ESCUELA SUPERIOR POLITÉCNICA DEL LITORAL

Facultad de Ingeniería en Mecánica y Ciencias de la Producción

"Instalación del sistema de Bombeo y Riego del Campus "Gustavo Galindo V." Área de Ingenierías"

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AGRADECIMIENTO

Es mi deseo expresar mi gratitud a cada una de las personas que de diversas maneras han colaborado para que la realización de este trabajo se materialice, especialmente a los ingenieros mecánicos:
Ing. Víctor Hugo González e Ing. Ernesto Martínez Director de Tesis.

DEDICATORIA

A mi esposa, hijos y con el mayor de los afectos a mis padres y hermanos.

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LUIS ALBERTO MEZA PACHECO

RESUMEN

El Campus Gustavo Galindo V. en lo que corresponde al área de Ingeniería era regado por aspersión sólo en el área comprendida por los jardines que circundan el Edificio del Rectorado. Siendo el agua potable la utilizada en el riego o el agua del lago que era transportada por un carro tanque y suministrada al sistema con una bomba de presión accionada por un motor a gasolina.

Como la idea desde que nació El Campus, era regar todas las áreas verdes que corresponden a los jardines del Área de ingenierías se procedió a realizar los estudios preliminares y diseño de lo que sería un riego automático por aspersión para regar la totalidad de los jardines.

La información correspondiente al diseño del riego se encuentra en dos tesis, las mismas que fueron dirigidas por el Ing. Víctor Hugo González, cuya participación en la totalidad del proyecto, inclusive de la instalación, fue fundamental para el éxito de este cometido, que le había sido encargado por la Fundación Pro Campo. Los títulos de las tesis mencionadas son:

a. "Diseño de una red por aspersión del Campus Prosperina "Gustavo Galindo" Sección Ingenierías".

b. "Cálculo y diseño de un sistema de bombeo de una red de riego por aspersión para el Campus Prosperina "Gustavo Galindo" Sección Ingenierías".

Por lo anteriormente mencionado este trabajo consiste en la implantación del sistema de riego desde el montaje del grupo de bombeo, la instalación de las tuberías de conducción, y los accesorios que garantizan un buen funcionamiento del sistema y finalmente la evaluación del sistema instalado.

Para llevar a cabo este cometido se considera los aspectos relacionados por el grupo de bombeo en si, tanto en lo eléctrico como en lo mecánico. En lo eléctrico se considera capacidad de los transformadores cable de la acometida, tablero de arranque, mientras que en lo mecánico se considera la curva de rendimiento de la bomba, aplicación de leyes de afinidad.

En cuanto al sistema de riego se realizará la instalación de la tubería de conducción y sus accesorios se determinan los elementos necesarios para evitar el colapso de la misma. Se automatiza las válvulas dispuestas en cada

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ABREVIATURAS

Amp	Amperio
atm	Atmósfera
Hp	Caballo de Potencia
cm	Centímetro
cm^2	Centímetro cuadrado
FS	Factor de Seguridad
psi	Libras por Pulgada Cuadrada
L	Longitud
GPM	Galones por minuto
Hz	Herzt
h	Hora
Kg	Kilogramo
K.w	Kilovatio
KVA	Kilo Voltio Amperios
l	Litro
m	Metro
m^2	Metro Cuadrado
m^3	Metros Cúbicos
m /h	Metro cúbico por hora
mm	Milímetro
mm/día	Milímetros por día
mm/mt	Milímetros por metro
mm/h	Milímetros por hora
Mpa	Megapascal
ft^2	Pie Cuadrado
%	Porcentaje
PVC	Policloruro de Vinilo
pulg	Pulgadas
rpm	Revoluciones por Minuto
S	Segundo
T	Temperatura
V	Voltios

SIMBOLOGÍA

Φ	Diámetro
a	Separación de tubería desde borde de zanja
y	Profundidad de Zanja
x	Ancho de la Zanja
ΔL	Expansión en centímetros
°C	Grado Centigrados
Q	Caudal
H	Altura dinámica total
BHP	Potencia al freno.
N	Velocidad Angular.
Pot	Potencia
db	Distancia al eje de la bomba
dm	Distancia al eje de motor
h	Holgura paralela
Vo	Volumen de amortiguador
P_m	Presión de funcionamiento del sistema
P_s	Presión máxima *admisible*.
P_r	Presión minima deseada.
P_0	Presión de llenado
M	Módulo
Etc	Uso consuntivo
Cc	Capacidad de campo
PM	Punto de Marchitez
S_a	Cantidad de retención de agua
D	Profundidad Radicular
p	Porcentaje de agua disponible en la raiz
l_n	Lámina neta
l_b	Lámina bruta
F	Frecuencia de Riego
T	Taza de infiltración

T_r	Tiempo de riego
$N°Hr$	Número de horas día
$N°Pos$	Número de Posiciones día
A_t	Área total a regar
A_d	Área diaria a regar
A_p	Área por posición o módulo
$N°Asp$	Número de aspersores por módulo
P_r	Precipitación
S	Espaciamiento entre aspersores
L	Espaciamiento entre alas de aspersores
■, ▲	Arreglo (Cuadrado, o triangular)

ÍNDICE DE PLANOS

INTRODUCCIÓN

Es primordial y necesario remitirse a las tesis que anteceden este trabajo. Se trata de dos tesis que contienen todo lo relacionado al riego de las áreas verdes del Campus " Gustavo Galindo V. " área de Ingenierías, de estas se toma toda la información que será de utilidad para laz instalación y evaluación del sistema de riego. Las tesis en referencia son:

Diseño de la Red de Aspersión para el Campus " Gustavo Galindo V.".

Diseño de un Sistema de Bombeo para el sistema de riego del Campus "Gustavo Galindo V."

En la primera de las nombradas se encuentra toda la información agronómica del cultivo de césped que en este caso se trata la variedad denominada Bermuda de la costa, es aquí donde se analiza la planta, el suelo, la cantidad y calidad de agua necesaria para el buen desarrollo de la misma.

La cantidad de agua aplicarse, la frecuencia de riego, el intervalo de riego fueron calculados tomando en consideración parámetros climatológicos como la velocidad del viento, temperatura ambiente, humedad relativa, se consideró también las características del suelo como la permeabilidad, la capacidad de campo, la infiltración y finalmente los aspectos relacionados al cultivo como la evapotranspiración , la profundidad de la raíz, punto de marchitez. La tabla 1 contiene estos resultados.

TABLA 1

RESULTADOS AGRONÓMICOS.

Tipo de cultivo:	Bermuda de la Costa
Tipo de suelo:	Franco Arcilloso
Capacidad de campo:	270mm/mt
Punto de Marchitez:	130mm/mt
Humedad disponible:	140 mm /mt
Uso Consuntivo:	5,484 mm/dia
Agotamiento Permisible en la zona de raíces:	50.75 mm/mt
Profundidad Radicular:	60 cm.
Lámina neta:	29.4 mm
Eficiencia de Riego:	70%
Lamina Bruta:	42 mm
Frecuencia de Riego:	5.35 días
Tasa de infiltración:	8 mm / hr
Tiempo de riego:	3.67 hr
Número de horas día:	11 hr
Número de posiciones día:	3
Area total a regar:	18.6 Has
Area diaria a regar:	3.47 Has

También configura el riego seleccionando y ordenando los aspersores para cada una de las superficies a regar, para ello se fundamenta en las características de los aspersores, es decir en el caudal, presión y radio de alcance del chorro.

En la segunda Tesis se puede observar el DISEÑO DE LA RED DE TUBERÍAS, para lo cual se determina las pérdidas por fricción en diferentes diámetros de tubería PVC; conociendo el caudal necesario para regar las superficies en estudio. Utilizando algunos criterios de diseño se encuentra el diámetro óptimo a utilizar, partiendo el cálculo desde la tubería de los aspersores o lateral, luego continúa con las secundarías, y por último la principal que es la que conducirá la totalidad del flujo.

Es importante tener presente estos criterios de diseño:

1. Las pérdidas admisibles tanto de la tubería secundaria, como de la principal debe ser como máximo el 20% de la presión de operación del aspersor.

2. Las pérdidas admisibles en la tubería lateral no debe exceder el 10% del promedio de operación del aspersor.

En el caso de laterales en contra pendiente la pérdida admisible debida a la fricción será igual al 10% del promedio de la presión de elevación de la tubería menos la presión que pierde por la diferencia de altura.

En el caso de laterales en dirección de la pendiente, la pérdida admisible en presión debido a la fricción será igual al 10% de la presión promedio de operación del aspersor más la presión que gana por la diferencia de altura en la tubería.

Calcula la altura dinámica total y con el caudal selecciona la bomba y determina la potencia del motor.

Resultados del sistema de riego

TABLA 2

RESULTADOS DEL SISTEMA DE RIEGO

Capacidad del Lago:	400.000 m3
Capacidad aprovechable:	80.000 m3
Caudal:	41 m3/hr
Altura dinámica total:	66 mt
Potencia:	16.26 hp
Diámetro Tuberia principal:	110 mm
Máxima Velocidad del agua:	1.5mt/s
Presión del aspersor:	35 psi
Módulos de riego:	21
Aspersores Turf Rotor	(Tiempo de riego 3.48 hr o 0.87hr)
Aspersores Turf Spray	(Tiempo de riego 0.85 hr o 0.22 hr)

Una vez conocida toda la información concerniente al diseño del sistema de riego y del cálculo para la selección de la bomba, el presente trabajo consiste en la ejecución de la instalación. Por lo que se realiza el cronograma de actividades (Diagrama de Gantt). Se inicia el procedimiento con la señalización del terreno para luego abrir las zanjas en donde se enterrará la tubería PVC, se dan las instrucciones para unir los tramos y accesorios. En la línea principal se prevé el efecto del fenómeno conocido como golpe de ariete, una vez que se ha empotrado y tapado la tubería dejando a la intemperie los accesorios y las uniones, se realiza la prueba hidrostática para determinar la presencia de fugas.

La información pertinente relacionada a las listas de tuberías, accesorios, aspersores, y válvulas que se instalaran fue determinada en un trabajo de Tesis anterior a esta, la misma que esta aprobada y que corresponde a la Referencia (1).

En el Apéndice A se presenta el Cronograma de actividades para la instalación.

La evaluación del sistema de riego permitirá obtener datos reales para parámetros como la presión de salida en los aspersores, la precipitación de agua y la medida de la evapotranspiración; que nos determinará si efectivamente le estamos entregando el agua que precisa el césped y eficientemente. Esto sería una primera parte de la evaluación y que estaría relacionada con las necesidades hídricas del cultivo. La segunda parte de la evaluación esta relacionada con el equipo de bombeo y la conducción del caudal por las tuberías en donde se analizará si se cumplen las consideraciones de diseño en lo relacionado a perdidas de presión admisibles en los diferentes ramales de la red y se determina el rango de máxima eficiencia en el cuál funciona la bomba.

CAPITULO 1

1. INSTALACIÓN DE LA RED.

1.1. GENERALIDADES.

En los sistemas de riego fijos, ya sea para regar jardines o cultivos por micro-aspersión o aspersión, la tubería que se utiliza para la conducción del agua es el PVC, por sus múltiples ventajas que superan a cualquier tubería de otro material hasta ahora conocido.

Las ventajas de las tuberías de PVC son:

Alta resistencia a la tensión.

Bajo coeficiente de fricción.

Resistencia al impacto.

No altera olor ni sabor al fluido.

Auto extinguible.

No se forman incrustaciones

No la atacan los roedores

Resistencia a la electrólisis

Bajo peso

La tubería de PVC puede ser espiga-campana o unión z, la diferencia está en que la primera es pegable y la otra es mediante acople mecánico.

1.2. SEÑALIZACIÓN DEL TERRENO.

Con el diseño de la red de riego lo que primero se realiza sobre el terreno es la marcación mediante estaquillas de lo que será la línea principal o madre, para lo cual nos valemos de un topógrafo, quién nos marcará los vértices y alineará las estaquillas que finalmente darán como resultado la línea de apertura de la zanja. Las estaquillas normalmente van pintadas del color con el que aparecen identificadas en el plano del que se sirve el topógrafo para realizar su trabajo.

FIGURA 1.1 MARCACIÓN DEL TERRENO MEDIANTE ESTAQUILLAS.

1.3. CONSTRUCCIÓN DE ZANJAS.

Los dos parámetros a considerar en la excavación de la zanja son el ancho y la profundidad. El ancho dependerá del diámetro de la tubería que se instale, deberá ser lo suficientemente amplia para permitir una apropiada cobertura del material de relleno alrededor de la tubería, aproximadamente 30 cm. mayor al diámetro del tubo. Se recomienda 60, 30,15 cm. de profundidad para la tubería principal, secundaria y lateral respectivamente según Norma UNE 53331.

Las dimensiones de la zanja fueron:

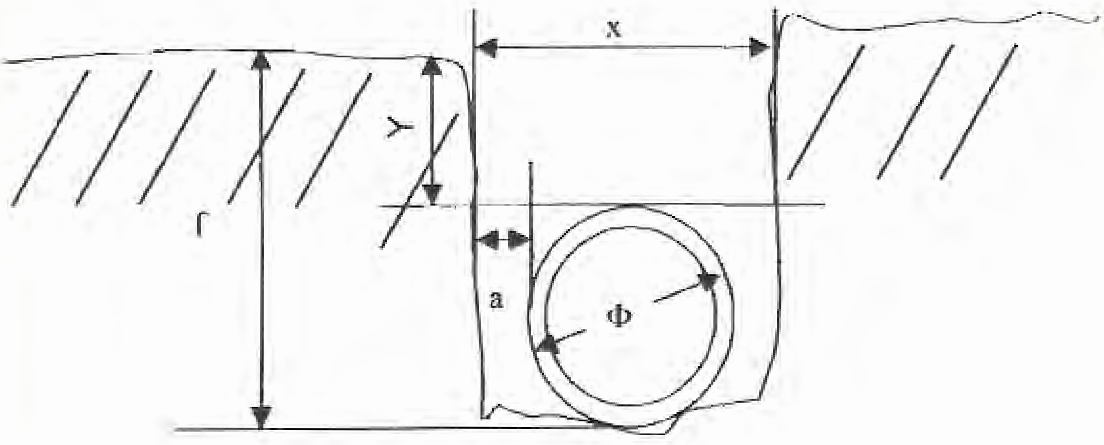


FIGURA 1.3.1 DIMENSIONES DE LAS ZANJAS.

Φ = 110 mm	a = 50 mm
Y = 400 mm	x = 200 mm

FIGURA 1.3.2 REMOCIÓN DE ADOQUINES

Para la apertura de zanjas se removió adoquines y se rompió carpeta asfáltica.

1.4. TENDIDO DE LA LÍNEA PRINCIPAL.

Se abren las zanjas y se instala la tubería principal o madre. De acuerdo al Plano A1 de la Referencia (1). La tubería utilizada cumple con la Norma INEN 1373.

TABLA 3

ESPECIFICACIONES DE MATERIAL DE TUBERÍA DE LÍNEA PRINCIPAL

Material	Unidad	Tipo	Cant.
Tubería	110mm. X6m.	Unión Z.	1450 m.

FIGURA 1.4 APERTURA DE ZANJA E INSTALACIÓN TUBERÍA PRINCIPAL.

La tubería que se empleará para la línea principal es tubería PVC tipo unión Z de 0.86 MPA en tramos de 6m. y de 110 mm. de diámetro. Los accesorios tipo pegables y las derivaciones se las hicieron con collares.

1.4.1. INSTRUCCIONES PARA LA UNIÓN DE TUBERÍAS Y ACCESORIOS.

El acoplamiento de dos tubos con unión Z es sencillo. Se coloca grasa en el extremo liso del primer tubo y luego se lo introduce en el otro que tiene el anillo de caucho.

Los pasos a seguir para efectuar una correcta unión son:

a) Limpiar y secar prolijamente el interior de la unión en especial la ranura, dejándola libre de cualquier rebaba.

b) Limpiar el sello de caucho y asegúrese que quedé bien asentado.

c) Poner grasa uniformemente en la longitud de la espiga.

d) Mover la espiga de tal manera que apenas se introduzca en la unión.

e) Verificar que el bisel de la espiga este alineado con respecto al eje del tubo, y que la longitud de entrada esté marcada.

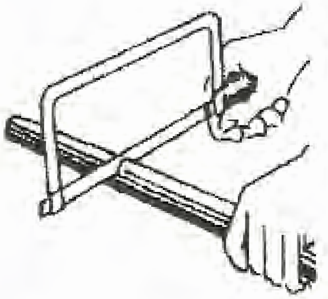
f) Alinear las dos tuberias perfectamente.

g) Penetre la espiga hasta la marca de entrada manteniendo fija la unión.

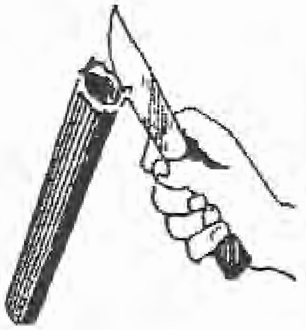
Los accesorios tales como codos, tees fueron pegables. Las instrucciones para soldar se muestran en el siguiente gráfico.

INSTRUCCIONES PARA SOLDAR

TUBERIAS *plastigama* PVC



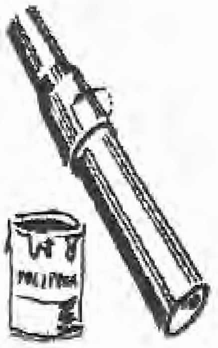
1. Corte el tubo con una sierra de mano. Asegúrese que el corte esté a escuadra, utilizando una caja de guía.



