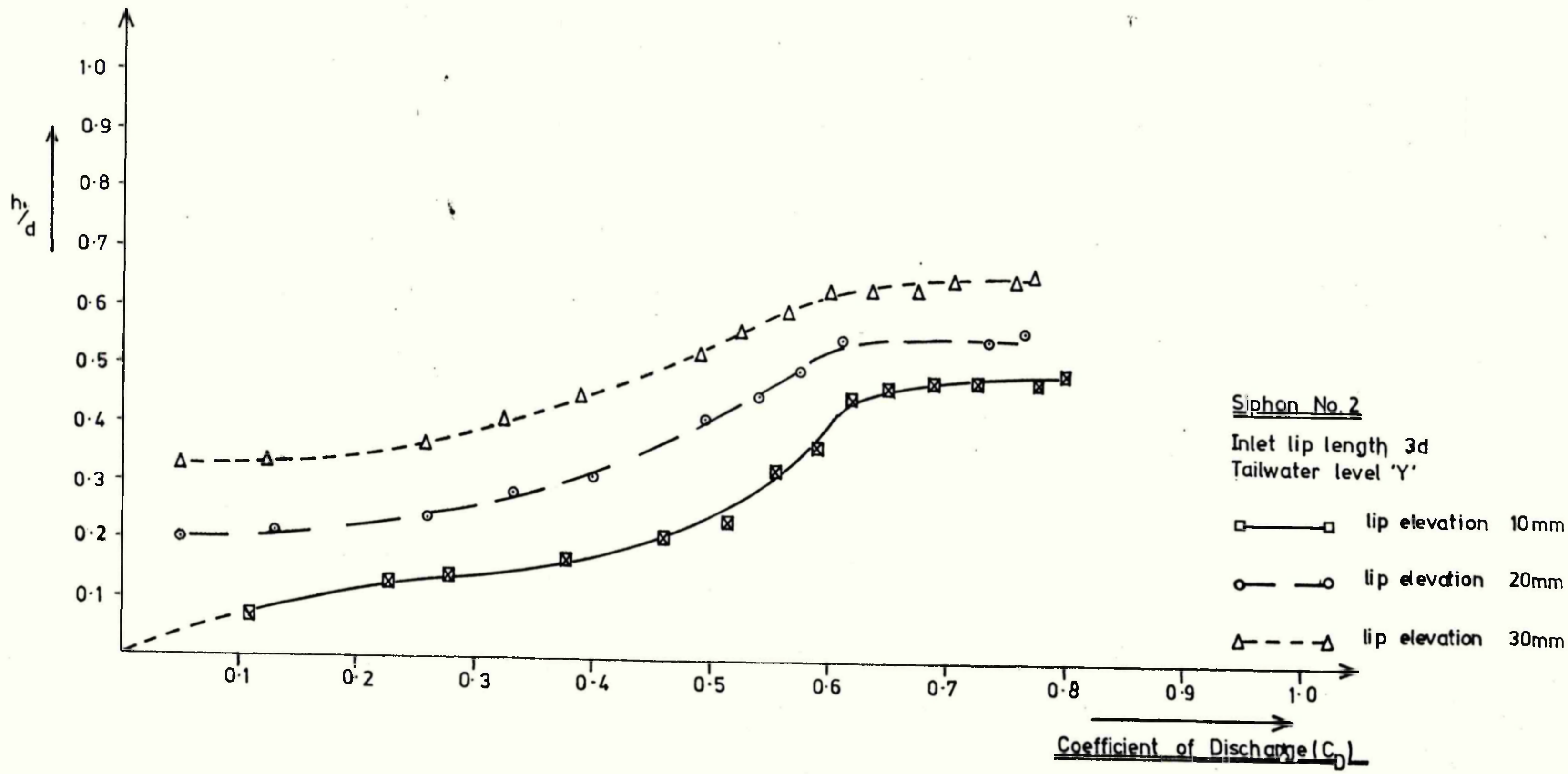
GRAPH 5·5 - GRAPH OF COEFFICIENT OF DISCHARGE ($C_D$) AGAINST DISCHARGE (Q) FOR VARYING INLET LIP ELEVATIONS



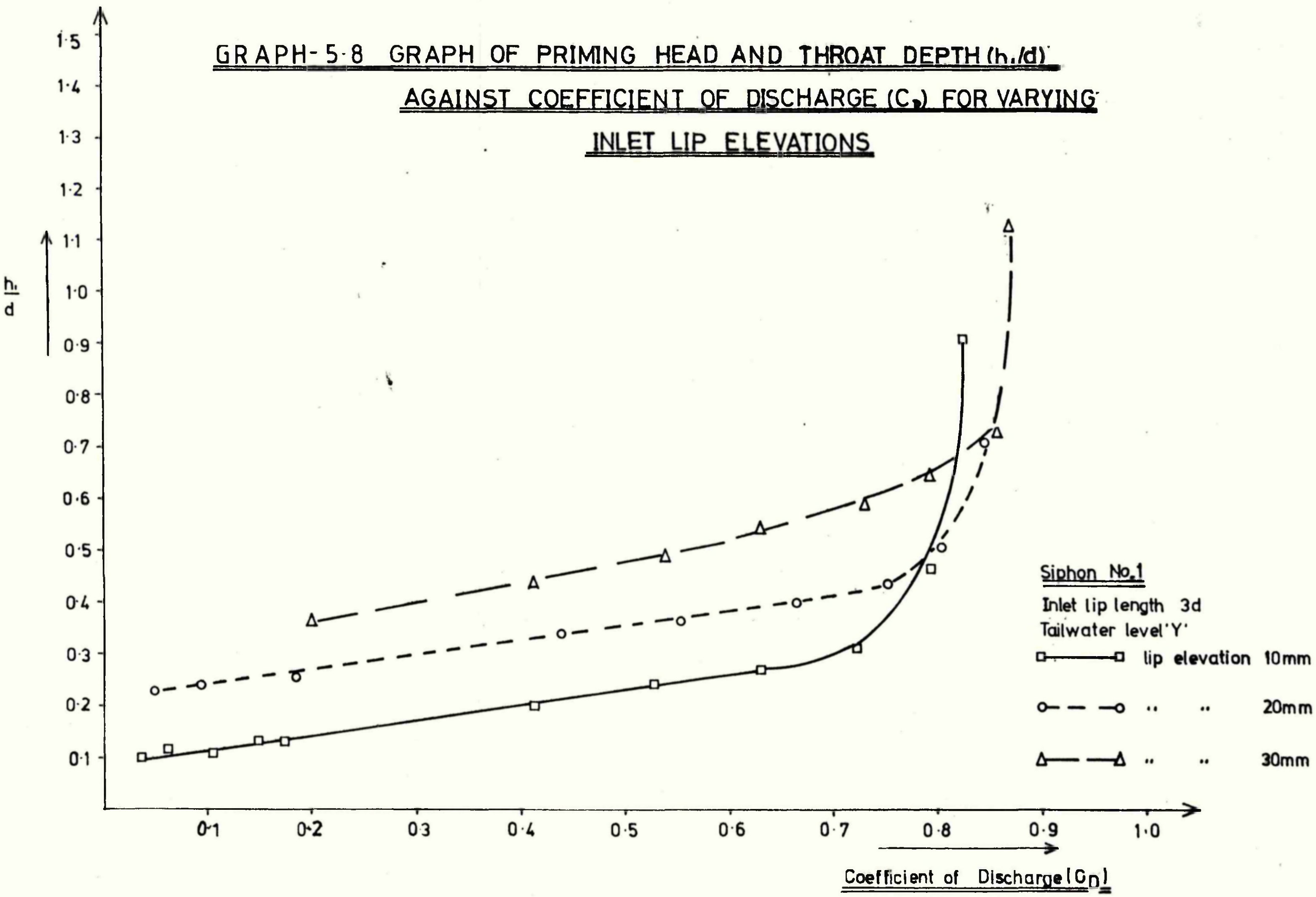
GRAPH 5·6 - GRAPH OF RATIO OF WORKING HEAD AND THROAT DEPTH (H/d) AGAINST COEFFICIENT OF DISCHARGE ($C_D$) FOR VARYING INLET LIP ELEVATIONS



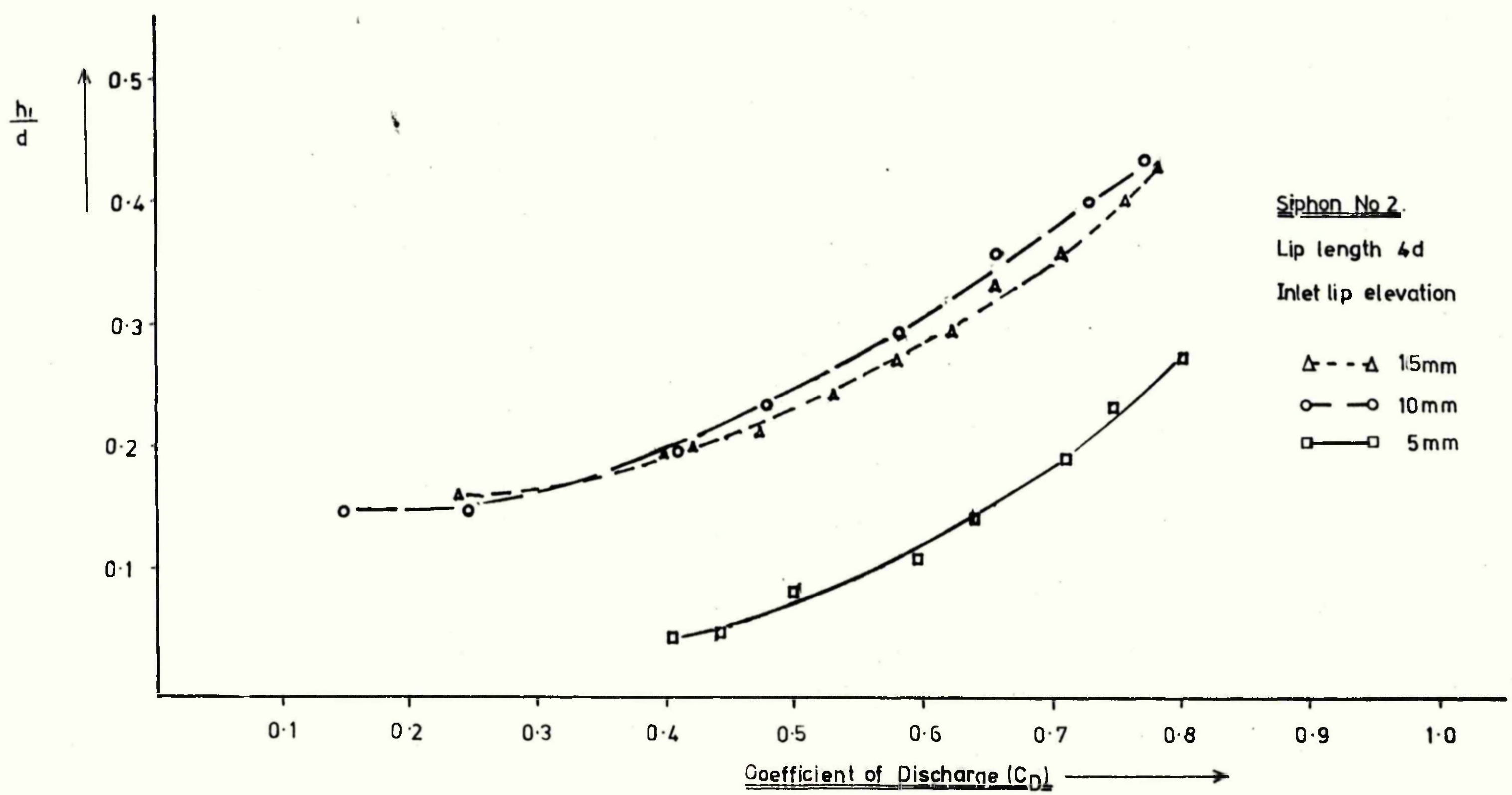
GRAPH-5·7 GRAPH OF RATIO OF PRIMING HEAD AND THROAT DEPTH ($h_1/d$) AGAINST COEFFICIENT OF DISCHARGE ($C_D$) FOR VARYING INLET LIP ELEVATION



GRAPH-5·8 GRAPH OF PRIMING HEAD AND THROAT DEPTH ($h_1/d$) AGAINST COEFFICIENT OF DISCHARGE ($C_D$) FOR VARYING INLET LIP ELEVATIONS



GRAPH- 5·9 GRAPH OF RATIO OF PRIMING HEAD AND THROAT DEPTH ($h_1/d$) AGAINST COEFFICIENT OF DISCHARGE FOR VARYING INLET LIP ELEVATION



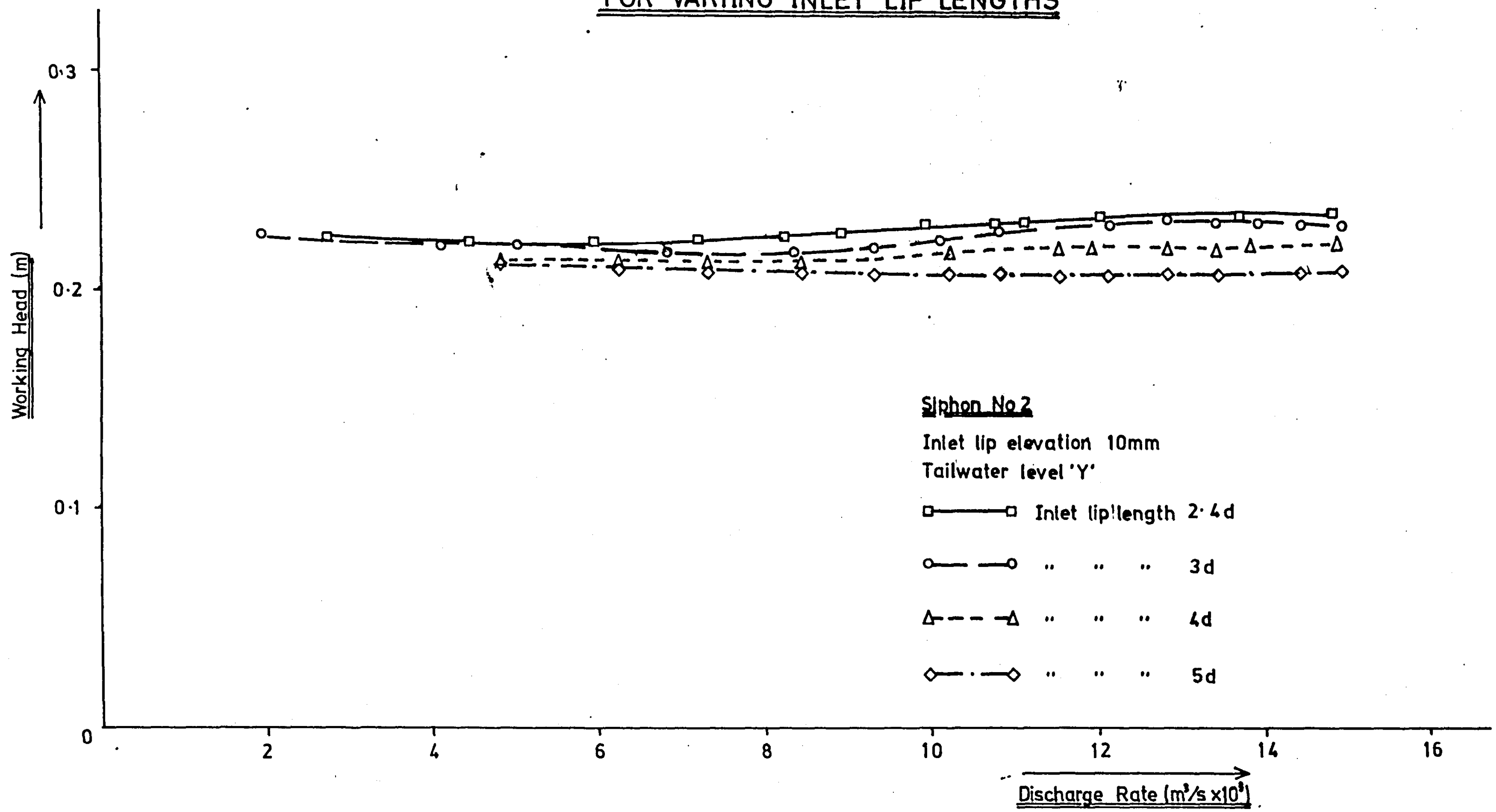
optimum value as an inlet lip elevation of 5mm hunts up to approximately $0.4C_D$ and is therefore unsuitable as an optimum value. Also, too low an inlet lip elevation inhibits priming and reduces $C_D$ due to contraction. To produce a more accurate optimum value of inlet lip elevation further tests on inlet lip elevations of between 5 and 15mm would prove valuable.

5.3 Effects of inlet lip length

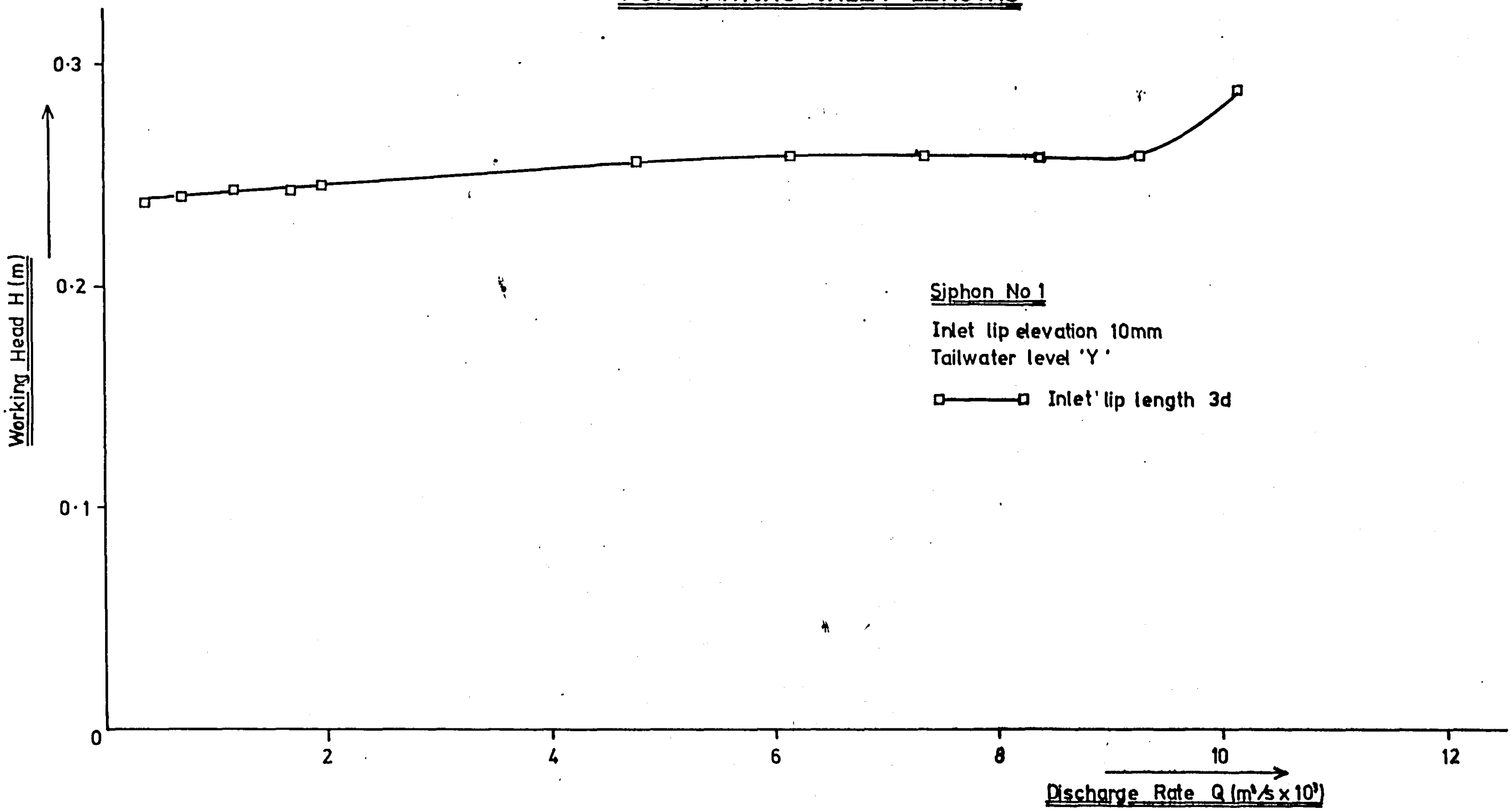
Due to fluctuations in upstream level during the hunting cycle, flow could not be evaluated so that the start of the plots in graph 5.10 represents the end of the hunting cycle. For tailwater level 'Y' (281mm), siphon No2 and inlet lip elevation 10mm, a lip length of 4d causes hunting for flows up to 25% of the range to onset of blackwater flow. This hunting stage increases the sub-atmospheric flow regime and hence shortens the region of air partialised flow. An inlet length of 5d results in increased hunting of up to 35% of the range to onset of blackwater flow, a characteristic to be avoided due to priming difficulties. Inlet lip lengths greater than 4d result in increasingly severe hunting and therefore an inlet lip length of 4d is the maximum desirable.

With reference to graphs 5.10 and 5.11 it can be seen that working heads remain approximately constant (graph 5.10) until blackwater flow is approached (graph 5.11), when they suddenly

## GRAPH- 5·10 GRAPH OF WORKING HEAD (H) AGAINST DISCHARGE RATE (Q) FOR VARYING INLET LIP LENGTHS



## GRAPH- 5·11 GRAPH OF WORKING HEAD (H) AGAINST DISCHARGE RATE (Q) FOR VARYING INLET LENGTHS



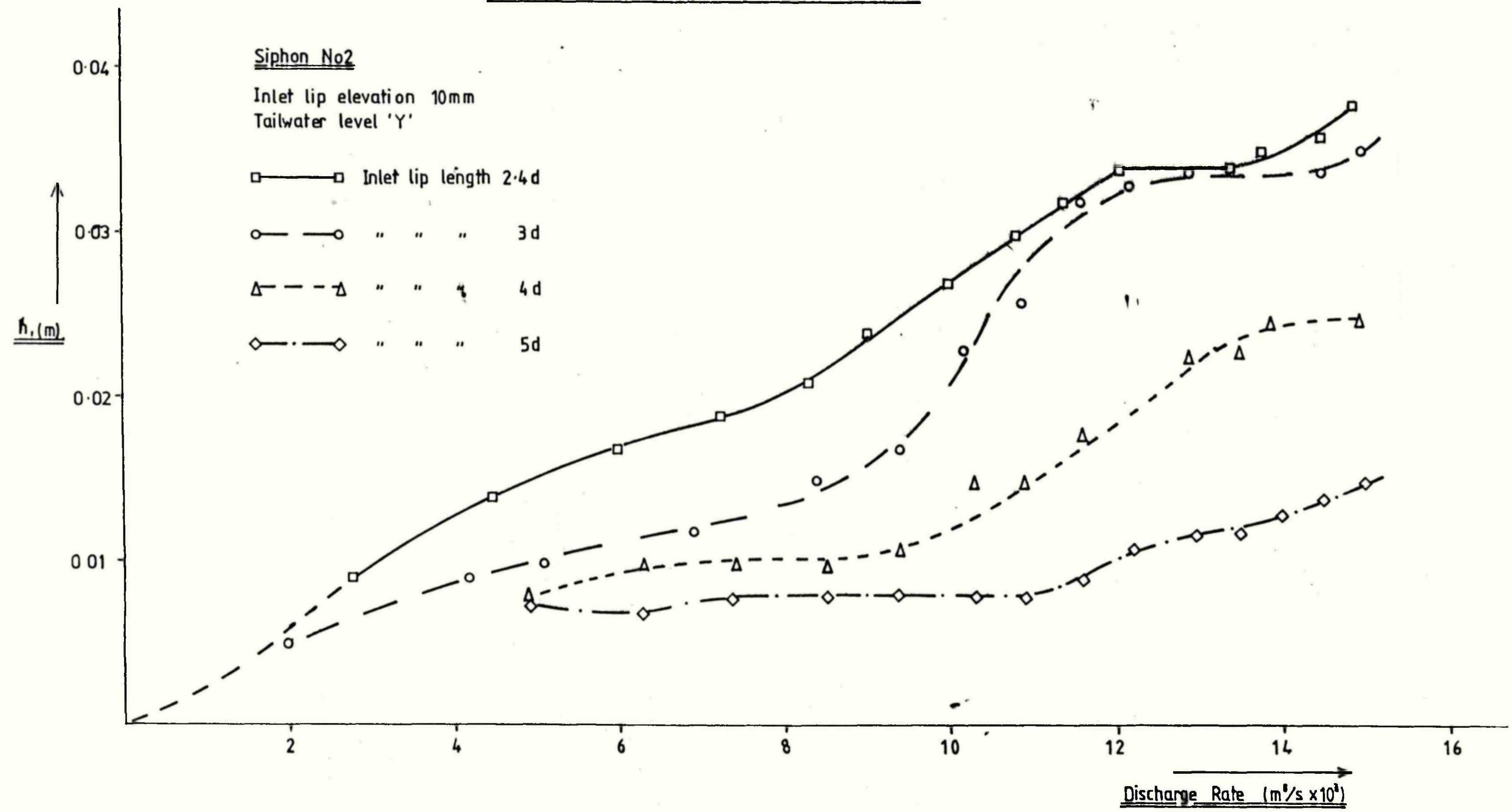
increase. Lip lengths above and including 3d were observed as requiring reduced working heads.

The lower the value of lip length the greater the required priming head. From graph 5.27 we can see inlet lip lengths of 3d compared for siphon Nos 1 and 2. These curves are dimensionless and should be the same, yet in a certain region of flow there are large discrepancies. Work was carried out to determine why this transition zone was only apparent with siphon No2 and it was found to be due to the weir crest being [illegible] off level and vortices forming at the higher inlet side. See conclusions for comments on fig 17.

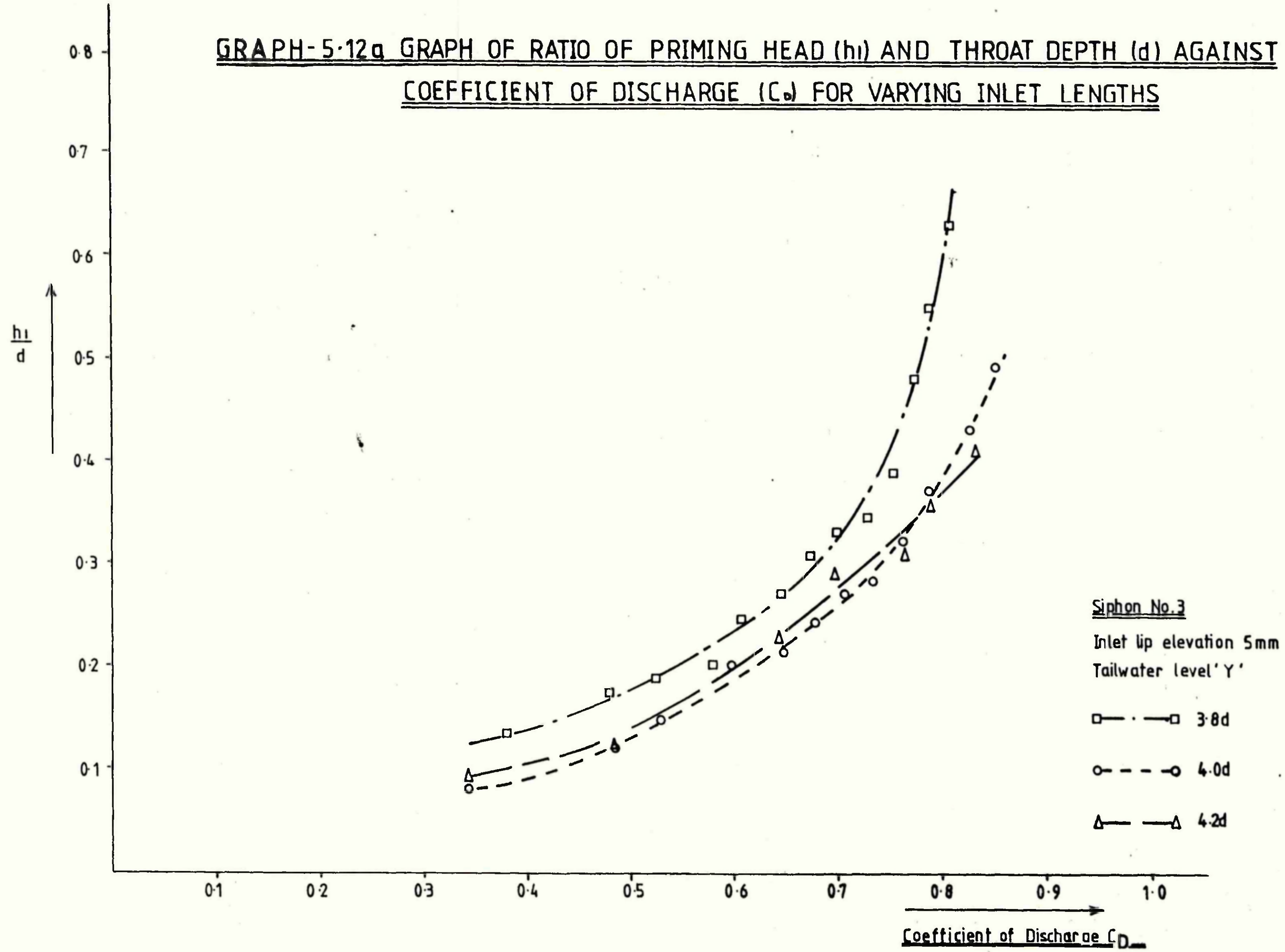
For siphon No1 the optimum configuration is 3d but for siphon No2 (graph 5.12) 3d is clearly not the optimum configuration. In fact 4d would seem to be the value of inlet lip length producing the smoothest discharge curves. Lip lengths above 4d show flatter discharge characteristics which at 5d and above, tend towards pure blackwater flow characteristics.