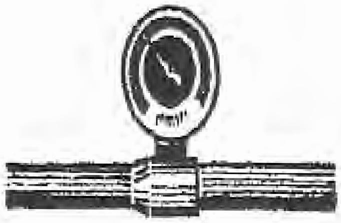
2. Quite las rebabas y las marcas dejadas por la sierra (use una lima o papel de lija).

3. Limpie bien las superficies o partes que se van a conectar, tanto del tubo como del accesorio. Use un trapo limpio, humedecido con el líquido limpiador (POLILIMPIA).

4. Aplique generosamente soldadura líquida POLIPEGA al exterior del extremo del tubo, por lo menos en un largo igual a la campana del accesorio.



5. Aplique una capa delgada de POLIPEGA en el interior de la campana del accesorio.



6. Una el tubo con el accesorio asegurándose de un buen asentamiento y déle un cuarto de vuelta para distribuir la soldadura. Mantenga firmemente la unión por unos 30 segundos.

FIGURA 1.4.1. INSTRUCCIONES PARA PEGAR TUBERIAS PVC

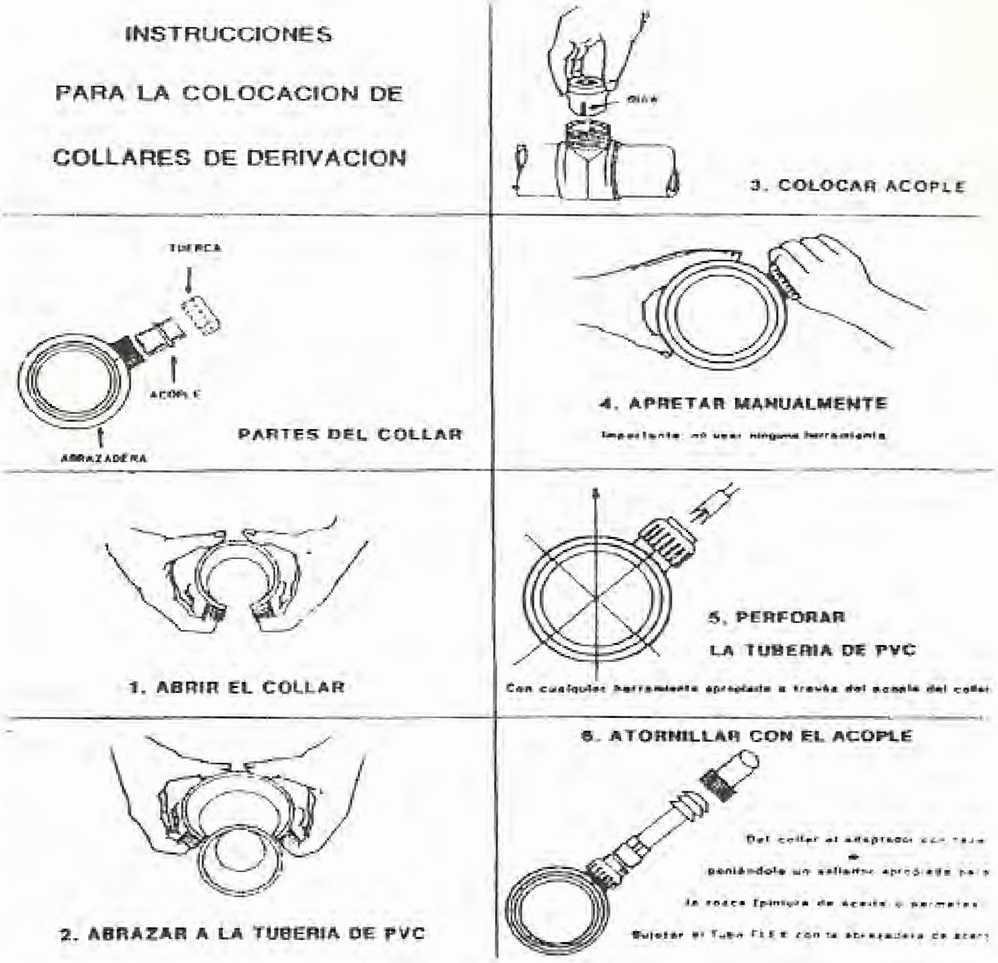


FIGURA 1.4.2. INSTRUCCIONES PARA LA COLOCACIÓN DE COLLARES

1.4.2. CONSIDERACIONES EN LA LINEA PRINCIPAL

Dilatación de la tubería PVC.- Los cambios de temperatura a que están sometidas la tierra y el agua por efectos de los rayos solares producirá sobre la tubería una expansión térmica que se la calcula con la siguiente fórmula.

$$\Delta L = C\ (T_2 - T_1)$$

Donde:

ΔL = Expansión en centímetros

C = Coeficiente de dilatación (8.5×10^{-5} cm./cm./°C para el PVC)

T_2 = Temperatura máxima (°C)

T_1 = Temperatura mínima (°C)

L = Longitud de la tubería en centímetros.

Sin embargo, cuando el incremento de temperatura es menor de 15°C, la expansión térmica en la tubería se la considera despreciable, ya que los cambios de dirección en el tendido de la red, le dan la flexibilidad para absorber tales incrementos de longitud.

Golpe de Ariete. Este fenómeno se produce cuando el flujo de una columna de agua es detenido intempestivamente por el cierre de una válvula, por ejemplo, lo que produce una variación de velocidad que hace que la inercia se convierta en un incremento de presión.

depende de:

Presión

Diámetro de la tubería

Tipo de suelo

Tipo de abrasivo.

Las siguientes tablas muestran la resistencia de los suelos y la fuerza de empuje sobre los accesorios.

Para obtener el área de anclaje se tiene:

ÁREA DE ANCLAJE = Fuerza de empuje/ Resistencia del Terreno.

Empuje en los anclajes. Ver Tabla 4.

TABLA 4

EMPUJE DE LOS ANCLAJES (A 7 KG./CM^2 DE PRESIÓN INTERNA).

Diámetro del tubo	Curva de 90^0	Curva de 45^0	Curva de 221/2	Tee
38 mm.	188Kg.	102Kg.	52 Kg.	134Kg.
50	293	158	82	206
60	624	231	118	300
75	633	342	175	447
100	1.041	556	288	735
150	2.435	1.320	666	1.723
200	3.960	2.800	1.450	2.433

TABLA 5

RESISTENCIA DE TERRENOS.

Tipo de suelo	Kg./m^2
Lodos	0
Barro suave	4.880
Arena	9.760
Arena y grava	14.640
Arena y grava mezclada con barro	18.520

Para obtener el área de empuje que soportará el anclaje en un accesorio, cuando está sometido a una presión menor o mayor a los 7 Kg. /cm^2, se lo hace proporcionalmente con los valores de la tabla 4. Para calcular las fuerzas de empuje se deberá tomar en consideración el golpe de ariete y tomarse un factor de seguridad de 2:1.

Para el anclaje de la tubería se la realizará por medio de un empotramiento de cemento; este consiste en fundir bloques de concreto que incluyan la tubería, el accesorio y la pared de la zanja. Las dimensiones de dicho bloque son función de la resistencia del suelo y las presiones hidráulicas.

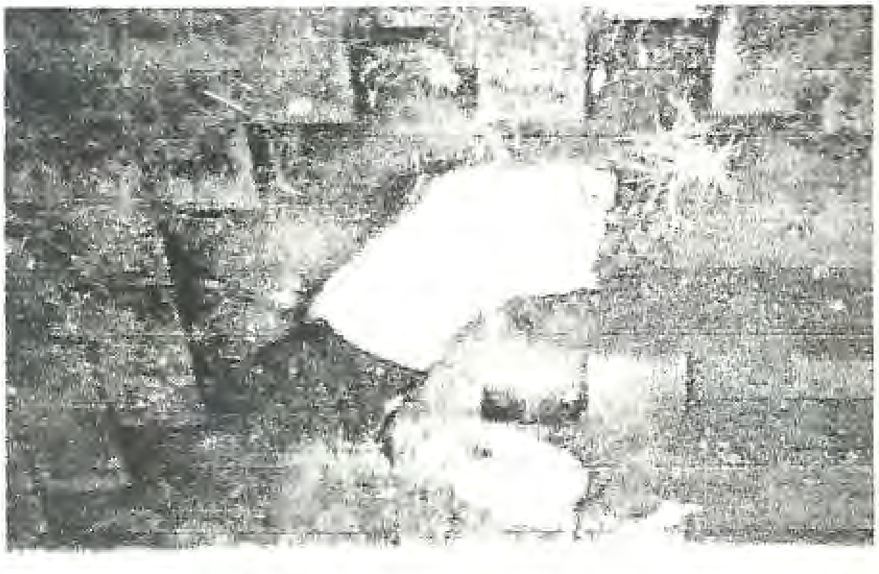


FIGURA1.4.3 EMPOTRAMIENTO DE TUBERÍA CON BLOQUE CONCRETO

Relleno de Zanjas.

Una vez instalada la tubería sobre el fondo de la zanja, está deberá estar nivelada, sin piedras ni objetos duros o punzantes que puedan dañarla, luego se procede a taparla con material fino y seleccionado, envolviéndola y compactándola en todo su alrededor. Si el fondo es de roca u otro material duro, se hace una cama de arena de aproximadamente 10cm. Si se encuentra el fondo de la zanja con agua se estabiliza con gravilla de 0.5 pulg. máximo y una capa de 30 cm.

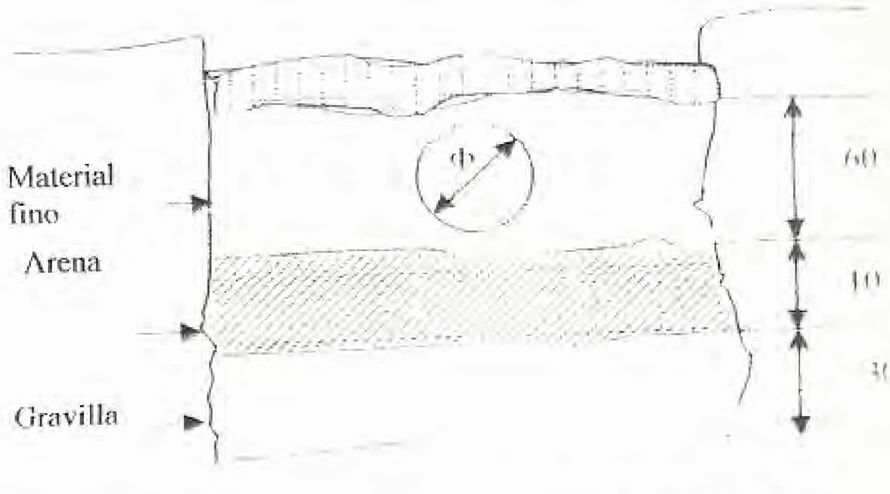


FIGURA 1.4.3.1 MATERIAL PARA RELLENO DE ZANJA

Primeramente el relleno de la zanja se la hace tapando la tubería, pero dejando a la intemperie las uniones y accesorios con la finalidad de ubicar las fugas de agua y proceder a eliminarlas.

Finalmente se realiza el relleno y compactación de la zanja.

FIGURA 1.4.3.2 RELLENO DE ZANJAS Y CUBIERTA DE TUBERÍAS.

1.5. PRUEBA HIDROSTÁTICA.

La prueba hidrostática tiene como objetivo determinar la existencia de algún escape de agua en la tubería principal. Para realizarla se rellena provisionalmente la zanja dejando sin cubrir las uniones de la tubería. Esta prueba consiste en llenar la tubería completamente de agua y elevarle la presión hidrostática a 3.5 Kg./cm^2 de la presión de trabajo u operación. Teóricamente, dicha presión debe permanecer constante por lo menos una hora, de no ser así existe algún escape de agua que lo debe detectar e identificar para corregirlo y repetir la prueba. La prueba debe realizarse mínimo 48 horas después del pegado de la tubería.

El equipo que se utiliza para la prueba hidrostática esta compuesto de:

Bomba de pistón de accionamiento manual.

Válvula cheque horizontal

Manómetro

Llave de globo

Válvula horizontal de retención

Tanque alimentador.

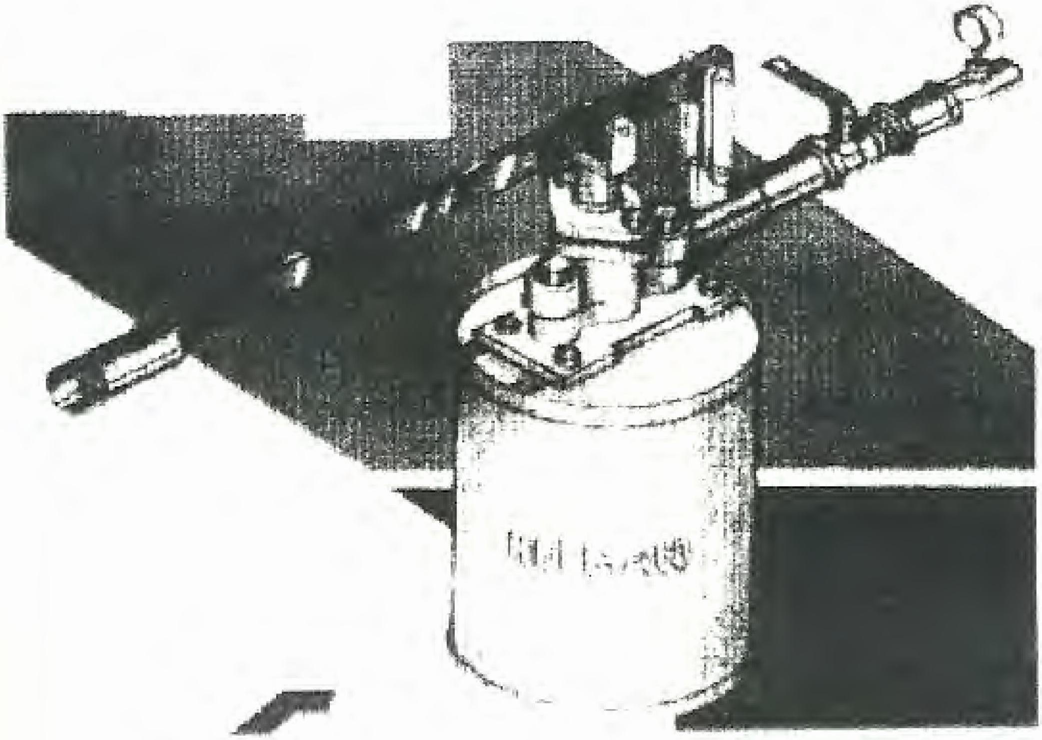


FIGURA 1.5.1 EQUIPO PARA PRUEBA HIDROSTÁTICA

CAPITULO 2

2. INSTALACIÓN DEL EQUIPO DE BOMBEO Y SUS COMPONENTES.

En este capítulo se procede a certificar los elementos a utilizar en el sistema.

2.1. Descripción de las partes del bombeo.

El sistema no puede operar sino tiene una bomba con su respectivo motor para impulsar el agua. El montaje del grupo de bombeo se basó en las normas dadas por el Hydraulic Institute Standards para bombas centrífugas.

2.1.1. Bomba

La selección de la bomba centrífuga se la realiza con los dos datos fundamentales que son: caudal y altura dinámica total, los mismos que fueron obtenidos de la tesis: Cálculo y Diseño de un Sistema de

Bombeo de una red de riego por aspersión para el Campus Prosperina "Gustavo Galindo" sección ingenierías.

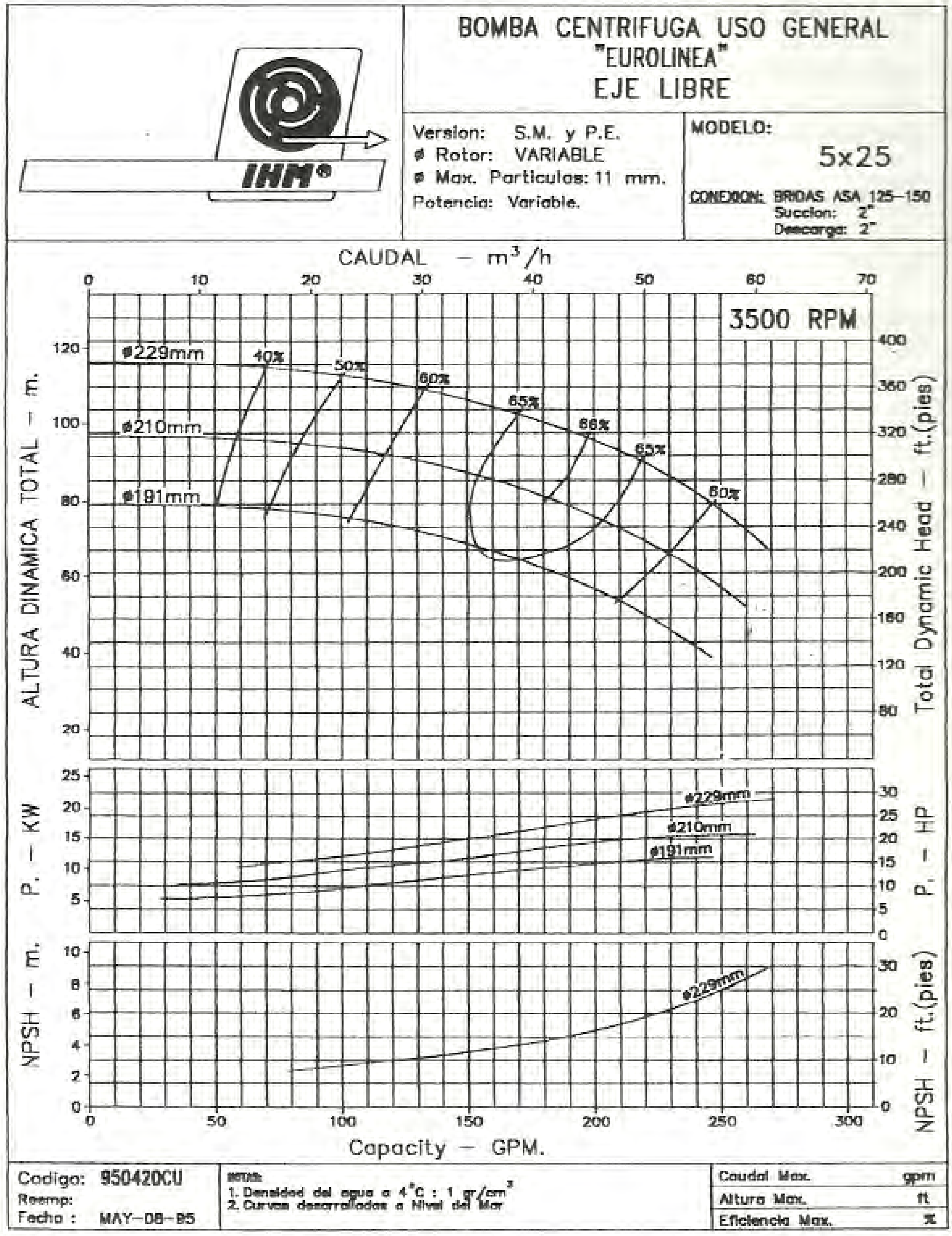


FIGURA 2.1.1 CURVA CARACTERISTICA DE LA BOMBA

El caudal dé diseño corresponde a 41m3/h y la altura dinámica total 66m. De la curva característica de la bomba seleccionada, ver Figura 2.1.1 se tiene de fábrica que el diámetro del impeler de la bomba es de 229mm, por lo que de acuerdo a los parámetros, de caudal y de presión que se requieren, siendo la capacidad de bombeo mayor a la requerida, por lo tanto se aplica las leyes de afinidad para determinar el diámetro del impelente.

FORMULAS DE LA LEY DE AFINIDAD

Con la velocidad de la bomba constante N = 3.500 rpm

1) $$\frac{\Phi_1}{\Phi_2} = \frac{Q_1}{Q_2}$$

2) $$\left(\frac{\Phi_1}{\Phi_2}\right)^2 = \frac{H_1}{H_2}$$

3) $$\left(\frac{\Phi_1}{\Phi_2}\right)^3 = \frac{BHP_1}{BHP_2}$$

Q = Caudal $\left[m^3/h\right]$

H = Alturá total [m]

BHP= Potencia [Hp]

N = Velocidad [rpm]

Φ= Diámetro [mm]

Aplicando (2)

$$\Phi_2 = (H_2/ H_1)^{1/2}\,\Phi_1$$

$$\Phi_2 = (66/100)^{1/2} \times 229 = 186.04$$

Para realizar esta reducción del impeler se procede a desmontar la carcaza de la bomba y aflojar la tuerca de seguridad. Una vez afuera el impeler, disminuir el diámetro, se lo realiza en el torno. El gráfico 1.3 muestra dimensiones de la bomba.

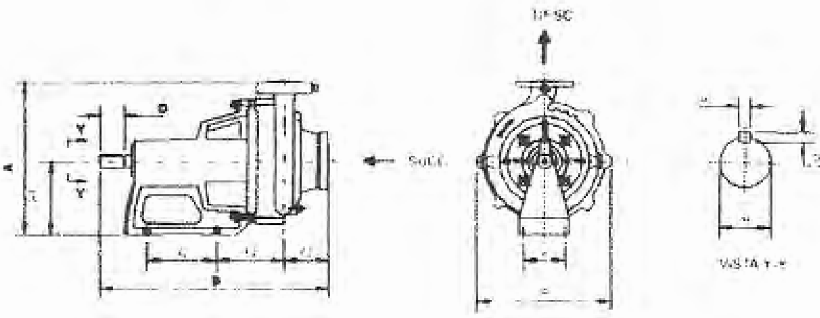
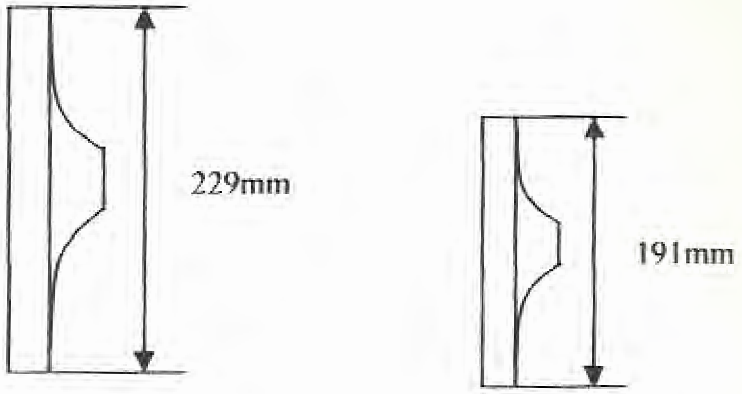


FIGURA 2.1.1.1 VISTAS Y NOMENCLATURA GENERAL DE LA BOMBA.

TABLA 6

DIMENSIONES DE LA BOMBA

Modelo	5*25 SM
DIAMETROS **Succión y descarga**	2" X 2"
A	376 mm
B	500 mm
C	161 mm
D	52 mm
E	125 mm
F	316 mm
F1	150 mm
F2	150 mm
F3	95 mm
GXG1	1/4"x1/4"
H H	28.59 mm 28.57 mm
PESO	58 Kg



Diámetro original　　　　Diámetro modificado

FIGURA 2.1.1.2 GRAFICO DEL IMPELER ANTES Y DESPUES DE SU MODIFICACIÓN

2.1.2 Motor

Las características del motor que va accionar la bomba se la determina en función de algunos aspectos:

La potencia del motor será igual a la potencia que consume la bomba en su punto de operación aumentada en un porcentaje que representa un factor de seguridad. Aplicando la fórmula (3) tenemos que la potencia del motor que se necesita es de 17,40Hp; si se toma como factor de servicio de 1.25, en el mercado encontramos motores eléctricos de 15,20, 25 HP, por lo que se seleccionó un motor de 20 HP siendo así muy conservadores.

$$BHP_2 = BHP_1 \left(\frac{\Phi_2}{\Phi_1} \right)^3$$

$$BHP_2 = 24 \left(\frac{191}{229} \right)^3$$

El valor de 24 en la fórmula anterior ha sido tomado de la curva de la bomba.

$BHP_2 = 13.9$

$Pot = BHP_2 * FS = 13.9 * 1.25 = 17.40HP$

La velocidad del motor debe ser igual a la velocidad a la que debe girar la bomba, por que serán acoplados directamente mediante un acople flexible.

La energía eléctrica que se tiene en el lugar es trifásica, 220V, 60hz. Otro aspecto a considerar es la capacidad de los transformadores que se requieren, cuya selección esta en función de la potencia del motor y del tipo de conexión que se haga con los transformadores.

El hecho de usar equipos que utilicen circuitos inductivos implica la presencia de corrientes reactivas, las cuales se incrementan cuando el número y capacidad de estos circuitos lo hacen.

La corrección del factor de potencia, el cuál es un índice de cuál es la proporción de cargas reactivas en el sistema es exigida por las empresas eléctricas debido a que contribuyen a sobresaturar el sistema con corrientes reactivas no utilizables, obligando ha usar cables de distribución de mayor capacidad, este problema podría también estar presente en la selección de los elementos que suministrarán energía a los equipos, en este caso las bombas, obligando a un sobre dimensionamiento de ellos.

Las conexiones consideradas son:

- **Conexión en delta abierto,** conexión que se realiza con dos transformadores cuando no existen las tres fases.

- **Conexión de tres fases completas,** que se la hace con tres transformadores.

En el Campus si existe corriente trifásica por lo que se utilizó la conexión de tres fases completas.

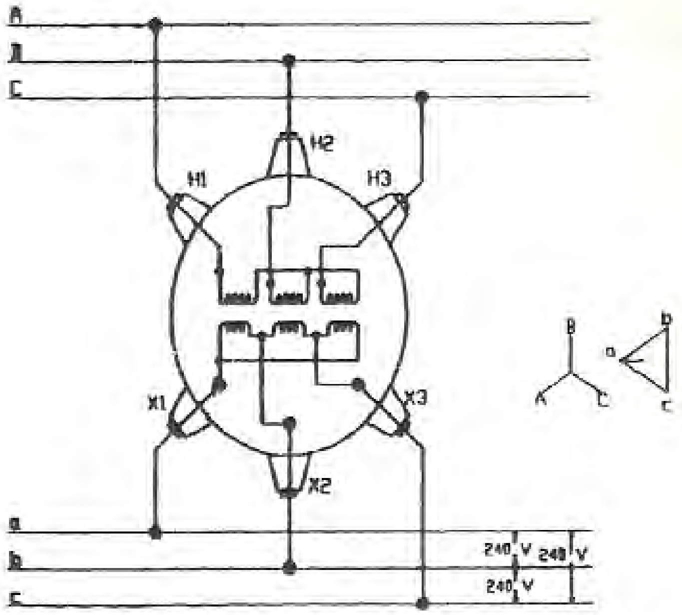


FIGURA 2.1.2.1 DIAGRAMA DE CONEXIÓN ESTRELLA DELTA SERVICIO A 240 V.

Los cálculos eléctricos y las características de los dispositivos a utilizar fueron proporcionados por un Ingeniero Eléctrico. Respecto a las posibles variaciones de los cálculos realizados y sus efectos, debido a que el motor de la bomba que había disponible en el mercado era de 25 Hp, dado que en ese momento no habían motores de 20 Hp recibimos la indicación de que la variación de 5Hp que representa un 25% de la Potencia calculada no implicaba cambios que obliguen a la inclusión de dispositivos adicionales o de mayor capacidad para la operación de la bomba, con lo que se descartó la colocación de un banco de capacitores que reduzca las corrientes reactivas para esa bomba.

TABLA 7

CAPACIDAD DE TRANSFORMADORES RECOMENDADA PARA SERVICIO A MOTORES TIPO CORRIENTE ALTERNA CON INTENSIDADES A PLENA CARGA

Potencia Hp	220 - 230 Voltios				440-480 Voltios			
	1 Fase		3 Fases		1 Fase		3 Fases	
	Amps	Kva	Amps	Kva	Amps	Kva	Amps	Kva
1/2	4.9	1.5	2.0	3.0	2.5	1.5	1.0	3.0
3/4	6.9	2.0	2.8	3.0	3.5	2.0	1.4	3.0
1	8.0	3.0	3.6	3.0	4.0	3.0	1.8	3.0
1 1/2	10.0	3.0	5.2	3.0	5.0	3.0	2.6	3.0
2	12.0	5.0	6.8	6.0	6.0	5.0	3.4	6.0
3	17.0	5.0	9.6	6.0	8.5	5.0	4.8	6.0
5	28.0	7.5	15.2	9.0	14.0	7.5	7.6	9.0
7 1/2	40.0	15.0	22.0	15	21.0	15.0	11.0	15.0
10	50.0	15	28.0	15	26.0	15.0	14.0	15.0
15	68.0	25	42.0	30.0	34.0	25.0	21.0	30.0
20	88.0	25	54.0	30.0	44.0	25.0	27.0	30.0
25	110.0	37.5	680	45.0	55.0	37.5	34.0	45.0
30	136.0	37.5	80.0	45.0	68.0	37.5	40.0	45.0
40	176.0	50.0	104.0	75.0	88.0	50.0	52.0	75.0
50	216.0	75.0	130.0	75.0	108.0	75.0	65.0	75.0
60	—	—	154.0	75.0	—	—	77.0	75.0
75	—	—	192.0	112. 5	—	—	96.0	112.5
100	—	—	248.0	112. 5	—	—	124.0	112.5

Nota. La capacidad recomendada en KVA incluye un 10% de reserva para asumir arranques frecuentes de los motores

En la tabla 7 podemos determinar la capacidad del transformador necesario en función de la potencia del motor utilizado.

TABLA 8

CAPACIDAD ADMISIBLE DE CORRIENTE CONDUTORES AISLADOS A TEMPERATURA AMBIENTE DE 30⁰ C, NO MAS DE TRES CONDUCTORES EN DUCTO.

TAMAÑO AWG ó MCM	TEMPERATURA DEL CONDUCTOR					
	60°C.	75°C.	90°C.	60°C.	75°C.	90°C.
	140°F.	167°F.	185°F.	140°F.	167°F.	185°F.
	TIPOS	TIPOS	TIPOS	TIPOS	TIPOS	TIPOS
	RUW	FEPW	TA, TBS	RUW	RH.RH	TAJBS
	T	RH.RH	FEP	T	RUH	SA.AVB
	TW	RUH	FEPB	TW	THW,	RHH
	UF	THW	SA.AVB	UF	THWN	THHN
		THWN	RHH		XHHW	
		XHHW				
	COBRE			ALUMINIO		
14	15	15	25			
12	20	20	30	15	15	25
10	30	30	40	25	25	30
8	40	45	50	30	40	40
6	55	65	70	40	50	55
4	70	85	90	55	65	70
3	80	100	105	65	75	80
2	95	115	120	75	90	95
1	110	130	140	85	100	110
0	125	150	155	100	120	125
00	145	175	185	115	135	145
000	165	200	210	130	155	165
0000	195	230	235	155	180	185
250	215	255	270	170	205	215
300	240	285	300	190	230	240
350	260	310	325	210	250	260
400	280	335	360	225	270	290
500	320	380	405	260	310	330
600	355	420	455	285	340	370
700	385	460	490	310	375	395

750	400	475	500	320	385	405
800	410	490	515	330	395	415
900	435	520	555	355	425	455
1000	455	545	585	375	445	480

En la tabla anterior determinamos el tipo, material y calibre del cable.

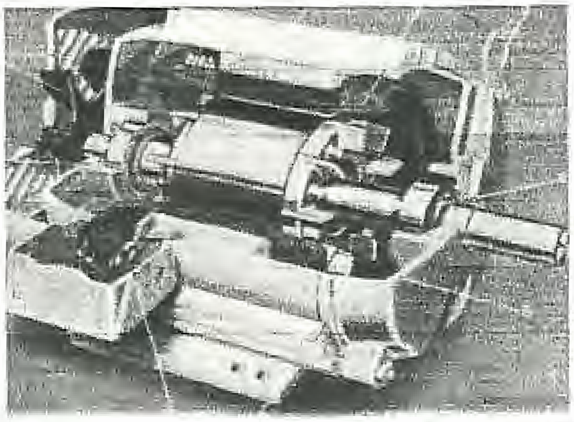


FIGURA 2.1.2.2 VISTA INTERNA DEL MOTOR ELÉCTRICO

2.1.3 Montaje.

Para formar una unidad de bombeo entre el motor y la bomba; se realiza el matrimonio o unión mediante un acople flexible, la misma que estará soportada por una base estructural de acero.

La selección del acople flexible Tabla 9 está en función de la velocidad de rotación, la potencia a transmitir y un factor de servicio que varía según la aplicación de la máquina.

Los diámetros de los ejes se los considera para establecer si el espesor de pared del acople seleccionado soportará el esfuerzo al que estará sometido.

La fórmula que relaciona la Potencia y la velocidad es:

$$Pot = T \cdot w$$

Donde:

Pot = Potencia

T = Torque

w =velocidad de rotación

TABLA 9

SELECCIÓN DE ACOPLES FLEXIBLES

Aplicación	Velocidad de rotación	Potencia	FS	Tipo de Acople	Diámetro máximo de eje
Bomba centrifuga	3500 rpm	25Hp	1.25	7	40mm

Una forma correcta de alinear el acopie flexible es poner una regla axialmente en las dos mitades del acople, esta deberá tener la misma distancia, al eje del motor y bomba, en todos los puntos de la circunferencia. Al mismo tiempo las dos mitades del acople deben tener la misma luz en todo el contorno.

La reglilla debe posicionarse en cuatro puntos opuestos, al tomar ias lecturas se debe rotar los puntos marcados en la misma dirección de rotación del motor y compararlas.

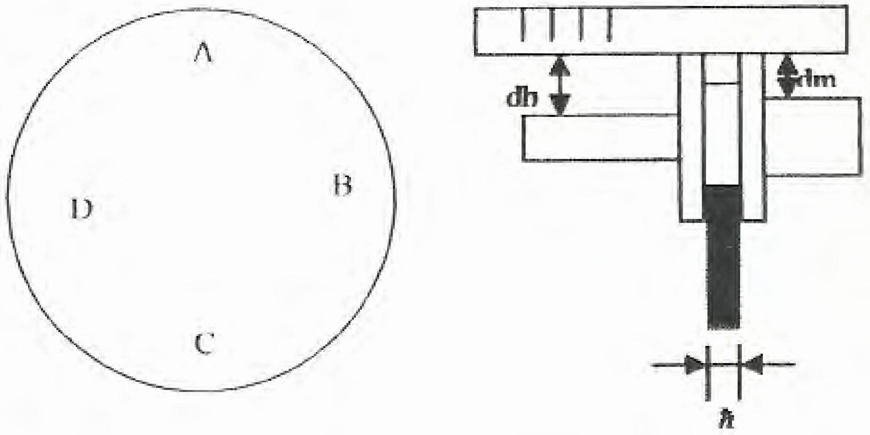


FIGURA 2.1.3.1 VERIFICACIÓN DE MEDIDAS DE ALINEACIÓN DE EJES Y ACOPLES FLEXIBLES.