As shown in graph 5.13 the coefficient of discharge ($C_D$) is linearly proportional to discharge rate (Q) for all inlet lip lengths. For a given flow the longer inlet lip lengths give higher values of coefficient of discharge. As was experienced with siphon No1, as blackwater flow was approached these curves diverge. In increasing blackwater flow conditions, the

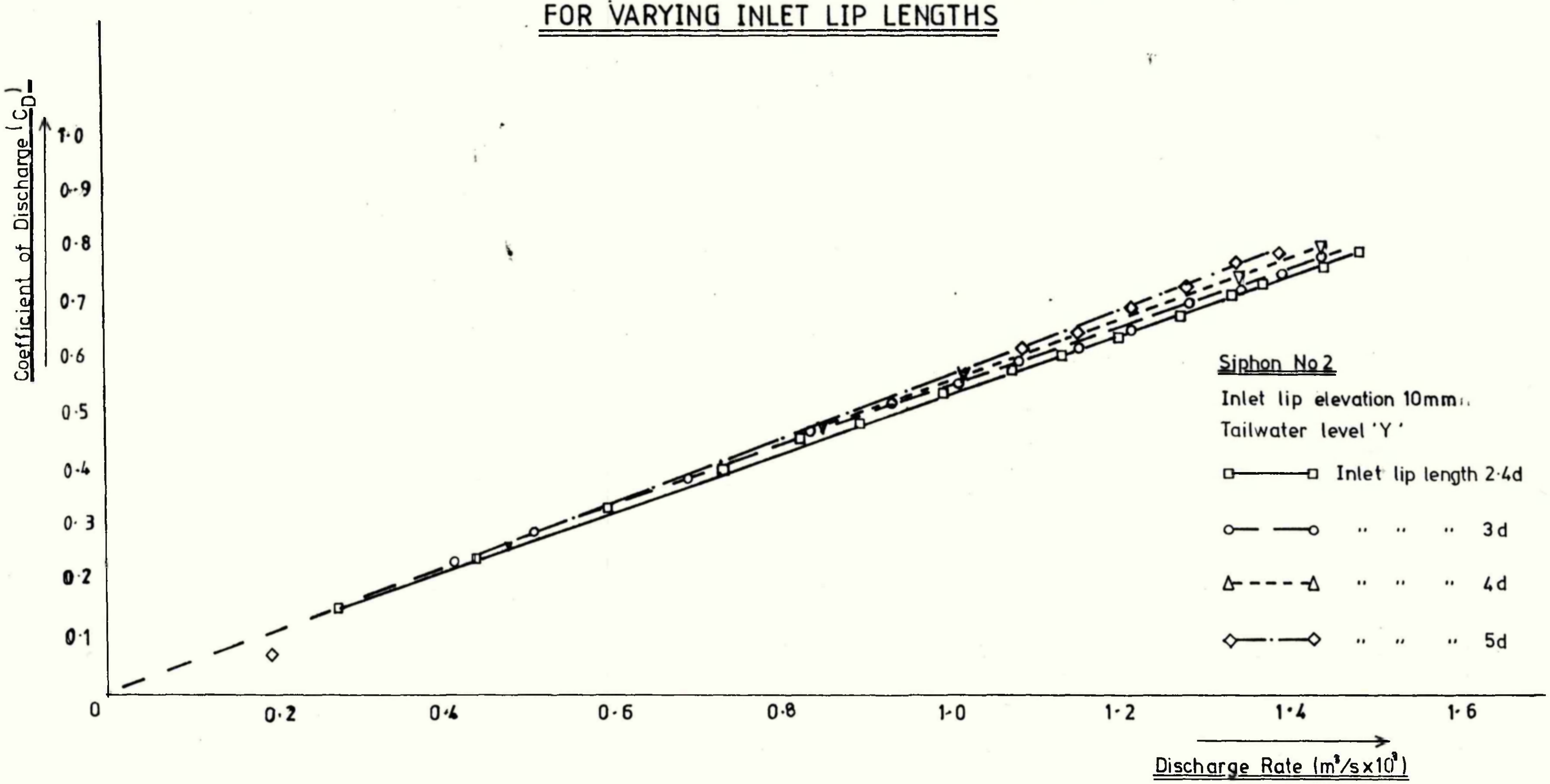
## GRAPH- 5·12 GRAPH OF PRIMING HEAD ($h_1$) AGAINST DISCHARGE RATE (Q) FOR VARYING INLET LIP LENGTHS



GRAPH-5·12a GRAPH OF RATIO OF PRIMING HEAD ($h_1$) AND THROAT DEPTH (d) AGAINST COEFFICIENT OF DISCHARGE ($C_D$) FOR VARYING INLET LENGTHS



GRAPH-5·13 GRAPH OF COEFFICIENT OF DISCHARGE ($C_D$) AGAINST DISCHARGE RATE (Q) FOR VARYING INLET LIP LENGTHS



coefficient of discharge rapidly levels off and even shows a peak with a slight fall-off following. This peak value is especially prevalent with non-optimum configurations.

Graphs 5.14 and 5.15, ratios of working head/throat depth ($^H/_D$) and priming head/throat depth ($^{h}1/_d$) against coefficient of discharge ($C_D$) corroborate the findings of graphs 5.10 and 5.12 , which correspond to the study of effects of working and priming heads on lip length. In graph 5.14 it is difficult to discern the two categories of lip length but this is not so for graph 5.15. 4d and 5d are in one category whilst 2.4d and 3d are in a category depicting uneven priming characteristics.

To summerise the effect of increasing lip length, in pre-blackwater flow phases, increased lip length results in:

(a) Increased hunting phase.

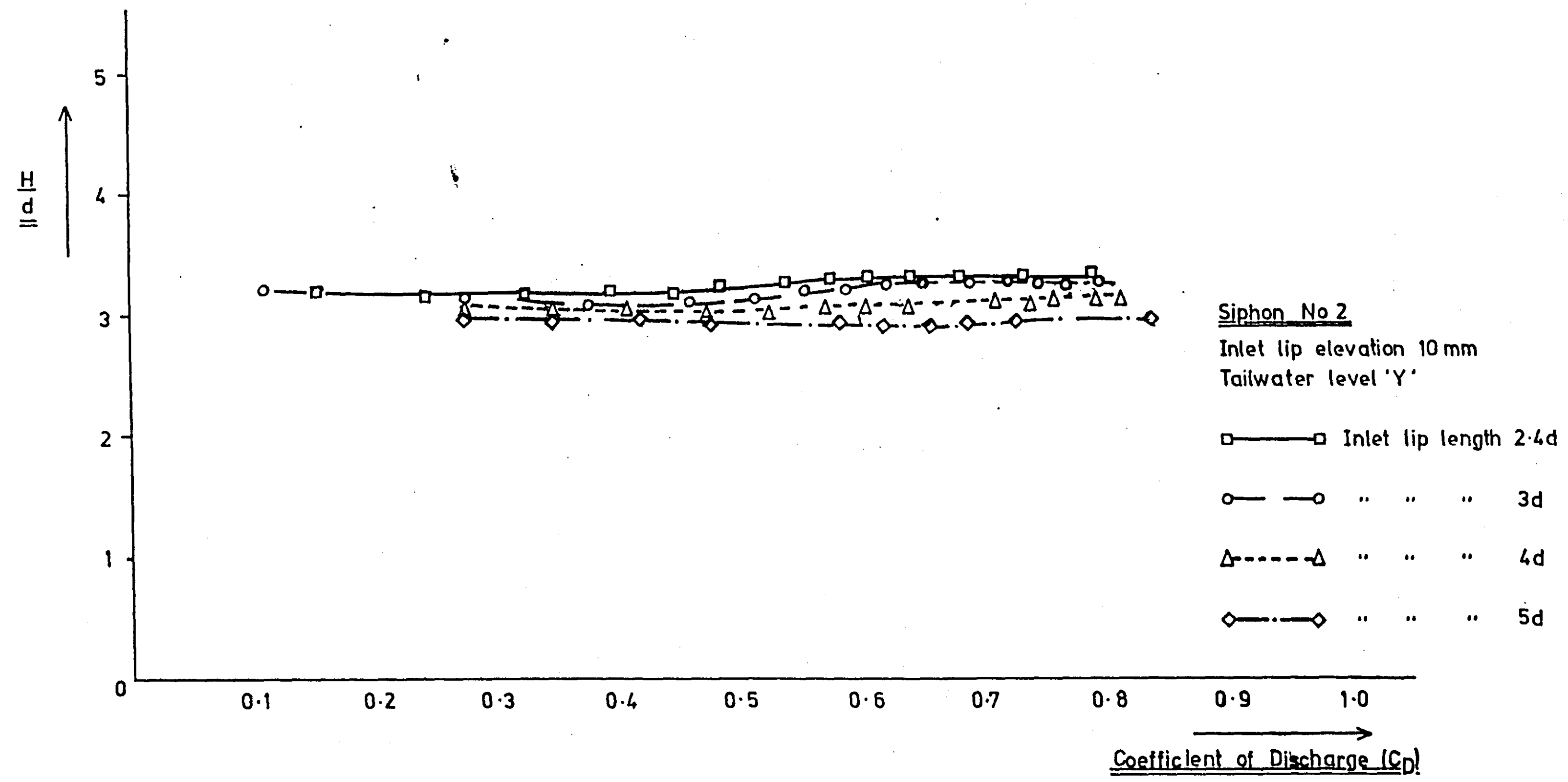
(b) Reduced working and priming heads necessary for a particular flow rate.

(c) Flatter priming head/discharge relationships tending towards blackwater flow characteristics.

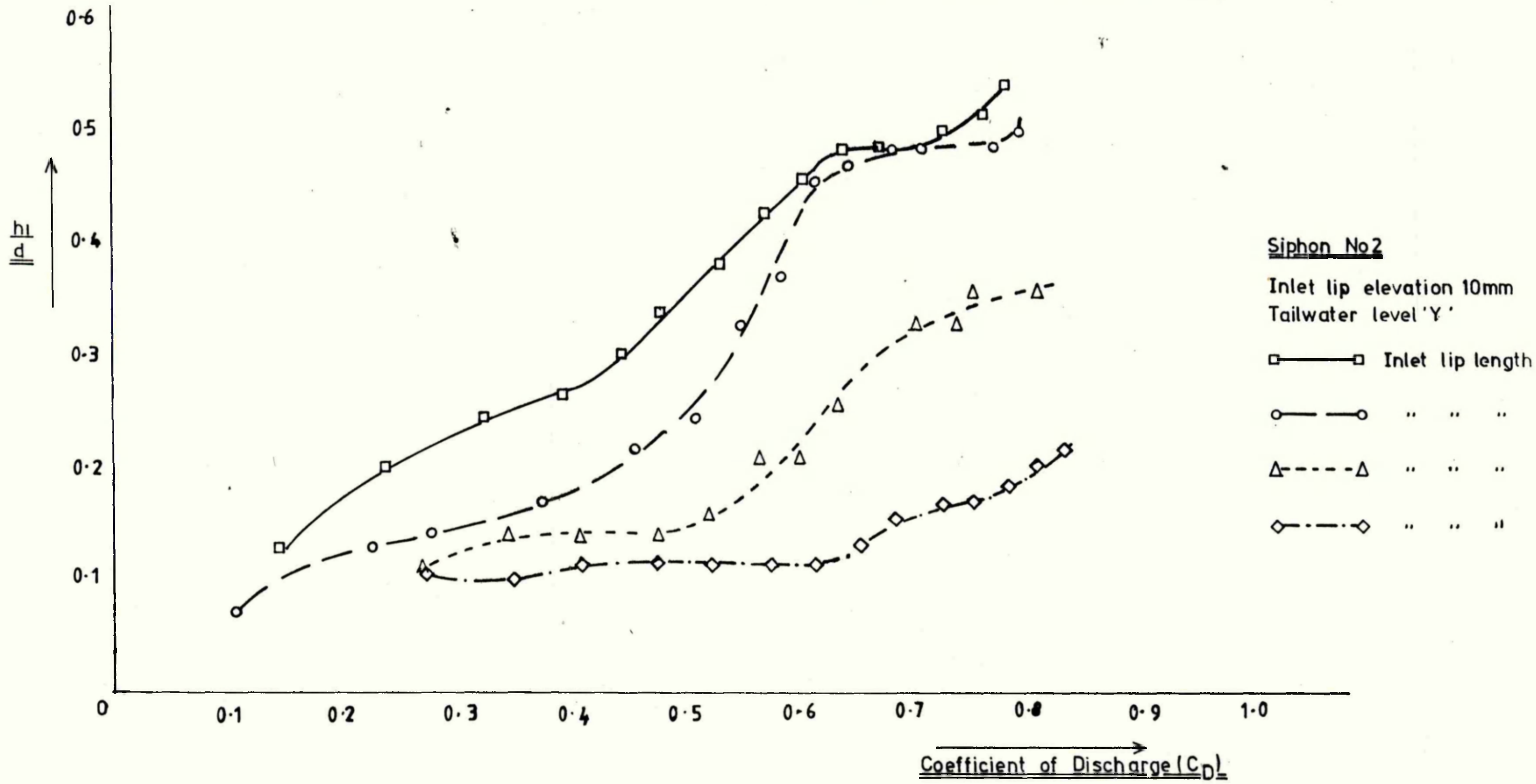
(d) Increasing coefficients of discharge for a given flow rate.

For siphon No1 a lip length of 3d was found to be optimum for good air regulation. For siphon No2 (graph 5.16) 4d, instead of 3d, was found to be the optimum inlet length. For siphon

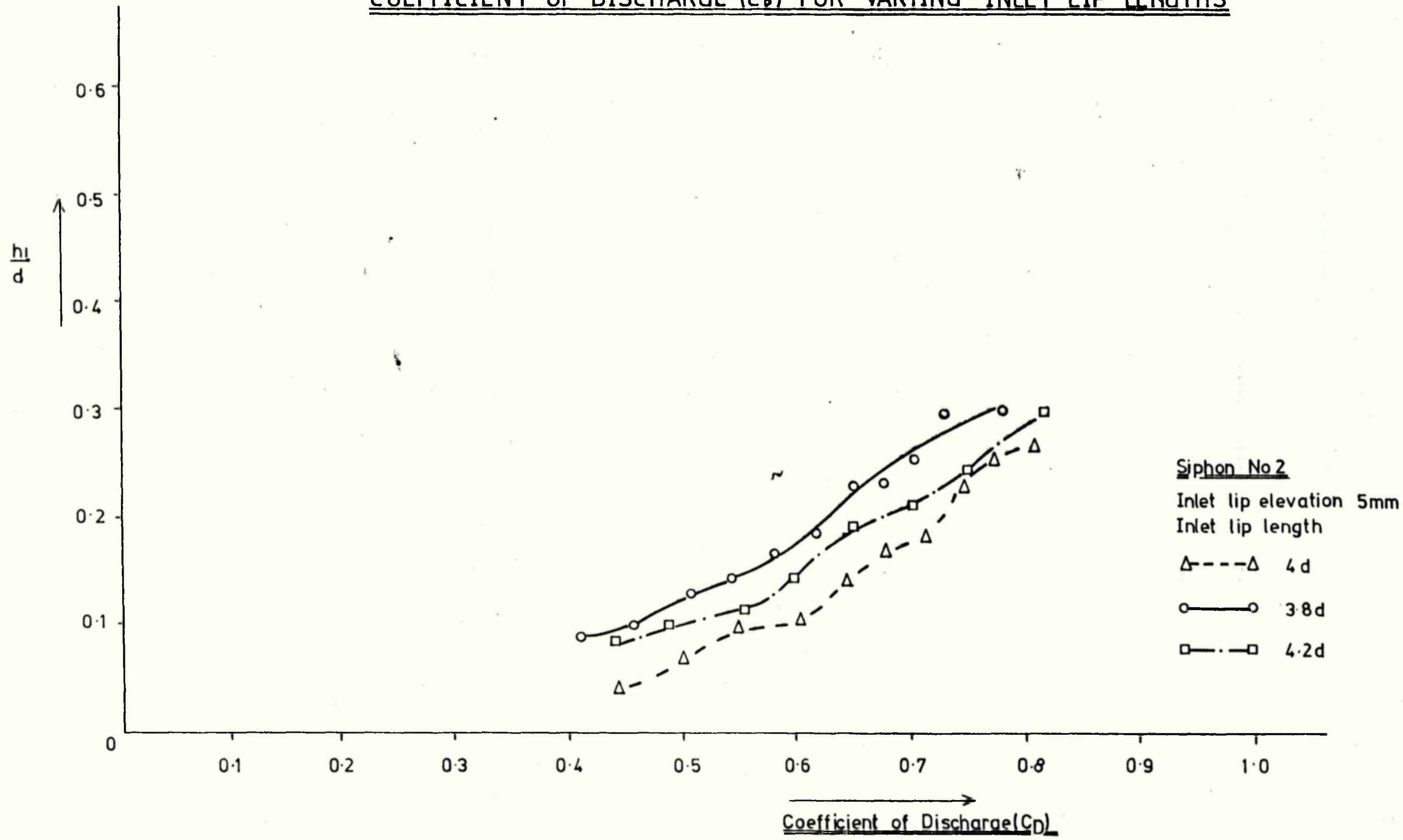
## GRAPH- 5·14 GRAPH OF RATIO OF WORKING HEAD AND THROAT DEPTH (H/d) AGAINST COEFFICIENT OF DISCHARGE ($C_D$) FOR VARYING INLET LIP LENGTHS



GRAPH - 5·15 GRAPH OF RATIO OF PRIMING HEAD AND THROAT DEPTH ($h_1/d$) AGAINST COEFFICIENT OF DISCHARGE ($C_D$) FOR VARYING INLET LIP LENGTHS



GRAPH 5·16 GRAPH OF RATIO OF PRIMING HEAD AND THROAT DEPTH ($h_l/d$) AGAINST COEFFICIENT OF DISCHARGE ($C_D$) FOR VARYING INLET LIP LENGTHS



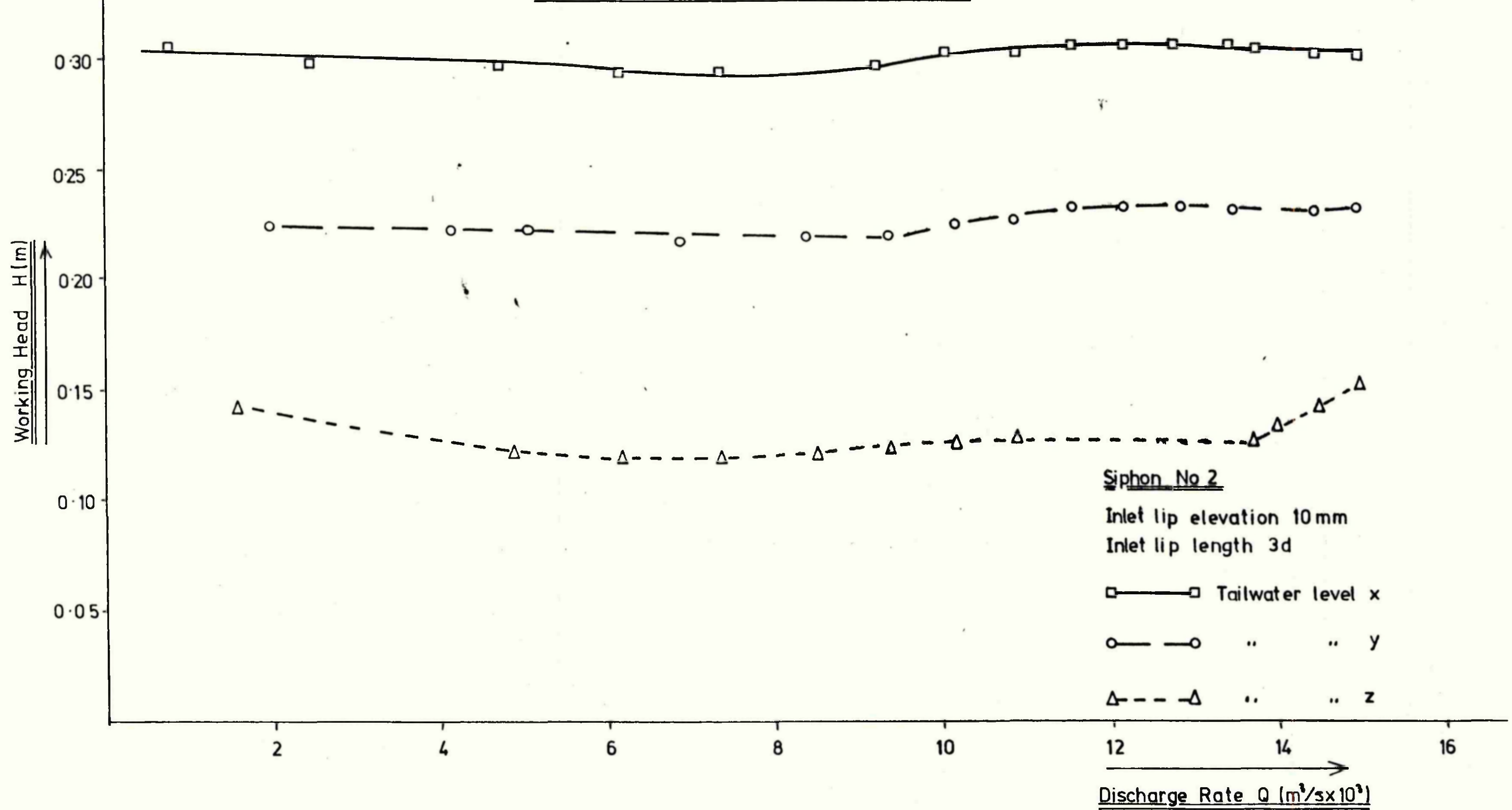
No3, 4d was found to be the optimum inlet lip length. This leads to the conclusion that for a square siphon section 3d is the optimum inlet lip length and for obvious rectangular sections 4d is the optimum inlet lip length. For a rectanguler section, 4d gives the best priming characteristics, exhibiting a gradually inclined, stable priming head/discharge relationship. It incurs reduced priming and working heads than lesser inlet lip lengths whilst being in the category giving higher coefficients of discharge.

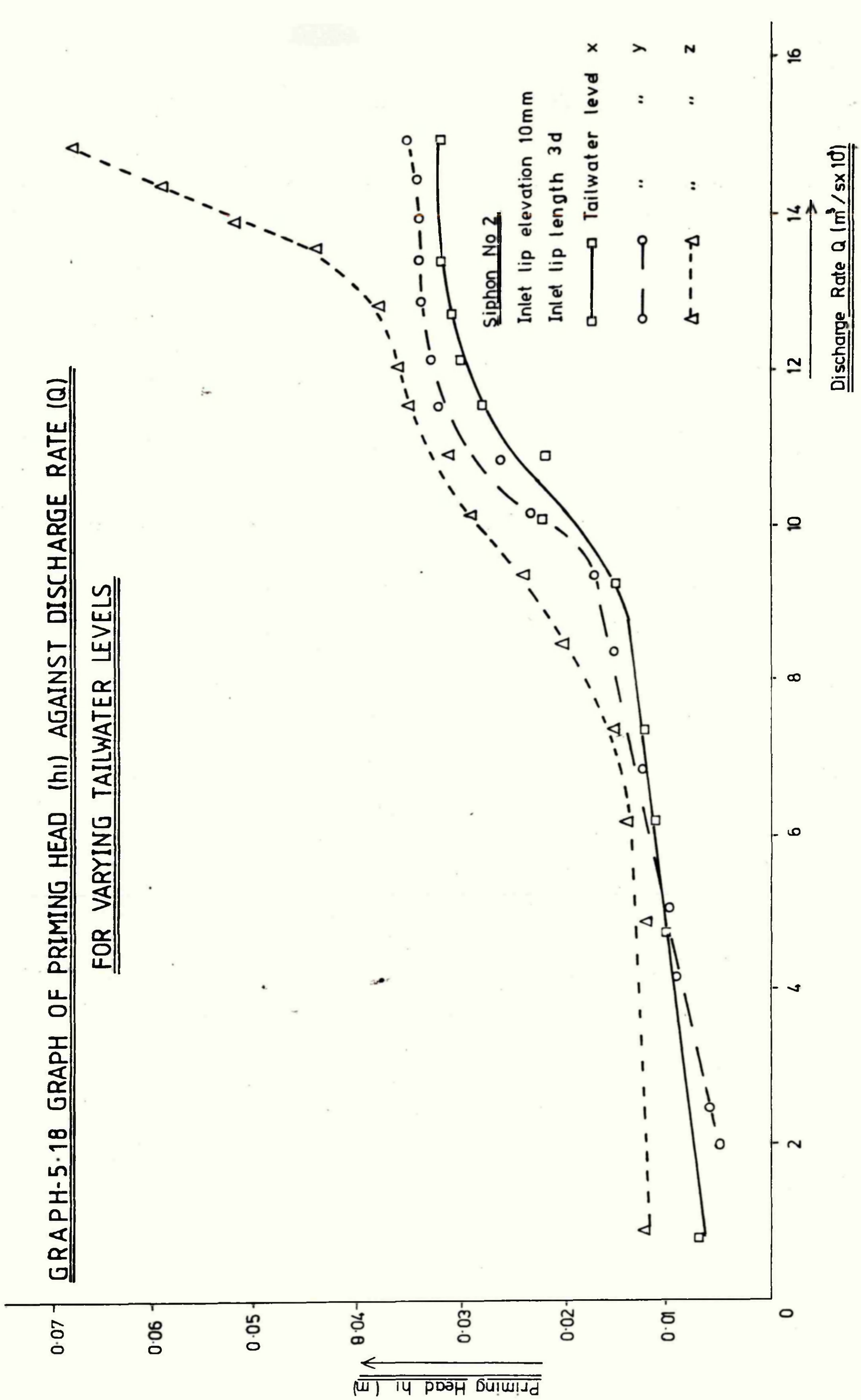
## 5.4 Effects of tailwater level

As can be seen from graph 5.18 the main effect of increasing tailwater level is to reduce the air partialised flow range. The higher the tailwater level the less the working head for any given value of discharge. For all three tailwater levels shown in graph 5.17 the working head reduces in the initial flow stages of increasing discharge. Also, from graph 5.18, it can be seen that up to blackwater flow the higher the tailwater level the greater the priming head necessary for a particular flow. For a particular discharge the required head is maintained and also the increased resistance due to the greater submergence of the exit is overcome.

From graph 5.19 it can be seen that coefficients of discharge ($C_D$) are linearly proportional to discharge rate (Q) for each tailwater level, as before. For a given flow rate, the highest tailwater level results in the highest coefficient of discharge

GRAPH-5·17 GRAPH OF WORKING HEAD (H) AGAINST DISCHARGE RATE (Q) FOR VARYING TAILWATER LEVELS






GRAPH-5.18 GRAPH OF PRIMING HEAD (hi) AGAINST DISCHARGE RATE (Q) FOR VARYING TAILWATER LEVELS and vice versa. As the working head is a component of the coefficient of discharge the coefficient of discharge compensates for the working head ie a lower working head requiring a higher discharge coefficient. As can be seen from graph 5.19 the approach of blackwater flow produces a levelling off producing a peak value. The highest tailwater level produced the highest maximum value of discharge coefficient.

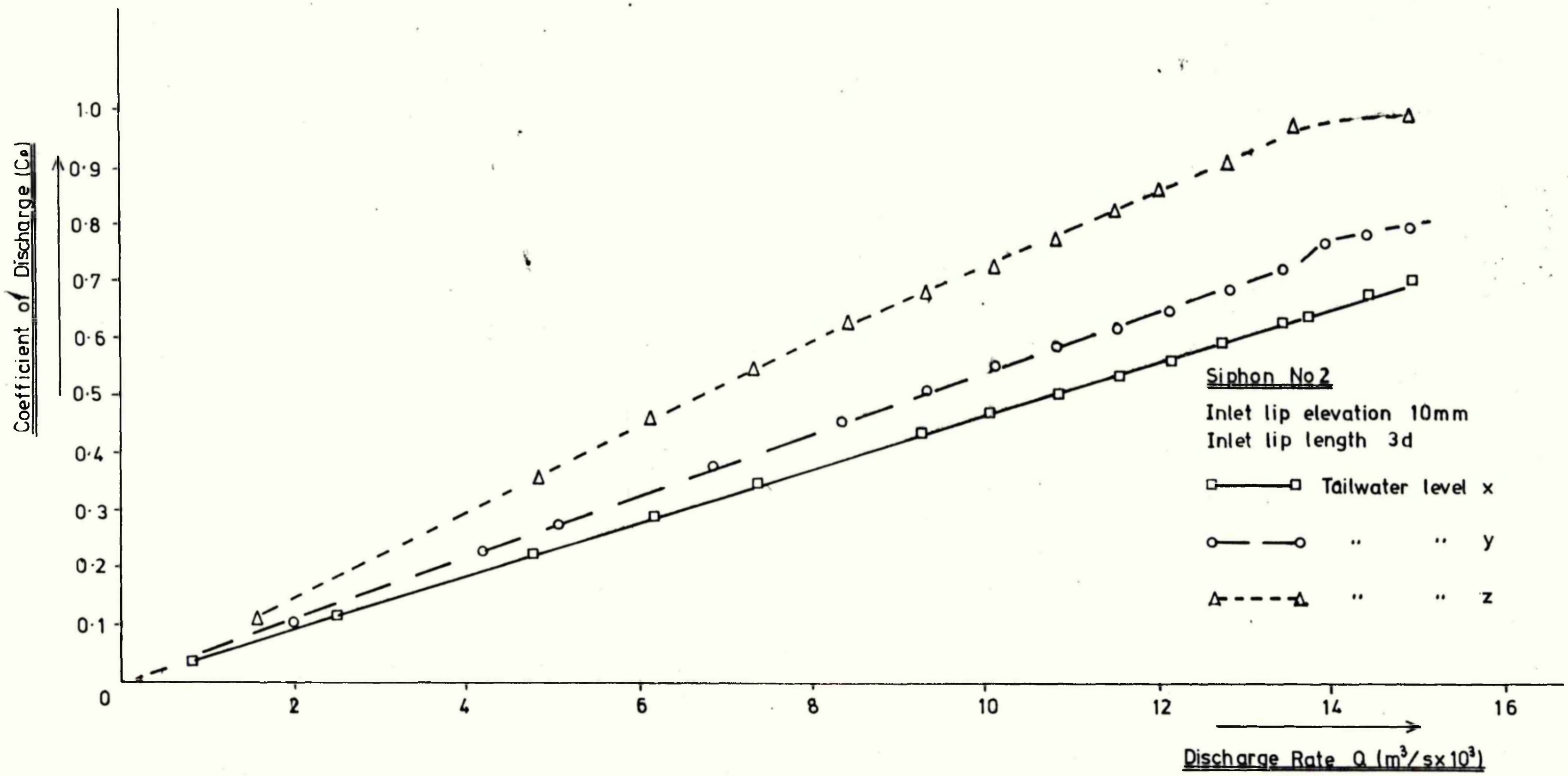
When examining graphs 5.20 and 5.21 of, ratios of working head/throat depth ($^H/_d$) and priming head/throat depth ($^{h}1/_d$) against coefficient of discharge, confirmation of the affect of tailwater level variation, on working and priming heads and the maximum discharge coefficients is apparent. Up to $0.45C_D$ equivalent priming heads produce equivalent coefficients of discharge.

With reference to graphs 5.17, 5.18 and 5.19 (especially graph 5.18) blackwater flow transpires at an earlier flow rate for higher tailwater levels and it was noticeable that the two lower tailwater levels commenced blackwater flow at approximately the same point.

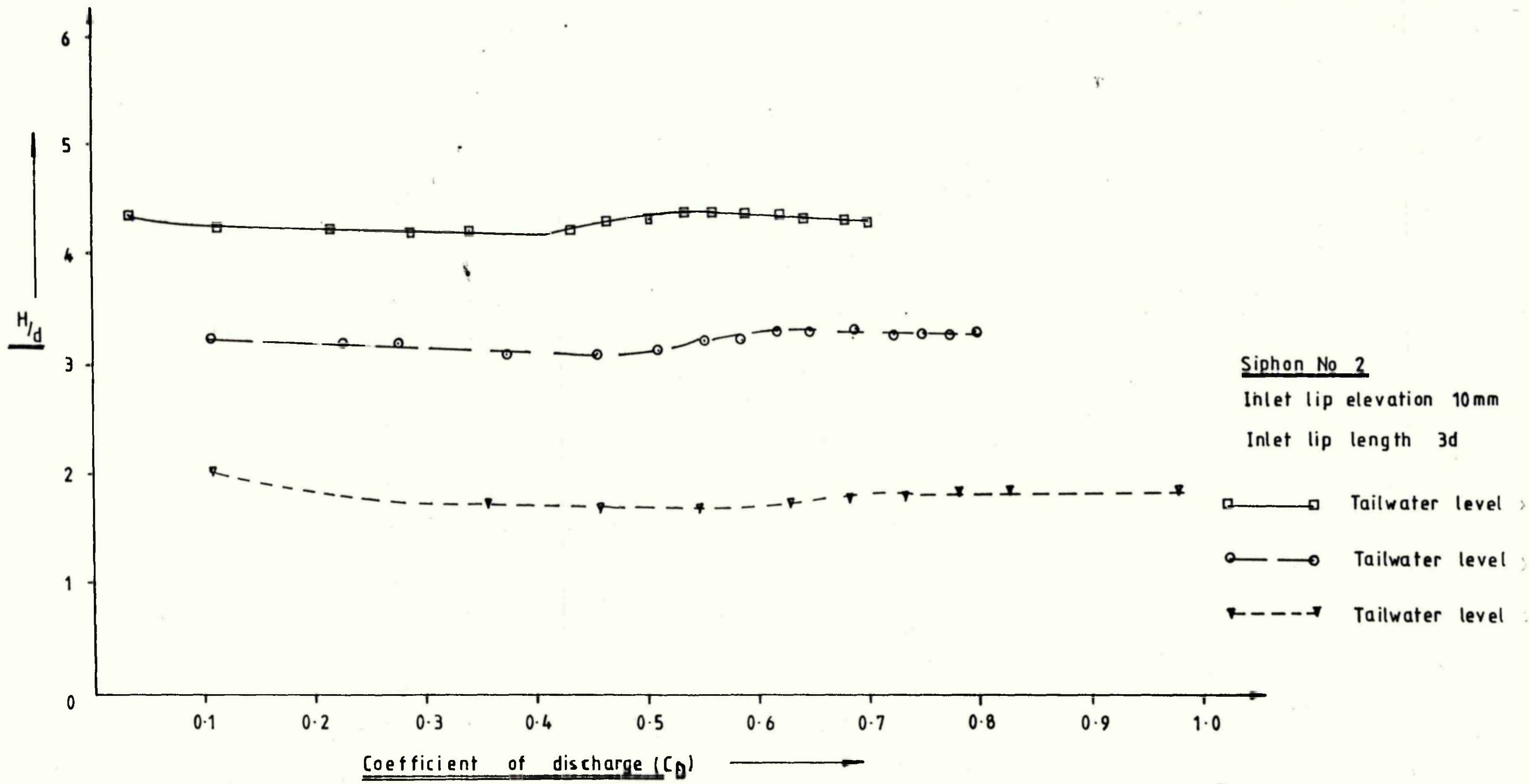
## 5.5 Effects of siphon width

Up to 9 L/s flow, siphons Nos 1 and 2 have similar patterns of working head and priming head/discharge relationships (graphs 5.22 and 5.23). It will be noticed that the wider siphon produces lower heads compared to those of the narrower siphon.

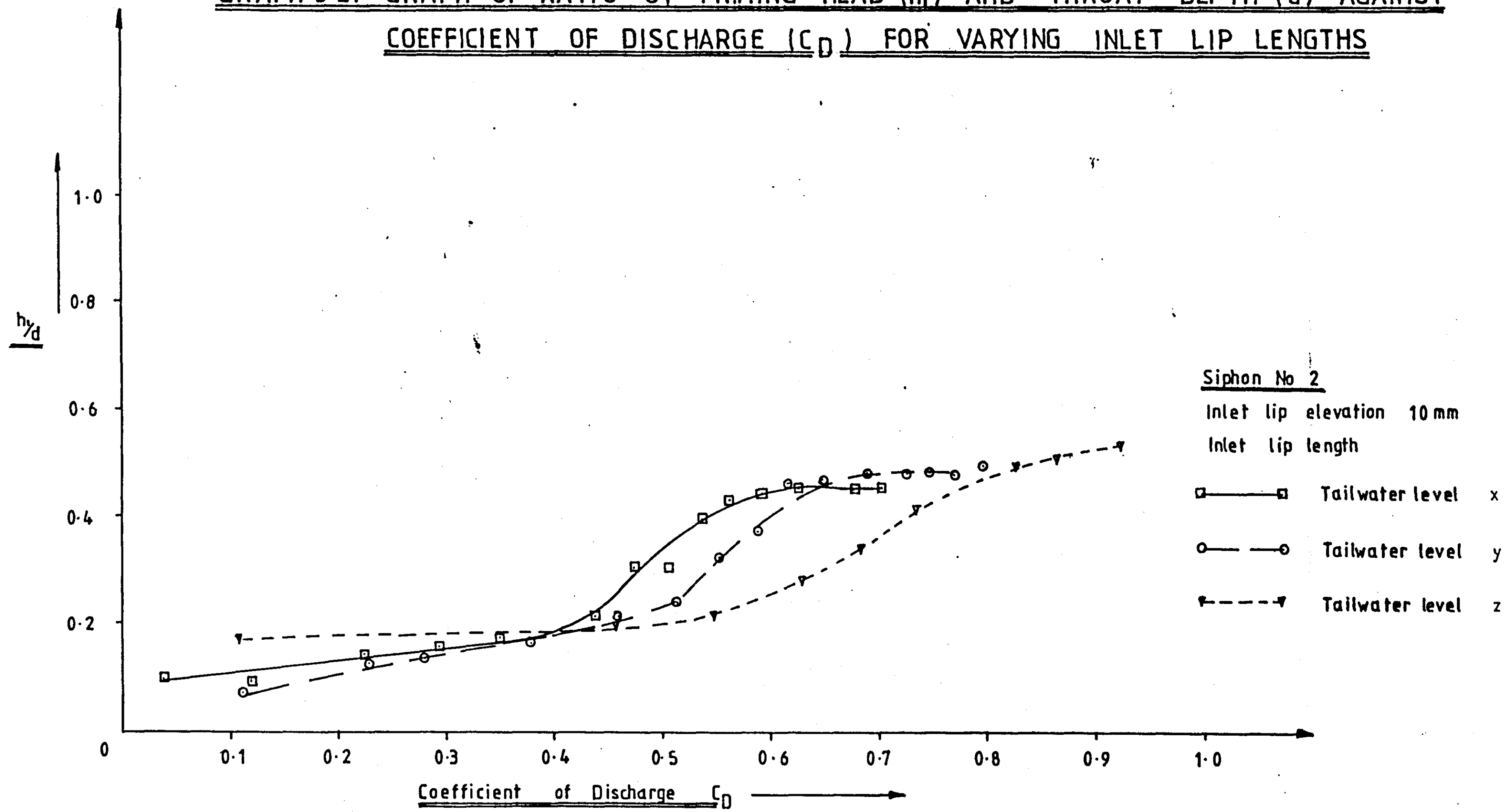
GRAPH-5·19 GRAPH OF COEFFICIENT OF DISCHARGE ($C_d$) AGAINST DISCHARGE RATE (Q) FOR VARYING TAILWATER LEVELS



GRAPH 5·20 – GRAPH OF RATIO OF WORKING HEAD (H) AND THROAT DEPTH (d) AGAINST COEFFICIENT OF DISCHARGE ($C_D$) FOR VARYING TAILWATER LEVELS



## GRAPH 5·21 - GRAPH OF RATIO OF PRIMING HEAD ($h_1$) AND THROAT DEPTH (d) AGAINST COEFFICIENT OF DISCHARGE ($C_D$) FOR VARYING INLET LIP LENGTHS



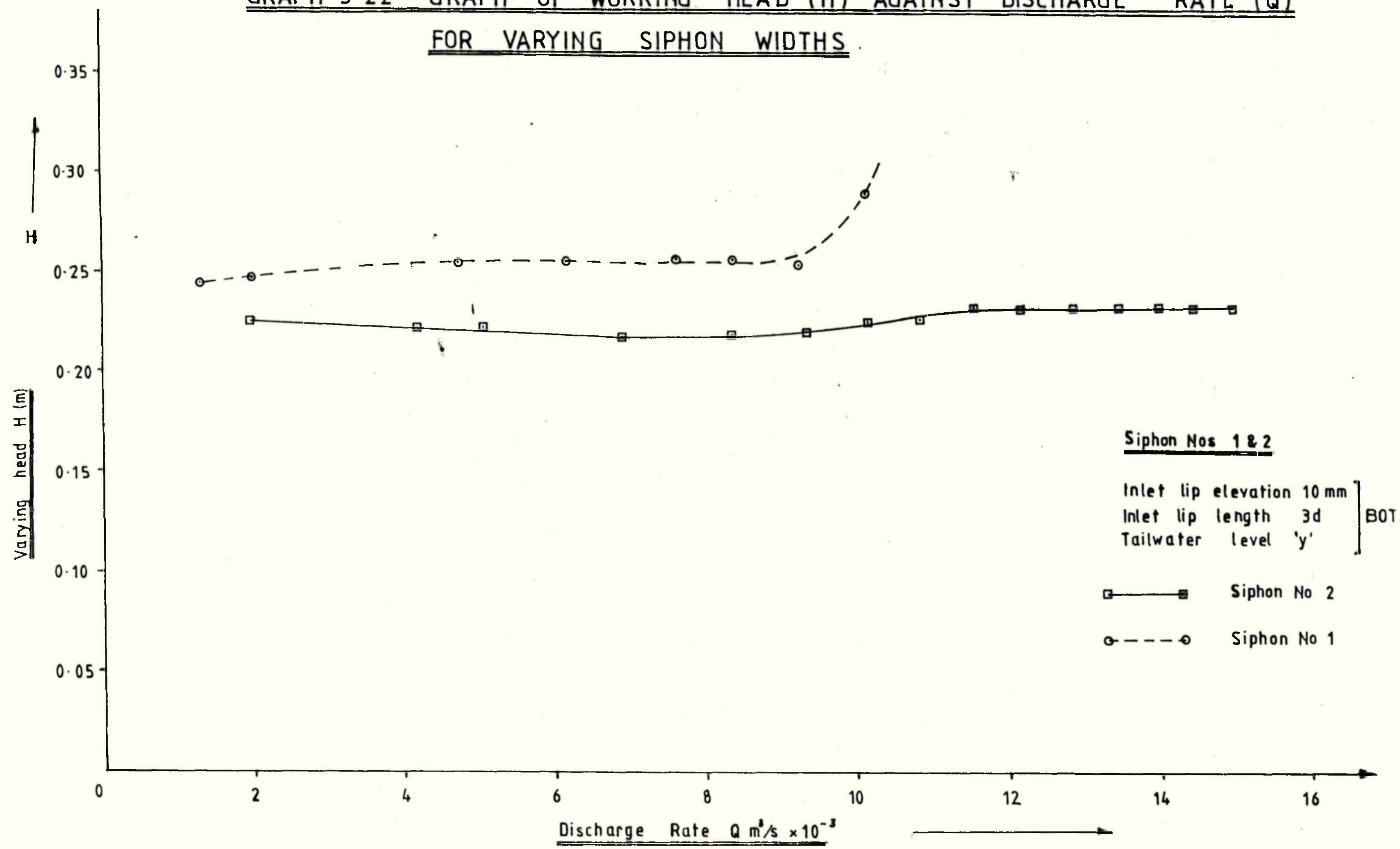
After 9 L/s the heads for the narrower siphon increase rapidly with the onset of blackwater flow. Due to limitations of equipment it was not possible to test the wider siphon under blackwater flow conditions. However siphon No2 was compared to siphon No3 and as expected the wider siphon (No2, width 125mm) produced lower heads than the narrower siphon (No3, width 100mm) as seen on graph 5.24.

Comparing siphons Nos 1 and 2 for a given discharge the coefficient of discharge is less for the wider siphon (siphon No2) than the narrower siphon (siphon No1) and this is attributable to the larger cross-sectional area of which the coefficient of discharge is a function ($C_D = \frac{Q}{bd\sqrt{2gh}}$ where bd is the cross-sectional area).

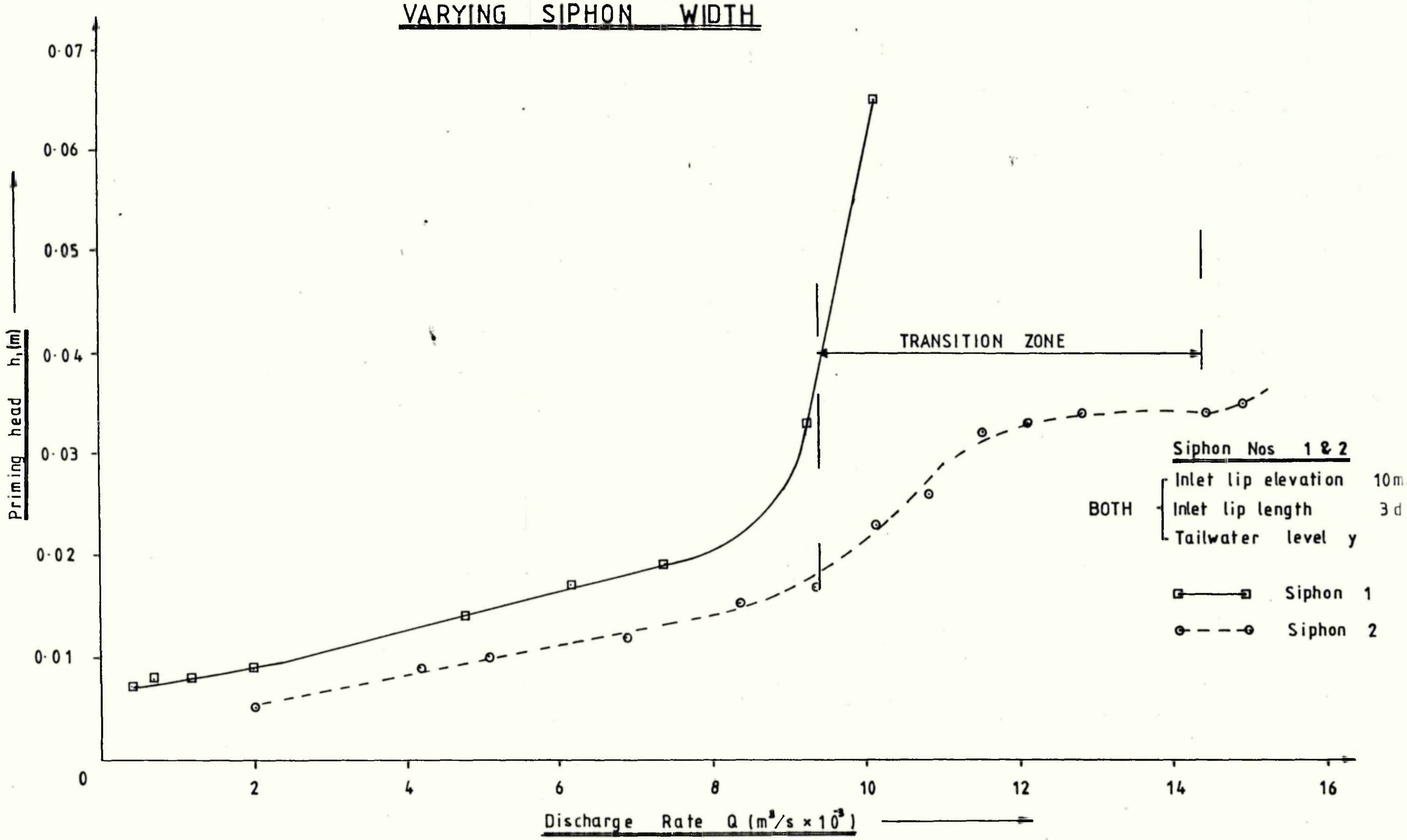
Comparing siphon Nos 2 and 3 (graph 5.26) confirms the fact that the wider the siphon the lower the coefficient of discharge for a given discharge rate.

For siphon No1 the coeffiecient of discharge is linearly proportional to discharge rate ie $C_D \propto Q$ until blackwater flow is reached and at this stage the coefficient of discharge value levels off in the blackwater flow phases. For siphon No2 $C_D \propto Q$ until the beginning of the transition range previously mentioned, the same being true of siphon No3.

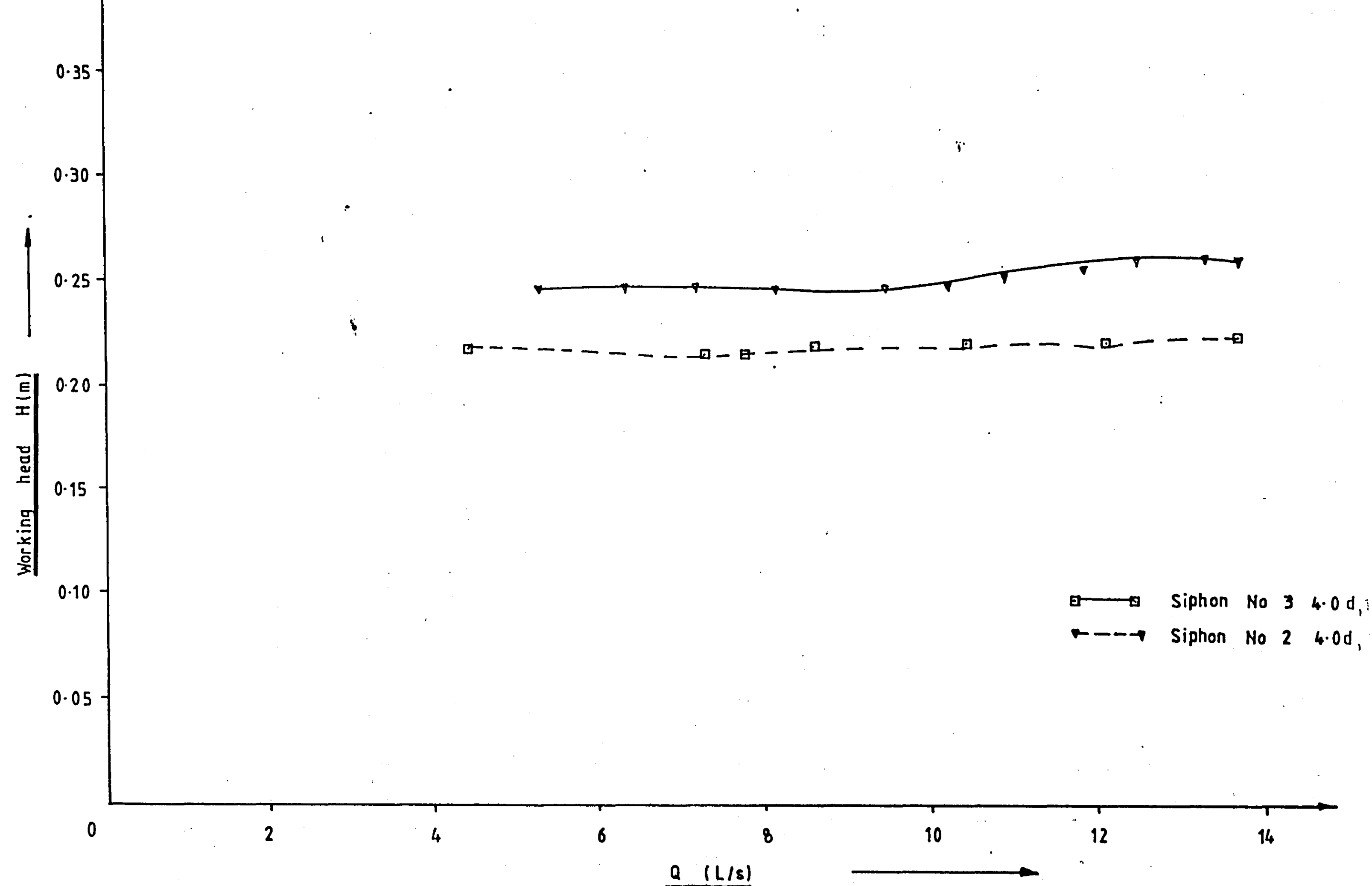
## GRAPH 5·22 - GRAPH OF WORKING HEAD (H) AGAINST DISCHARGE RATE (Q) FOR VARYING SIPHON WIDTHS



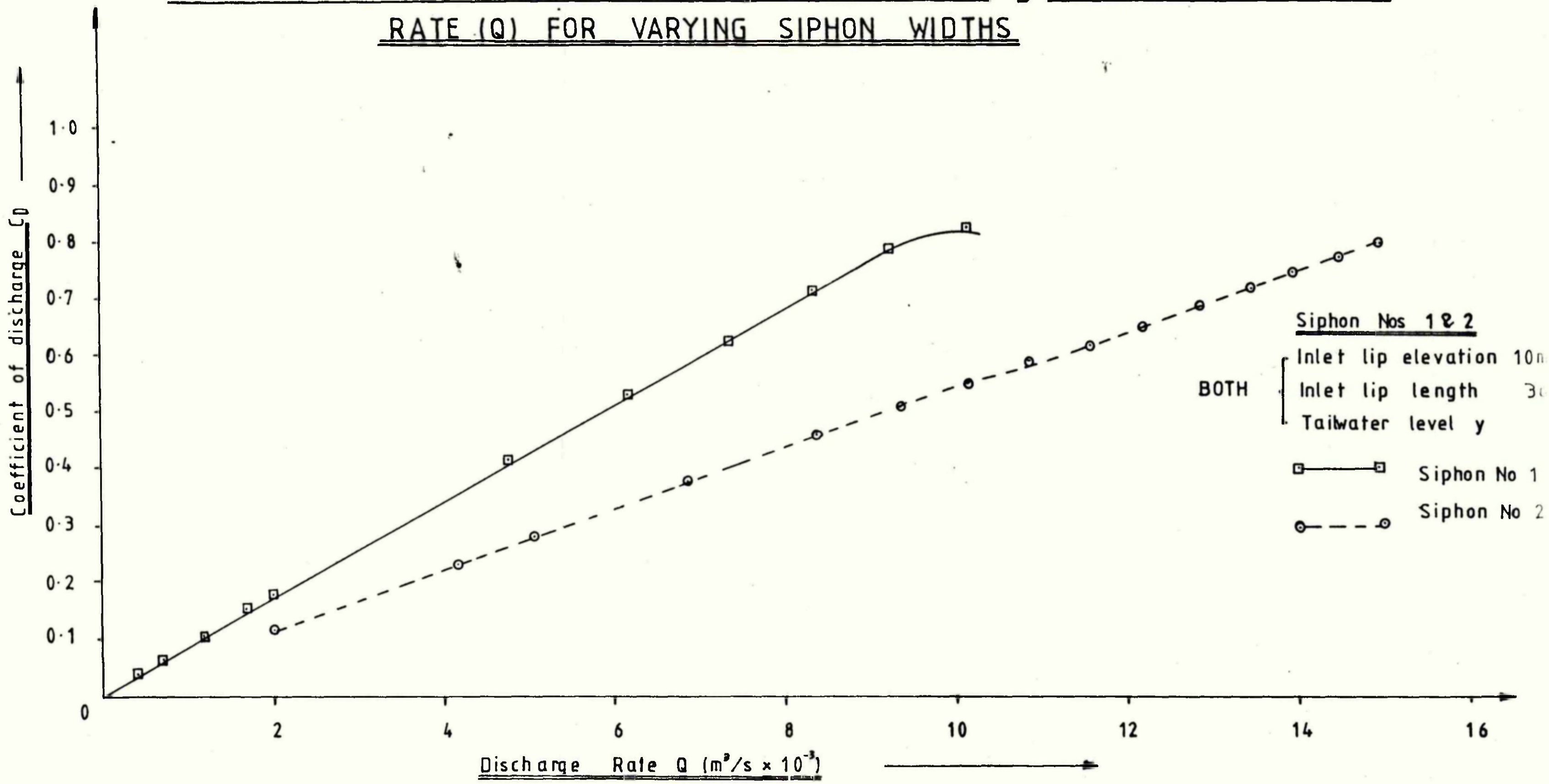
## GRAPH 5·23 GRAPH OF PRIMING HEAD ($h_1$) AGAINST DISCHARGE (Q) FOR VARYING SIPHON WIDTH



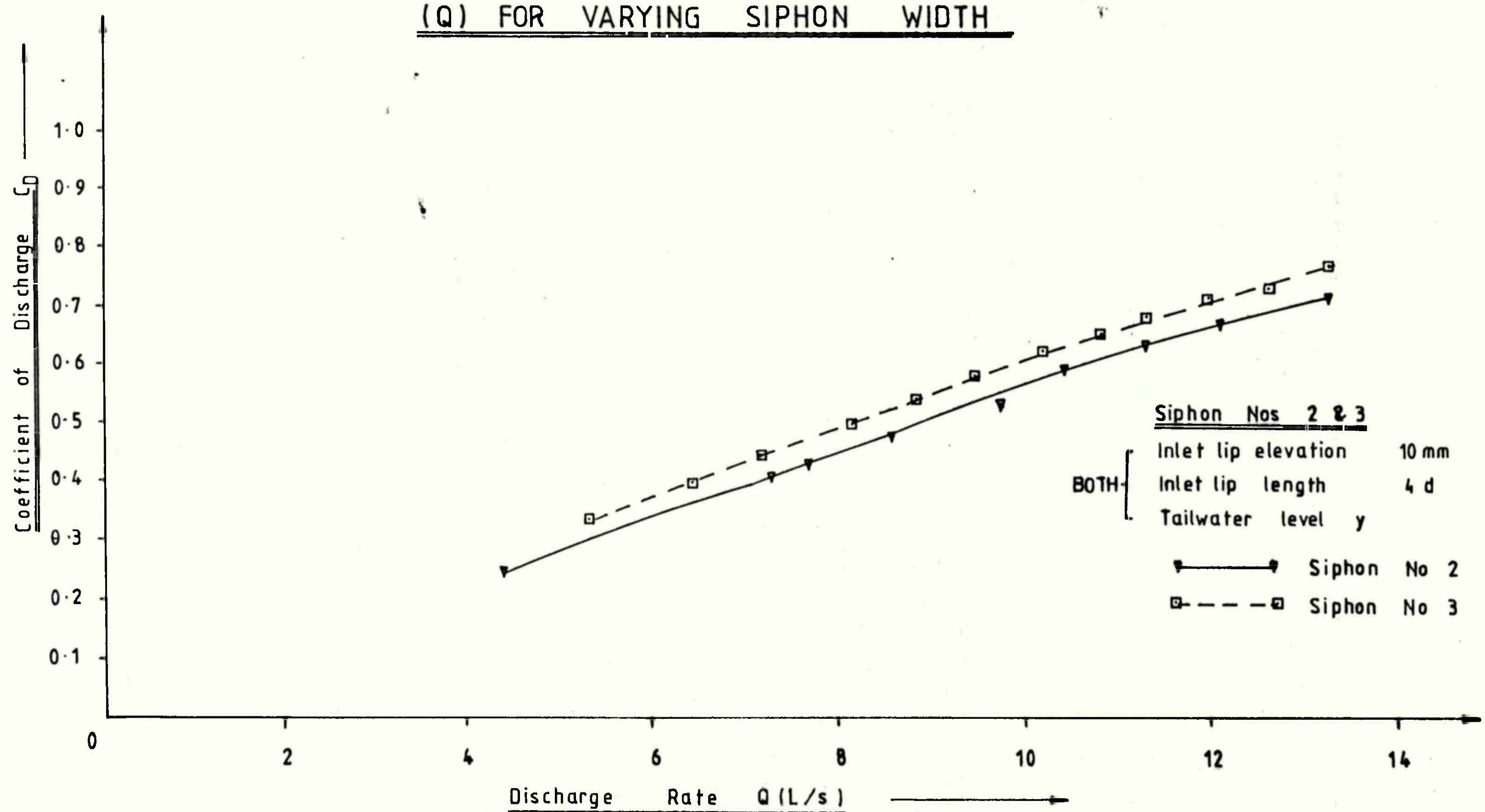
GRAPH 5·24 - GRAPH OF WORKING HEAD (H) AGAINST DISCHARGE (Q)



GRAPH 5·25 - GRAPH OF COEFFICIENT OF DISCHARGE ($C_D$) AGAINST DISCHARGE RATE (Q) FOR VARYING SIPHON WIDTHS



GRAPH 5·26 - GRAPH OF COEFFICIENT OF DISCHARGE ($C_D$) AGAINST DISCHARGE RATE (Q) FOR VARYING SIPHON WIDTH



On inspection of graph 5.27, the ratio of priming head/throat depth $\left(^{h_1}/_{d}\right)$ against coefficient of discharge ($C_D$) is almost constant up until approximately $0.45C_D$ (siphon No2). Above $0.45C_D$ the effects of this transition phase are apparent. The ratio for the wider siphon, of $^{h}/_{d}$ (graph 5.27 and 5.28) exceed the ratio for the narrower siphon but the same is not true of $^{H}/_{d}$ (graphs 5.29 and 5.30). This is because the working head contributes little to the transition phase previously mentioned.