TABLA 10.

MEDIDAS PARA ALINEACIÓN DEL GRUPO DE BOMBEO

	db	dm	*h*	
	Distancia al eje de la bomba	Distancia al eje del motor	Holgura Paralela	
A				
B				
C				
D				

La base estructural de acero del grupo bomba-motor se montará sobre la loza de hormigón perfectamente nivelada y asegurada con pernos de anclaje.

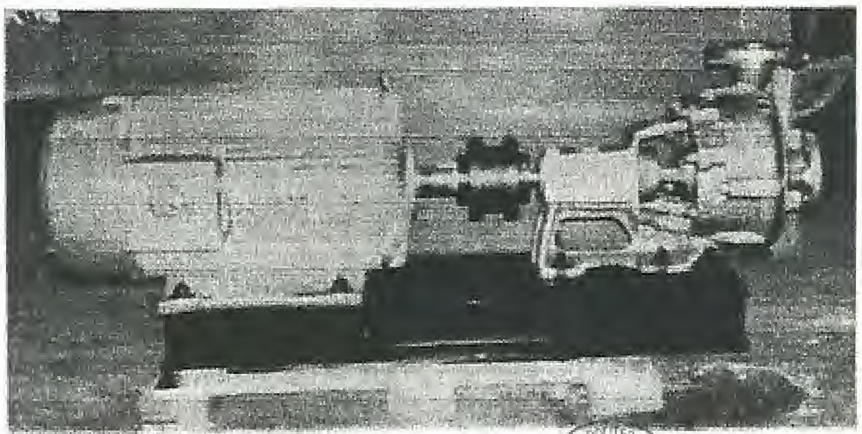


FIGURA 2.1.3.2 GRUPO DE BOMBEO

2.1.4 Tablero de Arranque.

El tablero está configurado en Estrella -Triángulo, con el objeto de aliviar el pico de amperaje que produce el arranque de 25HP, 220V. En la Figura 2.1.4.2 se muestra el diagrama del sistema de arranque de la bomba.

Está provisto de un "logo", que permite realizar algunas tareas de maniobra y mando, entre ellos podemos ajustar el tiempo de pasar de Estrella-Triángulo retardar la conexión, retardar la desconexión.

Breaker principal.

Contactores

Relé térmico

Botonera de marcha y paro

Selector manual-o-automático.

Horómetro

Gabinete metálico

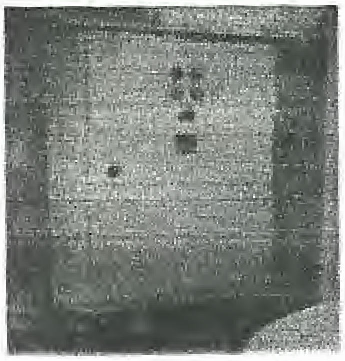


FIGURA 2.1.4.1 TABLERO DE ARRANQUE

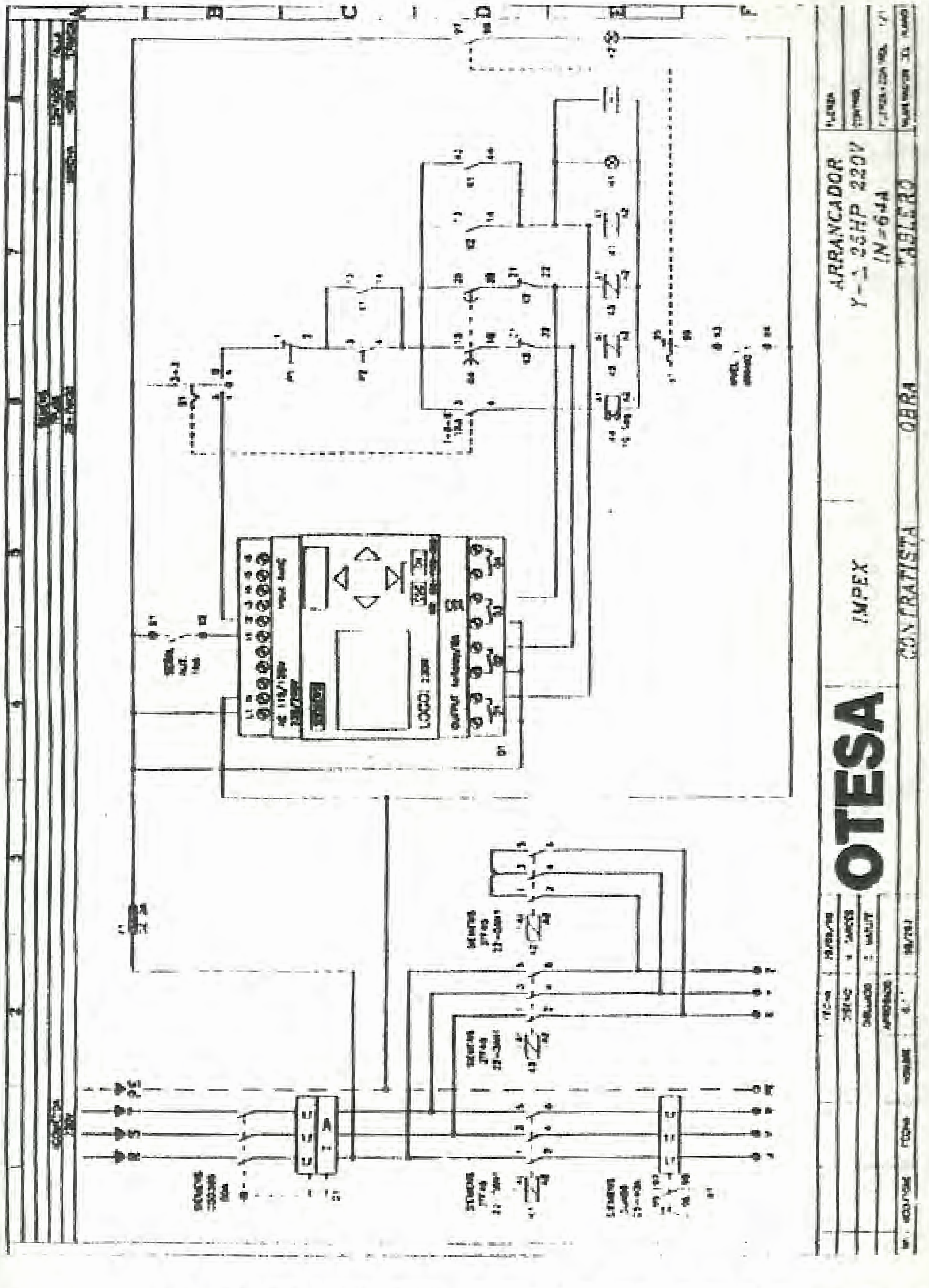


FIGURA 2.1.4.2 DIAGRAMA DEL SISTEMA DE ARRANQUE DE LA BOMBA.

2.1.5 Tanques hidroneumáticos.

El tanque es construido en dos partes de acero unidos por un cordón de soldadura, en su superficie exterior viene incorporada una válvula de aire que sirve para presurizar la cámara. En el interior del tanque tiene una membrana que alberga y desaloja un cierto volumen de agua según el diferencial de presión en el sistema.

FIGURA 2.1.5.1. TANQUES HIDRONEUMÁTICOS

La membrana es de Butyl, soporta temperaturas máximas de 100 grados centígrados, es de gran elasticidad lo que garantiza mayor resistencia ante repetitivos ciclos, protege internamente el tanque de la corrosión. El tanque puede ubicarse cerca o lejos de la motobomba. La tabla del Apéndice B muestra la entrega de agua en función del volumen del tanque y del diferencial de presión dado por la calibración del presostato.

El principio de operación de los tanques hidroneumáticos se esquematiza a continuación.

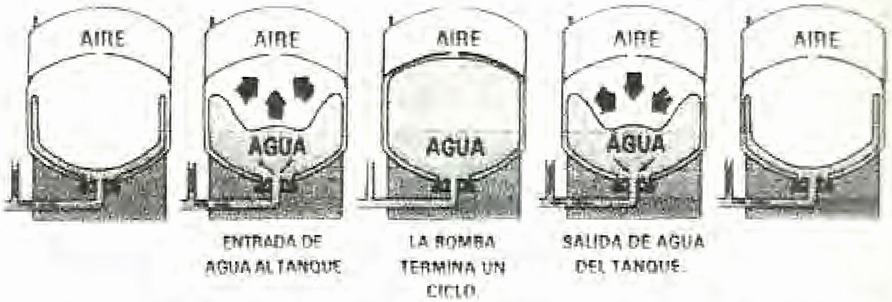


FIGURA 2.1.5.2 SECUENCIA DE OPERACIÓN DEL TANQUE HIDRONEUMÁTICO

A.- Tanque con precarga de aire, y bomba apagada.

B.- Ingreso de agua, bomba encendida.

C.- Salida de agua, bomba apagada.

D.- Inicio del ciclo.

Para determinar el volumen del tanque con vejiga que se deberá utilizar para evitar el golpe de ariete se emplea la fórmula Mendiluce, aplicable al tipo de tanque mencionado, la cual permite, a partir de la sobre presión admitida, calcular directamente el volumen del aire.

$$V_O = \frac{W.L.Q^2}{\Phi^2.Pm} \qquad W = \frac{90.\alpha}{(\alpha-1)(7+3\alpha)}$$

Pm = presión de funcionamiento del sistema (atm. absolutas)

P_A = presión de funcionamiento máxima admisible (atm. absolutas)

$$\alpha = \frac{P_A}{P_m}$$

L Longitud de la tubería

Q caudal de funcionamiento (m^3/s)

Φ Diámetro de la tubería (m)

Vo Volumen de amortiguador en (l)

Conocido Vo, es posible seleccionar el tanque hidroneumático en cuanto a su capacidad volumétrica, el tanque que en realidad se encuentre disponible raramente tendrá el volumen que hemos calculado por lo tanto deberemos elegir uno con una capacidad algo mayor cuyo valor será Vo'.

A partir de este punto se debe recalcular la sobre presión P_A' para este volumen Vo' standard.

$$W = \frac{Vo'.Pm.\Phi^2}{L.Q^2}$$

$$P_A' = \alpha.Pm$$

Frecuentemente en este fenómeno se pueden producir presiones inferiores a la atmósfera para evitarla habrá que actuar sobre la sobre presión de llenado de la vejiga.

Si denominamos P_1 la presión mínima deseada, P_A es la máxima que admitimos, hacemos.

Po = 0,9 - P_1

siendo Po la presión de llenado y deducimos

$$Vo = \frac{0{,}8.W.L.Q^2}{P_o.\Phi^2}$$

con este volumen, llenado a Po (atm. absolutas) obtendremos una presión máxima P_A y una mínima P_1.

2.1.6 Filtros de arena.

La utilización de filtros nos asegura agua libre de impurezas. La selección de los filtros está en función del caudal de agua que se requiere limpiar.

La operación de filtrado se produce al ingresar el flujo de agua por la válvula dispuesta en la parte superior, para seguidamente atravesar la cama de arena , llegando al fondo en donde se encuentra un colector de malla en acero inoxidable para luego descargar en el fondo del tanque.

FIGURA 2.1.6 FILTRO DE ARENA

La siguiente fórmula es usada para calcular el Caudal que pasaría a través del filtro en GPM, para lo cuál debe ser conocida el área del

2.3 Línea de Descarga

Se inicia en la salida de la bomba con:

Ampliación concéntrica.- acopla la bomba a la tubería de conducción, debido a que el diámetro de salida es pequeño y obligan a tener velocidades muy altas.

Tapón de cebado.- permite llenar la tubería de succión en caso de descebamiento.

Filtros de arena.- retienen las impurezas del agua.

Válvula de compuerta.- permite aislar la bomba en caso de mantenimiento.

Válvula cheque.- para evitar el contra flujo

Unión mecánica.- permite el montaje y desmontaje de válvulas y piezas.

Válvula de alivio.- disminuye las sobre presiones por golpe ariete.

Tanques Hidroneumáticos.- Alivia el golpe de ariete y permite regular el tiempo de encendido de la bomba.

Presostato.- Determina el rango de presión para el encendido y apagado del motor.

Válvulas de aire.- Evitan el colapso de la tubería cuando se forman vacío o bolsas de aire, se las coloca a lo largo de la tubería principal en los sitios en donde se producen cambios bruscos de dirección, y al final de la tubería.

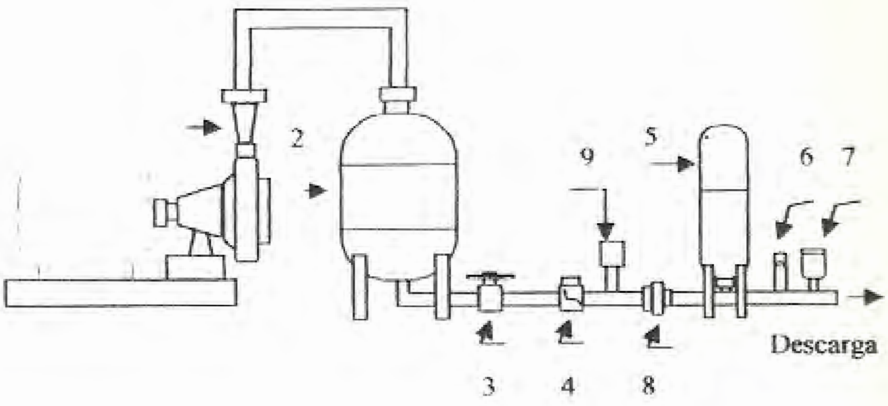


FIGURA 2.3.1 VISUALIZACIÓN DE LÍNEA DE DESCARGA.

1. Ampliación cónica.
2. Filtro de arena.
3. Válvula de compuerta.
4. Válvula de retención.
5. Tanque hidroneumático.
6. Válvula de alivio
7. Válvula de aire.
8. Unión universal.
9. Presostato.

2.4 Automatización del sistema.

En este sistema de riego primero se presuriza la tubería principal mediante el encendido y apagado de la bomba, la cual recibe la señal de un presostato, la automatización del sistema de riego se la realiza mediante un programa que permite operar cada cierto tiempo un sector determinado.

2.4.1 Válvulas de control automático.

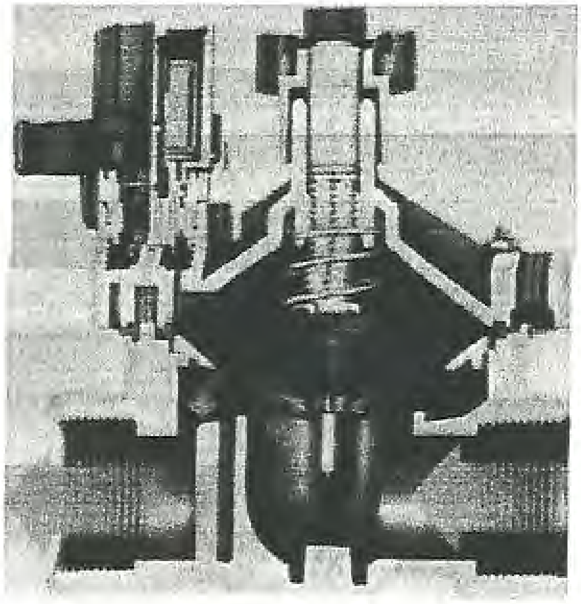


FIGURA 2.4.1.1 VÁLVULA DE CONTROL.

Estas válvulas son construidas en plástico PVC, tienen incorporadas un solenoide para la apertura o cierre, para su funcionamiento reciben una señal eléctrica de 24V y una corriente de entrada de 0.41 AMP, además tienen un regulador de presión que permite tener una presión constante a la salida de la válvula. Las características técnicas, las instrucciones para su instalación y ajuste se encuentran a continuación:

Ver Plano 1.

Instrucciones para el ajuste

1) Para determinar la presión de salida, ponga un manómetro de manguera a la válvula de retención de presión de lado de regulador de presión. La válvula de retención se parece a las válvulas de aire para inflar llantas.

2) Active manualmente la válvula, abriendo la solenoide aproximadamente 1/4 de vuelta, o bien active la válvula eléctricamente, no use el purgado manual externo.

3) Lentamente abra el vástago de control de flujo hasta que la lectura de la presión real ligeramente exceda la presión deseada a la salida. El regulador de presión de la válvula está ajustado de fábrica a 100 psi.

4) Quite la tapa negra de plástico que cubre a la perilla de ajuste. Sintonice el regulador de presión a la presión de salida deseada.

Decremento: Gire la perilla de ajuste en dirección contraria la dirección del giro de las manecillas del reloj.

Incremento: Gire la perilla de ajuste en dirección del giro de las manecillas del reloj.

5) Coloque de nuevo la tapa negra de plástico sobre la perilla.

6) Abra el vástago de control de flujo de 1/2 a 1 vuelta adicional.

7) Desactive la válvula manualmente mediante el cierre de la solenoide 1/4 de vuelta aproximadamente (en dirección del giro de las manecillas del reloj, o bien por desactivación eléctrica.

2.4.2 Tablero de control automático.

Se trata básicamente de un controlador digital, este nos permite realizar un itinerario de riego programando el tiempo que queremos regar en cada módulo o estación, enviando una señal eléctrica a las válvulas para que se abran.

Las funciones y características de programación se presentan en el Apéndice D. Ver Plano 2.

2.4.3 Cronograma de riego

El cronograma de riego establecido es alterado cuando las condiciones climáticas del momento cambian por ejemplo con la presencia de lluvias.