## 5.6 Effects of upstream channel widths

This work was completed using siphon No1 where the upstream channel width was altered using aluminium sheets and dexion framework. The upstream tank's width was reduced and the effects studied.

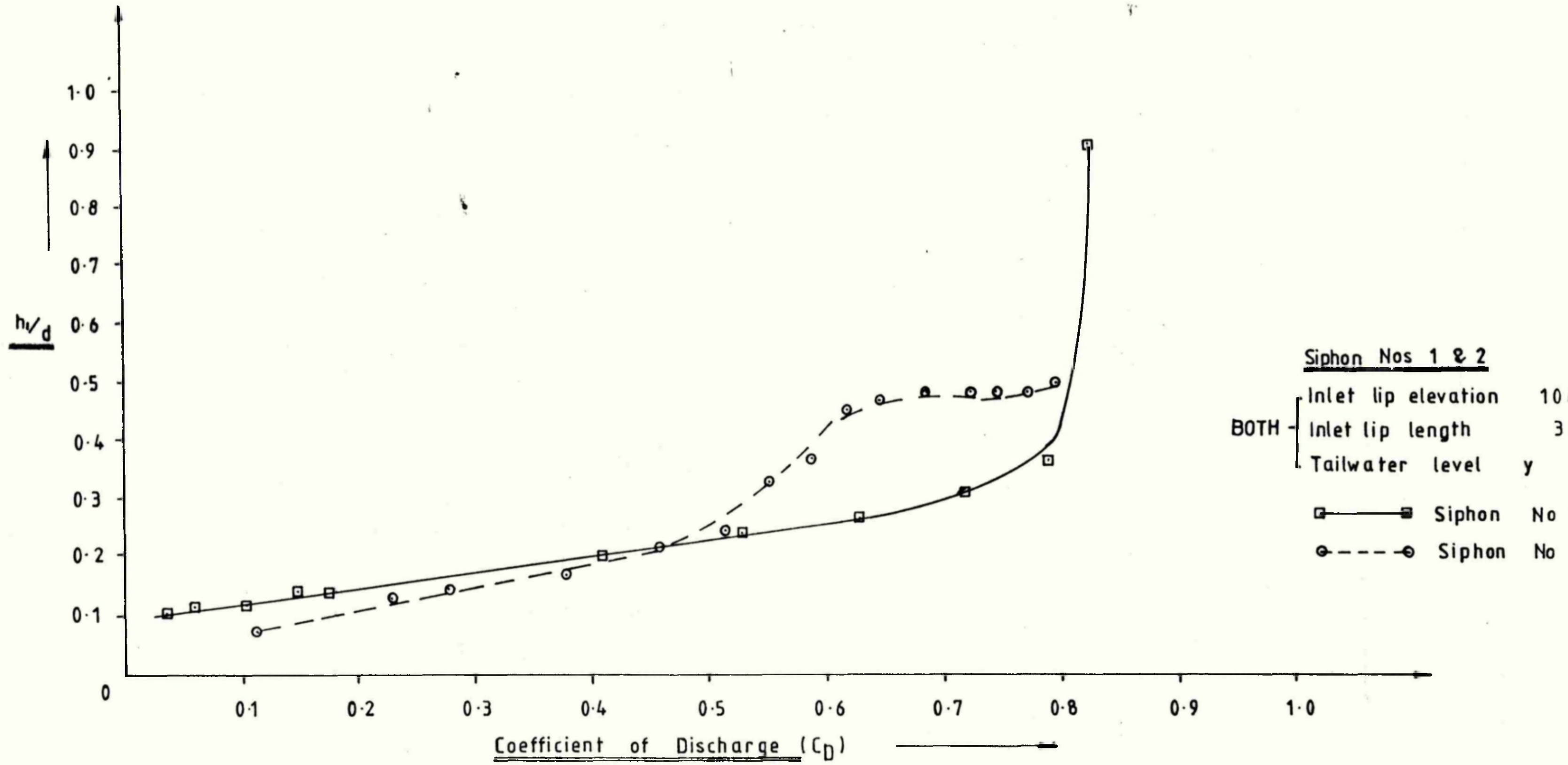
Siphon No2 was tested using an upstream tank width of 43cms. It was postulated that by using a channel width proportional to siphon width, siphon No1, with adjusted upstream channel conditions, would produce similar results to siphon No2.

Siphon No1 width = 75cms - channel width to be determined = Xcms

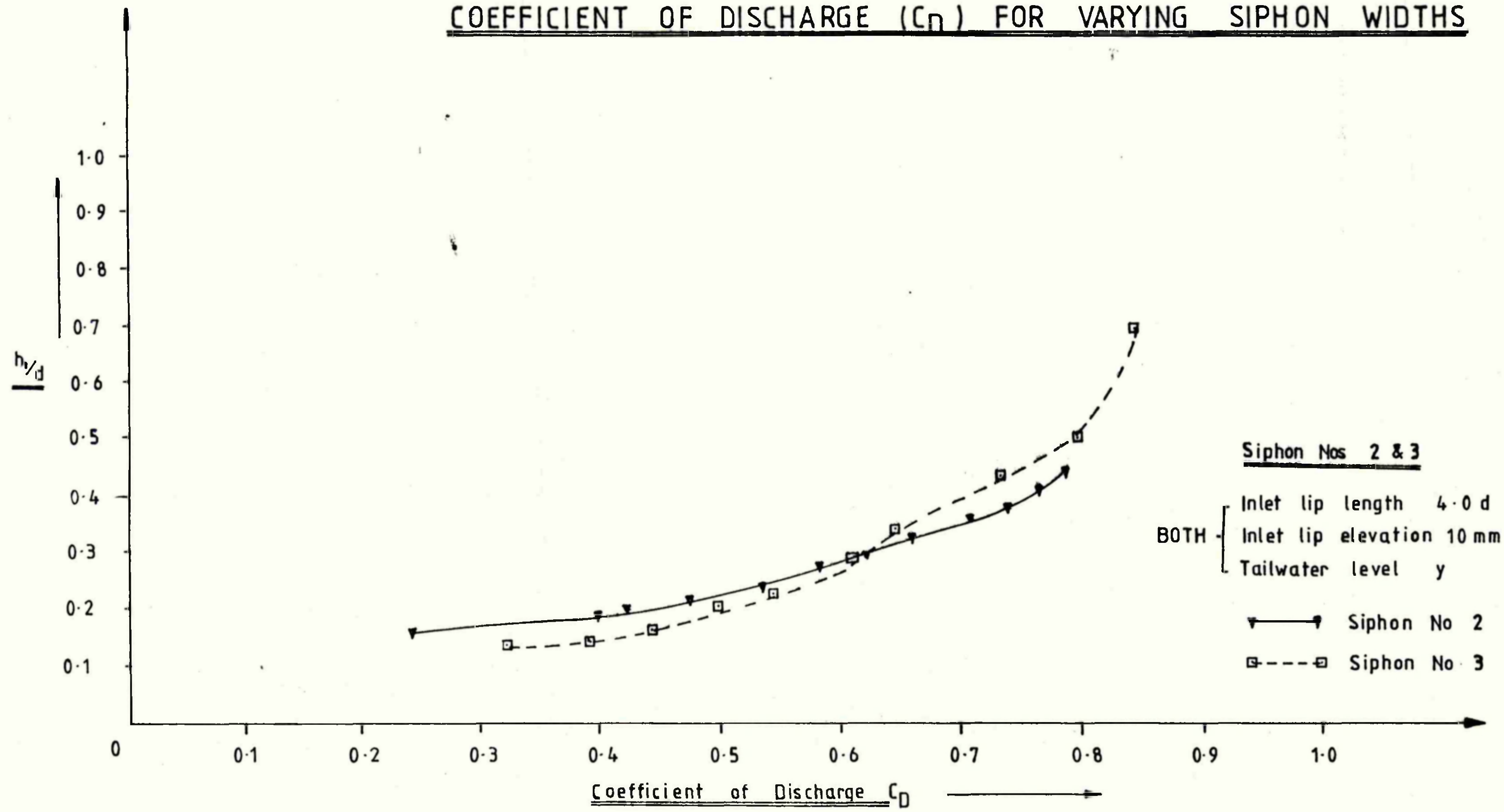
Siphon No2 width = 125 cms. Channel width = 43cms

$$\therefore \quad \frac{75}{125} = \frac{X}{43} \qquad \therefore \quad X = \frac{75 \times 43}{125} \simeq 25\text{cms}$$

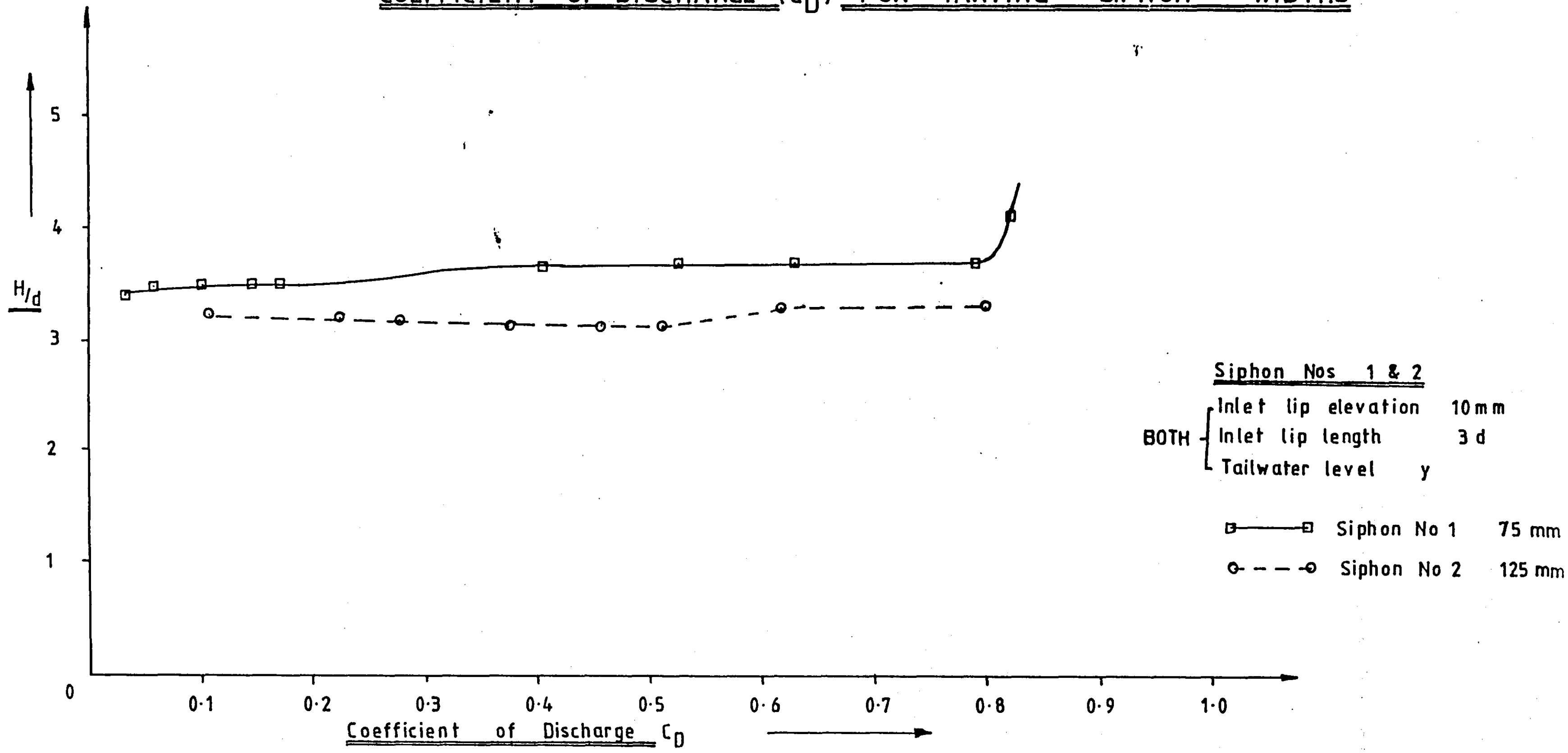
GRAPH 5·27 GRAPH OF RATIO OF PRIMING HEAD AND THROAT DEPTH ($h_1/d$) AGAINS COEFFICIENT OF DISCHARGE ($C_D$) FOR VARYING SIPHON WIDTHS



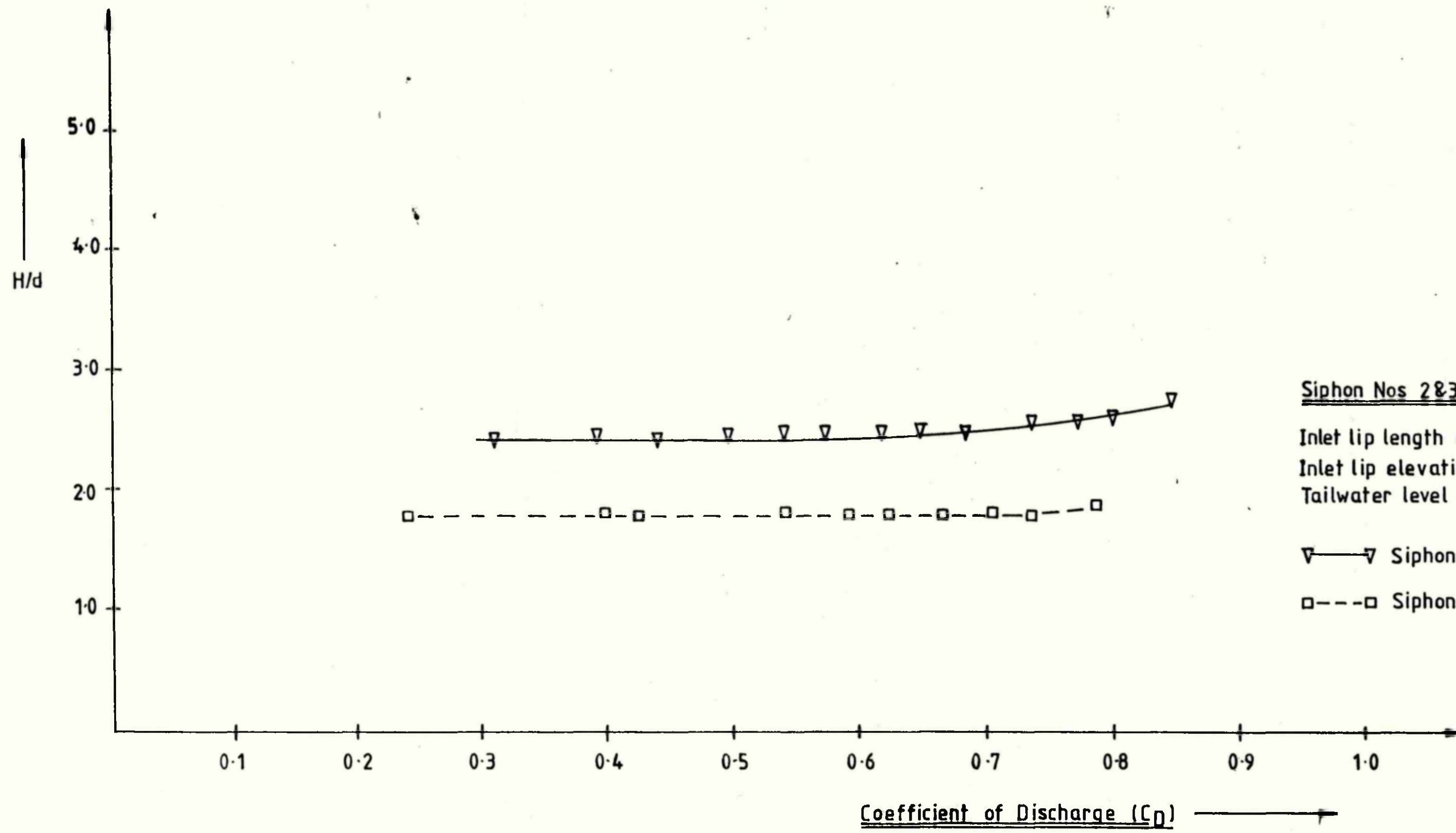
GRAPH 5·28 - GRAPH OF PRIMING HEAD AND THROAT DEPTH ($h_1/d$) AGAINST COEFFICIENT OF DISCHARGE ($C_D$) FOR VARYING SIPHON WIDTHS



GRAPH 5·29 - GRAPH OF RATIO OF WORKING HEAD TO THROAT DEPTH (H/d) AGAINST COEFFICIENT OF DISCHARGE ($C_D$) FOR VARYING SIPHON WIDTHS



GRAPH 5·30 - GRAPH OF RATIO OF WORKING HEAD AND THROAT DEPTH (H/d) AGAINST COEFFICIENT OF DISCHARGE ($C_D$) FOR VARYING SIPHON WIDTH.



Using a channel width of 25 cms for siphon No1 and plotting the results on graph 5.27 it can be seen that the original siphon No1 plot has moved closer to the siphon No2 plot by this variation in approach conditions. This of course is a dimensionless approach.

Again at approximately 0.45 x $C_D$ the curves diverge due to the transition of flow in siphon No2 but it is possible to see that even in this region the alteration of channel width produces marginally more comparible results.

The point again must be made that a two-dimensional approach has been made ie no consideration was given to reducing upstream tank depth. This non-scaling of depth and also experimental error probably causes the discrepancies between siphon No2 and siphon No1 with altered upstream channel width.

## 5.7 Effects of vortices at inlet

With reference to graph 5.27 it is possible to see the previously mentioned 'hump'. This is probably due to a 'depressed nappe' flow phase which is not apparent in the smaller of the two siphons or due to increased flow resistance (increase in priming head). Using Reddy and Pickfords[10] work and referring to Ali and Patemans'[20] papers it would be more sensible to adopt a 3-dimensional approach to air entrainment. Looking at the laboratory sheets in Appendix B this characteristic commences at a point where air entrainment is in a transient stage ie from gulping of air under the inlet to vortex/side vortex induced air entrainment.

To apply Reddy and Pickfords' work on vortices, the depth of water above the intake, low air-entraining vortices develop, and these adversely affect the efficiency of the hydraulic machinery by reducing flow rate and by giving extra swirl to the fluid, in addition to causing vibration and noise.

In shallow reservoirs wave action develops an unstable boundary layer (depending on the wave length and celerity) and this is generally responsible for the change in vorticity which leads to the formation of air-entraining vortices.

Applying this in a sectional sense it would be a feasible suggestion that vortex formation is a function of siphon width and this is borne out by the observations made on the laboratory sheets. With siphon No2 side vortices were more obvious and conclusive proof that vortices are instrumental in producing the transition zone could be given in a number of ways. Physical prevention of vortex formation could be achieved by (1) introduction of baffle boards to regulate flow into inlet, (2) alteration of upstream tank depth and (3) attachment of triangular side plates to siphon mouth and inlet.

The attachment of aluminium side plates greatly reduced the effect of vortices on siphon flow and therefore improves their efficiency (fig 17 refers).

## 5.8 Effects of revised outlet configuration

To investigate the effect of outlet conditions a revised outlet configuration was set up in the downstream tank of the apparatus. The new configuration incorporated a side exit to the outlet chamber and a moveable downstream chamber wall as shown in fig 16. Tests were carried out for each of the six chamber wall positions. As can be seen from graph 5.31 this variable produced no significant change in siphon performance.

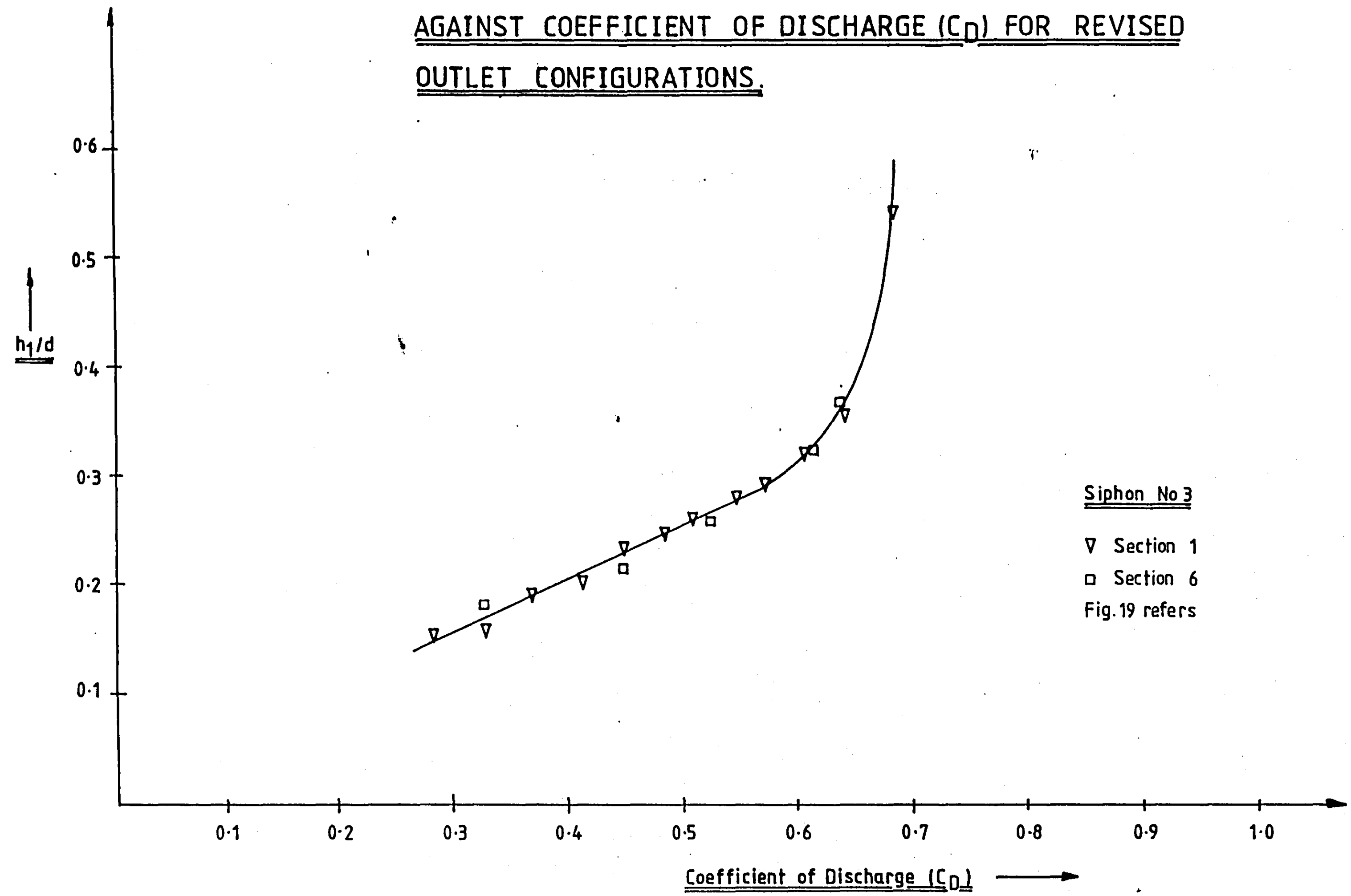
## 5.9 Dimensional analysis of the optimum siphon configuration

(Lip length 4d, lip elevation 10mm, tailwater level 'Y'(281mm)).

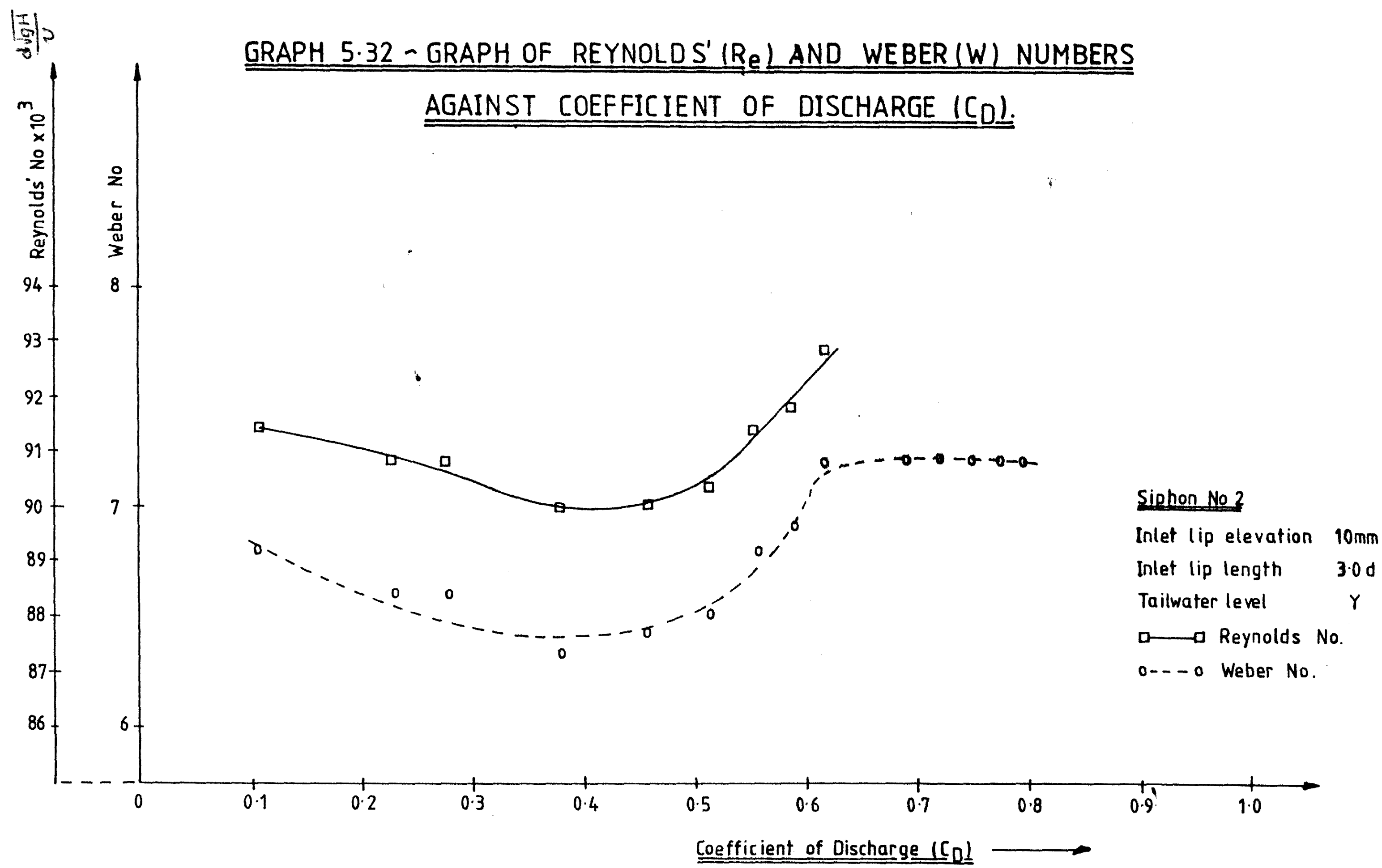
### Reynolds' number and Weber number

From graph 5.32 it can be seen that both ratios follow identical trends to that of the working head for variations in flow rate and coefficient of discharge. This is a result of both expressions of $R_e$ and W being functions of working head. As such they reveal little. However, the Reynolds' number is directly influenced by velocity of flow which varies little in the air partialised flow regime but rapidly increases with the approach and development of blackwater flow. This can be construed as being related to the proportion of air flow.

GRAPH 5·31 – GRAPH OF RATIO OF PRIMING HEAD AND THROAT DEPTH ($h_1/d$) AGAINST COEFFICIENT OF DISCHARGE ($C_D$) FOR REVISED OUTLET CONFIGURATIONS.



## GRAPH 5·32 - GRAPH OF REYNOLDS' ($R_e$) AND WEBER (W) NUMBERS AGAINST COEFFICIENT OF DISCHARGE ($C_D$).



The Weber number is at it's lowest value in the air partialised flow regime, remaining reasonably constant. This indicates that in this phase of flow, surface tension effects are likely to be greatest. Once blackwater flow occurs surface tension effects become negligible. This may appear to validate the concept of Froudian models not accurately portraying the air partialised flow phase. However, to put this matter into perspective, although the effects of surface tension are greater in the air partialised flow regime than in blackwater flow, surface tension effects are still negligible.

Siphon No 1 produced a transition region, as indicated between points A and B on fig 17, where a higher upstream level is required to produce an equivalent discharge. This transition region was initially thought to be produced by the action of vortices at inlet reducing the effective cross-sectional area of the siphon and therefore increasing the upstream head to achieve the same discharge. Side plates, forming the shape of a hood, were added to siphon insert pieces and tests completed to confirm the origin of this transition zone.

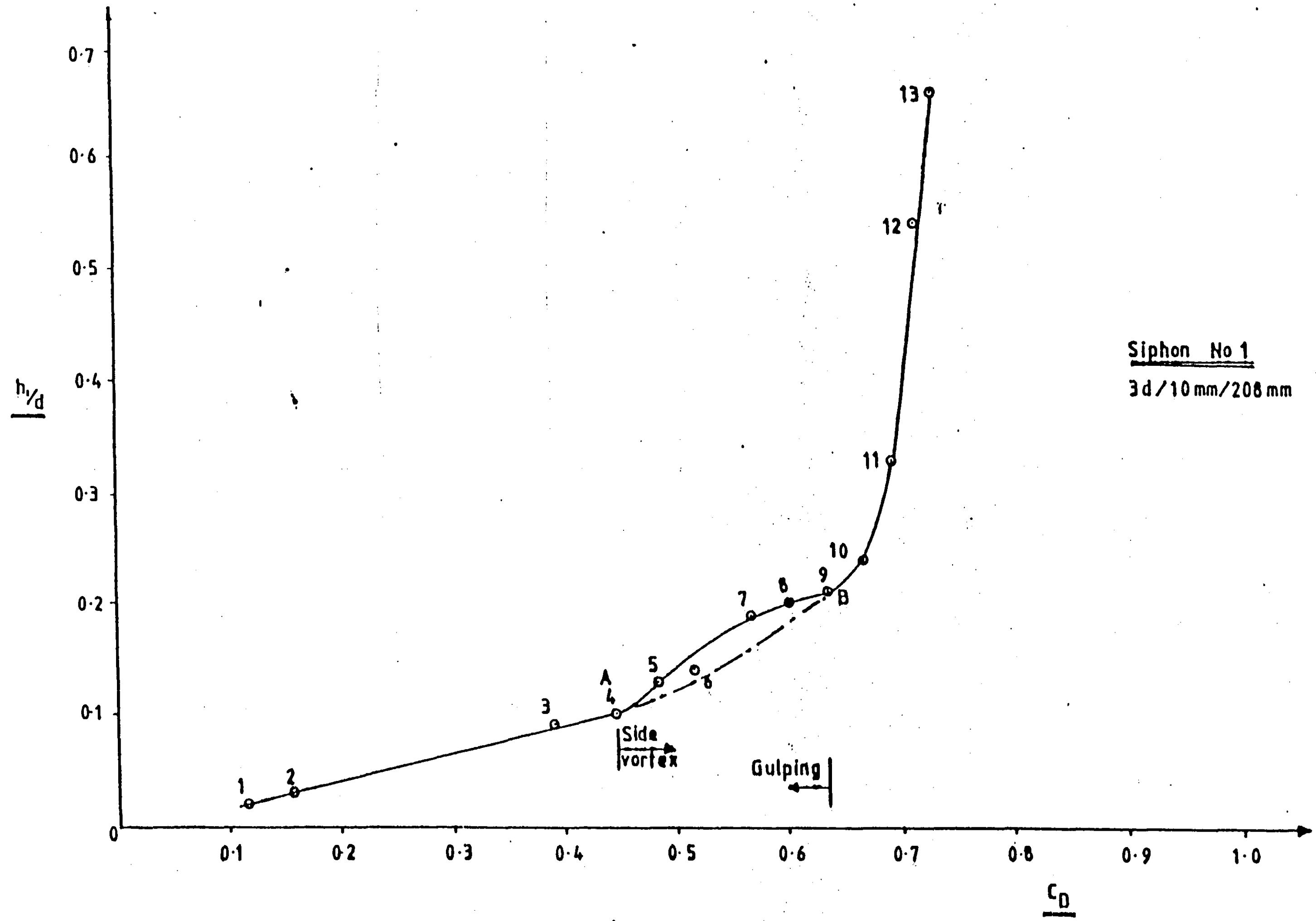



FIG 17 GRAPH OF $h/d$ AGAINST $C_D$

# CHAPTER SIX

# CONCLUSIONS

6.1 Comments and conclusions

6.2 Suitability for use in a combined sewer overflow

6.1 Comments and Conclusions

The general geometry of the siphon gave good flow conveyance, minimising the risk of flow separation at the bends and giving a good coefficient of discharge for blackwater flow of between 0.75 to 0.80.

The optimum inlet configuration for Siphon No 1 was inlet lip length 3d and inlet lip elevation 10mm. For Siphon No 2 the optimum configuration was found to be an inlet lip length of 4d and an inlet lip elevation of 5mm above crest level. The optimum inlet configuration for Siphon No 3 was found to be 4d and an inlet lip elevation of 5mm. Therefore, an aspect ratio of 1:1.3 or greater produces consistent optimum values of inlet geometry. Aspect ratios of less than 1:1.3 would require individual assessment and testing if they were to be used in a working prototype.

The optimum bend ratio, r1 and R2 (fig 14) were found to be 0.5d and 1.5 d respectively. (19) These optimum dimensions produced the best flow conveyance for all flow phases.

As can be seen from sections 5.2 and 5.3 the inlet lip configuration determines the priming and depriming characteristics of the siphon and especially the range of the hunting cycle. However variation in tailwater level had little effect on the fundamental characteristics of the air-partialised flow phase apart from higher downstream levels curtailing the range of this flow regime. Also the working head and initial priming head requirements were affected as well as the pressure regions in the siphon.

The following conclusions may be drawn from the results in Chapter 5.

(i) The effect of siphon width produces increased discharges.

(ii) The optimum lip length previously thought to have been a function of siphon width may now be a function of shape.

(iii) The effect of upstream channel width is that a proportional channel width/siphon width will produce similar results to another siphon model with the same channel width/siphon width on a dimensionless plot.

(iv) The width of the chamber into which the channel is fitted has little influence on discharge.

(v) The revised outlet configuration produced little change to the hydraulic characteristics of the siphon.

(vi) Although the air-mixture in air-partialised flow is not precisely scaled using a Froude Law of scaling previous research by Ali and Pateman[20] has shown that model scales no smaller than 1 to 10 do not suffer significantly from scale effects. Indeed, the prototype performance can be expected to be marginally better than the model. Thus the dimensionless results given above could be applied with confidence for siphons discharging up to $4m^3/s$, although at the higher flows a bank of smaller siphons might be more effective due to restrictions on sewer levels[21].

The optimum design for each of the three siphons gives rapid priming, little tendancy to hunt and a progressive discharge characteristic with little rise in upstream water level up to blackwater flow making it an excellent choice for a storm sewage overflow device. A conclusion which will be dealt with in section 6.2.

The S-shaped siphon has been successfully constructed on site using preformed permanent formwork surrounded with mass concrete. This formwork can be of steel, glass, reinforced plastic or any other material able to withstand the rigours of vibro compaction of concrete around it and also produce a permanent, smooth finish on the inside face. With further developments in materials, especially plastics, it is not inconceivable to consider an S-shaped siphon being replaced unprotected in the ground and backfilled like any other pipe fitting.

## 6.2 Suitability for use as a combined sewer overflow

From results previously discussed it may now be seen that an air-regulated siphon is ideally suited for use as a storm water overflow. It may be designed to operate under low head conditions with coefficients of discharge of around 0.75. If the invert level downstream of the overflow is restricted to some minimum value then low working heads are held to be particularly advantageous, especially in deep sewers, or if sewers are in close proximity to the river into which the overflow is to be passed.

For their size siphons discharge large quantities in relation to other overflow devices and hence their compactness is a distinct advantage in the restrictive nature of sewer systems.

For relatively small increases in priming head a large range of discharges are achieved, this is beneficial for two reasons:

(a) High discharges are accommodated for with relatively small increases in upstream levels thereby preventing the possibility of surcharges in the sewer upstream of the overflow.

(b) Whilst maintaining the ability to discharge equvalent flows the crest level may be positioned higher, ie at a higher elevation than for other devices. This increase in level in the sewer before overflow occurs increases the diluting effect and thereby reduces the polluting effect and also reduces the frequency and volume of spill.

Due to space requirements preventing use of a sufficiently large/wide downstream weir arrangement difficulties may arise in achieving the required elevation of tailwater level. High downstream velocities must be avoided as they are associated with scouring problems. With the provision of two siphon exits it would be possible to eliminate the high downstream velocities and achieve a sufficiently high tailwater level. If the two siphon effluxes were arranged so that they were directed against each other the result would be an effective dissipation of the high velocity energies by conversion to a head of slower moving water. The simplest way to achieve such an arrangement would be to position two smaller siphons side by side and for their bottom bends to be in a plane perpendicular to the plane at the top bend, so that the two exits faced each other. For a single siphon the flow may be divided in the downflow leg or in the bottom bend and for a double exit arrangement to be provided, again facing each other. Considering all these factors and solutions, downstream weir arrangements could be dispensed with, scour problems eliminated and increased compactness achieved. This criterion was not used in the sectional models but may be a valid source of research in the future.

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| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 22.0" | 25.5" | 0.7 | 0.4 | 477 | 7 | 238 | 239 | 0.036 | .100 | 3.41 | | |
| 2 | 21.0" | 27.0" | 1.2 | 0.7 | 478 | 8 | 236 | 242 | 0.062 | .114 | 3.46 | | |
| 3 | 18.5" | 29.5" | 2.2 | 1.2 | 478 | 8 | 234 | 244 | 0.106 | .114 | 3.49 | | |
| 4 | 16.0" | 32.0" | 3.2 | 1.7 | 479 | 9 | 233 | 246 | 0.149 | .129 | 3.51 | | |
| 5 | 14.5" | 34.0" | 3.9 | 2.0 | 479 | 9 | 232 | 247 | 0.175 | .129 | 3.53 | | |
| 6 | 100.3 | 84.4 | 15.9 | 4.8 | 484 | 14 | 227 | 257 | 0.413 | .200 | 3.67 | | |
| 7 | 105.3 | 78.3 | 27.0 | 6.2 | 487 | 17 | 228 | 259 | 0.531 | .243 | 3.70 | | |
| 8 | 110.5 | 71.3 | 39.2 | 7.4 | 489 | 19 | 228 | 261 | 0.631 | .271 | 3.73 | | |
| 9 | 115.2 | 66.0 | 49.2 | 8.4 | 492 | 22 | 231 | 260 | 0.718 | .314 | 3.71 | | |
| 10 | 120.0 | 59.8 | 60.2 | 9.3 | 503 | 33 | 244 | 259 | 0.796 | .471 | 3.70 | | |
| 11 | 125.5 | 53.5 | 72.0 | 10.2 | 534 | 64 | 244 | 290 | 0.826 | .914 | 4.14 | | |
| 12 | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | |

| | |
|---|---|
| SIPHON No. | 1 |
| INLET LIP LENGTH | 3d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 24.7" | 20.7" | 1.0 | .0.6 | 486 | 16 | 239 | 247 | 0.053 | .229 | 3.53 | | HUNTING 30 second cycles |
| 2 | 28.0" | 18.0" | 2.0 | 1.1 | 487 | 17 | 240 | 247 | 0.096 | .243 | 3.53 | | SAWF |
| 3 | 33.0" | 13.0" | 4.0 | 2.1 | 488 | 18 | 245 | 243 | 0.186 | .257 | 3.50 | | SAWF/APF |
| 4 | 100.5 | 84.5 | 16.0 | 4.9 | 494 | 24 | 257 | 237 | 0.439 | .342 | 3.39 | | APF SLIGHT GULPING |
| 5 | 105.5 | 78.5 | 27.0 | 6.2 | 496 | 26 | 259 | 237 | 0.555 | .371 | 3.39 | | APF INCREASED GULPING |
| 6 | 110.3 | 72.3 | 38.0 | 7.4 | 498 | 28 | 262 | 236 | 0.664 | .400 | 3.37 | | APF |
| 7 | 115.5 | 65.8 | 49.7 | 8.5 | 501 | 31 | 259 | 242 | 0.753 | .443 | 3.46 | | APF |
| 8 | 120.5 | 59.5 | 61.0 | 9.4 | 506 | 36 | 247 | 259 | 0.805 | .514 | 3.70 | | APF LARGE SIDE VORTEX |
| 9 | 125.5 | 53.2 | 72.3 | 10.2 | 520 | 50 | 243 | 277 | 0.844 | .714 | 3.96 | | BWF |
| 10 | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | |

| | |
|---|---|
| SIPHON No. | 1 |
| INLET LIP LENGTH | 3d |
| INLET LIP ELEVATION | 20mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 25.5" | 19.1" | 1.3 | 0.8 | 510 - 488 | – | 250 - 238 | – | – | – | – | | HUNTING 24 second cycles |
| 2 | 28.0" | 16.5" | 2.3 | 1.3 | 516 - 490 | – | 250 - 244 | – | – | – | – | | HUNTING 20 second cycles |
| 3 | 34.0" | 11.2" | 4.6 | 2.3 | 496 | 26 | 247 | 249 | 0.201 | .371 | 3.56 | | SAWF/APF |
| 4 | 100.3 | 85.0 | 15.3 | 4.7 | 502 | 32 | 252 | 250 | 0.410 | .457 | 3.57 | | APF |
| 5 | 105.5 | 78.5 | 27.0 | 6.2 | 505 | 35 | 253 | 252 | 0.538 | .500 | 3.60 | | APF |
| 6 | 110.3 | 72.2 | 38.1 | 7.3 | 509 | 39 | 254 | 255 | 0.630 | .557 | 3.64 | | APF |
| 7 | 115.5 | 65.9 | 49.6 | 8.5 | 512 | 42 | 255 | 257 | 0.731 | .600 | 3.67 | | APF LARGE VORTEX |
| 8 | 120.4 | 59.8 | 60.6 | 9.3 | 516 | 46 | 255 | 261 | 0.793 | .657 | 3.73 | | APF |
| 9 | 125.7 | 53.3 | 72.4 | 10.2 | 522 | 52 | 254 | 268 | 0.859 | .742 | 3.83 | | BWF |
| 10 | 130.4 | 47.2 | 83.2 | 10.9 | 550 | 80 | 254 | 296 | 0.873 | 1.14 | 4.23 | | BWF |
| 11 | 135.8 | 40.5 | 95.3 | 11.6 | 572 | 102 | 254 | 318 | 0.897 | 1.46 | 4.54 | | BWF |
| 12 | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | |

| | |
|---|---|
| SIPHON No. | 1 |
| INLET LIP LENGTH | 3d |
| INLET LIP ELEVATION | 30mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 20.6" | 13.9" | 6.7" | 0.9 | 475 | 7 | 170 | 305 | 0.042 | .100 | | | SAWF |
| 2 | 25.1" | 9.6" | 15.5" | 1.6 | 476 | 8 | 176 | 300 | 0.075 | .114 | | | SAWF |
| 3 | 32.6" | 2.8" | 29.8" | 2.8 | 476 | 8 | 178 | 298 | 0.132 | .114 | | | SAWF |
| 4 | 100.1 | 85.6 | 14.5 | 4.6 | 479 | 11 | 179 | 300 | 0.217 | .157 | | | APF |
| 5 | 105.0 | 79.7 | 25.3 | 6.0 | 483 | 15 | 182 | 301 | 0.282 | .214 | | | APF |
| 6 | 110.3 | 72.9 | 37.4 | 7.3 | 486 | 18 | 184 | 302 | 0.343 | .257 | | | APF VORTICES FORMING |
| 7 | 115.3 | 66.8 | 48.5 | 8.3 | 488 | 20 | 186 | 302 | 0.390 | .286 | | | APF |
| 8 | 120.2 | 60.6 | 59.6 | 9.3 | 490 | 22 | 186 | 304 | 0.435 | .314 | | | APF |
| 9 | 125.3 | 54.4 | 70.9 | 10.1 | 495 | 27 | 187 | 308 | 0.469 | .386 | | | APF |
| 10 | 130.5 | 47.6 | 82.9 | 10.9 | 496 | 28 | 188 | 308 | 0.507 | .400 | | | APF |
| 11 | 135.0 | 41.9 | 93.1 | 11.5 | 499 | 31 | 190 | 309 | 0.534 | .442 | | | APF |
| 12 | 140.2 | 35.6 | 104.6 | 12.1 | 501 | 33 | 192 | 309 | 0.562 | .471 | | | APF |
| 13 | 145.7 | 29.1 | 116.6 | 12.9 | 501 | 33 | 192 | 309 | 0.599 | .471 | | | APF |
| 14 | 150.6 | 23.2 | 127.4 | 13.5 | 501 | 33 | 190 | 311 | 0.624 | .471 | | | APF |
| 15 | 155.2 | 17.8 | 137.4 | 14.0 | 502 | 34 | 190 | 312 | 0.647 | .486 | | | APF LITTLE AIR ENTRAINED |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 2.4d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | X |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 31·8" | 3·1" | 28·7" | 2·8 | 477 | 9 | 252 | 225 | 0·152 | ·129 | 3·21 | | WEIR FLOW |
| 2 | 100·0 | 85·6 | 14·4 | 4·5 | 482 | 14 | 260 | 222 | 0·246 | ·200 | 3·17 | | SAWF |
| 3 | 105·1 | 79·6 | 25·5 | 6·0 | 485 | 17 | 262 | 223 | 0·328 | ·243 | 3·19 | | APF |
| 4 | 110·3 | 72·9 | 37·4 | 7·3 | 487 | 19 | 263 | 224 | 0·398 | ·271 | 3·20 | | APF |
| 5 | 115·3 | 66·7 | 48·6 | 8·3 | 489 | 21 | 264 | 225 | 0·451 | ·300 | 3·21 | | APF |
| 6 | 120·1 | 60·9 | 59·2 | 9·0 | 492 | 24 | 264 | 228 | 0·486 | ·343 | 3·26 | | APF VORTICES AT INLET |
| 7 | 125·0 | 54·7 | 70·3 | 10·0 | 495 | 27 | 264 | 231 | 0·537 | ·386 | 3·30 | | APF VORTICES AT INLET |
| 8 | 130·3 | 47·9 | 82·4 | 10·8 | 498 | 30 | 266 | 232 | 0·579 | ·429 | 3·31 | | APF VORTICES AT INLET |
| 9 | 135·1 | 42·2 | 92·9 | 11·4 | 500 | 32 | 267 | 233 | 0·609 | ·457 | 3·33 | | APF 2 STRONG VORTIC |
| 10 | 140·3 | 35·4 | 104·9 | 12·1 | 502 | 34 | 268 | 234 | 0·645 | ·486 | 3·34 | | APF 2 STRONG VORTICE |
| 11 | 145·2 | 29·9 | 115·3 | 12·8 | 502 | 34 | 268 | 234 | 0·683 | ·486 | 3·34 | | APF 2 STRONG VORTICE |
| 12 | 150·2 | 23·9 | 126·3 | 13·4 | 502 | 34 | 268 | 234 | 0·715 | ·486 | 3·34 | | APF 2 STRONG VORTICE |
| 13 | 155·4 | 17·5 | 137·9 | 13·8 | 503 | 35 | 269 | 234 | 0·736 | ·500 | 3·34 | | APF 2 STRONG VORTICE |
| 14 | 160·3 | 11·7 | 148·6 | 14·5 | 504 | 36 | 269 | 235 | 0·772 | ·514 | 3·36 | | APF LESS AIR ENTRAINED |
| 15 | 165·6 | 5·2 | 160·4 | 14·9 | 506 | 38 | 270 | 236 | 0·791 | ·543 | 3·37 | | APF NEARLY BWF |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 2·4d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS ('' or cms) | RHS ('' or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 21·3" | 13·0" | 8·3" | 0·9 | 475 | 7 | 351 | 124 | 0·066 | ·100 | | | WEIR FLOW |
| 2 | 26·1" | 8·6" | 17·5" | 1·9 | 476 | 8 | 355 | 121 | 0·141 | ·114 | | | SAWF |
| 3 | 31·9" | 3·1" | 28·8" | 2·8 | 477 | 9 | 356 | 121 | 0·208 | ·129 | | | SAWF |
| 4 | 100·2 | 85·4 | 14·8 | 4·7 | 481 | 13 | 361 | 120 | 0·350 | ·186 | | | APF |
| 5 | 105·3 | 79·0 | 26·3 | 6·1 | 487 | 19 | 364 | 123 | 0·449 | ·271 | | | VORTICES FORMING |
| 6 | 109·9 | 73·3 | 36·6 | 7·2 | 488 | 20 | 364 | 124 | 0·528 | ·286 | | | APF |
| 7 | 115·5 | 66·2 | 49·3 | 8·4 | 493 | 25 | 367 | 126 | 0·611 | ·357 | | | APF 2 STRONG VORTICES |
| 8 | 120·4 | 60·2 | 60·2 | 9·4 | 495 | 27 | 368 | 127 | 0·681 | ·386 | | | APF 2 STRONG VORTICE |
| 9 | 124·9 | 54·4 | 70·5 | 10·0 | 497 | 29 | 369 | 128 | 0·721 | ·414 | | | APF LESS AIR ENTRAINED |
| 10 | 130·0 | 47·7 | 82·3 | 10·8 | 500 | 32 | 371 | 129 | 0·776 | ·457 | | | APF |
| 11 | 135·8 | 40·9 | 94·9 | 11·6 | 503 | 35 | 374 | 129 | 0·833 | ·500 | | | APF |
| 12 | 140·2 | 35·5 | 104·7 | 12·1 | 505 | 37 | 379 | 126 | 0·880 | ·529 | | | APF |
| 13 | 145·5 | 29·3 | 116·2 | 12·9 | 506 | 38 | 381 | 125 | 0·941 | ·543 | | | APF |
| 14 | 150·7 | 23·0 | 127·7 | 13·5 | 509 | 41 | 384 | 125 | 0·985 | ·586 | | | APF |
| 15 | 160·9 | 10·7 | 150·2 | 14·5 | 533 | 65 | 389 | 144 | 0·986 | ·929 | | | BWF |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 2·4d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | Z |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8·7" | 15·5" | 3·2" | 0·3 | 492 | 24 | 169 | 323 | 0·014 | ·343 | | | WEIR FLOW |
| 2 | 24·3" | 10·3" | 14·0" | 1·5 | 484 | 16 | 175 | 309 | 0·070 | ·229 | | | SAWF |
| 3 | 32·0" | 3·1" | 28·9" | 2·7 | 485 | 17 | 177 | 308 | 0·126 | ·243 | | | SAWF |
| 4 | 100·5 | 84·9 | 15·6 | 4·8 | 487 | 19 | 181 | 306 | 0·224 | ·271 | | | APF |
| 5 | 105·5 | 78·6 | 26·9 | 6·2 | 491 | 23 | 182 | 309 | 0·288 | ·329 | | | APF 2 VORTICES AT INLET |
| 6 | 111·3 | 71·2 | 40·1 | 7·5 | 494 | 26 | 184 | 310 | 0·348 | ·371 | | | APF |
| 7 | 116·8 | 64·8 | 52·0 | 8·7 | 496 | 28 | 185 | 311 | 0·403 | ·400 | | | APF |
| 8 | 122·1 | 57·4 | 64·7 | 9·6 | 497 | 29 | 185 | 312 | 0·443 | ·414 | | | APF |
| 9 | 127·2 | 49·6 | 77·6 | 10·5 | 501 | 33 | 185 | 316 | 0·482 | ·471 | | | APF |
| 10 | 133·8 | 43·9 | 89·9 | 11·3 | 505 | 37 | 186 | 319 | 0·516 | ·529 | | | APF |
| 11 | 139·5 | 36·5 | 103·0 | 12·0 | 508 | 40 | 190 | 318 | 0·549 | ·571 | | | APF |
| 12 | 145·0 | 30·0 | 115·0 | 12·8 | 508 | 40 | 192 | 316 | 0·588 | ·571 | | | APF |
| 13 | 151·7 | 22·2 | 129·5 | 13·6 | 508 | 40 | 193 | 315 | 0·625 | ·571 | | | APF |
| 14 | 158·6 | 13·8 | 144·8 | 14·3 | 508 | 40 | 197 | 311 | 0·662 | ·571 | | | APF |
| 15 | 163·7 | 8·0 | 155·7 | 14·8 | 510 | 42 | 199 | 311 | 0·685 | ·600 | | | APF |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 2·4d |
| INLET LIP ELEVATION | 20mm |
| TAILWATER LEVEL | X |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 21.5" | 13.1" | 8.4" | 0.9 | 483 | 15 | 241 | 242 | 0.050 | .214 | | | SAWF |
| 2 | 28.4" | 6.5" | 21.9" | 2.3 | 485 | 17 | 252 | 233 | 0.123 | .243 | | | SAWF |
| 3 | 100.3 | 85.4 | 14.9 | 4.7 | 490 | 22 | 258 | 232 | 0.252 | .314 | | | SAWF |
| 4 | 105.9 | 78.4 | 27.5 | 6.3 | 493 | 25 | 261 | 232 | 0.337 | .357 | | | APF |
| 5 | 111.0 | 72.1 | 38.9 | 7.5 | 495 | 27 | 262 | 233 | 0.401 | .386 | | | APF |
| 6 | 115.5 | 66.7 | 48.8 | 8.4 | 497 | 29 | 264 | 233 | 0.449 | .414 | | | APF |
| 7 | 121.8 | 58.8 | 63.0 | 9.5 | 501 | 33 | 264 | 237 | 0.503 | .471 | | | APF |
| 8 | 127.3 | 51.7 | 75.6 | 10.4 | 504 | 36 | 264 | 240 | 0.548 | .514 | | | APF VORTICES AT INLET |
| 9 | 131.0 | 39.7 | 91.3 | 11.8 | 509 | 41 | 266 | 243 | 0.618 | .586 | | | APF |
| 10 | 145.7 | 29.3 | 116.4 | 12.9 | 509 | 41 | 269 | 240 | 0.679 | .586 | | | APF |
| 11 | 154.3 | 19.1 | 135.2 | 13.9 | 509 | 41 | 269 | 240 | 0.732 | .586 | | | APF |
| 12 | 159.7 | 12.5 | 147.2 | 14.2 | 510 | 42 | 269 | 241 | 0. 46 | .600 | | | APF LARGE VORTEX AT INLET |
| 13 | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 2.4d |
| INLET LIP ELEVATION | 20mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3·5" | 31·5" | 28" | 2·6 | 486 | 18 | 357 | 129 | 0.187 | ·257 | | | SAWF |
| 2 | 100·1 | 85·6 | 14·5 | 4·7 | 488 | 20 | 360 | 128 | 0.339 | ·286 | | | SAWF |
| 3 | 105·2 | 79·3 | 25·9 | 6·1 | 493 | 25 | 362 | 131 | 0.435 | ·357 | | | APF |
| 4 | 110·4 | 72·9 | 37·5 | 7·3 | 496 | 28 | 363 | 133 | 0.516 | ·400 | | | APF |
| 5 | 115·4 | 66·8 | 48·6 | 8·3 | 500 | 32 | 364 | 136 | 0.581 | ·457 | | | APF |
| 6 | 120·2 | 60·7 | 59·5 | 9·2 | 502 | 34 | 365 | 137 | 0.641 | ·486 | | | APF |
| 7 | 125·2 | 54·5 | 70·7 | 10·1 | 505 | 37 | 367 | 138 | 0.701 | ·529 | | | APF VORTEX AT INLET |
| 8 | 130·2 | 48·2 | 82·0 | 10·8 | 508 | 40 | 369 | 139 | 0.747 | ·571 | | | APF |
| 9 | 135·7 | 41·4 | 94·3 | 11·6 | 511 | 43 | 372 | 139 | 0.803 | ·614 | | | APF |
| 10 | 140·5 | 35·2 | 105·3 | 12·2 | 512 | 44 | 378 | 134 | 0.860 | ·629 | | | APF |
| 11 | 145·7 | 29·2 | 116·5 | 12·9 | 513 | 45 | 379 | 134 | 0.909 | ·643 | | | APF |
| 12 | 150·6 | 23·5 | 127·1 | 13·4 | 512 | 44 | 380 | 132 | 0.952 | ·629 | | | BWF |
| 13 | 155·2 | 18·0 | 137·2 | 14·0 | 515 | 47 | 382 | 133 | 0.990 | ·671 | | | BWF |
| 14 | 160·6 | 11·3 | 149·3 | 14·5 | 529 | 61 | 383 | 146 | 0.979 | ·871 | | | BWF |
| 15 | 165·3 | 5·5 | 159·8 | 15·0 | 546 | 78 | 387 | 159 | 0.971 | 1·114 | | | BWF |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 2·4d |
| INLET LIP ELEVATION | 20mm |
| TAILWATER LEVEL | Z |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 9.3" | 28.0" | 3.8 | 2.4 | 492 | 24 | 170 | 322 | 0.109 | .343 | — | — | Weir flow |
| 2 | 5.2" | 32.8" | 5.6 | 2.9 | 492 | 24 | 174 | 318 | 0.133 | .343 | — | — | SAWF |
| 3 | 101.9 | 81.8 | 20.1 | 5.4 | 499 | 31 | 182 | 317 | 0.247 | .443 | — | — | SAWF |
| 4 | 105.8 | 76.6 | 29.2 | 6.4 | 499 | 31 | 186 | 313 | 0.295 | .443 | — | — | SAWF |
| 5 | 110.8 | 70.4 | 40.4 | 7.6 | 500 | 32 | 186 | 314 | 0.350 | .457 | — | — | SAWF |
| 6 | 115.8 | 64.3 | 51.5 | 8.6 | 503 | 35 | 186 | 317 | 0.394 | .500 | — | — | APF |
| 7 | 120.7 | 58.3 | 62.4 | 9.5 | 506 | 38 | 186 | 320 | 0.433 | .543 | — | — | APF |
| 8 | 125.6 | 51.9 | 73.7 | 10.3 | 508 | 40 | 185 | 323 | 0.468 | .571 | — | — | APF |
| 9 | 130.6 | 45.7 | 84.9 | 11.0 | 510 | 42 | 187 | 323 | 0.500 | .600 | — | — | APF |
| 10 | 136.0 | 39.0 | 97.0 | 11.8 | 512 | 44 | 188 | 324 | 0.535 | .629 | — | — | APF |
| 11 | 141.0 | 32.8 | 108.2 | 12.4 | 512 | 44 | 190 | 322 | 0.564 | .629 | — | — | APF |
| 12 | 146.6 | 26.3 | 120.3 | 13.1 | 512 | 44 | 192 | 320 | 0.598 | .629 | — | — | APF |
| 13 | 151.6 | 20.2 | 131.4 | 13.7 | 514 | 46 | 192 | 322 | 0.623 | .657 | — | — | APF vortex formation |
| 14 | 156.2 | 14.7 | 141.5 | 14.2 | 516 | 48 | 193 | 323 | 0.645 | .686 | — | — | APF " |
| 15 | | | | | | | | | | | | | |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 2.4d |
| INLET LIP ELEVATION | 30mm |
| TAILWATER LEVEL | X |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6·7" | 31·0" | 24·3 | 4·5 | 494 | 26 | 255 | 239 | 0·237 | ·371 | — | – | Weir flow |
| 2 | 100·5 | 83·3 | 17·2 | 5·0 | 496 | 28 | 258 | 238 | 0·264 | ·400 | — | – | SAWF |
| 3 | 105·7 | 76·8 | 28·9 | 6·5 | 500 | 32 | 260 | 240 | 0·342 | ·457 | — | – | SAWF |
| 4 | 110·5 | 70·9 | 39·6 | 7·5 | 502 | 34 | 262 | 240 | 0·395 | ·486 | — | – | APF |
| 5 | 115·5 | 64·7 | 50·8 | 8·5 | 506 | 38 | 264 | 242 | 0·446 | ·543 | — | – | APF |
| 6 | 120·8 | 58·2 | 62·6 | 9·5 | 507 | 39 | 263 | 244 | 0·496 | ·557 | — | – | APF |
| 7 | 125·8 | 51·7 | 74·1 | 10·3 | 510 | 42 | 263 | 247 | 0·535 | ·600 | — | – | APF |
| 8 | 130·4 | 45·9 | 84·5 | 11·0 | 512 | 44 | 264 | 248 | 0·570 | ·629 | — | – | APF |
| 9 | 135·5 | 39·5 | 96·0 | 11·7 | 515 | 47 | 266 | 249 | 0·605 | ·671 | — | – | APF |
| 10 | 140·9 | 33·1 | 107·8 | 12·4 | 516 | 48 | 268 | 248 | 0·642 | ·686 | — | – | APF |
| 11 | 145·9 | 27·2 | 118·7 | 13·0 | 514 | 46 | 270 | 244 | 0·679 | ·657 | — | – | APF |
| 12 | 151·0 | 20·8 | 130·2 | 13·6 | 515 | 47 | 270 | 245 | 0·709 | ·671 | — | – | APF |
| 13 | 157·3 | 13·5 | 143·8 | 14·2 | 516 | 48 | 270 | 246 | 0·739 | ·686 | — | – | APF LARGE VORTICES |
| 14 | 163·8 | 5·5 | 158·3 | 14·8 | 518 | 50 | 270 | 248 | 0·767 | ·714 | — | – | |
| 15 | | | | | | | | | | | | | |