La medida de la Capacidad de Campo del suelo es la que nos indica cuando y cuanto tiempo regar, la manera de determinarla sería con un lisímetro, sin embargo la falta de este instrumentó se la suple con una prueba manual que consiste en tomar una muestra de suelo ubicado a unos 35cm de la superficie y apretarla con la mano, si la palma de la mano queda húmeda se puede concluir que está en su capacidad de campo, si el agua se chorrea por la mano se dice que el suelo está saturado y se debe suspender el riego.

Instrucciones para programar el controlador.

- Ajuste la hora.
- Ajuste la fecha
- Seleccione el programa
- Ajuste el ciclo de días de riego
- Ajuste los tiempos de operación de las estaciones Ajuste de las horas de inicio del programa
- Ajuste de las pausas entre estaciones Ajuste de las suspensiones por lluvias

- Ajuste del apagado en fechas determinadas
- Ejecución del programa de prueba
- Operación automática del controlador

En la siguiente tabla tomada de la Tesis Diseño y Selección de un Grupo De Bombeo Para El Campus "Gustavo Galindo" se presenta la programación de riego que se había realizado previamente, en los cuales se han sombreado aquellos que se concluyeron y posteriormente se evaluaron, la causa de que no se haya culminado el proyecto de acuerdo a lo previamente planificado fueron las limitaciones de recursos económicos que sufrió el proyecto.

CAPÍTULO 3

3.- PRUEBAS DE EVALUACIÓN DEL GRUPO DE BOMBEO CON MÓDULOS DE RIEGO.

Para realizar la evaluación debemos partir conociendo los parámetros del cultivo y del riego que se muestran en la Tabla 12.

La evaluación se inicia elaborando una tabla que contenga lo siguiente para cada módulo y cuyos valores se determinan en la prueba de campo:

- Caudal
- Altura dinámica total
- Tiempo de riego.
- Presión en la boquilla y a lo largo de las alas regadoras.
- Precipitación.
- Espaciamiento.

El material necesario para la realización de los ensayos es el siguiente:

1. Un manómetro unido a un tubo pitot.
2. Cronómetro
3. Un recipiente aforado
4. Un tramo de manguera de aproximadamente 1.20m de longitud.
5. Cinco vasijas metálicas 25 o 50 unidades
6. Varilla para medir la altura recogida en las vasijas
7. Cinta métrica.
8. Trozos de alambre

Procedimiento

1. Se elige el módulo a evaluar
2. Se colocan las vasijas formando cuadrículas de tal manera que se cubra toda el área ensayada.
3. Se coloca una vasija testigo con el fin de valorar la cuantía de las pérdidas por evaporación.
4. Se anota el modelo de aspersor y diámetro de la boquilla. El aspersor se sujeta con alambre para impedir que gire.
5. Se mantiene la presión para la que se desea hacer el ensayo.

6. Se mide la presión de los aspersores en varios puntos del ala y al final de ella con objeto de conocer las variaciones que existen, las cuales serán debidas a las pérdidas por rozamiento y a la diferencia de cotas.
7. A continuación se anota el tiempo que tarda el aspersor en llenar el recipiente aforado. Para ello se une el tramo de manguera por uno de sus extremos a la boquilla y el otro se introduce en el recipiente.
8. Se comienza el ensayo dejando que los aspersores giren libremente y comprobando hasta ese momento no ha caído agua en las vasijas. Se anota la hora en que empieza el ensayo.
9. Se anotan las condiciones climatológicas: Temperatura, humedad, nubosidad, he intensidad y dirección del viento.
10. La duración del ensayo conviene que sea la misma que la de un riego completo con el fin de que se pueda observar el efecto total del viento. Y la evaporación.
11. Antes de cortar la entrada del agua se comprueba la presión y se anota la hora.
12. Se mide la altura de agua recogida en las vasijas observando si todas ellas están en posición correcta. Se toma nota de aquellas vasijas que hayan recibido una cantidad de agua excesivamente grande o pequeña en relación con las demás, intentando encontrar el motivo que lo justifique.
13. Los datos registrados se transforman en milímetros/hora.

14. Con los valores de altura de agua recogida se establecen los valores, mínimos, máximos, medio, y el valor medio suministrado para poder establecer los porcentajes de eficiencia

$$\text{Eficiencia de distribución} = \frac{\text{Valor mínimo recibido}}{\text{Valor medio recibido}} \times 100\%$$

$$\text{Eficiencia del sistema riego} = \frac{\text{Valor mínimo}}{\text{Valor medio suministrado}} \times 100\%$$

$$\text{Eficiencia de aplicación} = \frac{\text{altura mínima retenida en zona radicular}}{\text{Altura media aplicada}} \times 100\%$$

TABLA 12 PARÁMETROS DEL CULTIVO Y DEL RIEGO

Uso consuntivo	Etc	mm/día
Capacidad de campo	CC	mm/mt
Punto de marchitez	PM	mm/mt
Cantidad de retención de agua	Sa	mm/mt
Profundidad radicular	D	mm
Porcentaje de agua disponible en la raíz	p	%
Lámina neta	l_n	mm
Lámina bruta	l_b	mm
Frecuencia de riego	F	días
Taza de infiltración	Ti	mm/hr
Tiempo de riego	Tr	horas
Número de horas día	N°.-Hr	horas
Número de posiciones día	N°.-Pos	posiciones
Área total a regar	A_t	mt^2
Área diaria a regar	A_d	mt^2/día
Área por posición o módulo	A_p	mt^2/posición
Caudal requerido	Q	mt^3/hora
Número de aspersores por módulo	N° Asp	u
Precipitación	Pr	mm/hr
Arreglo (cuadrado, o triangular)	■, ▲	

La evaluación del grupo de bombeo debe ir de la mano con ciertos criterios de diseño que deben cumplirse tanto en la conducción de un fluido por tubería, como los parámetros agronómicos que se enlistaron al inicio del capítulo.

En lo que se refiere a la conducción del agua por tuberías para un sistema de riego por aspersión debe cumplirse en el módulo que las pérdidas de presión en cada tubería secundaria que lleva el agua hasta cada uno de los módulos no debe ser mayor del 20% de la presión del aspersor. Una vista lateral del aspersor es presentada en el Plano 3.

Las pérdidas de presión entre el primer aspersor de un ramal y el último del mismo ramal no debe ser mayor del 10%.

Mientras que otra condicionante que se debe cumplir es que la precipitación de agua o taza de aplicación debe ser menor a la taza de infiltración del suelo. Para determinarla se considera el tipo de arreglo que tienen los aspersores sobre el terreno.

En arreglo cuadrado la precipitación es:

$$P_r = \frac{96.3\,xQ}{SxL}$$

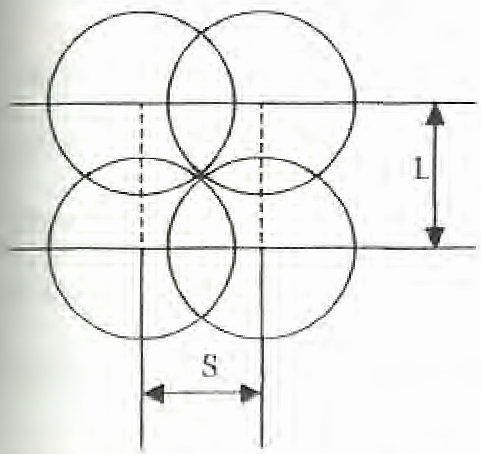


FIGURA 3.1 PRECIPITACIÓN ARREGLO CUADRADO

En arreglo triangular

$$P_r = \frac{96.3\,xQ}{0.866xSxL}$$

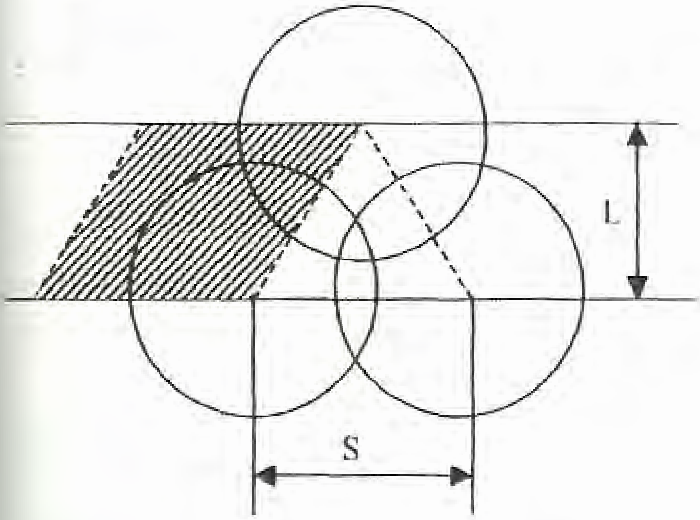
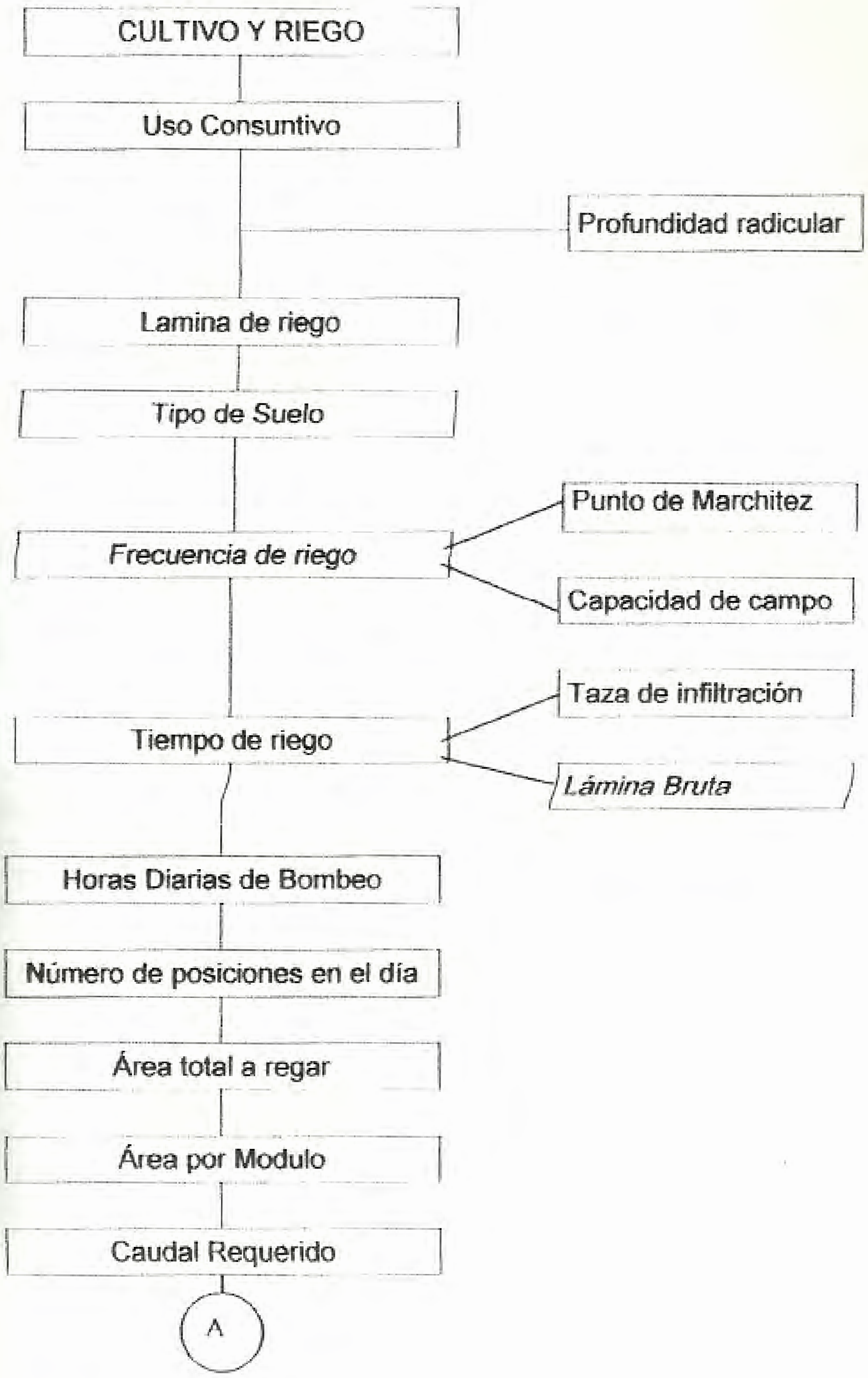
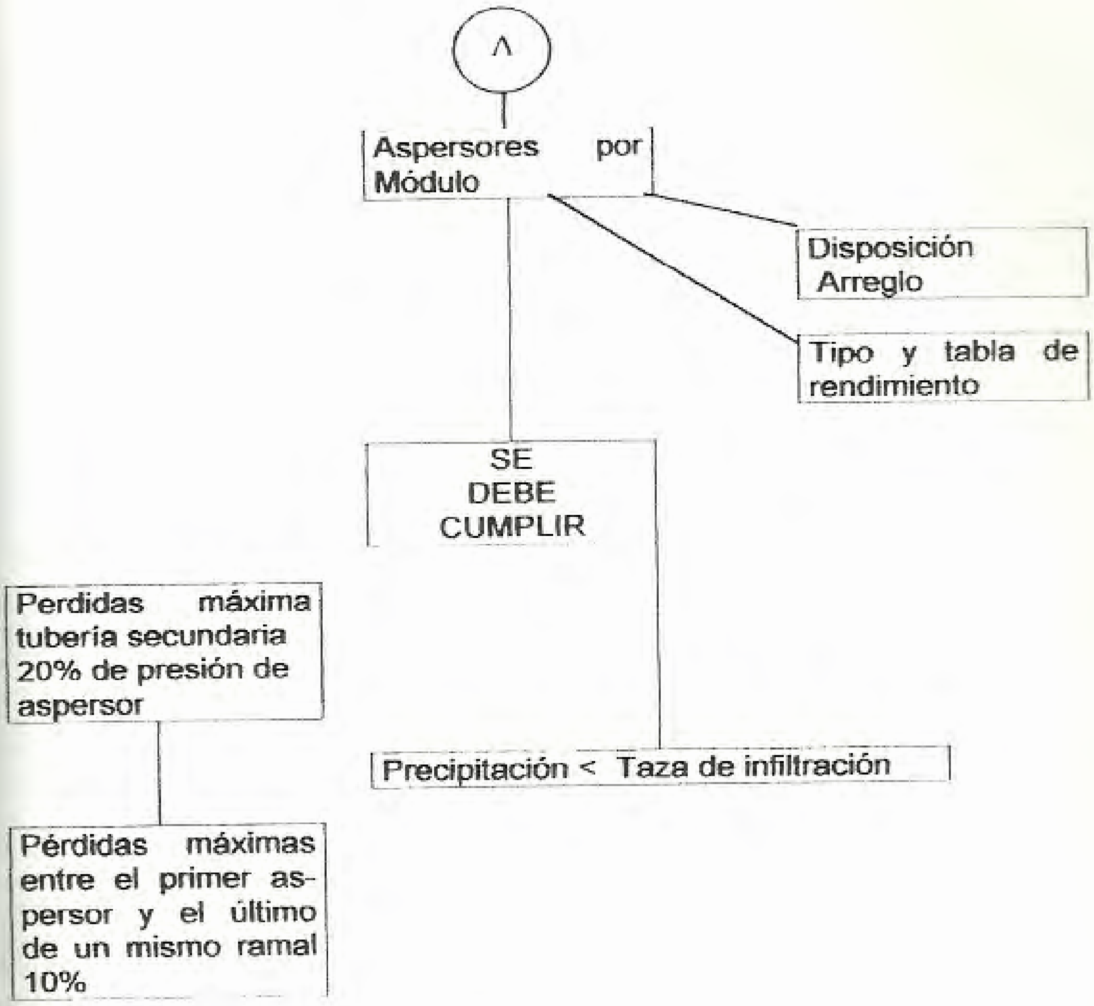


FIGURA 3.2 PRECIPITACIÓN ARREGLO TRIANGULAR.

Si se parte que el sistema de riego tiene la línea principal presurizada dentro de un rango de presión que se regula en función del caudal y de la altura dinámica total tabuladas en el terreno, con la finalidad de calibrar el presostato en un rango de presión que incluya todos los requerimientos para los diferentes módulos y que además sea lo más cercano al punto de mayor eficiencia de la bomba.

Todo lo anterior se lo representa con el siguiente diagrama de flujo.


CULTIVO Y RIEGO
Uso Consuntivo
Profundidad radicular
Lamina de riego
Tipo de Suelo
Punto de Marchitez
Frecuencia de riego
Capacidad de campo
Taza de infiltración
Tiempo de riego
Lámina Bruta
Horas Diarias de Bombeo
Número de posiciones en el día
Área total a regar
Área por Modulo
Caudal Requerido
A



	BOMBA						
	Regulación Presostato			Caudal			
MODULO	1	2	3	4	5	6	7
CAUDAL							
PRESIÓN							
TIEMPO							

B

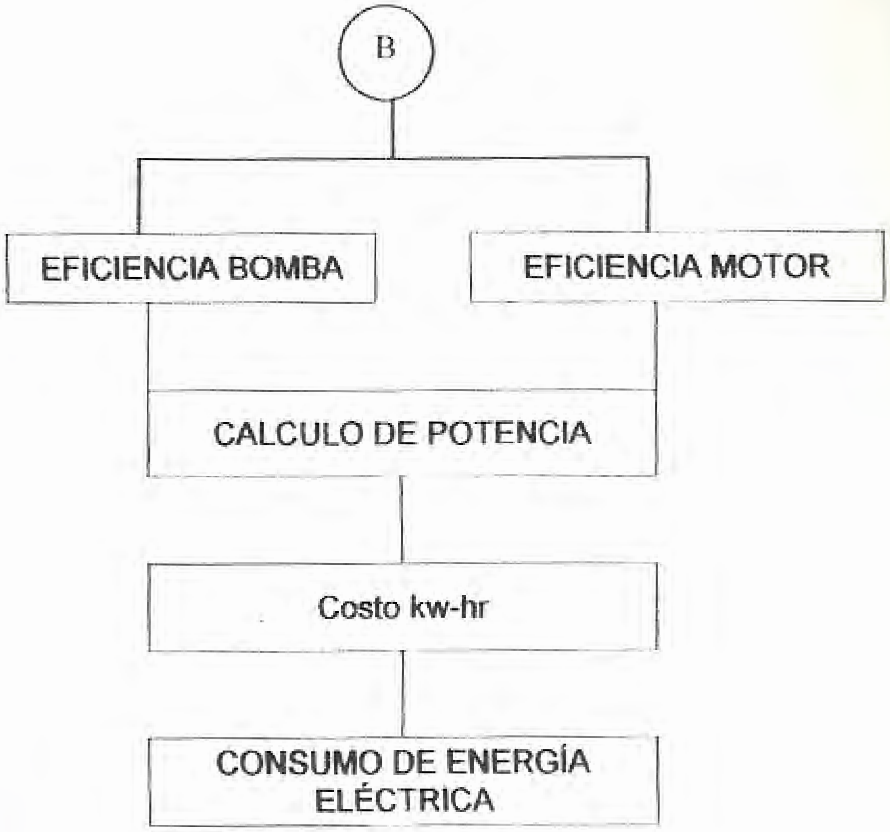


FIGURA 3.3 **DIAGRAMA** DEL PROCESO DE RIEGO.

Siguiendo paso a paso el diagrama se tendrá todos los elementos de juicio para emitir un análisis concreto sobre el funcionamiento del riego y del grupo de bombeo tanto en lo técnico como en lo económico.

Con la finalidad de tener todos los datos reunidos en una sola hoja se elaboró un formato, que se presenta a continuación.

HOJA DE EVALUACION

NOMBRE

DIRECCION

CULTIVO

Uso consuntivo..................... Tipo de Suelo...............................
Profundidad radicular........... Punto Marchites.......... Taza infiltración......
Lámina de riego.................... Capacidad campo....... Lamina bruta...........
Frecuencia riego.................. Tiempo riego................

RIEGO

Horas diarias de bombeo................... Área total a regar..................................
Número de posiciones en el día.......... Área de módulo..

Caudal requerido.

Modelo aspersor.................................. Pérdidas tuberia secundaria...................
Arreglo.. Pérdidas tuberías laterales............................
Cantidad.. Precipitación...
Presión boquilla...................................

BOMBA

Regulación Presostato..............
Altura de Succión........................

Módulo............
...
Caudal
....
ADT
....
Tiempo..............
-

Eficiencia bomba................ Costo Kw.-h.....................
Eficiencia motor..................

Potencia Consumida...........................
Gasto en energía eléctrica..................

Las áreas a las que se instaló el riego son las siguientes.

TABLA 13

MÓDULO Y DESCRIPCIÓN DEL ÁREA.

Módulo	**Sector**	**Áreas**
6	Rectorado	Área frontal
7	Rectorado	Área posterior
9	Facultad Ingeniería Eléctrica	Áreas Exteriores
10	Facultad Ingeniería Mecánica	Áreas Exteriores

Realizamos la evaluación al modelo 6 perteneciente a los jardines de la parte frontal del rectorado, por ser este el más representativo; aplicando la hoja de evaluación que se presenta en el formulario 1.

Una vez concluido el tiempo de riego se determina la capacidad de campo para lo cual se utiliza un barreno para realizar una excavación en el suelo y saber hasta que profundidad se encuentra humedecida la tierra para luego comparar con el valor de la capacidad de campo tabulada.

HOJA DE EVALUACION

NOMBRE

DIRECCION

CULTIVO

Uso consuntivo... *5.4 mm/dia*
Profundidad radicular.*60 cm*
Lámina de riego......*29.4 mm.*
Frecuencia riego.....*5 dias....*

Tipo de Suelo..... *franco arcilloso*
Punto Marchitez. *130mm/m* Taza infiltración *8mm/h*
Capacidad campo..*270mm/m* Lamina bruta..*42mm*
Tiempo riego.......*3.67 h*

RIEGO

Horas diarias de bombeo..........*11 h*
Número de posiciones en el día.....*3*

Área total a regar....................*18.6 has.*
Área de módulo..............................*3.47 has*

Caudal requerido.

Modelo aspersor...........*R–50*
Arreglo...................*Triangular*
Cantidad........................*85*
Presión boquilla............ *35 psi*

Pérdidas tubería secundaria.............*3.5 m*
Pérdidas tuberías laterales................*1.2 m*
Precipitación.......................................*8 mm/h.*

BOMBA

Regulación Presostato.. *70 -100 psi*

Altura de Succión.............*5 m*

Módulo......*6.*
Caudal *30 m³/h*
ADT ...*67 m*
Tiempo... *3.5hr*

Eficiencia bomba...........*65%.*
Eficiencia motor.............*90%*

Costo Kw.-h.........*$ 0.05*

Potencia Consumida..............*13.5 Hp*
Gasto en energía eléctrica.......*$ 1.75.*

CAPITULO 4

4. INSTRUCCIONES DE PUESTA EN MARCHA Y MANTENIMIENTO.

Antes de la puesta en marcha es indispensable verificar que gire libremente el grupo motobomba, esta operación se la realiza girando el acople con la mano.

La bomba se debe llenar completamente de agua. Este llenado se puede efectuar por el tapón del codo de descarga. El cebado debe, asegurar el total desalojo del aire tanto en la tubería de succión, como en la carcaza misma de la bomba. Esta condición es obligatorio cumplirla para evitar molestias durante la operación.

Para el arranque cualquier válvula de compuerta del lado de succión debe abrirse completamente. La válvula de compuerta del lado descarga debe estar cerrada.

Se comprueba el sentido de giro de la bomba, arrancando y parando rápidamente el motor. Este sentido debe coincidir con el indicado en la flecha grabada en la carcasa de la bomba.

Se arranca el grupo bomba motor, al llegar a la velocidad del régimen abrimos poco a poco la válvula de la descarga, hasta encontrar el punto de operación deseado. En sistemas automatizados, la operación de arranque a válvula cerrada no se realiza sino la primera vez.

La válvula de descarga no debe abrirse completamente sin verificar el amperaje que está consumiendo el motor ya que puede darse una condición de excesivo caudal, el cual llevará al motor a consumir una comente mayor a la permitida en la placa del motor y éste se puede quemar.

En las paradas del motor se comprueba que lo hace suavemente. En caso de paradas por largos periodos de tiempo, se cierra también la válvula de succión y se retira el tapón de purga de la bomba para vaciar su carcaza y evitar la corrosión de su interior.

Durante la operación debe ejercerse una vigilancia permanente tanto a la bomba como al motor.

La marcha debe ser tranquila y libre de trepidaciones p ruidos.

Comprobar constantemente el consumo de amperaje del motor y la presión indicada en el manómetro colocado en la tubería de descarga.

Vigilar que no funcione en seco, y que no opere mucho tiempo contra la válvula de compuerta de la descarga cerrada.

La temperatura de los rodamientos se mide en la parte externa del soporte de rodamientos. Allí no debe sobrepasar los 90°C. Por lo general esa temperatura se halla sumando, a la temperatura ambiente, máximo 50°C.

El sello mecánico no debe producir ningún goteo. En algunos casos se presenta un leve goteo inicial pero este debe desaparecer en las primeras horas de operación. Esta situación debe vigilarse y de persistir se debe parar la bomba y revisar el sello.

El sello mecánico es un elemento que no requiere de ningún mantenimiento. Su cambio se hace necesario solo cuando se presenta un goteo constante y de aumento progresivo, lo cual es un índice de deterioro de dicho elemento. Antes del reensamble deben limpiarse muy bien los casquillos posicionadores del sello y retirar todo signo de oxidación que exista en la zona del eje donde se posicionará de nuevo la parte dinámica del sello.

La lubricación de los rodamientos se efectúa por medio de grasa lítica, con detergentes exentos de resinas y ácidos y que sirva al mismo tiempo de anticorrosivo. Se recomienda grasa para rodamientos SKF 65-2 o similar, el cambio de grasa se lo puede realizar después de las 3000 horas de trabajo ó 2 años de uso.

Mantenimiento

En el formulario 1 se muestra un formato de orden de mantenimiento para la bomba del sistema.

El mantenimiento de las bombas centrífugas es muy sencillo y depende de las condiciones de trabajo a que se sometan. Debe verificarse periódicamente que los apoyos, uniones flexibles, acoples, cumplen a cabalidad su función, o cambiarlos si es preciso.

Desenrosque periódicamente el tapón de purga de la carcasa, con el fin de extraer los sedimentos acumulados en ella, reponiendo posteriormente el liquido perdido una vez enroscado el tapón nuevamente en la carcasa.

ORDEN DE MANTENIMIENTO

EQUIPO: BOMBA MODELO: 5X25 Nombre: Mecánico			Fecha: Tarea: Desensamble total		
ÍTEM	Descripción	Herramienta	Tiempo	Cantidad	Observaciones
1	Preparación y localización		30'		
2	Retirar tuercas de la carcasa	Llave de ½	15'	8	
3	Retirar carcasa y empaques		4'		
4	Retirar tuerca, rotor, y arandelas		3'		Rosca con hilo izquierdo
5	Retirar rotor y cuña rotor	Llave de 1"	10'	1	Evite golpearlo
6	Retirar prensa sello		2'		
7	Retirar plato estopas		2'		
8	Retirar casquillo sello		1'		
9	Retirar sello mecánico del eje		2'		Verifique estado de la cerámica, muelle.
10	Retirar empaque prensa sello		2'		
11	Retirar deflector		1'		
12	Retirar tornillo tapa rodamiento.	Destornillador plano	2'		
13	Retirar eje con rodamientos		3'		

FORMULARIO 1. ORDEN DE MANTENIMIENTO

Él desensamble y ensamble de la bomba necesita un riguroso cuidado por parte del operario y del seguimiento exacto de las indicaciones que muestran los planos respectivos es decir de corte y de despiece isométrico o elevación.

El proceso debe partir del desmontaje de las líneas de tubería existentes, la revisión y cambio de las partes dependerá del estado en que se encuentren cada uno de los elementos, sin embargo es recomendable cambiar siempre todos los empaques planos por uno nuevos conservando el espesor que poseían dichos empaques, limpiar todas las superficies atornilladas y untarse de grasa o productos similares para prevenir su corrosión, lubricar las roscas y limpiar de oxido, casquillos, anillos, canales de conducción.

En el Apéndice E se muestra una vista isométrica del despiece de la bomba.

El ensamble de la bomba se efectúa en orden de sucesión inverso al antes indicado en el desensamble y debe procurarse fijar completamente la tornillería en la medida en que se vayan recorriendo uno a uno dichos pasos.

En cuanto al motor eléctrico para el arranque verifique primeramente por medio de un voltímetro si el voltaje de la línea de corriente es el que corresponde.

En los equipos trifásicos es necesario comprobar el sentido de rotación del motor, poniéndole en funcionamiento durante una fracción de segundo sin que alcance gran velocidad. Si el sentido no es correcto, se deben intercambiar dos cualesquiera de los conductores eléctricos para cambiar el sentido de rotación del motor. El sentido de giro adecuado se indica por medio de una flecha en la carcasa o plato sello de la bomba.

En la caja de bornes del motor encontrará las instrucciones para la conexión de las puntas terminales de tal forma que coincidan con el voltaje de la fuente.

Si el arrancador o sistema de protección del motor opera y desconecta la unidad, investigue la causa antes de poner la motobomba nuevamente en funcionamiento.

Es causa de daños graves en el motor, dejar los terminales o conexiones sueltas o mal apretadas.

En lo relacionado al sistema de riego se debe observar el funcionamiento de los aspersores en cada módulo, en el momento que en uno de ellos, o varios no salga agua, se deberá desmontar el aspersor, y verificar si el agua sale por la tubería.

Si sale agua significa que el aspersor esta tapado se debe proceder a limpiarle el filtro.

Si no sale agua por la tubería se debe verificar las válvulas, podría estar cerrada, dañada u obstruida, en el caso de que suceda lo anterior se debe abrir o reparar.

La frecuencia para la limpieza de los filtros de arena será función de la cantidad de impurezas que contenga el agua.

El llenado inicial de la tubería principal se lo debe hacer lentamente para evitar los golpes de ariete ocasionados por la formación de bolsas de aire. Mientras más rápido es el cierre o apertura de las válvulas más rápido y más probables son los golpes de ariete. Una vez que tenemos presurizado el sistema de riego la formación de bolsas de aire es mínima. El apéndice F muestra el diagnóstico del sistema en genera del grupo de bombeo.

CAPITULO 5

5. CONCLUSIONES Y RECOMENDACIONES

1.- La optimización del consumo de energía del grupo de bombeo, está limitada por el caudal y la presión, si bien es cierto el criterio de mantener un consumo de agua constante por cada módulo, no podemos hacer lo mismo con la presión debido a las irregularidades que presenta el terreno, teniendo las válvulas reguladoras de presión que estrangularse provocando de esta manera un desperdicio de energía.

2.- Cuidar que se cumplan todos los detalles para realizar una instalación de la tubería de PVC, es de suma importancia, puesto que un mal empotramiento, un mal acoplamiento o falla en la pegada de los accesorios es seguro que producirá una avería, paralizando el riego, produciéndose un gasto en la compra de materiales y tiempo de reparación.

3.- La Hoja de evaluación es necesaria para controlar lo que requiere el cultivo, de lo que esta entregando el sistema de riego; que nos permite de manera rápida y sencilla aplicarla, para reprogramar el sistema.

4.- Durante el lapso comprendido entre el final de un día de riego y el inicio del siguiente día, las pequeñas fugas de agua en la línea principal no deben exceder la capacidad de agua almacenada en los tanques de presión. En caso de que ocurra se deberá localizar la fuga y eliminarla.

5.- Un sistema de riego pasa la evaluación con éxito cuando se cumplen las condiciones relacionadas a los porcentajes de perdida de presión en las tuberías y la taza de aplicación sea menor a la taza de infiltración

6.- La interrelación de las variables que involucran el cultivo, el riego, y el equipo de bombeo asegura un buen resultado en el desarrollo de la planta y un óptimo consumo de energía.

7.- El mantenimiento del sistema de riego involucra aspectos mecánicos, eléctricos, y agronómicos.

8.- Para regar áreas verdes es recomendable un espaciamiento del 100% del radio de acción de la aspersión como distancia entre dos aspersores.

9.- La instalación de la tubería y el grupo de bombeo estuvo siempre muy cercana y parecido al diseñado en las dos Tesis que anteceden este trabajo, lo cual ha permitido obtener resultados satisfactorios tanto en lo agronómico como en lo técnico.

10.- Se recomienda culminar el sistema de riego con la instalación de los módulos faltantes para que el riego sea programado y evitar continuar regando con mangueras o con el carro tanque. Una vez concluida la instalación de la totalidad de los módulos se conseguirá resultados favorables en lo económico.

11.- La capacidad de agua en el lago es limitada y esta condicionada a la intensidad de las lluvias en el invierno, por lo que se recomienda en lo posterior realizar un estudio para la construcción de sistemas alternos de almacenamiento.

12.- Si bien el sistema es automático sin embargo será necesario la presencia de una persona que se encargue de vigilar el buen funcionamiento del sistema de riego en general.