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|---|---|
| SIPHON No. | 2 |
| INLET LIP LENGTH | 2·4d |
| INLET LIP ELEVATION | 30mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6·3" | 14·0" | 7·7" | 1·6 | 492 | 24 | 351 | 141 | 0·110 | – | – | – | – |
| 2 | 30·2" | 7·6" | 22·6" | 2·6 | 493 | 25 | 356 | 137 | 0·181 | – | – | – | – |
| 3 | 100·3 | 83·4 | 16·9 | 5·0 | 496 | 28 | 357 | 139 | 0·346 | – | – | – | – |
| 4 | 105·4 | 77·2 | 28·2 | 6·4 | 500 | 32 | 360 | 140 | 0·441 | – | – | – | – |
| 5 | 110·8 | 70·3 | 40·5 | 7·5 | 504 | 36 | 362 | 142 | 0·514 | – | – | – | – |
| 6 | 115·5 | 64·4 | 51·1 | 8·5 | 508 | 40 | 364 | 144 | 0·578 | – | – | – | – |
| 7 | 120·7 | 58·2 | 62·7 | 9·5 | 510 | 42 | 366 | 144 | 0·646 | – | – | – | – |
| 8 | 126·0 | 51·4 | 74·7 | 10·4 | 514 | 46 | 368 | 146 | 0·702 | – | – | – | – |
| 9 | 131·6 | 44·3 | 87·3 | 11·2 | 515 | 47 | 369 | 146 | 0·756 | – | – | – | – |
| 10 | 136·8 | 38·0 | 98·8 | 11·9 | 518 | 50 | 370 | 148 | 0·798 | – | – | – | – |
| 11 | 141·5 | 32·3 | 109·2 | 12·5 | 519 | 51 | 373 | 146 | 0·844 | – | – | – | – |
| 12 | 147·5 | 25·4 | 122·1 | 13·0 | 517 | 49 | 375 | 142 | 0·890 | – | – | – | – |
| 13 | 152·9 | 18·7 | 134·2 | 13·8 | 520 | 52 | 377 | 143 | 0·942 | – | – | – | – |
| 14 | 157·6 | 13·0 | 144·6 | 14·2 | 536 | 68 | 380 | 146 | 0·959 | – | – | – | – |
| 15 | 162·7 | 6·6 | 156·1 | 14·7 | 536 | 68 | 382 | 144 | 0·999 | – | – | – | – |

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|---|---|
| SIPHON No. | 2 |
| INLET LIP LENGTH | 2·4d |
| INLET LIP ELEVATION | 30mm |
| TAILWATER LEVEL | Z |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 23·3" | 16·5" | 1·36 | 0·8 | 475 | 7 | 170 | 305 | 0·037 | ·100 | 4·36 | – | SAWF |
| 2 | 33·0" | 7·5" | 5·14 | 2·5 | 474 | 6 | 176 | 298 | 0·118 | ·090 | 4·26 | – | SAWF slight gulping |
| 3 | 100·4 | 84·5 | 15·9 | 4·8 | 478 | 10 | 181 | 297 | 0·227 | ·143 | 4·24 | – | SAWF Rapid gulping |
| 4 | 105·3 | 78·5 | 26·8 | 6·2 | 479 | 11 | 183 | 296 | 0·294 | ·157 | 4·23 | – | APF |
| 5 | 110·6 | 71·8 | 38·8 | 7·4 | 480 | 12 | 185 | 295 | 0·352 | ·171 | 4·21 | – | APF |
| 6 | 120·2 | 60·2 | 60·0 | 9·3 | 483 | 15 | 186 | 297 | 0·440 | ·214 | 4·24 | – | APF side vortices |
| 7 | 125·0 | 54·0 | 71·0 | 10·1 | 490 | 22 | 186 | 304 | 0·473 | ·314 | 4·34 | – | APF |
| 8 | 130·5 | 46·9 | 83·6 | 10·9 | 490 | 22 | 186 | 304 | 0·510 | ·314 | 4·34 | – | APF |
| 9 | 135·8 | 40·7 | 95·1 | 11·6 | 496 | 28 | 188 | 308 | 0·539 | ·400 | 4·4 | – | APF |
| 10 | 140·8 | 34·5 | 106·3 | 12·2 | 498 | 30 | 189 | 309 | 0·566 | ·429 | 4·41 | – | APF |
| 11 | 145·5 | 29·1 | 116·4 | 12·8 | 499 | 31 | 190 | 309 | 0·594 | ·443 | 4·41 | – | APF |
| 12 | 150·7 | 22·7 | 128·0 | 13·5 | 500 | 32 | 193 | 307 | 0·629 | ·457 | 4·39 | – | APF |
| 13 | 155·3 | 17·3 | 138·0 | 13·8 | 500 | 32 | 194 | 306 | 0·644 | ·457 | 4·37 | – | APF |
| 14 | 160·5 | 11·0 | 149·5 | 14·5 | 500 | 32 | 196 | 304 | 0·679 | ·457 | 4·34 | – | APF |
| 15 | 165·5 | 4·0 | 160·8 | 15·0 | 500 | 32 | 198 | 302 | 0·704 | ·457 | 4·31 | – | APF |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 3·0d |
| INLET LIP ELEVATION | 10MM |
| TAILWATER LEVEL | X |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 29·3" | 11·0" | 3·7 | 2·0 | 473 | 5 | 247 | 226 | 0·109 | ·071 | 3·23 | – | SAWF Slight Gulping |
| 2 | 100·7 | 84·2 | 16·5 | 4·2 | 477 | 9 | 254 | 223 | 0·229 | ·129 | 3·19 | – | SAWF " |
| 3 | 105·6 | 78·2 | 27·4 | 5·1 | 478 | 10 | 255 | 223 | 0·279 | ·143 | 3·19 | – | APF " |
| 4 | 110·2 | 72·3 | 37·9 | 6·9 | 480 | 12 | 262 | 218 | 0·381 | ·171 | 3·11 | – | APF RAPID Gulping |
| 5 | 115·3 | 65·8 | 49·5 | 8·4 | 483 | 15 | 264 | 219 | 0·463 | ·214 | 3·13 | – | APF " |
| 6 | 120·6 | 59·5 | 61·1 | 9·4 | 485 | 17 | 264 | 221 | 0·516 | ·243 | 3·16 | – | APF Gulping + side vortices |
| 7 | 125·8 | 53·2 | 72·6 | 10·2 | 491 | 23 | 265 | 226 | 0·554 | ·329 | 3·23 | – | APF " " |
| 8 | 130·7 | 46·8 | 83·9 | 10·9 | 494 | 26 | 266 | 228 | 0·589 | ·371 | 3·26 | – | APF " " |
| 9 | 135·8 | 40·3 | 95·5 | 11·6 | 500 | 32 | 267 | 233 | 0·620 | ·457 | 3·33 | – | APF " " |
| 10 | 140·8 | 34·3 | 106·5 | 12·2 | 501 | 33 | 268 | 233 | 0·652 | ·471 | 3·33 | – | APF |
| 11 | 145·7 | 28·5 | 117·2 | 12·9 | 502 | 34 | 268 | 234 | 0·688 | ·486 | 3·34 | – | APF |
| 12 | 150·8 | 22·5 | 128·3 | 13·5 | 502 | 34 | 270 | 232 | 0·723 | ·486 | 3·31 | – | APF |
| 13 | 155·3 | 17·3 | 138·0 | 14·0 | 502 | 34 | 270 | 232 | 0·750 | ·486 | 3·31 | – | APF |
| 14 | 160·2 | 11·3 | 148·9 | 14·5 | 502 | 34 | 270 | 232 | 0·777 | ·486 | 3·31 | – | APF |
| 15 | 165·8 | 4·5 | 161·3 | 15·0 | 503 | 35 | 270 | 233 | 0·802 | ·500 | 3·33 | – | APF |

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|---|---|
| SIPHON No. | 2 |
| INLET LIP LENGTH | 3·0d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 27.0" | 12.7" | 2.9 | 1.6 | 480 | 12 | 338 | 142 | 0.110 | ·171 | 2.03 | | SAWF |
| 2 | 100.5 | 84.6 | 15.9 | 4.9 | 480 | 12 | 358 | 122 | 0.362 | ·171 | 1.74 | | SAWF Gulping |
| 3 | 105.3 | 78.6 | 26.7 | 6.2 | 482 | 14 | 362 | 120 | 0.462 | ·200 | 1.71 | | APF Gulping |
| 4 | 110.3 | 72.2 | 38.1 | 7.4 | 483 | 15 | 363 | 120 | 0.551 | ·214 | 1.71 | | APF Gulping |
| 5 | 115.7 | 65.5 | 50.2 | 8.5 | 488 | 20 | 366 | 122 | 0.628 | ·286 | 1.74 | | APF Gulping |
| 6 | 120.7 | 59.3 | 61.4 | 9.4 | 492 | 24 | 367 | 125 | 0.686 | ·343 | 1.79 | | APF Gulping |
| 7 | 125.8 | 53.3 | 72.5 | 10.2 | 497 | 29 | 369 | 128 | 0.736 | ·414 | 1.83 | | APF Gulping |
| 8 | 130.5 | 47.2 | 83.3 | 10.9 | 499 | 31 | 370 | 129 | 0.783 | ·443 | 1.84 | | APF Gulping |
| 9 | 135.7 | 40.5 | 95.2 | 11.6 | 503 | 35 | 373 | 130 | 0.830 | ·500 | 1.86 | | APF Vortices at sides |
| 10 | 140.3 | 34.8 | 105.5 | 12.1 | 504 | 36 | 374 | 130 | 0.866 | ·514 | 1.86 | | APF Vortices at sides |
| 11 | 145.6 | 28.5 | 117.1 | 12.9 | 506 | 38 | 376 | 130 | 0.923 | ·543 | 1.86 | | APF Vortices at sides |
| 12 | 150.7 | 22.5 | 128.2 | 13.7 | 512 | 44 | 382 | 130 | 0.980 | ·629 | 1.86 | | APF Vortices at sides |
| 13 | 155.5 | 16.5 | 139.0 | 14.0 | 520 | 52 | 384 | 136 | 0.980 | ·743 | 1.94 | | BWF Occasional air |
| 14 | 160.3 | 11.3 | 149.0 | 14.5 | 527 | 59 | 385 | 142 | 0.993 | ·843 | 2.03 | | BWF Occasional air |
| 15 | 165.5 | 5.3 | 160.2 | 15.0 | 536 | 68 | 385 | 151 | 0.996 | ·971 | 2.16 | | BWF Occasional air |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 3d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | Z |

| TEST No. | MANOMETER RULE LHS ('' or cms) | MANOMETER RULE RHS ('' or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.5" | 15.7" | 2.8" | .0.3 | – | – | – | – | – | – | – | – | SAWF |
| 2 | 24.5" | 10.1" | 14.4" | 1.6 | 482 | 14 | 174 | 308 | 0.074 | .200 | | | SAWF |
| 3 | 32.0" | 3.1" | 28.9" | 2.8 | 483 | 15 | 175 | 308 | 0.130 | .214 | | | SAWF/APF |
| 4 | 100.5 | 85.0 | 15.5 | 4.8 | 485 | 17 | 178 | 307 | 0.224 | .243 | | | APF |
| 5 | 105.5 | 78.5 | 27.0 | 6.2 | 487 | 19 | 181 | 306 | 0.289 | .271 | | | APF |
| 6 | 111.0 | 71.5 | 39.5 | 7.5 | 490 | 22 | 183 | 307 | 0.349 | .314 | | | APF |
| 7 | 117.0 | 65.0 | 52.0 | 8.7 | 492 | 24 | 185 | 307 | 0.405 | .343 | | | APF |
| 8 | 122.0 | 57.5 | 64.5 | 9.6 | 495 | 27 | 186 | 309 | 0.446 | .386 | | | APF |
| 9 | 127.2 | 49.6 | 77.6 | 10.5 | 498 | 30 | 188 | 310 | 0.487 | .429 | | | APF |
| 10 | 133.8 | 43.8 | 90.0 | 11.3 | 502 | 34 | 188 | 314 | 0.520 | .486 | | | APF |
| 11 | 139.8 | 36.3 | 103.5 | 12.0 | 505 | 37 | 190 | 315 | 0.552 | .529 | | | APF |
| 12 | 145.2 | 29.8 | 115.4 | 12.8 | 505 | 37 | 192 | 313 | 0.590 | .529 | | | APF |
| 13 | 150.5 | 23.2 | 127.3 | 13.5 | 505 | 37 | 194 | 311 | 0.625 | .529 | | | APF |
| 14 | 159.5 | 13.0 | 146.5 | 14.2 | 505 | 37 | 196 | 309 | 0.659 | .529 | | | APF |
| 15 | 163.6 | 8.0 | 155.6 | 14.7 | 507 | 39 | 197 | 310 | 0.681 | .557 | | | APF |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 3d |
| INLET LIP ELEVATION | 20mm |
| TAILWATER LEVEL | x |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 23.4" | 16.4" | 7.0" | 0.9 | 482 | 14 | 246 | 236 | 0.050 | .200 | 3.37 | | |
| 2 | 33.2" | 7.3" | 25.9" | 2.5 | 483 | 15 | 248 | 235 | 0.133 | .214 | 3.36 | | |
| 3 | 100.5 | 84.5 | 16.0 | 4.8 | 485 | 17 | 255 | 230 | 0.258 | .243 | 3.29 | | |
| 4 | 105.5 | 78.3 | 27.0 | 6.2 | 488 | 20 | 260 | 228 | 0.335 | .286 | 3.26 | | |
| 5 | 110.6 | 71.5 | 39.1 | 7.4 | 490 | 22 | 261 | 229 | 0.399 | .314 | 3.27 | | |
| 6 | 120.0 | 60.0 | 60.0 | 9.3 | 497 | 29 | 263 | 234 | 0.496 | .414 | 3.34 | | |
| 7 | 125.5 | 54.7 | 70.8 | 10.1 | 500 | 32 | 265 | 235 | 0.538 | .457 | 3.36 | | |
| 8 | 130.5 | 47.0 | 83.5 | 10.9 | 503 | 35 | 266 | 237 | 0.578 | .500 | 3.39 | | |
| 9 | 135.0 | 40.5 | 94.5 | 11.6 | 507 | 39 | 267 | 240 | 0.611 | .557 | 3.43 | | |
| 10 | 140.5 | 34.3 | 106.2 | 12.2 | 507 | 39 | 267 | 240 | 0.643 | .557 | 3.43 | | |
| 11 | 145.3 | 29.0 | 116.3 | 12.9 | 507 | 39 | 267 | 240 | 0.679 | .557 | 3.43 | | |
| 12 | 150.5 | 23.0 | 127.5 | 13.5 | 507 | 39 | 268 | 239 | 0.712 | .557 | 3.41 | | |
| 13 | 155.2 | 17.4 | 137.8 | 13.9 | 507 | 39 | 269 | 238 | 0.735 | .557 | 3.40 | | |
| 14 | 160.5 | 11.0 | 149.5 | 14.5 | 508 | 40 | 269 | 239 | 0.765 | .571 | 3.41 | | |
| 15 | 165.2 | 4.9 | 160.3 | 14.9 | 508 | 40 | 270 | 238 | 0.788 | .571 | 3.40 | | |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 3d |
| INLET LIP ELEVATION | 20mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 20.5" | 14.0" | 6.5" | 1.0 | 480 | 12 | 342 | 138 | 0.070 | .171 | | | |
| 2 | 25.0" | 9.7" | 15.3" | 1.5 | 483 | 15 | 345 | 138 | 0.104 | .214 | | | |
| 3 | 32.5" | 3.0" | 29.5" | 2.8 | 484 | 16 | 352 | 132 | 0.200 | .229 | | | |
| 4 | 100.0 | 85.8 | 14.2 | 4.5 | 486 | 18 | 356 | 130 | 0.322 | .257 | | | |
| 5 | 105.2 | 79.5 | 25.7 | 6.1 | 489 | 21 | 359 | 130 | 0.437 | .300 | | | |
| 6 | 110.3 | 73.0 | 37.3 | 7.3 | 495 | 27 | 363 | 132 | 0.518 | .386 | | | |
| 7 | 115.5 | 66.8 | 48.7 | 8.4 | 498 | 30 | 366 | 132 | 0.597 | .429 | | | |
| 8 | 120.2 | 60.5 | 59.7 | 9.3 | 501 | 33 | 367 | 134 | 0.656 | .471 | | | |
| 9 | 125.3 | 54.5 | 70.8 | 10.1 | 506 | 38 | 368 | 138 | 0.701 | .543 | | | |
| 10 | 130.5 | 47.6 | 82.9 | 10.9 | 508 | 40 | 369 | 139 | 0.754 | .571 | | | |
| 11 | 135.2 | 41.7 | 93.5 | 11.5 | 510 | 42 | 371 | 139 | 0.796 | .600 | | | |
| 12 | 140.0 | 35.8 | 104.2 | 12.1 | 510 | 42 | 374 | 136 | 0.847 | .600 | | | |
| 13 | 145.0 | 30.0 | 115.0 | 12.8 | 510 | 42 | 377 | 133 | 0.906 | .600 | | | |
| 14 | 150.5 | 23.5 | 127.0 | 13.5 | 512 | 44 | 379 | 133 | 0.955 | .629 | | | |
| 15 | 155.0 | 18.0 | 137.0 | 13.8 | 515 | 47 | 381 | 134 | 0.973 | .671 | | | |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 3d |
| INLET LIP ELEVATION | 20mm |
| TAILWATER LEVEL | Z |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 23.4" | 16.6" | 6.8" | 0.9 | 491 | 23 | 244 | 247 | 0.047 | ·329 | 3·53 | | SAWF |
| 2 | 32.0" | 8.5" | 23.5" | 2.4 | 492 | 24 | 247 | 245 | 0.125 | ·343 | 3·50 | | SAWF |
| 3 | 100.5 | 84.2 | 16.3 | 4.9 | 494 | 26 | 255 | 239 | 0.259 | ·371 | 3·41 | | APF |
| 4 | 105.0 | 78.8 | 26.2 | 6.1 | 497 | 29 | 260 | 237 | 0.323 | ·414 | 3·39 | | APF |
| 5 | 110.5 | 72.0 | 38.5 | 7.4 | 500 | 32 | 261 | 239 | 0.391 | ·457 | 3·41 | | APF VORTICES AT INLET |
| 6 | 120.2 | 60.0 | 60.2 | 9.3 | 505 | 37 | 263 | 242 | 0.488 | ·529 | 3·46 | | APF |
| 7 | 125.3 | 53.7 | 71.6 | 10.1 | 508 | 40 | 264 | 244 | 0.528 | ·571 | 3·49 | | APF |
| 8 | 130.5 | 47.0 | 83.5 | 10.9 | 510 | 42 | 264 | 246 | 0.567 | ·600 | 3·51 | | APF |
| 9 | 135.8 | 40.5 | 95.3 | 11.6 | 513 | 45 | 266 | 247 | 0.602 | ·643 | 3·53 | | APF |
| 10 | 140.5 | 34.6 | 105.9 | 12.2 | 513 | 45 | 267 | 246 | 0.635 | ·643 | 3·51 | | APF |
| 11 | 145.6 | 29.0 | 116.6 | 12.9 | 513 | 45 | 268 | 245 | 0.672 | ·643 | 3·50 | | APF |
| 12 | 150.5 | 22.9 | 127.6 | 13.5 | 514 | 46 | 269 | 245 | 0.704 | ·657 | 3·50 | | APF |
| 13 | 155.2 | 17.3 | 137.9 | 13.9 | 514 | 46 | 270 | 244 | 0.726 | ·657 | 3·49 | | APF |
| 14 | 160.5 | 11.2 | 149.3 | 14.5 | 514 | 46 | 270 | 244 | 0.757 | ·657 | 3·49 | | APF |
| 15 | 165.5 | 4.9 | 160.6 | 14.9 | 515 | 47 | 270 | 245 | 0.777 | ·671 | 3·50 | | APF |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 3d |
| INLET LIP ELEVATION | 30mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13·5" | 20·0" | 1·31 | 0·7 | 468–514 | — | — | | | | | | HUNTING, 35 SECOND CYCLE |
| 2 | 3·0" | 31·2" | 5·6 | 2·6 | 477 | 7 | 179 | 298 | 0·123 | 0·1 | 4·3 | 42·6 | SAWF |
| 3 | 100·9 | 83·8 | 17·1 | 5·0 | 478 | 8 | 184 | 294 | 0·238 | 0·11 | 4·2 | 36·8 | SAWF |
| 4 | 105·5 | 78·3 | 27·2 | 6·2 | 478 | 8 | 186 | 292 | 0·296 | 0·11 | 4·2 | 36·5 | SAWF |
| 5 | 110·7 | 71·7 | 39·0 | 7·4 | 479 | 9 | 188 | 291 | 0·354 | 0·13 | 4·16 | 32·3 | APF |
| 6 | 115·6 | 65·5 | 50·1 | 8·6 | 479 | 9 | 188 | 291 | 0·411 | 0·13 | 4·16 | 32·3 | APF GULPING SMALL |
| 7 | 120·8 | 59·2 | 61·6 | 9·4 | 480 | 10 | 189 | 291 | 0·450 | 0·14 | 4·16 | 29·1 | APF GULPING SMALL |
| 8 | 125·7 | 53·0 | 72·7 | 10·2 | 481 | 11 | 190 | 291 | 0·488 | 0·16 | 4·16 | 26·5 | APF MORE GULPING |
| 9 | 130·3 | 47·3 | 83·0 | 10·9 | 482 | 12 | 190 | 292 | 0·520 | 0·17 | 4·17 | 24·3 | APF MORE GULPING |
| 10 | 140·4 | 34·8 | 105·6 | 12·1 | 489 | 19 | 192 | 297 | 0·573 | 0·27 | 4·24 | 15·6 | APF SIDE VORTEX |
| 11 | 145·5 | 28·7 | 116·8 | 12·9 | 490 | 20 | 193 | 297 | 0·611 | 0·29 | 4·24 | 14·9 | APF SIDE VORTEX |
| 12 | 150·3 | 23·2 | 127·1 | 13·5 | 490 | 20 | 194 | 296 | 0·640 | 0·29 | 4·23 | 14·8 | APF SIDE VORTEX |
| 13 | 155·2 | 17·2 | 138·0 | 13·8 | 490 | 20 | 194 | 296 | 0·654 | 0·29 | 4·23 | 14·8 | APF SIDE VORTEX |
| 14 | 160·0 | 11·0 | 149 | 14·4 | 490 | 20 | 195 | 295 | 0·684 | 0·29 | 4·21 | 14·8 | APF SIDE VORTEX |
| 15 | 165·5 | 4·5 | 161·0 | 14·9 | 494 | 24 | 199 | 295 | 0·708 | 0·34 | 4·21 | 12·3 | BWF |

TEMP 14·4°C

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 4d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | x |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 11·8" | 22" | 2·1 | 1·1 | 502–471 | – | 260–244 | – | – | – | – | – | SAWF HUNTING |
| 2 | 4·5" | 29·6" | 5·1 | 2·5 | 492–474 | – | 252–260 | – | – | – | – | – | SAWF HUNTING |
| 3 | 100·4 | 84·5 | 15·9 | 4·9 | 478 | 8 | 262 | 216 | 0·272 | 0·11 | 3·09 | 27·0 | SAWF/APF |
| 4 | 105·5 | 78·1 | 27·4 | 6·3 | 480 | 10 | 263 | 217 | 0·349 | 0·14 | 3·10 | 21·7 | APF GULPING AIR |
| 5 | 110·6 | 71·7 | 38·9 | 7·4 | 480 | 10 | 265 | 215 | 0·411 | 0·14 | 3·07 | 21·5 | APF GULPING DIMINISHING |
| 6 | 115·6 | 65·7 | 49·9 | 8·5 | 480 | 10 | 266 | 214 | 0·474 | 0·14 | 3·06 | 21·4 | APF GULPING DIMINISHING |
| 7 | 120·6 | 59·3 | 61·3 | 9·4 | 481 | 11 | 267 | 214 | 0·524 | 0·16 | 3·06 | 19·5 | APF GULPING DIMINISHING |
| 8 | 125·9 | 52·5 | 73·4 | 10·3 | 485 | 15 | 267 | 218 | 0·569 | 0·21 | 3·11 | 14·5 | APF GULPING DIMINISHING |
| 9 | 130·3 | 47·2 | 88·1 | 10·9 | 485 | 15 | 268 | 217 | 0·604 | 0·21 | 3·10 | 14·5 | APF VORTEX AT SIDES |
| 10 | 135·5 | 40·4 | 95·1 | 11·6 | 488 | 18 | 270 | 218 | 0·641 | 0·26 | 3·11 | 12·1 | APF VORTEX AT SIDES |
| 11 | 145·5 | 28·3 | 117·2 | 12·9 | 493 | 23 | 272 | 221 | 0·708 | 0·33 | 3·16 | 9·6 | APF VORTEX AT SIDES |
| 12 | 150·3 | 22·5 | 127·8 | 13·5 | 493 | 23 | 272 | 221 | 0·741 | 0·33 | 3·16 | 9·6 | APF VORTEX AT SIDES |
| 13 | 155·4 | 16·7 | 138·7 | 13·9 | 495 | 25 | 272 | 223 | 0·759 | 0·36 | 3·19 | 8·9 | APF VORTEX AT SIDES |
| 14 | 160·9 | 10·3 | 150·6 | 14·5 | 495 | 25 | 273 | 222 | 0·794 | 0·36 | 3·17 | 8·9 | APF VORTEX AT SIDES |
| 15 | 165·5 | 4·5 | 161·0 | 14·9 | 495 | 25 | 273 | 222 | 0·816 | 0·36 | 3·17 | 8·9 | APF NEARLY BWF |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 4d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100·2 | 84·7 | 15·5 | 4·8 | 478 - 481 | – | 363 - 366 | – | – | – | – | – | SAWF RAPID HUNTING |
| 2 | 105·1 | 78·7 | 26·4 | 6·2 | 490 - 481 | – | 364 - 370 | – | – | – | – | – | SAWF RAPID HUNTING |
| 3 | 110·5 | 72·0 | 38·5 | 7·4 | 493 - 482 | – | 369 - 371 | – | – | – | – | – | SAWF RAPID HUNTING |
| 4 | 115·5 | 65·7 | 49·8 | 8·5 | 486 | 16 | 372 | 114 | 0·650 | ·229 | 1·63 | 7·13 | APF |
| 5 | 120·9 | 58·7 | 62·2 | 9·5 | 488 | 18 | 373 | 115 | 0·723 | ·257 | 1·64 | 6·39 | APF OCCASIONAL GULPING |
| 6 | 125·8 | 52·9 | 72·9 | 10·3 | 490 | 20 | 374 | 116 | 0·780 | ·286 | 1·66 | 5·80 | APF |
| 7 | 130·8 | 46·8 | 84·0 | 10·9 | 493 | 23 | 376 | 117 | 0·822 | ·329 | 1·67 | 5·09 | APF VORTICES AT SIDES |
| 8 | 135·6 | 40·5 | 95·1 | 11·6 | 495 | 25 | 378 | 117 | 0·875 | ·357 | 1·67 | 4·68 | APF VORTICES AT SIDES |
| 9 | 140·4 | 34·7 | 105·7 | 12·1 | 498 | 28 | 381 | 117 | 0·913 | 0·4 | 1·67 | 4·18 | APF VORTICES AT SIDES |
| 10 | 145·5 | 28·3 | 117·2 | 12·9 | 499 | 29 | 382 | 117 | 0·973 | ·414 | 1·67 | 4·03 | APF NO VORTEX |
| 11 | 150·9 | 22·3 | 128·6 | 13·5 | 508 | 38 | 384 | 124 | 0·984 | ·543 | 1·77 | 3·26 | APF ALMOST BWF |
| 12 | 155·5 | 16·5 | 139·0 | 14·0 | 519 | 49 | 385 | 134 | 0·987 | 0·7 | 1·91 | 2·73 | BWF |
| 13 | 160·9 | 10·1 | 150·8 | 14·5 | 530 | 60 | 385 | 145 | 0·982 | ·857 | 2·07 | 2·42 | BWF |
| 14 | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 4d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | Z |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100·4 | 84·5 | 15·9 | 4·9 | 477 | 7 | 184 | 293 | 0·295 | 0·1 | 4·19 | 41·9 | SAWF AIR IN GULPS |
| 2 | 105·6 | 78·1 | 27·5 | 6·3 | 476 | 6 | 186 | 290 | 0·377 | 0·86 | 4·14 | 48·3 | SAWF/APF AIR IN GULPS |
| 3 | 110·7 | 71·5 | 39·2 | 7·4 | 476 | 6 | 188 | 288 | 0·440 | 0·86 | 4·11 | 48·0 | APF AIR GULPED |
| 4 | 115·3 | 65·7 | 49·6 | 8·4 | 477 | 7 | 189 | 288 | 0·499 | 0·10 | 4·11 | 41·1 | APF AIR GULPED |
| 5 | 120·6 | 59·3 | 61·3 | 9·4 | 477 | 7 | 189 | 288 | 0·558 | 0·10 | 4·11 | 41·1 | APF AIR GULPED |
| 6 | 125·5 | 53·2 | 72·3 | 10·2 | 478 | 8 | 190 | 288 | 0·604 | 0·11 | 4·11 | 36·0 | APF AIR GULPED |
| 7 | 130·7 | 46·5 | 84·2 | 10·9 | 478 | 8 | 191 | 287 | 0·644 | 0·11 | 4·10 | 35·9 | APF AIR GULPED |
| 8 | 135·4 | 40·5 | 94·9 | 11·6 | 478 | 8 | 192 | 286 | 0·683 | 0·11 | 4·09 | 35·8 | APF RAPID GULPING |
| 9 | 140·8 | 34·2 | 106·6 | 12·2 | 479 | 9 | 193 | 286 | 0·717 | 0·13 | 4·09 | 31·8 | APF RAPID GULPING |
| 10 | 145·2 | 28·8 | 116·4 | 12·9 | 479 | 9 | 194 | 285 | 0·756 | 0·13 | 4·07 | 31·8 | APF LESS GULPING |
| 11 | 150·8 | 22·1 | 128·7 | 13·5 | 480 | 10 | 195 | 285 | 0·789 | 0·14 | 4·07 | 28·5 | APF LESS GULPING |
| 12 | 155·5 | 16·8 | 138·7 | 14·0 | 481 | 11 | 196 | 285 | 0·816 | 0·16 | 4·07 | 25·9 | APF LESS GULPING |
| 13 | 160·5 | 10·8 | 149·7 | 14·5 | 482 | 12 | 199 | 283 | 0·839 | 0·17 | 4·04 | 23·6 | APF VORTEX FORMING |
| 14 | 165·3 | 4·8 | 160·5 | 14·9 | 482 | 12 | 200 | 282 | 0·860 | 0·17 | 4·03 | 23·5 | APF VORTEX FORMING |
| 15 | | | | | | | | | | | | | |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 5d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | x |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100·5 | 84·3 | 16·2 | 4·9 | 478 | 8 | 263 | 215 | 0·273 | 0·114 | 3·07 | 26·9 | SAWF |
| 2 | 105·5 | 77·8 | 27·7 | 6·3 | 477 | 7 | 266 | 211 | 0·354 | 0·100 | 3·01 | 30·1 | APF GULPING |
| 3 | 110·5 | 71·8 | 38·7 | 7·4 | 478 | 8 | 267 | 211 | 0·416 | 0·114 | 3·01 | 26·4 | APF GULPING |
| 4 | 115·4 | 65·7 | 49·7 | 8·5 | 478 | 8 | 268 | 210 | 0·479 | 0·114 | 3·00 | 26·3 | APF GULPING |
| 5 | 120·4 | 59·5 | 60·9 | 9·4 | 478 | 8 | 269 | 209 | 0·531 | 0·114 | 2·99 | 26·1 | APF GULPING |
| 6 | 125·7 | 52·8 | 72·9 | 10·3 | 478 | 8 | 270 | 208 | 0·583 | 0·114 | 2·97 | 26·0 | APF GULPING |
| 7 | 130·5 | 46·8 | 83·7 | 10·9 | 478 | 8 | 270 | 208 | 0·617 | 0·114 | 2·97 | 26·0 | APF GULPING |
| 8 | 135·8 | 40·2 | 95·6 | 11·6 | 479 | 9 | 272 | 207 | 0·658 | 0·129 | 2·95 | 23·0 | APF DECREASING GULPING |
| 9 | 140·4 | 34·5 | 105·9 | 12·2 | 481 | 11 | 273 | 208 | 0·690 | 0·157 | 2·97 | 18·9 | APF AND VORTEX FORMING |
| 10 | 145·2 | 28·8 | 116·4 | 12·9 | 482 | 12 | 273 | 209 | 0·728 | 0·171 | 2·99 | 17·4 | APF VORTEX FORMING |
| 11 | 150·6 | 22·5 | 128·1 | 13·5 | 482 | 12 | 273 | 209 | 0·762 | 0·171 | 2·99 | 17·4 | APF VORTEX FORMING |
| 12 | 155·5 | 16·6 | 138·9 | 14·0 | 483 | 13 | 273 | 210 | 0·788 | 0·186 | 3·00 | 16·2 | APF VORTEX FORMING |
| 13 | 160·2 | 10·8 | 149·4 | 14·5 | 484 | 14 | 274 | 210 | 0·816 | 0·20 | 3·00 | 15·0 | APF VORTEX |
| 14 | 165·5 | 4·5 | 161·0 | 15·0 | 485 | 15 | 274 | 211 | 0·843 | 0·214 | 3·01 | 14·1 | APF VORTEX |
| 15 | | | | | | | | | | | | | |