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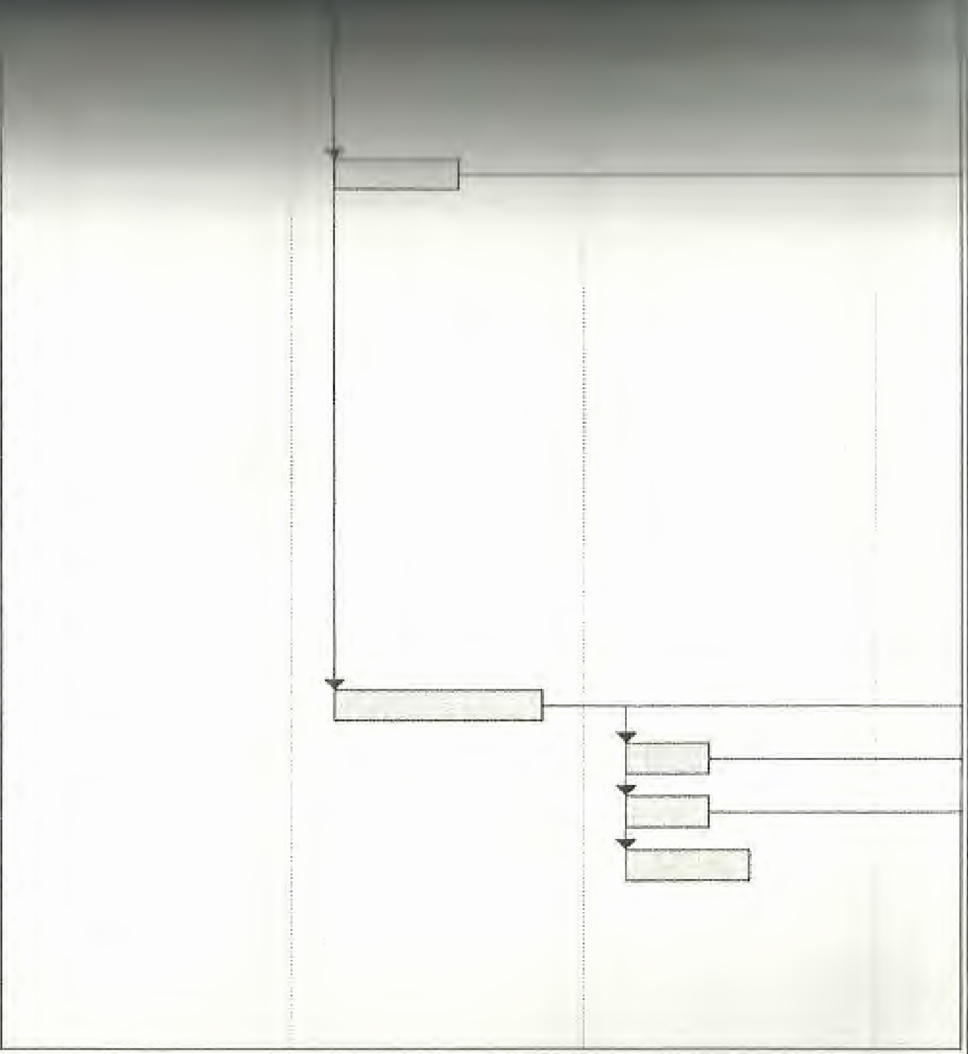
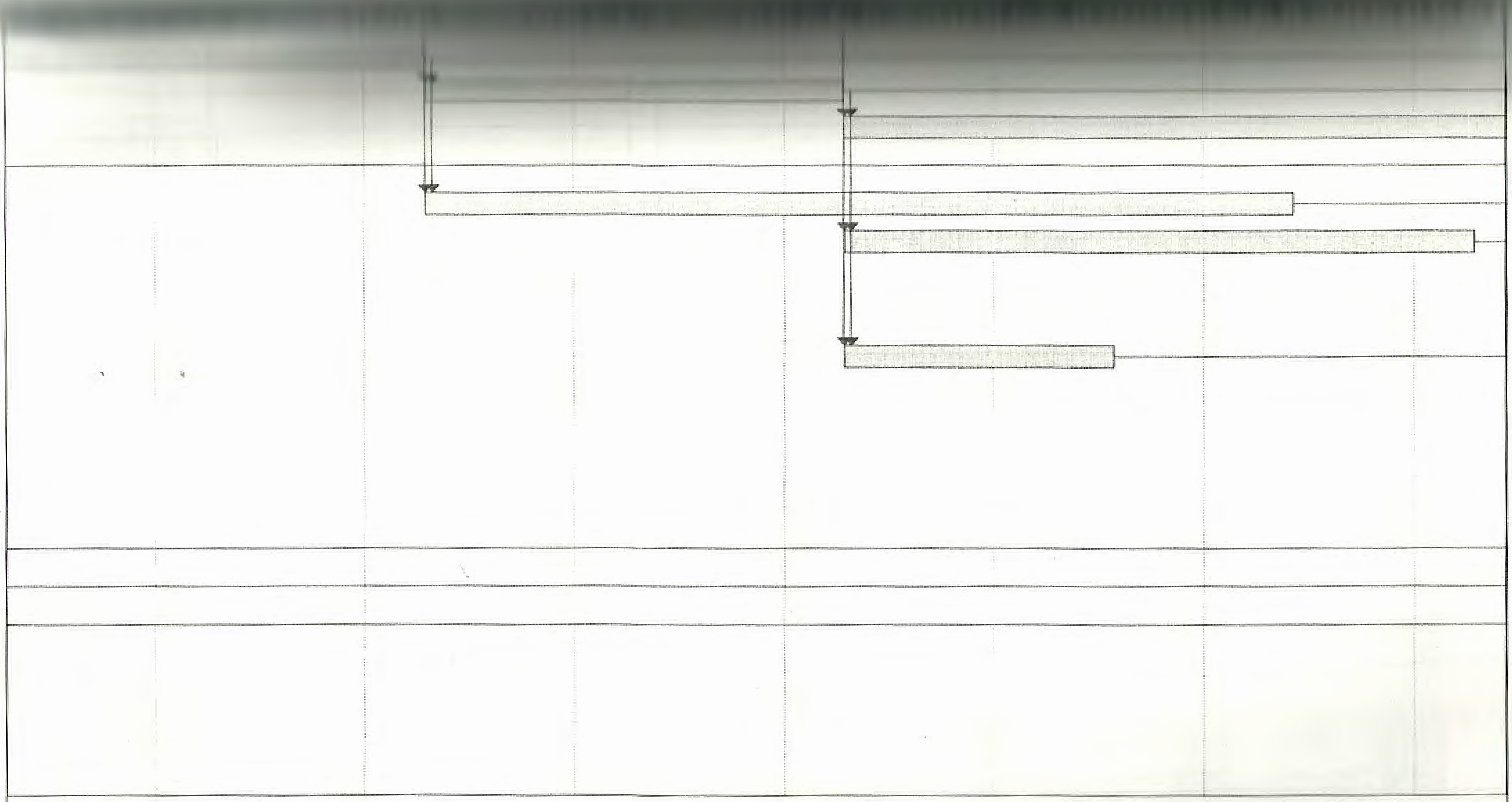
APÉNDICE A

CRONOGRAMA DE ACTIVIDADES

3	Apertura zanja Tubería Secundaria	[illegible]	[illegible]	[illegible]
4	Apertura de zanja Tubería Terciaria	21 días	[illegible]	[illegible]
5	Corte de carpeta asfáltica	3 días	lu 18/01/99	mi 20/01/99
6	Pegar Tubería Principal	21 días	ma 16/02/99	ma 16/03/99
7	Pegar Tubería Secundaria	15 días	ma 02/03/99	lu 22/03/99
8	Pegar Tubería Terciaria	15 días	mi 31/03/99	ma 20/04/99
9	Pegar accesorios de tubería	17 días	mi 21/04/99	ju 13/05/99
10	Colocar de arena en zanja	7 días	ma 02/03/99	mi 10/03/99
11	Tapar zanja Tubería Principal	10 días	mi 31/03/99	ma 13/04/99
12	Tapar zanja Tubería Secundaria	10 días	mi 31/03/99	ma 13/04/99
13	Tapar zanja de Tubería Terciaria	21 días	vi 14/05/99	vi 11/06/99
14	Prueba hidrostática a la Tubería Principal	1 día	mi 14/04/99	mi 14/04/99
15	Instalación de grupos de bombeo	5 días	lu 18/01/99	vi 22/01/99
16	Colocar accesorios de succión	2 días	lu 25/01/99	ma 26/01/99
17	Colocar accesorios de descarga	2 días	lu 25/01/99	ma 26/01/99
18	Instalación acometida eléctrica	3 días	lu 25/01/99	mi 27/01/99
19	Insatalación de tablero de control	5 días	ju 15/04/99	mi 21/04/99
20	Colocación de aspersores	10 días	lu 14/06/99	vi 25/06/99
21	Puesta en marcha	2 días	lu 28/06/99	ma 29/06/99



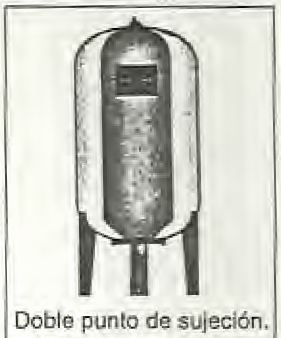


APÉNDICE B

RENDIMIENTO DE LOS TANQUES HIDRONEUMÁTICOS

QUIPOS DE PRESION HIDROFLO

CARACTERISTICAS DE DISEÑO


Doble punto de sujeción.

[illegible] Resiste muy bien aguas alcalinas. Aplicable con temperaturas hasta de [illegible] contacto con la lámina del tanque aumentando la vida útil de la membrana, y [illegible] del tanque.

[illegible] con agua potable por varios organismos normalizadores internacionales.

[illegible] para un rápido y fácil servicio.

[illegible] en una sola pieza, garantizando mayor seguridad y resistencia mecánica.

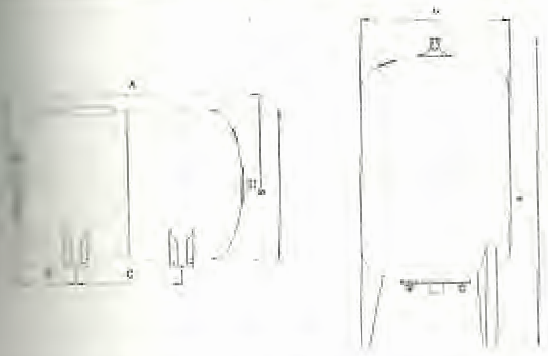
[illegible] espacios por su opción de ubicación en forma horizontal o vertical, así [illegible] motobomba.

[illegible] al no perderse la cámara de aire por contacto con el agua, y no requerir [illegible] accesorios adicionales.

TABLA DE ENTREGA DE LOS TANQUES

[illegible]	DIFERENCIAL ON - OFF DE PRESIONES. BARES / (PSI)												
[illegible]	1.5-2.5	1.5-3.0	2-3.0	2-3.5	2-4.0	2.5-3.5	2.5-4.0	2.5-4.5	3.0-4.0	4.0-6.0	5.0-7.5	6-9.5	7.0-10.0
	(22-36)	(22-44)	(29-44)	(29-51)	(29-58)	(36-51)	(36-58)	(36-62)	(49-58)	(58-87)	(73-109)	(87-138)	(102-145)
	ENTREGA DE AGUA EN LITROS												
[illegible]	26	34	23	26	37	21	28	34	19	27	28	32	26
[illegible]	52	69	46	52	74	41	56	69	38	54	56	65	52
[illegible]	78	103	70	78	112	62	84	103	57	82	85	97	78
[illegible]	131	172	116	131	186	104	141	172	95	137	142	162	131
[illegible] DE PRESION [illegible] EN PSI	20-40		30-50				40-60		60-90		90-140		

DIMENSION Y TABLAS DE SELECCION



[illegible]	A	B	ø C	D	E	F	VERSIONES
[illegible]	775	505	450	355	150	350	HORIZONTAL
[illegible]	1365	595	550	455	200	455	
[illegible]	1345	670	630	515	250	515	
[illegible]	[illegible]	-	630	-	-	-	VERTICAL
[illegible]	[illegible]	-	780	-	-	-	

MODELO	RANGO DE PRESION - PSI			
	20-40	30-50	40-60	60-80
	GPM	GPM	GPM	GPM
JS1-1/2-L 100H	14	13	-	-
JS1-3/4-L 100H	16	15	14	-
JS1-1.0-L 100H	20	19	18	-
JS2-1.5-L 100H	20	19	18	-
1 1/2A-1.0-L 100H	50	45	-	-
1 1/2A-1.5 L 100H	44	35	-	-
15H-1.8-L 200H	50	45	-	-
15H-2.0 L 200H	50	45	-	-
15H-2.4J L 200H	50	45	-	-
15H-3.0C-L 200H	60	55	-	-
15H-3.6J-L 200H	60	55	-	-
15H-5.0T-L 300*	90	85	80	-
15H-5.0C-L 300*	90	85	80	-
20H-5.0T-L 300*	-	90	70	-
20H-5.0C-L 300*	-	90	70	-
20H-6.6-L 300*	-	100	95	90
20H-9.0-L 300	-	-	120	110
20A-5.0T-L 300*	-	120	100	-
20A-5.0C-L 300*	-	120	100	-
20A-6.6-L 500	160	140	120	-
20A-9.0-L 500	-	-	170	120
20A-12.0-L 500	-	-	-	180

NOTA: Todos los equipos indicados con (*) pueden obtenerse con tanques L 300H horizontales

Desde 1924

Calle 18 No. 39B - 53 Tel.: 3686911
A.A. 80049 Santafé de Bogotá.

APÉNDICE C

TABLA PARA SELECCIÓN FILTROS DE ARENA

...co

World Leader
in Irrigation
Since 1947

SAND MEDIA FILTER

... popular and efficient filtration ... agricultural irrigation systems is ... media filter. It removes debris, ... sand, and silt from large volumes of ... low pressure loss. This prevents the ... of lines, nozzles, and emitters and ... the wear on sprinkler bearings. ... minimal for there are no moving ... flushing is a quick and efficient ... of cleaning.

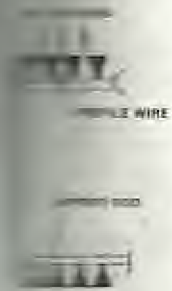
... DESIGN ASSURES ... ATION

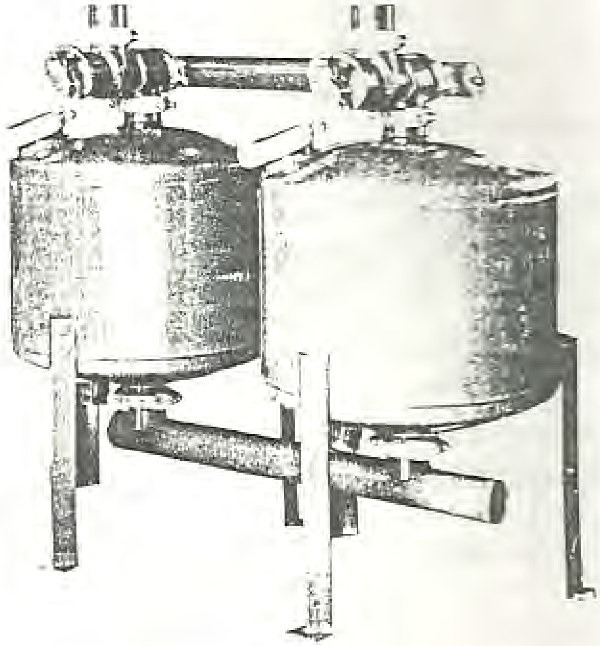
... AND SPRINKLER SYSTEMS

... constant refinement of the basic features ... from a leader in media filtration. A number ... ors attest to Irridelco's leadership by ... to copy. These refinements are:

...—Symetrical distribution of incoming ... at all flow rates, as well as concentric ... on of backwash water.

... Steel Underdrain—The high strength pro... screen retains medias finer than No. 20 silica sand thus eliminating the need for filter back up screens. The strategic placement of these screens gives a uniform backwash and eliminates raw water short circuits. The non-clogging characteristic of the screen makes it the most field servicable and rugged media filter available.





OTHER OUTSTANDING FEATURES

- Complete Fluidic Media and Gravel Bed
- Built-in Safety Screen
- Modular Design
- Meets ASAE Requirement
- Field Serviceable
- Available Manual, Semi-automatic or Automatic
- Uses Locally Available Media and Gravel

OPTIONS

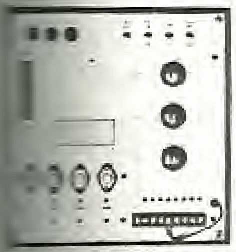
- High Pressure
- Epoxy Coating
- Solar Power
- Semi-automatic
- Manifold Termination
- Stainless Steel
- Sizes through 108″

Underdrains may be retrofitted to upgrade or repair competitor's filters.

... LABOR COST COMPARED WITH ...GES OF AUTOMATIC OPERATION

...re gauges indicate an excessive pressure differential within the filter system, it is time to initiate ... Periodic inspection is necessary for efficient filtration. Automatic systems provide for unattended ... on a prescheduled basis and more frequent backwashing, if needed, by activation of a differ-...de circuit. The higher initial cost of automation will provide efficiency and safety.

... BACKWASH CONTROL



...NSTRUCTION
...mputerized control housed in weather-... No moving parts to wear out or ...

...NS
...—12 Volts DC
...—12 Volts DC

...eration — 10 MA
... Operation — 150 MA
...acity — 2.0 Amps
...ons — 8-16 Optional
...on — 1" (2 amps)
... is active through entire sequence

...AC
... Panel

CONTROLS

1. Sequence Lamp — The lamp lights during the sequencing operation.
2. 24 Hour Timer — Min. ½ hour. Starts sequencing operation at pre-selected time.
3. Test — For testing control operation and output stations.
4. 1 Second to 10 min. Cycle Control — Controls backwash time per filter.
5. 1 Second to 10 min. Dwell Control — Controls time between backwash of each filter.
6. Power Switch — Disconnects power to control.
7. Manual Start — Initiates new cycle whenever it is pressed.
8. P.D. — Disconnects pressure differential sensor from control.
9. Fuse — Overload protection for control.

SOLENOID VALVE

3 Port, 2 Way Manual Override Solenoid Valve.

Voltage — 12 Volts DC
Operating Wattage — 10 Watts
Manual Override — On-Override
Off-Normal Operation

...CAL OR HORIZONTAL FERTILIZER TANK

FERTILIZER TANK
EPOXY COATED CARBON STEEL

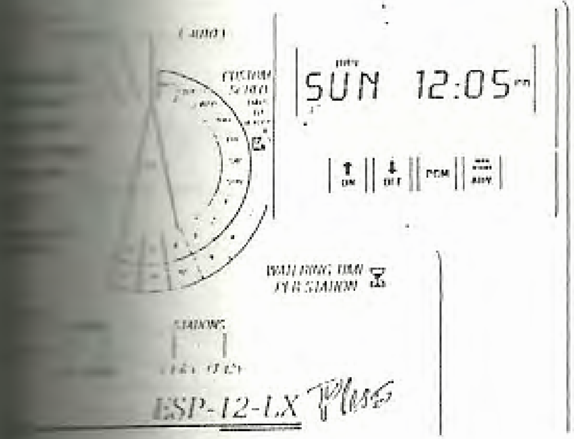
Model #	Diam. x L.	Max. Working Pressure	Liquid/ Dry Capacity
F-15	18 x 12	125	15 gal/ 80 lb.
F-30	18 x 24	125	30 gal/160 lb.
F-45	24 x 24	125	45 gal/240 lb.
F-75	24 x 36	125	75 gal/400 lb.