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|---|---|
| SIPHON No. | 2 |
| INLET LIP LENGTH | 5d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100·5 | 84·5 | 16·0 | 4·9 | 474-484 | – | 359-368 | – | – | – | – | – | SAWF HUNTING 6 SECOND CYCLES |
| 2 | 105·5 | 78·2 | 27·3 | 6·2 | 476-494 | – | 364-371 | – | – | – | – | – | 8 SECOND CYCLES |
| 3 | 110·5 | 71·9 | 38·6 | 7·4 | 476-494 | – | 368-372 | – | – | – | – | – | SAWF/APF |
| 4 | 115·4 | 65·9 | 49·5 | 8·5 | 480 | 10 | 370 | 110 | 0·661 | 0·14 | 1·57 | 11 | APF |
| 5 | 120·7 | 59·2 | 61·5 | 9·3 | 481 | 11 | 373 | 108 | 0·730 | 0·16 | 1·54 | 9·82 | APF GULPING |
| 6 | 125·9 | 52·7 | 73·2 | 10·3 | 481 | 11 | 375 | 106 | 0·816 | 0·16 | 1·51 | 9·64 | APF GULPING |
| 7 | 130·2 | 47·5 | 82·7 | 10·9 | 481 | 11 | 377 | 104 | 0·872 | 0·16 | 1·49 | 9·45 | APF VORTEX FORMATION |
| 8 | 135·9 | 39·8 | 96·1 | 11·7 | 488 | 18 | 379 | 109 | 0·914 | 0·26 | 1·56 | 6·06 | APF VORTEX |
| 9 | 140·7 | 34·8 | 105·8 | 12·2 | 498 | 28 | 380 | 118 | 0·916 | 0·4 | 1·69 | 4·21 | APF VORTEX |
| 10 | 145·2 | 29·3 | 115·9 | 12·8 | 498 | 28 | 384 | 114 | 0·978 | 0·4 | 1·63 | 4·07 | APF/BWF |
| 11 | 150·9 | 22·4 | 128·5 | 13·6 | 510 | 40 | 386 | 124 | 0·996 | 0·57 | 1·77 | 3·10 | BWF |
| 12 | 155·2 | 17·5 | 137·7 | 14·0 | 520 | 50 | 386 | 134 | 0·987 | 0·71 | 1·91 | 2·68 | BWF |
| 13 | 160·3 | 11·3 | 149·0 | 14·5 | 529 | 59 | 387 | 148 | 0·993 | 0·84 | 2·02 | 2·41 | BWF |
| 14 | 165·5 | 5·0 | 160·5 | 15·0 | 538 | 68 | 388 | 150 | 0·999 | 0·97 | 2·14 | 2·21 | BWF |
| 15 | | | | | | | | | | | | | |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 5d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | Z |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 110·3 | 67·8 | 42·5 | 7·7(5) | 476 | 6 | 268 | 208 | 0·438 | ·086 | — | — | APF/SAWF |
| 2 | 116·2 | 63·2 | 53·0 | 8·6 | 477 | 7 | 269 | 208 | 0·487 | ·100 | — | — | APF |
| 3 | 120·5 | 60·0 | 60·5 | 9·2 | 478 | 8 | 270 | 208 | 0·520 | ·107 | — | — | APF |
| 4 | 125·0 | 56·4 | 68·6 | 9·9 | 478 | 8 | 270 | 208 | 0·560 | ·114 | — | — | APF |
| 5 | 130·5 | 52·0 | 78·5 | 10·6 | 480 | 10 | 270 | 210 | 0·598 | ·143 | — | — | APF |
| 6 | 135·6 | 48·4 | 87·2 | 11·1 | 481 | 11 | 271 | 210 | 0·625 | ·157 | — | — | APF |
| 7 | 140·8 | 44·5 | 96·3 | 11·6 | 483 | 13 | 271 | 212 | 0·650 | ·186 | — | — | APF |
| 8 | 145·3 | 41·0 | 104·3 | 12·1 | 484 | 14 | 272 | 212 | 0·677 | ·207 | — | — | APF |
| 9 | 150·5 | 37·2 | 113·3 | 12·6(5) | 485 | 15 | 273 | 212 | 0·708 | ·214 | — | — | APF |
| 10 | 155·3 | 33·3 | 122·0 | 13·1 | 487 | 17 | 273 | 214 | 0·730 | ·243 | — | — | APF |
| 11 | 160·5 | 29·3 | 131·2 | 13·6(5) | 487 | 17 | 272 | 215 | 0·760 | ·243 | — | — | APF |
| 12 | 165·0 | 26·2 | 138·8 | 14·0 | 487 | 17 | 272 | 215 | 0·778 | ·243 | — | — | APF |
| 13 | 170·3 | 22·0 | 148·3 | 14·3 | 488 | 18 | 272 | 216 | 0·793 | ·257 | — | — | APF |
| 14 | 176·0 | 17·8 | 158·2 | 14·9 | 491 | 21 | 272 | 219 | 0·821 | ·30 | — | — | APF/BWF |
| 15 | | | | | | | | | | | | | |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 4·2d |
| INLET LIP ELEVATION | 5mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 95·5 | 79·0 | 16·5 | 4·8(5) | 477 | 7 | 264 | 213 | 0·271 | ·100 | – | – | APF/SAWF Gulping |
| 2 | 100·3 | 75·2 | 25·1 | 6·0 | 477 | 7 | 267 | 210 | 0·338 | ·100 | – | – | APF/SAWF " |
| 3 | 105·5 | 71·0 | 34·5 | 7·0 | 479 | 9 | 268 | 211 | 0·393 | ·129 | – | – | APF |
| 4 | 110·7 | 67·2 | 43·5 | 7·8 | 480 | 10 | 269 | 211 | 0·439 | ·136 | – | – | APF |
| 5 | 120·5 | 59·5 | 61·0 | 9·3 | 481 | 11 | 269 | 212 | 0·521 | ·157 | – | – | APF |
| 6 | 126·3 | 55·0 | 71·3 | 10·1 | 48·2 | 12 | 270 | 212 | 0·566 | ·171 | – | – | APF |
| 7 | 130·7 | 51·8 | 78·9 | 10·6 | 483 | 13 | 271 | 212 | 0·594 | ·186 | – | – | APF |
| 8 | 135·7 | 47·8 | 87·9 | 11·1 | 484 | 14 | 272 | 212 | 0·621 | ·200 | – | – | APF |
| 9 | 140·3 | 44·5 | 95·8 | 11·6 | 485 | 15 | 273 | 212 | 0·650 | ·207 | – | – | APF |
| 10 | 145·8 | 40·3 | 105·5 | 12·2 | 486 | 16 | 273 | 213 | 0·681 | ·229 | – | – | APF |
| 11 | 150·2 | 36·9 | 113·3 | 12·6(5) | 487 | 17 | 273 | 214 | 0·706 | ·243 | – | – | APF |
| 12 | 156·3 | 32·0 | 124·3 | 13·3 | 490 | 20 | 274 | 216 | 0·738 | ·286 | – | – | APF |
| 13 | 160·4 | 29·2 | 131·2 | 13·6 | 491 | 21 | 272 | 219 | 0·750 | ·300 | – | – | APF |
| 14 | 170·3 | 21·5 | 148·8 | 14·5 | 493 | 23 | 272 | 221 | 0·797 | ·321 | – | – | APF |
| 15 | 175·0 | 18·5 | 156·5 | 14·8(5) | 493 | 23 | 273 | 220 | 0·816 | ·329 | – | – | APF |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 4.2d |
| INLET LIP ELEVATION | 15mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 96·0 | 79·4 | 16·6 | 4·9 | 473 | 3 | 263 | 210 | 0·276 | ·043 | – | – | APF/SAUF Gulping |
| 2 | 100·5 | 75·6 | 24·9 | 6·0 | 473 | 3 | 266 | 207 | 0·340 | ·05 | – | – | APF " |
| 3 | 105·4 | 71·7 | 33·7 | 6·9 | 474 | 4 | 268 | 206 | 0·392 | ·057 | – | – | APF " |
| 4 | 110·5 | 67·9 | 42·6 | 7·7(5) | 474 | 4 | 269 | 205 | 0·442 | ·057 | – | – | APF " |
| 5 | 115·2 | 64·2 | 51·0 | 8·4(5) | 475 | 5 | 270 | 205 | 0·481 | ·071 | – | – | APF " |
| 6 | 120·7 | 59·8 | 60·9 | 9·3 | 476 | 6 | 270 | 206 | 0·529 | ·086 | – | – | APF " |
| 7 | 130·5 | 52·3 | 78·2 | 10·5(5) | 479 | 9 | 273 | 208 | 0·596 | ·129 | – | – | APF " |
| 8 | 135·4 | 48·5 | 86·9 | 11·0(5) | 480 | 10 | 272 | 208 | 0·625 | ·143 | – | – | APF " |
| 9 | 140·4 | 44·8 | 95·6 | 11·5(5) | 482 | 12 | 272 | 210 | 0·651 | ·164 | – | – | APF |
| 10 | 145·5 | 40·9 | 104·6 | 12·1 | 482·5 | 12·5 | 273 | 209·5 | 0·682 | ·179 | – | – | APF |
| 11 | 150·7 | 36·8 | 113·9 | 12·7 | 485 | 15 | 273 | 212 | 0·711 | ·214 | – | – | APF |
| 12 | 155·5 | 33·2 | 122·3 | 13·1 | 488 | 18 | 272 | 216 | 0·728 | ·250 | – | – | APF |
| 13 | 160·8 | 29·0 | 131·8 | 13·6(5) | 491 | 21 | 272 | 219 | 0·753 | ·300 | – | – | APF |
| 14 | 170·5 | 21·7 | 148·8 | 14·5 | 491 | 21 | 272 | 219 | 0·799 | ·300 | – | – | APF |
| 15 | 175·7 | 18·2 | 157·5 | 14·8(5) | 492 | 22 | 272 | 220 | 0·816 | ·314 | – | – | APF |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 4·2d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | ✓ |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 123·3 | 85·5 | 37·8 | 7·3 | 476 | 6 | 268 | 208 | 0·413 | ·086 | – | – | APF Gulping under Inlet |
| 2 | 127·0 | 80·2 | 46·8 | 8·1(5) | 477 | 7 | 268 | 209 | 0·460 | ·100 | – | – | APF " " |
| 3 | 131·5 | 73·8 | 57·7 | 9·1 | 479 | 9 | 269 | 210 | 0·512 | ·129 | – | – | APF " " |
| 4 | 134·5 | 69·0 | 65·5 | 9·6(5) | 480 | 10 | 269 | 211 | 0·542 | ·143 | – | – | APF " " |
| 5 | 138·3 | 63·8 | 74·5 | 10·3 | 482 | 12 | 271 | 211 | 0·579 | ·171 | – | – | APF " " |
| 6 | 142·8 | 57·5 | 85·3 | 11·0 | 483 | 13 | 272 | 211 | 0·618 | ·186 | – | – | APF " " |
| 7 | 146·5 | 52·0 | 94·5 | 11·6 | 486 | 16 | 272 | 214 | 0·647 | ·229 | – | – | APF " " |
| 8 | 150·5 | 46·0 | 104·5 | 12·2 | 486 | 16 | 272 | 214 | 0·680 | ·229 | – | – | APF " " |
| 9 | 154·3 | 40·5 | 113·8 | 12·6(5) | 488 | 18 | 273 | 215 | 0·704 | ·257 | – | – | APF " " |
| 10 | 158·5 | 34·2 | 124·3 | 13·2(5) | 491 | 21 | 273 | 218 | 0·732 | ·300 | – | – | APF |
| 11 | 162·5 | 29·0 | 133·5 | 13·7(5) | 490 | 20 | 272 | 218 | 0·760 | ·286 | – | – | APF |
| 12 | 166·5 | 22·5 | 144 | 14·1(5) | 491 | 21 | 272 | 219 | 0·780 | ·300 | – | – | APF |
| 13 | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 3·8d |
| INLET LIP ELEVATION | 5mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 109·8 | 96·0 | 13·8 | 4·5 | 481 | 11 | 263 | 218 | 0·249 | ·157 | – | – | SAWE |
| 2 | 123·5 | 85·0 | 38·5 | 7·4 | 484 | 14 | 267 | 217 | 0·410 | ·200 | – | – | APF |
| 3 | 128·7 | 77·7 | 51·0 | 8·5 | 486 | 16 | 269 | 217 | 0·471 | ·229 | – | – | APF Gulping |
| 4 | 133·3 | 71·0 | 62·3 | 9·4 | 487 | 17 | 269 | 218 | 0·519 | ·243 | – | – | APF " |
| 5 | 138·2 | 64·0 | 74·2 | 10·3 | 490 | 20 | 270 | 220 | 0·561 | ·286 | – | – | APF " |
| 6 | 143·8 | 56·0 | 87·8 | 11·1(5) | 492 | 22 | 272 | 220 | 0·613 | ·314 | – | – | APF " |
| 7 | 148·5 | 49·0 | 99·5 | 11·90 | 494 | 24 | 272 | 222 | 0·652 | ·343 | – | – | APF " |
| 8 | 153·5 | 41·5 | 112·0 | 12·6 | 496 | 26 | 272 | 224 | 0·687 | ·371 | – | – | APF " |
| 9 | 159·0 | 33·5 | 125·5 | 13·3(5) | 497 | 27 | 272 | 225 | 0·726 | ·386 | – | – | APF " |
| 10 | 163·4 | 27·5 | 135·9 | 13·9(5) | 498 | 28 | 272 | 226 | 0·757 | ·40 | – | – | APF " |
| 11 | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | |

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| SIPHON No. | 2 |
| INLET LIP LENGTH | 3·8d |
| INLET LIP ELEVATION | 15mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 84·5 | 124 | 39·5 | 7·5 | 479 | 9 | 268 | 211 | 0·421 | ·129 | – | – | APF |
| 2 | 129·5 | 76·4 | 53·1 | 8·7 | 480 | 10 | 269 | 211 | 0·489 | ·143 | – | – | APF |
| 3 | 134·7 | 69·0 | 65·7 | 9·7 | 482 | 12 | 270 | 212 | 0·544 | ·171 | – | – | APF |
| 4 | 139·2 | 62·2 | 77·0 | 10·5 | 486 | 16 | 270 | 216 | 0·583 | ·229 | – | – | APF |
| 5 | 144·5 | 54·6 | 89·9 | 11·3 | 487 | 17 | 272 | 215 | 0·629 | ·243 | – | – | APF |
| 6 | 149·8 | 47·2 | 102·6 | 12·1 | 490 | 20 | 272 | 218 | 0·669 | ·286 | – | – | APF |
| 7 | 154·5 | 40·2 | 114·3 | 12·7 | 491 | 21 | 272 | 219 | 0·700 | ·300 | – | – | APF |
| 8 | 159·2 | 33·3 | 125·9 | 13·4 | 493 | 23 | 272 | 221 | 0·735 | ·329 | – | – | APF |
| 9 | 164·5 | 25·5 | 139·0 | 13·8(5) | 493 | 23 | 271 | 222 | 0·758 | ·329 | – | – | APF |
| 10 | 169·0 | 19·5 | 149·5 | 14·5 | 496 | 26 | 271 | 225 | 0·789 | ·371 | – | – | APF |
| 11 | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | |

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|---|---|
| SIPHON No. | 2 |
| INLET LIP LENGTH | 3·8d |
| INLET LIP ELEVATION | 10MM |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 123·2 | 86·0 | 37·2 | 7·3 | 473 | 3 | 265 | 208 | 0·413 | ·04 | – | – | APF Gulping |
| 2 | 125·4 | 83·2 | 42·2 | 7·7(S) | 473 | 3 | 266 | 207 | 0·440 | ·04 | – | – | APF " |
| 3 | 130·7 | 75·3 | 55·4 | 8·9 | 475 | 5 | 267 | 208 | 0·504 | ·07 | – | – | APF |
| 4 | 135·3 | 68·7 | 66·5 | 9·8 | 477 | 7 | 268 | 209 | 0·553 | ·10 | – | – | APF |
| 5 | 140·7 | 60·5 | 80·2 | 10·7 | 478 | 8 | 269 | 209 | 0·604 | ·11 | – | – | APF |
| 6 | 145·5 | 53·8 | 91·7 | 11·4(S) | 480 | 10 | 269 | 211 | 0·643 | ·14 | – | – | APF |
| 7 | 150·3 | 47·2 | 103·1 | 12·1 | 482 | 12 | 270 | 212 | 0·678 | ·17 | – | – | APF |
| 8 | 155·5 | 39·2 | 116·3 | 12·8 | 483 | 13 | 271 | 212 | 0·717 | ·18 | – | – | APF |
| 9 | 160·2 | 32·5 | 127·7 | 13·5 | 486 | 16 | 271 | 215 | 0·751 | ·23 | – | – | APF |
| 10 | 165·5 | 24·5 | 141·0 | 14·0 | 488 | 18 | 271 | 217 | 0·775 | ·26 | – | – | APF |
| 11 | 170·3 | 17·5 | 152·8 | 14·7 | 489 | 19 | 271 | 218 | 0·812 | ·27 | – | – | APF |
| 12 | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | |

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|---|---|
| SIPHON No. | 2 |
| INLET LIP LENGTH | 4·0d |
| INLET LIP ELEVATION | 5mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 106·2 | 100·0 | 6·2 | 2·7 | 478 | 8 | 257 | 221 | 0·148 | ·11 | — | — | SAWF/APF |
| 2 | 110·0 | 96·0 | 14 | 4·6 | 480 | 10 | 260 | 220 | 0·253 | ·14 | — | — | APF Gulping under inlet. |
| 3 | 123·2 | 86·0 | 37·2 | 7·3 | 483 | 13 | 267 | 216 | 0·405 | ·19 | — | — | APF " |
| 4 | 125·5 | 83·0 | 42·5 | 7·7(5) | 485 | 15 | 267 | 218 | 0·428 | ·21 | — | — | APF " |
| 5 | 130·0 | 76·5 | 53·5 | 8·7 | 486 | 16 | 267 | 219 | 0·480 | ·23 | — | — | APF " |
| 6 | 135·2 | 68·8 | 66·4 | 9·7(5) | 485 | 15 | 267 | 219 | 0·538 | ·21 | — | — | APF Gulping + side vortices |
| 7 | 140·2 | 62·0 | 78·2 | 10·6 | 488 | 18 | 268 | 220 | 0·583 | ·26 | — | — | APF " " |
| 8 | 145·7 | 53·7 | 92·0 | 11·4 | 493 | 23 | 270 | 223 | 0·623 | ·33 | — | — | APF " " |
| 9 | 150·4 | 46·7 | 103·7 | 12·1(5) | 495 | 25 | 270 | 225 | 0·661 | ·36 | — | — | APF " " |
| 10 | 155·5 | 39·5 | 115·0 | 12·8 | 496 | 26 | 270 | 226 | 0·695 | ·37 | — | — | APF " " |
| 11 | 160·3 | 32·5 | 127·8 | 13·6 | 498 | 28 | 270 | 227 | 0·736 | ·40 | — | — | APF " " |
| 12 | 165·5 | 24·8 | 140·7 | 13·9 | 500 | 30 | 271 | 229 | 0·749 | ·43 | — | — | APF " " |
| 13 | 170·3 | 18·2 | 152·1 | 14·4 | 500 | 30 | 271 | 229 | 0·776 | ·43 | — | - | APF/BWF |
| 14 | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | |

| | |
|---|---|
| SIPHON No. | 2 |
| INLET LIP LENGTH | 4·0d |
| INLET LIP ELEVATION | 15mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 109·3 | 95·9 | 13·4 | 4·4 | 481 | 11 | 262 | 219 | 0·243 | ·16 | – | – | SAWF/APF |
| 2 | 122·5 | 85·7 | 36·8 | 7·3 | 483 | 13 | 266 | 217 | 0·404 | ·19 | – | – | APF Gulping under Inlet |
| 3 | 125·6 | 81·4 | 44·2 | 7·7 | 483 | 13 | 267 | 216 | 0·427 | ·20 | – | – | APF " |
| 4 | 130·3 | 74·6 | 55·7 | 8·6 | 485 | 15 | 268 | 217 | 0·476 | ·21 | – | – | APF Gulping & slight vortices |
| 5 | 135·3 | 67·3 | 68·0 | 9·7 | 487 | 17 | 269 | 218 | 0·536 | ·24 | – | – | APF " " |
| 6 | 140·2 | 60·2 | 80·0 | 10·5(5) | 489 | 19 | 270 | 219 | 0·582 | 0·27 | – | – | APF " " |
| 7 | 145·4 | 52·8 | 92·6 | 11·3(5) | 490 | 20 | 271 | 219 | 0·626 | ·29 | – | – | APF " " |
| 8 | 150·6 | 45·2 | 105·4 | 12·1(5) | 493 | 23 | 271 | 222 | 0·665 | ·33 | – | – | APF " " |
| 9 | 155·5 | 37·5 | 118·0 | 13·1 | 495 | 25 | 271 | 224 | 0·714 | ·36 | – | – | APF Vortex entrainment only |
| 10 | 160·5 | 31·0 | 129·5 | 13·6 | 496 | 26 | 271 | 225 | 0·740 | ·37 | – | – | APF " |
| 11 | 165·8 | 22·8 | 143·0 | 14·1 | 498 | 28 | 271 | 227 | 0·764 | ·40 | – | – | APF " |
| 12 | 170·7 | 16·2 | 154·5 | 14·6 | 500 | 30 | 271 | 229 | 0·787 | ·43 | – | – | APF " |
| 13 | 175·5 | 9·8 | 165·7 | — | 502 | 32 | 271 | 231 | — | – | – | – | APF/BWF |
| 14 | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | |

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|---|---|
| SIPHON No. | 2 |
| INLET LIP LENGTH | 4d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 96·0 | 76·8 | 19·2 | 5·3(5) | 502 | 11 | 262 | 240 | 0·327 | 0·146 | — | — | SAWF {Gulping under inlet |
| 2 | 101·5 | 72·6 | 28·9 | 6·4 | 502 | 11 | 263 | 239 | 0·391 | ·146 | – | – | SAWF/APF {Gulping under inlet |
| 3 | 106·0 | 69·0 | 37·0 | 7·2(5) | 503 | 12 | 263 | 240 | 0·442 | ·159 | – | – | APF {Gulping under inlet |
| 4 | 111·5 | 64·8 | 46·7 | 8·1(5) | 506 | 15 | 264 | 242 | 0·495 | ·199 | – | – | APF " |
| 5 | 116·7 | 60·8 | 55·9 | 8·9 | 508 | 17 | 265 | 243 | 0·540 | ·225 | – | – | APF slight side Vorte |
| 6 | 121·0 | 57·5 | 63·5 | 9·5 | 509 | 18 | 265 | 244 | 0·576 | ·234 | – | – | APF " |
| 7 | 126·8 | 53·1 | 73·7 | 10·2(5) | 513 | 22 | 265 | 247 | 0·616 | ·291 | – | – | APF " |
| 8 | 131·6 | 49·2 | 82·4 | 10·8(5) | 516 | 25 | 266 | 251 | 0·648 | ·331 | — | – | APF " |
| 9 | 136·5 | 45·7 | 90·4 | 11·3(5) | 517 | 26 | 266 | 251 | 0·677 | ·344 | — | – | APF " |
| 10 | 141·4 | 42·2 | 99·2 | 11·9 | 518 | 27 | 266 | 253 | 0·708 | ·358 | – | – | APF " |
| 11 | 146·5 | 38·4 | 108·1 | 12·4 | 524 | 33 | 266 | 258 | 0·730 | ·437 | – | – | APF " |
| 12 | 151·4 | 34·4 | 117·0 | 12·9 | 528 | 37 | 266 | 261 | 0·754 | ·49 | – | – | APF " |
| 13 | 156·0 | 31·0 | 125·0 | 13·3(5) | 528 | 37 | 267 | 262 | 0·781 | ·49 | — | – | APF Strong side Vortice |
| 14 | 161·2 | 26·8 | 134·4 | 13·7 | 528 | 37 | 267 | 262 | 0·802 | ·49 | — | – | APF " |
| 15 | 174·5 | 16·6 | 157·9 | 14·9 | 543 | 52 | 268 | 275 | 0·850 | ·689 | — | – | APF Vortices diminishin |

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| SIPHON No. | 3 |
| INLET LIP LENGTH | 4·0d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 97·0 | 76·5 | 20·5 | 5·4(5) | 506 | 15 | 262 | 244 | 0·330 | ·199 | — | — | SAWF |
| 2 | 110·4 | 66·2 | 44·2 | 7·9 | 511 | 20 | 263 | 248 | 0·474 | ·265 | — | — | APF RAPID GULPING Side Vortices |
| 3 | 115·2 | 62·3 | 52·9 | 8·7 | 512 | 21 | 263 | 247 | 0·523 | ·278 | — | — | APF " |
| 4 | 120·2 | 58·3 | 61·9 | 9·4 | 514 | 23 | 264 | 250 | 0·562 | ·304 | — | — | APF " |
| 5 | 125·4 | 54·3 | 71·1 | 10·0(5) | 518 | 27 | 265 | 253 | 0·597 | ·358 | — | — | APF " |
| 6 | 130·0 | 50·7 | 79·3 | 10·6 | 522 | 31 | 264 | 258 | 0·624 | ·411 | — | — | APF " |
| 7 | 135·5 | 46·8 | 88·7 | 11·2(5) | 523 | 32 | 264 | 259 | 0·661 | ·424 | — | — | APF " |
| 8 | 140·4 | 43·2 | 97·2 | 11·7(5) | 526 | 35 | 264 | 262 | 0·686 | ·464 | — | — | APF " |
| 9 | 145·3 | 39·4 | 105·9 | 12·2(5) | 531 | 40 | 265 | 266 | 0·710 | ·530 | — | — | APF " |
| 10 | 150·5 | 35·2 | 115·3 | 12·8 | 530 | 39 | 265 | 266 | 0·743 | ·517 | — | — | APF " |
| 11 | 155·5 | 31·5 | 124·0 | 13·2(5) | 534 | 43 | 265 | 269 | 0·764 | ·570 | — | — | APF " |
| 12 | 160·2 | 28·0 | 132·2 | 13·7 | 532 | 41 | 265 | 267 | 0·793 | ·543 | — | — | APF " |
| 13 | 165·5 | 24·0 | 141·5 | 14·1 | 542 | 51 | 265 | 277 | 0·801 | ·675 | — | — | APF " |
| 14 | 170·5 | 20·0 | 150·5 | 14·6 | 544 | 53 | 265 | 279 | 0·826 | ·702 | — | — | BWF/APF |
| 15 | 175·3 | 16·8 | 158·5 | 14·9 | 547 | 56 | 265 | 282 | 0·840 | ·742 | — | — | BWF |

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| SIPHON No. | 3 |
| INLET LIP LENGTH | 4·0d |
| INLET LIP ELEVATION | 15mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 97·8 | 75·8 | 22·0 | 5·6 | 497 | 6 | 260 | 237 | 0·344 | ·08 | – | – | SAWF |
| 2 | 110·2 | 66·2 | 44·0 | 7·9 | 500 | 9 | 262 | 238 | 0·484 | ·12 | – | – | APF/SAWF |
| 3 | 115·8 | 62·2 | 53·6 | 8·7 | 502 | 11 | 262 | 240 | 0·531 | ·147 | – | – | APF GULPING AT INLET |
| 4 | 120·3 | 58·2 | 62·1 | 9·4 | 504 | 13 | 263 | 241 | 0·573 | ·173 | – | – | APF " |
| 5 | 125·0 | 54·6 | 70·4 | 10·0 | 506 | 15 | 263 | 243 | 0·607 | ·20 | – | – | APF Gulping And side vortices |
| 6 | 130·5 | 50·6 | 79·9 | 10·7 | 507 | 16 | 264 | 243 | 0·649 | ·213 | – | – | APF " |
| 7 | 135·5 | 46·8 | 88·7 | 11·2(5) | 509 | 18 | 264 | 245 | 0·680 | ·24 | – | – | APF " |
| 8 | 140·3 | 43·0 | 97·3 | 11·7(5) | 511 | 20 | 264 | 246 | 0·708 | ·27 | – | – | APF " |
| 9 | 145·2 | 39·3 | 105·9 | 12·2(5) | 512 | 21 | 264 | 248 | 0·735 | ·28 | – | – | APF " |
| 10 | 150·5 | 35·2 | 115·3 | 12·8 | 515 | 24 | 264 | 251 | 0·764 | ·32 | – | – | APF " |
| 11 | 155·5 | 31·4 | 124·1 | 13·2(5) | 517 | 26 | 265 | 252 | 0·789 | ·37 | – | – | APF " |
| 12 | 160·6 | 27·5 | 133·1 | 13·8 | 516 | 25 | 265 | 251 | 0·824 | ·33 | – | – | APF " |
| 13 | 165·3 | 24·6 | 140·7 | 14·1 | 523 | 32 | 266 | 257 | 0·832 ? | ·43 | – | – | APF " |
| 14 | 170·8 | 20·0 | 150·8 | 14·6 | 528 | 37 | 266 | 261 | 0·854 | ·49 | – | – | APF/BWF " |
| 15 | 175·0 | 16·7 | 158·3 | 14·9 | 539. | 48 | 266 | 262 | | ·64 | – | – | BWF |

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| SIPHON No. | 3 |
| INLET LIP LENGTH | 4·0d |
| INLET LIP ELEVATION | 5mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS ('' or cms) | MANOMETER RULE RHS ('' or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 96·0 | 76·2 | 19·8 | 5·4 | 505 | 14 | 263 | 242 | 0·328 | 0·187 | – | – | SAWF slight Gulping at inlet |
| 2 | 100·5 | 72·8 | 27·7 | 6·2(5) | 506 | 15 | 265 | 241 | 0·381 | ·200 | – | – | SAWF " |
| 3 | 105·3 | 69·0 | 36·3 | 7·15 | 508 | 17 | 265 | 243 | 0·434 | ·227 | – | – | APF side vortex Gulping at Inlet |
| 4 | 110·2 | 65·3 | 44·9 | 8·0 | 510 | 19 | 266 | 244 | 0·484 | ·253 | – | – | APF " |
| 5 | 115·5 | 61·2 | 54·3 | 8·9 | 513 | 22 | 267 | 247 | 0·535 | ·293 | – | – | APF " |
| 6 | 120·2 | 57·2 | 63·0 | 9·6 | 514 | 23 | 267 | 247 | 0·578 | ·307 | – | – | APF " |
| 7 | 125·4 | 53·3 | 72·1 | 10·2 | 517 | 26 | 267 | 250 | 0·610 | ·347 | – | – | APF " |
| 8 | 130·6 | 49·4 | 81·2 | 10·8 | 520 | 29 | 267 | 253 | 0·642 | ·387 | – | – | APF/BWF vortex only |
| 9 | 136·0 | 45·4 | 90·6 | 11·3(5) | 526 | 35 | 267 | 259 | 0·667 | ·467 | – | – | APF/BWF " |
| 10 | 140·4 | 42·1 | 98·3 | 11·8 | 536 | 45 | 267 | 269 | 0·680 | ·60 | – | – | BWF occasional air |
| 11 | 146·0 | 38·0 | 108·0 | 12·4 | 551 | 60 | 268 | 283 | 0·697 | ·80 | – | – | BWF " |
| 12 | 150·0 | 35·2 | 114·8 | 12·8 | 556 | 65 | 270 | 336 | 0·660 | ·867 | – | – | BWF |
| 13 | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | |

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| SIPHON No. | 3 |
| INLET LIP LENGTH | 3·8d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 97·8 | 75·5 | 22·3 | 5·6(S) | 498 | 7 | 260 | 238 | 0·346 | ·093 | – | – | SAWF - Hunting |
| 2 | 110·5 | 65·8 | 44·7 | 7·9(S) | 500 | 9 | 263 | 237 | 0·488 | ·119 | – | – | APF/SAWF |
| 3 | 115·5 | 62·0 | 53·5 | 8·7 | 501 | 10 | 263 | 238 | 0·533 | ·132 | – | – | APF Rapid Gulping |
| 4 | 120·3 | 58·0 | 62·3 | 9·4(S) | 504 | 13 | 263 | 241 | 0·576 | ·172 | – | – | APF " |
| 5 | 125·3 | 54·2 | 71·1 | 10·0(S) | 508 | 17 | 264 | 244 | 0·608 | ·225 | – | – | APF side vortex |
| 6 | 130·2 | 50·5 | 79·7 | 10·6(S) | 508 | 17 | 264 | 244 | 0·645 | ·225 | – | – | APF " |
| 7 | 135·5 | 46·4 | 89·1 | 11·2(S) | 512 | 21 | 264 | 248 | 0·675 | ·278 | – | – | APF " |
| 8 | 140·5 | 42·7 | 97·8 | 11·8 | 513 | 22 | 264 | 249 | 0·707 | ·291 | – | – | APF " |
| 9 | 145·4 | 39·0 | 106·4 | 12·3 | 513 | 22 | 264 | 249 | 0·737 | ·291 | – | – | APF " |
| 10 | 150·3 | 35·4 | 114·9 | 12·8 | 514 | 23 | 265 | 249 | 0·767 | ·305 | – | – | APF " |
| 11 | 155·5 | 31·2 | 124·3 | 13·3 | 518 | 27 | 265 | 253 | 0·791 | ·358 | – | – | APF " |
| 12 | 160·5 | 27·7 | 132·8 | 13·7(S) | 518 | 27 | 265 | 253 | 0·817 | ·358 | – | – | APF Strong Vortices |
| 13 | 165·5 | 23·8 | 141·7 | 14·1(S) | 522 | 31 | 265 | 257 | 0·835 | ·411 | – | – | APF " |
| 14 | 170·0 | 20·4 | 149·6 | 14·6 | 526 | 35 | 265 | 261 | 0·858 | ·464 | – | – | APF/BWF " |
| 15 | 175·5 | 16·4 | 159·1 | 14·9(S) | 533 | 42 | 266 | 267 | 0·865 | ·556 | – | – | APF/BWF " |

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| SIPHON No. | 3 |
| INLET LIP LENGTH | 4·2d |
| INLET LIP ELEVATION | 5mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 97.0 | 76.4 | 20.6 | 5.4(5) | 508 | 17 | 261 | 247 | 0.328 | .225 | — | — | SAWF Rapid Gulping |
| 2 | 110.2 | 66.2 | 44.0 | 7.9 | 511 | 20 | 261 | 250 | 0.472 | .265 | — | — | APF " |
| 3 | 115.3 | 62.0 | 53.3 | 8.7 | 512 | 21 | 262 | 250 | 0.520 | .278 | — | — | APF Rapid Gulping slight side Vortices |
| 4 | 120.2 | 58.2 | 62.0 | 9.4 | 514 | 23 | 263 | 251 | 0.561 | .305 | — | — | APF " |
| 5 | 125.5 | 54.2 | 71.3 | 10.0(5) | 516 | 25 | 264 | 252 | 0.596 | .331 | — | — | APF " |
| 6 | 130.2 | 50.5 | 79.7 | 10.6(5) | 519 | 28 | 264 | 255 | 0.631 | .371 | — | — | APF " |
| 7 | 135.3 | 46.6 | 88.7 | 11.2 | 522 | 31 | 264 | 258 | 0.659 | .411 | — | — | APF " |
| 8 | 140.2 | 43.0 | 97.2 | 11.7(5) | 523 | 32 | 264 | 259 | 0.690 | .424 | — | — | APF " |
| 9 | 145.2 | 39.3 | 105.9 | 12.2(5) | 526 | 35 | 264 | 262 | 0.716 | .464 | — | — | APF occ. gulping LARGE VORTICES |
| 10 | 150.7 | 35.0 | 115.7 | 12.8 | 528 | 37 | 264 | 264 | 0.745 | .490 | — | — | APF " |
| 11 | 155.7 | 31.2 | 124.5 | 13.3 | 531 | 40 | 265 | 266 | 0.770 | .530 | — | — | APF " |
| 12 | 160.3 | 27.7 | 132.6 | 13.7(5) | 532 | 41 | 265 | 267 | 0.795 | .543 | — | — | APF " |
| 13 | 165.6 | 23.6 | 142.0 | 14.2 | 537 | 46 | 265 | 272 | 0.813 | .609 | — | — | APF " |
| 14 | 170.3 | 20.0 | 150.3 | 14.6 | 538 | 47 | 265 | 273 | 0.835 | .632 | — | — | APF " |
| 15 | 175.8 | 15.8 | 160.0 | 14.9(5) | 540 | 49 | 265 | 275 | 0.852 | .649 | — | — | APF " |

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| SIPHON No. | 3 |
| INLET LIP LENGTH | 4.2d |
| INLET LIP ELEVATION | 15mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 97·4 | 76·2 | 21·2 | 5·5 | 502 | 11 | 262 | 240 | 0·336 | ·146 | — | — | SAWF |
| 2 | 105·0 | 70·2 | 34·8 | 7·0 | 503 | 12 | 263 | 240 | 0·427 | ·159 | — | — | SAWF/APF Gulping |
| 3 | 110·3 | 66·2 | 44·1 | 7·9 | 505 | 14 | 264 | 241 | 0·481 | ·185 | — | — | APF " |
| 4 | 115·4 | 62·2 | 53·2 | 8·7 | 507 | 16 | 263 | 244 | 0·527 | ·212 | — | — | APF " |
| 5 | 120·3 | 58·4 | 61·9 | 9·4 | 508 | 17 | 264 | 244 | 0·569 | ·225 | — | — | APF Gulping & slight side vortex |
| 6 | 125·4 | 54·5 | 70·9 | 10·0(5) | 511 | 20 | 264 | 247 | 0·605 | ·265 | — | — | APF " " |
| 7 | 130·7 | 50·5 | 80·2 | 10·7 | 514 | 23 | 264 | 250 | 0·641 | ·305 | — | — | APF slight side vortices |
| 8 | 135·5 | 46·7 | 88·8 | 11·2 | 515 | 24 | 264 | 251 | 0·668 | ·325 | — | — | APF " |
| 9 | 140·0 | 43·4 | 96·6 | 11·7 | 519 | 28 | 264 | 255 | 0·693 | ·377 | — | — | APF " |
| 10 | 145·2 | 39·5 | 105·7 | 12·2(5) | 520 | 29 | 265 | 255 | 0·726 | ·384 | — | — | APF " |
| 11 | 150·3 | 35·5 | 114·8 | 12·8 | 523 | 32 | 265 | 258 | 0·754 | ·424 | — | — | APF " |
| 12 | 155·5 | 31·5 | 124·0 | 13·2(5) | 527 | 36 | 266 | 261 | 0·775 | ·477 | — | — | APF " |
| 13 | 160·5 | 27·7 | 132·8 | 13·7(5) | 523 | ? | 266 | — | — | — | — | — | APF " |
| 14 | 165·2 | 24·0 | 141·2 | 14·1 | 532 | 41 | 266 | 266 | 0·817 | ·543 | — | — | APF |
| 15 | 170·2 | 20·5 | 149·7 | 14·5(5) | 538 | 47 | 267 | 271 | 0·836 | ·623 | — | — | APF |

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| SIPHON No. | 3 |
| INLET LIP LENGTH | 4·2d |
| INLET LIP ELEVATION | 10mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100·5 | 73·6 | 26·9 | 6·2 | 501 | 10 | 262 | 239 | 0·379 | ·133 | — | — | SAWF/APF |
| 2 | 110·3 | 66·0 | 44·3 | 7·9 | 504 | 13 | 262 | 242 | 0·480 | ·173 | — | — | APF Gulping under inlet |
| 3 | 115·3 | 62·2 | 53·1 | 8·6(5) | 505 | 14 | 263 | 242 | 0·526 | ·187 | — | — | APF " " " |
| 4 | 120·2 | 58·2 | 62·0 | 9·4 | 506 | 15 | 264 | 242 | 0·571 | ·20 | — | — | APF " " " |
| 5 | 125·5 | 54·3 | 71·2 | 10·0(5) | 509 | 18 | 264 | 245 | 0·607 | ·24 | — | — | APF " " " |
| 6 | 130·3 | 50·3 | 80·0 | 10·6(5) | 511 | 20 | 266 | 245 | 0·643 | ·267 | — | — | APF Gulping + slight side vortex |
| 7 | 135·5 | 46·8 | 88·7 | 11·2(5) | 514 | 23 | 265 | 249 | 0·674 | ·307 | — | — | APF " " |
| 8 | 140·2 | 43·3 | 96·9 | 11·7 | 516 | 25 | 265 | 251 | 0·698 | ·33 | — | — | APF " " |
| 9 | 145·3 | 39·0 | 106·3 | 12·2(5) | 517 | 26 | 265 | 252 | 0·730 | ·346 | — | — | APF " " |
| 10 | 150·3 | 35·5 | 114·8 | 12·7(5) | 520 | 29 | 265 | 255 | 0·755 | ·387 | — | — | APF " strong side vortex |
| 11 | 155·5 | 31·2 | 124·3 | 13·2(5) | 527 | 36 | 265 | 262 | 0·774 | ·48 | — | — | APF " " |
| 12 | 160·2 | 28·0 | 132·2 | 13·7 | 532 | 41 | 264 | 268 | 0·791 | ·547 | — | — | APF " " |
| 13 | 165·2 | 24·0 | 141·2 | 14·1(5) | 538 | 47 | 264 | 274 | 0·810 | ·627 | — | — | APF " " |
| 14 | 170·5 | 20·2 | 150·3 | 14·6(5) | 538 | 47 | 266 | 272 | 0·837 | ·627 | — | — | APF " swirling vortex |
| 15 | 175·5 | 16·2 | 159·3 | 14·9 | 542 | 51 | 266 | 276 | 0·849 | ·680 | — | — | APF " " |

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| SIPHON No. | 3 |
| INLET LIP LENGTH | 3·8d |
| INLET LIP ELEVATION | 5mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 98.5 | 75.2 | 23.3 | 5.7(5) | 509 | 18 | 261 | 248 | 0.345 | .24 | – | – | SAWF/APF |
| 2 | 110.5 | 65.8 | 44.7 | 7.9(5) | 511 | 20 | 262 | 249 | 0.476 | .267 | – | – | APF Gulping under inlet |
| 3 | 115.3 | 62.1 | 53.2 | 8.8 | 514 | 23 | 263 | 251 | 0.525 | .307 | – | – | AFF " + slight side vortex |
| 4 | 120.5 | 58.2 | 62.3 | 9.5 | 515 | 24 | 263 | 252 | 0.566 | .320 | – | – | APF " " |
| 5 | 125.5 | 54.3 | 71.2 | 10.1 | 519 | 28 | 265 | 254 | 0.599 | .373 | – | – | APF " " |
| 6 | 130.3 | 50.5 | 79.8 | 10.7 | 521 | 30 | 265 | 256 | 0.632 | .40 | – | – | APF " " |
| 7 | 135.2 | 46.8 | 88.4 | 11.2(5) | 523 | 32 | 264 | 259 | 0.662 | .427 | – | – | APF " " |
| 8 | 140.3 | 43.2 | 97.1 | 11.7 | 523 | 32 | 264 | 259 | 0.689 | .427 | – | – | APF " " |
| 9 | 145.2 | 39.5 | 105.7 | 12.3 | 526 | 35 | 265 | 261 | 0.719 | .467 | – | – | APF " " |
| 10 | 150.2 | 35.5 | 114.7 | 12.8 | 529 | 38 | 265 | 264 | 0.744 | .507 | – | – | APF No Gulping. Side vortices still present |
| 11 | 155.2 | 31.3 | 123.9 | 13.3 | 531 | 40 | 265 | 266 | 0.770 | .533 | – | – | APF " " |
| 12 | 160.3 | 27.5 | 132.8 | 13.7(5) | 534 | 43 | 264 | 270 | 0.791 | .573 | – | – | APF " " |
| 13 | 165.3 | 24.0 | 141.3 | 14.1(5) | 538 | 47 | 265 | 273 | 0.810 | .627 | – | – | APF " " |
| 14 | 170.8 | 19.8 | 151.0 | 14.6 | 542 | 51 | 265 | 277 | 0.829 | .68 | – | – | APF " " |
| 15 | 175.8 | 16.5 | 159.3 | 14.9 | 547 | 56 | 265 | 282 | 0.838 | .75 | – | – | APF " " |

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| SIPHON No. | 3 |
| INLET LIP LENGTH | 3.8d |
| INLET LIP ELEVATION | 15mm |
| TAILWATER LEVEL | Y |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 95·8 | 76·5 | 19·3 | 5·3 | 520? | — | 65 | — | — | — | — | — | Hunting 15 sec cycles |
| 2 | 100·6 | 72·5 | 28·1 | 6·3 | 506 | 15 | 69 | 437 | 0·287 | 0·15 | – | – | APF |
| 3 | 105·3 | 69·1 | 36·2 | 7·2 | 507 | 16 | 77 | 430 | 0·331 | 0·16 | – | – | APF |
| 4 | 110·5 | 64·8 | 45·7 | 8·0(5) | 509 | 18 | 85 | 424 | 0·372 | 0·18 | – | – | APF |
| 5 | 115·5 | 61·1 | 54·4 | 8·8 | 511 | 20 | 98 | 413 | 0·412 | 0·20 | – | – | APF |
| 6 | 120·2 | 57·5 | 62·7 | 9·5 | 514 | 23 | 107 | 407 | 0·448 | 0·23 | – | – | APF |
| 7 | 125·2 | 53·7 | 71·5 | 10·1 | 515 | 24 | 116 | 399 | 0·481 | 0·24 | – | – | APF |
| 8 | 130·5 | 49·6 | 80·9 | 10·7(5) | 517 | 26 | 125 | 392 | 0·517 | 0·26 | – | – | APF |
| 9 | 135·5 | 45·7 | 89·8 | 11·3 | 518 | 27 | 132 | 386 | 0·547 | 0·27 | – | – | APF |
| 10 | 140·3 | 42·3 | 98·0 | 11·8 | 519 | 28 | 141 | 378 | 0·578 | 0·28 | – | – | APF |
| 11 | 145·7 | 38·1 | 107·6 | 12·3(5) | 523 | 32 | 153 | 370 | 0·611 | 0·32 | – | – | APF |
| 12 | 150·7 | 34·2 | 116·5 | 12·9 | 527 | 36 | 161 | 366 | 0·642 | 0·36 | – | – | APF |
| 13 | 155·4 | 30·5 | 124·9 | 13·3 | 533 | 42 | 166 | 367 | 0·661 | 0·42 | – | – | APF / BWF |
| 14 | 160·5 | 26·8 | 133·7 | 13·8 | 545 | 54 | 174 | 371 | 0·682 | 0·54 | – | – | BWF |
| 15 | | | | | | | | | | | | | |

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| SIPHON No. | 3 |
| INLET LIP LENGTH | 3·8d |
| INLET LIP ELEVATION | 15mm |
| TAILWATER LEVEL | WEIR POSN 1. |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100 | 73·2 | 26·8 | 6·2 | 507 | 16 | 86 | 421 | 0·288 | 0·16 | – | – | S.AWF |
| 2 | 105·2 | 69·2 | 36·0 | 7·1(5) | 507 | 16 | 92 | 415 | 0·334 | 0·16 | – | – | APF |
| 3 | 110·5 | 65·2 | 45·3 | 8·0 | 509 | 18 | 99 | 410 | 0·376 | 0·18 | – | – | APF |
| 4 | 115·7 | 61·0 | 54·7 | 8·8 | 511 | 20 | 108 | 403 | 0·417 | 0·20 | – | – | APF |
| 5 | 120·3 | 57·5 | 62·8 | 9·5 | 515 | 24 | 114 | 401 | 0·452 | 0·24 | – | – | APF |
| 6 | 125·5 | 53·3 | 72·2 | 10·1 | 515 | 24 | 118 | 397 | 0·483 | 0·24 | – | – | APF |
| 7 | 130·3 | 49·6 | 80·7 | 10·7 | 517 | 26 | 130 | 387 | 0·518 | 0·26 | – | – | APF |
| 8 | 135·2 | 46·0 | 89·2 | 11·3 | 520 | 29 | 142 | 378 | 0·553 | 0·29 | – | – | APF |
| 9 | 140·5 | 42·0 | 98·5 | 11·8 | 522 | 31 | 150 | 372 | 0·582 | 0·31 | – | – | APF |
| 10 | 145·5 | 38·5 | 107·0 | 12·3 | 523 | 32 | 161 | 362 | 0·615 | 0·32 | – | – | APF |
| 11 | 150·4 | 34·5 | 115·9 | 12·8(5) | 524 | 33 | 173 | 351 | 0·653 | 0·33 | – | – | APF |
| 12 | 155·5 | 30·5 | 125·0 | 13·3 | 527 | 36 | 181 | 346 | 0·681 | 0·36 | – | – | APF |
| 13 | 160·5 | 26·7 | 133·8 | 13·8 | 530 | 39 | 193 | 337 | 0·716 | 0·39 | – | – | APF |
| 14 | 165·8 | 22·8 | 143·0 | – | 535 | 44 | 198 | 337 | – | – | – | – | BWF |
| 15 | | | | | | | | | | | | | |

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| SIPHON No. | 3 |
| INLET LIP LENGTH | 3·8d |
| INLET LIP ELEVATION | 15mm |
| TAILWATER LEVEL | weir Posn 2 |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100·5 | 72·7 | 27·8 | 6·3 | 507 | 16 | 82 | 425 | 0·291 | 0·16 | – | – | SAWF/APF |
| 2 | 105·2 | 69·0 | 36·2 | 7·1(5) | 507 | 16 | 94 | 413 | 0·335 | 0·16 | – | – | SAWF/APF |
| 3 | 110·3 | 65·0 | 45·3 | 8·0 | 509 | 18 | 100 | 409 | 0·377 | 0·18 | – | – | APF |
| 4 | 115·5 | 61·2 | 54·3 | 8·8 | 511 | 20 | 109 | 402 | 0·418 | 0·20 | – | – | APF |
| 5 | 120·4 | 57·3 | 63·1 | 9·5 | 514 | 23 | 118 | 396 | 0·454 | 0·23 | – | – | APF |
| 6 | 125·5 | 53·5 | 72·0 | 10·1 | 515 | 24 | 121 | 394 | 0·484 | 0·24 | – | – | APF |
| 7 | 130·5 | 49·5 | 81·0 | 10·7(5) | 520 | 29 | 125 | 395 | 0·515 | 0·29 | – | – | APF |
| 8 | 135·3 | 45·8 | 89·5 | 11·3 | 522 | 31 | 137 | 385 | 0·548 | 0·31 | – | – | APF |
| 9 | 140·3 | 42·1 | 98·2 | 11·8 | 522 | 31 | 148 | 374 | 0·581 | 0·31 | – | – | APF |
| 10 | 145·5 | 38·3 | 107·2 | 12·3(5) | 524 | 33 | 160 | 364 | 0·616 | 0·33 | – | – | APF |
| 11 | 150·8 | 34·0 | 116·8 | 12·9 | 525 | 34 | 170 | 355 | 0·652 | 0·34 | – | – | APF |
| 12 | 155·5 | 30·5 | 125·0 | 13·3 | 526 | 35 | 182 | 344 | 0·683 | 0·35 | – | – | APF |
| 13 | 160·5 | 26·8 | 133·7 | 13·8 | 527 | 36 | 193 | 334 | 0·719 | 0·36 | – | – | APF |
| 14 | 165·2 | 23·0 | 142·2 | – | 528 | 37 | 198 | 330 | – | – | – | – | APF |
| 15 | 170·5 | 19·5 | 151·0 | – | 528 | 37 | 204 | 324 | – | – | – | – | APF |

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| SIPHON No. | 3 |
| INLET LIP LENGTH | 3·8d |
| INLET LIP ELEVATION | 15mm |
| TAILWATER LEVEL | Weir Posn 3 |

| TEST No. | MANOMETER RULE LHS (" or cms) | RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100·5 | 72·8 | 27·7 | 6·3 | 507 | 16 | 86 | 421 | 0·292 | 0·16 | – | – | APF |
| 2 | 105·3 | 69·2 | 36·1 | 7·1(5) | 507 | 16 | 97 | 410 | 0·336 | 0·16 | – | – | APF |
| 3 | 110·5 | 64·8 | 45·7 | 8·0(5) | 508 | 17 | 108 | 400 | 0·383 | 0·17 | – | – | APF |
| 4 | 115·5 | 61·2 | 54·3 | 8·8 | 510 | 19 | 117 | 393 | 0·423 | 0·19 | – | – | APF |
| 5 | 120·4 | 57·3 | 63·1 | 9·5 | 513 | 22 | 122 | 391 | 0·457 | 0·22 | – | – | APF |
| 6 | 125·3 | 53·0 | 72·3 | 10·1(5) | 514 | 23 | 131 | 383 | 0·494 | 0·23 | – | – | APF |
| 7 | 130·3 | 49·8 | 80·5 | 10·7 | 519 | 28 | 134 | 385 | 0·519 | 0·28 | – | – | APF |
| 8 | 135·2 | 46·0 | 89·2 | 11·2(5) | 519 | 28 | 144 | 375 | 0·553 | 0·28 | – | – | APF |
| 9 | 140·5 | 41·8 | 98·7 | 11·8(5) | 521 | 30 | 152 | 369 | 0·587 | 0·30 | – | – | APF |
| 10 | 145·6 | 38·2 | 107·4 | 12·3(5) | 523 | 32 | 157 | 366 | 0·614 | 0·32 | – | – | APF |
| 11 | 150·5 | 34·5 | 116·0 | 12·8(5) | 527 | 36 | 175 | 352 | 0·652 | 0·36 | – | – | APF |
| 12 | 155·5 | 30·5 | 125·0 | 13·3 | 530 | 39 | 180 | 350 | 0·677 | 0·39 | – | – | APF |
| 13 | 160·3 | 26·9 | 133·4 | 13·8 | 531 | 40 | 192 | 339 | 0·713 | 0·40 | – | – | APF |
| 14 | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | |

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| SIPHON No. | 3 |
| INLET LIP LENGTH | 3·8d |
| INLET LIP ELEVATION | 15mm |
| TAILWATER LEVEL | weir Posn 4 |

| TEST No. | MANOMETER RULE LHS (" or cms) | MANOMETER RULE RHS (" or cms) | MANOMETER HEAD (mm) | DISCHARGE RATE, Q (L/S) | U/S LEVEL (mm) | HEAD $h_1$ (mm) | D/S LEVEL (mm) | WORKING HEAD H, (mm) | COEFF. OF DISCHARGE $C_D$ | $\frac{h_1}{d}$ | $\frac{H}{d}$ | $\frac{H}{h_1}$ | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100·2 | 73·1 | 27·1 | 6·2 | — | — | — | — | — | - | - | - | Rapid Hunting |
| 2 | 105·2 | 69·2 | 36·0 | 7·1(5) | 507 | 16 | 89 | 418 | 0·333 | 0·16 | - | - | SAWF/APF |
| 3 | 110·5 | 65·0 | 45·5 | 8·0 | 509 | 18 | 96 | 413 | 0·375 | 0·18 | - | - | APF |
| 4 | 115·1 | 61·5 | 53·6 | 8·7 | 510 | 19 | 105 | 405 | 0·412 | 0·19 | - | - | APF |
| 5 | 120·2 | 57·3 | 62·9 | 9·5 | 513 | 22 | 116 | 397 | 0·454 | 0·22 | - | - | APF |
| 6 | 125·2 | 53·5 | 71·7 | 10·1 | 515 | 24 | 126 | 389 | 0·487 | 0·24 | - | - | APF |
| 7 | 130·7 | 49·5 | 81·2 | 10·7(5) | 517 | 26 | 135 | 382 | 0·524 | 0·26 | - | - | APF |
| 8 | 135·7 | 45·8 | 89·9 | 11·3 | 519 | 28 | 140 | 379 | 0·553 | 0·28 | - | - | APF |
| 9 | 140·8 | 42·2 | 98·6 | 11·8(5) | 522 | 31 | 147 | 375 | 0·582 | 0·31 | - | - | APF |
| 10 | 145·4 | 38·2 | 107·2 | 12·3(5) | 525 | 34 | 154 | 371 | 0·610 | 0·34 | - | - | APF |
| 11 | 150·3 | 34·7 | 115·6 | 12·8 | 527 | 36 | 161 | 366 | 0·637 | 0·36 | - | - | APF |
| 12 | 155·5 | 30·5 | 125·0 | 13·3 | 534 | 43 | 175 | 359 | 0·668 | 0·43 | - | - | APF |
| 13 | 160·4 | 27·0 | 133·4 | 13·8 | 546 | 45 | 185 | 361 | 0·691 | 0·45 | - | - | APF/BWF |
| 14 | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | |

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| SIPHON No. | 3 |
| INLET LIP LENGTH | 3·8d |
| INLET LIP ELEVATION | 15mm |
| TAILWATER LEVEL | weir Posn 6 |