APÉNDICE D

FUNCIONES Y CARACTERÍSTICAS DE PROGRAMACIÓN

-LX+ y ESP-LXi+

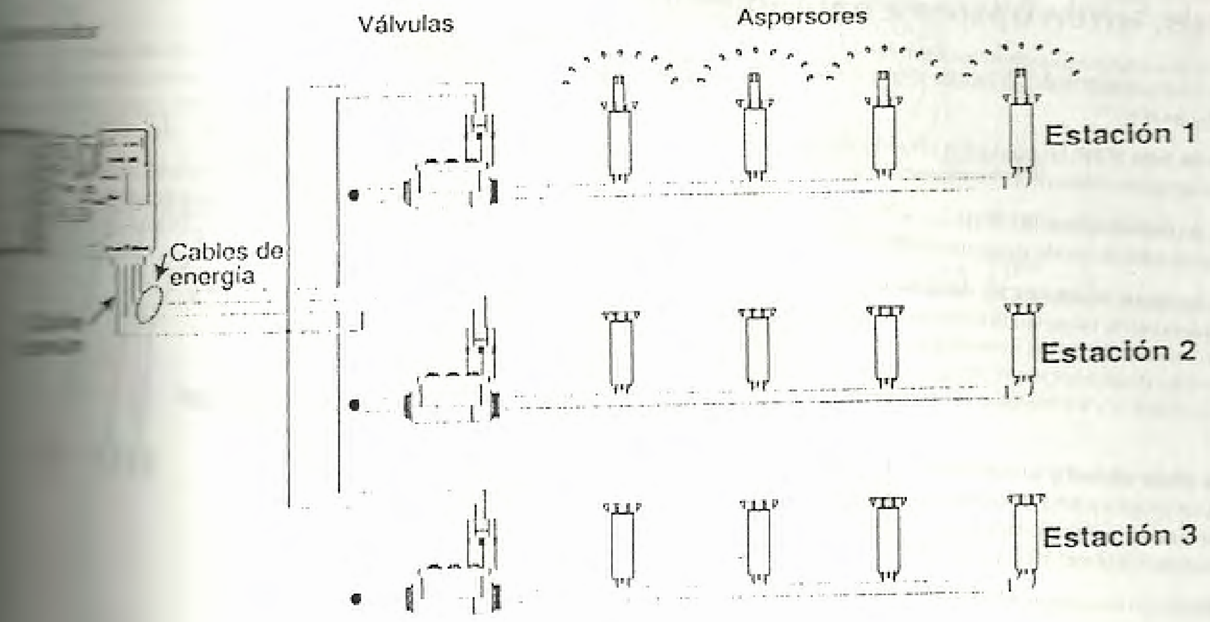
de instalación, programación y operación



Interiores y exteriores
ESP-6LX+
ESP-8LX+
ESP-12LX+
ESP-16LX+
ESP-24LX+

Interiores
ESP-8LXi+
ESP-12LXi+
ESP-16LXi+

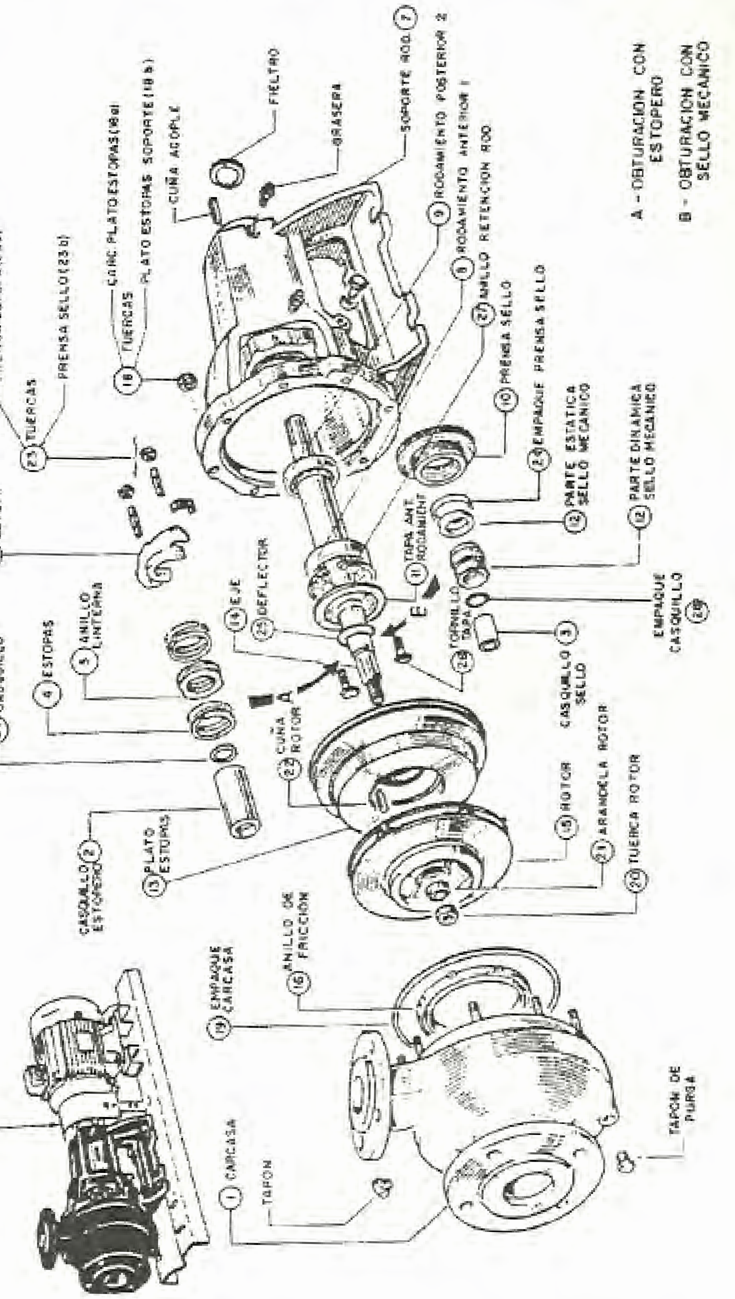
BIRD
ONALS WORLDWIDE


Válvulas
Aspersores
Estación 1
Cables de energía
Estación 2
Estación 3

APÉNDICE E

VISTA ISOMÉTRICA DEL DESPIECE DE BOMBA
(VISTA EN ELEVACIÓN)

DIAGRAMA EXPLOSIONADO DE BOMBA



APÉNDICE F

DIAGNÓSTICO GENERAL DEL GRUPO DE BOMBEO

TABLA DE REVISIÓN DE PROBLEMAS EN LAS BOMBAS

Síntomas	Causas posibles del problema
La bomba no da agua	1,2,3,4,6,7,8,11,14,16,17,22,23
Capacidad es insuficiente	2,3,4,5,6,7,8,9,10,11,14,17, 20,22,23,29,30,31
Presión insuficiente	5,10,14,16,17,20,22,26,30,31
Bomba se desceba después de arrancar	2,3,5,6,7,8,11,12,13
Bomba requiere potencia excesiva,	15,16,17,18,19,20,23,24 26,2729,33,34,37
Prensa estopas gotea	13, 24, 26, 32,3 3, 34, 35, 36, 37, 38, 39, 40
Empaquetadura tiene corta vida	12,13,24,26,28,32,33,34,35,36, 37,38,39,40
Bomba vibra o es ruidosa	2,3,4,9,10,11,21,23,24,25,26,27, 28,30,35,36,41,42,43,44,45,46
Rodamientos tienen corta vida	24,26,27,28,35,36,41,42,43,44, 45,46
Bomba se sobrecalienta	1,4,21,22,24,27,28,35,36,41,42,43

PROBLEMA EN LA SUCCIÓN

1. Bomba no está cebada
2. Bomba o tubo de succión no está completamente lleno de líquido
3. Altura de succión muy alta
4. Margen insuficiente de presión de succión y presión de vapor
5. Cantidad excesiva de aire én el líquido

6. Bolsas de aire en la tubería de succión
7. Aire entra en la tubería de succión
8. Aire entra en la bomba por el prensa estopa
9. Válvula de pie muy pequeña
10. Válvula de pie parcialmente tapada
11. Entrada tubo de succión insuficientemente sumergido
12. Tubería sello de agua tapada
13. Anillo linterna localizado inapropiadamente en el prensa estopas no dejando entrar el líquido en el espacio de sellamiento

PROBLEMAS DE SISTEMA

14. Velocidad muy baja
15. Velocidad muy alta
16. Sentido de velocidad invertido
17. Altura total del sistema más alta que la diseñada de la bomba
18. Altura total del sistema más baja que la diseñada de la bomba
19. Gravedad especificada del líquido diferente de la diseñada
20. Viscosidad del líquido diferente de la diseño
21. Operación a muy baja capacidad
22. Operación de bombas en paralelo no apta para esa condición

PROBLEMAS MECÁNICOS

23. Materia extraña en el rotor
24. Desalineamiento

25. Cimentación no está rígida
26. Eje doblado
27. Partes que rotan rozando con partes estacionarias.
28. Rodamientos gastados
29. Anillos de desgaste gastados
30. Rotor dañado
31. Empaquetadura carcasa defectuosa, permitiendo goteo externo
32. Eje o camisas del eje gastados en la empaquetadura
33. Empaquetadura instalada inapropiadamente
34. Tipo incorrecto de empaquetadura para las condiciones de operación
35. Eje girando descentradamente debido a desgaste de los rodamientos y desalineamiento
36. Rotor desbalanceado, causando vibración
37. Prensa estopas muy apretado, no dejando pasar líquido para lubricar la empaquetadura
38. Falla en el suministro de líquido refrigerante a los prensa estopas enfriados por agua
39. Tolerancia excesiva en el fondo del prensa estopas entre el eje y carcasa, causando que la empaquetadura sea forzada al interior de la bomba
40. Mugre o arenilla en el líquido de sello, llevando a desgaste el eje o camisa del eje
41. Empuje excesivo causado por una falla mecánica dentro de la bomba
42. Exceso de grasa en el caja de rodamientos o falta de enfriamiento, causando excesiva temperatura en los rodamientos
43. Falta de lubricación
44. Instalación inapropiada de los rodamientos
45. Mugre en los rodamientos
46. Oxidación de los rodamientos debido al agua en la caja de rodamientos.

APÉNDICE G

FORMULAS PARA EL CÁLCULO DEL RIEGO

FORMULAS PARA CALCULO DEL RIEGO.

CAPACIDAD DE CAMPO = C.C (mm/Mt)

1. PUNTO DE MARCHITEZ PERMANENTE = PMP (mm/Mt)
2. HUMEDAD DISPONIBLE = Sa = CC – PMP
3. HUMEDAD FÁCILMENTE APROVECHABLE = Sfa = 0.5*Sa
4. LAMINA NETA = Sfa x Profundidad Radicular Efectiva.

   LN = Sfa x PRE (mm)
5. LAMINA BRUTA = LN / EFICIENCIA DE RIEGO
6. FRECUENCIA DE RIEGO = FR = LN / USO CONSUNTIVO (Días)
7. TIEMPO DE RIEGO = TR = LB / TAZA INFILTRACIÓN (Hora)
8. No DE HORAS DIA = CRITERIO DE ACUERDO AL SITIO DE TRABAJO
9. No DE POSICIONES DIA = No HORAS DIA / TR
10. AREA TOTAL A REGAR = DATO DADO POR USUARIO (Mt 2)
11. AREA DIARIA A REGAR = AREA TOTAL / FR (Mt2 / dia)
12. AREA POR POSICION = AREA DIARIA / No POSICIONES DIA (Mt2/ pos)
13. CAUDAL REQUERIDO = AREA POR POSIC x LB / TR (Mt3/ hora)
14. PARA CORROBORAR EL DISEÑO : LA PRECIPITACION DEBE SER MENOR QUE LA TAZA DE INFILTRACIÓN DEL SUELO.

APÉNDICE H

MATERIAL Y MÓDULOS INSTALADOS

Material instalado enterrado y anclado

Tubería PVC de 110mm x 6mt UNION Z	1450mt
Tubería PVC de 90mm x 6mt ESPIGA CAMPANA	350mt
Tubería PVC de 63mm x 6mt ESPIGA CAMPANA	250mt
Tubería PVC de 50mm x 6mt ESPIGA CAMPANA	300mt
Tubería PVC de 40mm x 6mt ESPIGA CAMPANA	70mt
Tubería PVC de 32mm x 6mt ESPIGA CAMPANA	24mt

Módulos instalados

1. Rectorado, sector frontal y lateral
2. Facultades de ingeniería eléctrica y mecánica
3. Escalinatas entre el rectorado y Cesercomp

Áreas por instalarse

1. Rectorado (frente a tesorería)
2. Facultad de ingeniería Marítima (laboratorio y administración)
3. Parte posterior de rectorado, comedor de ingenierías y caminera que une el comedor con la facultad de ingeniería Marítima
4. Área entre la facultad de ingeniería Marítima y el CEMA
   Institutos.

APÉNDICE I

NORMATIVAS PARA INSTALACIÓN DE TUBERÍA PVC

…ma …riana	TUB… PLASTICA DETERMINACION DE LA …SISTENCIA A LA PRESION HIDROSTATICA INTERIOR SOSTENIDA	INEN 503 1980-11

…IGATORIA

1. OB ETO

… Esta norma establece el método de ensayo para determinar la resistencia a la presión hidrostática inte… …stenida de las tuberías plásticas.

2. ALCANCE

… Esta norma se aplica a la tubería de materiales termoplásticos y termoestables, cuya relación diámetro … a espesor de pared es mayor o igual a cinco.

3. TERMINOLOGIA

… Fallas de la probeta.

… *Fugas.* Trasmisión del fluido de ensayo a través de grietas o perforaciones del cuerpo de la probeta, … consecuente pérdida de la presión suministrada. No se considerará falla si ésta se produce a una dis… desde los extremos de la probeta menor o igual a un diámetro de la misma, más la longitud de aco…nto.

…2 *Hinchamiento.* Cualquier expansión local anormal de la probeta producida por la presión interna.

…3 *Reventamiento.* Falla por rotura de la pared de la probeta.

…4 *Exudación.* Filtración que ocurre a través de fisuras microscópicas en la pared de la probeta. Se evi… en forma de manchas o gotas en la pared de la misma.

4. RESUMEN

… El método consiste en someter a las probetas tubulares a una presión interna determinada y constante, … un lapso prolongado, bajo condiciones de ensayo prefijadas.

5. INSTRUMENTAL

… *Sistemas de presión.* Capaz de llegar gradualmente y sin fluctuaciones bruscas a la presión de prueba, … mantenerla dentro de las tolerancias indicadas en la Tabla 1.

…2 *Baño a temperatura constante.* Sistema constituido por un recipiente que contenga agua u otro fluido … no ataque a la probeta, que se mantenga a temperatura constante y uniforme dentro de las tolerancias … Tabla 1.

(Continúa)

5.3 *Manómetro.* Con una exactitud y precisión no menor al 1⁰/o de toda la escala, con aguja de arrastre y con una capacidad tal que los mayores rasgos de presión de ensayo estén dentro del 60⁰/o de la escala.

5.4 *Reloj.* Con graduaciones en horas, de preferenci accionando automáticamente.

5.5 *Tapas terminales de cierre.* Aptas para el fácil montaje de la probeta, que garantice la estanquei del conjunto, permitan la expansión longitudinal de la probeta y que no sean causa de falla de la misma.

5.6 *Soportes.* Que permitan colocar las probetas sin que ocurran deflexiones en las mismas y les den libertad de movimiento circunferencial y longitudinal.

6. PREPARACION DE LOS RESULTADOS

6.1 *Longitud de la probeta tubular.* La longitud de l probetas se obtendrá de la fórmula siguiente:

$$L = 250 + 3D + X$$

Siendo:

L = longitud total (mm).
D = diámetro exterior (mm).
X = longitud total necesaria para fijar las tapas terminales (mm).

6.1.1 Los extremos de las probetas deben estar libres de defectos y sus planos de corte deben ser perpendiculares al eje de las mismas.

6.2 *Número de probetas.* Se ensayarán al menos seis probetas por lote.

6.3 *Acondicionamiento.* Las probetas deben acondicionarse a la temperatura de ensayo ± 2°C durante 1 ± 0,2 h en un baño de agua o bien en un medio gaseoso durante 16 ± 0,2 h, de acuerdo a la Norma INEN 501.

7. PROCEDIMIENTO

7.1 Determinar el espesor mínimo de pared en cada extremo de las probetas y el diámetro exterior promedio en los extremos y en la mitad de las mismas, de acuerdo al método de ensayo INEN 499.

7.2 Limpiar las probetas y acoplar correctamente en sus extremos las tapas correspondientes, cuidando de no dañar la sección del tubo y asegurando su estanqueidad.

7.3 Acoplar cada probeta al sistema de presión, llenarla de agua, purgar el aire del sistema y sumergirla en el baño para su acondicionamiento, de acuerdo al numeral 6.3.

7.4 Someter el conjunto a presión e incrementarla de manera uniforme, hasta alcanzar la presión de ensayo con las tolerancias indicadas en la Tabla 1, dentro de un lapso de 60 s, y mantenerla durante el tiempo especificado para el ensayo.

(Continúa)

TABLA 1. Tolerancias de los parámetros de ensayo.

Período de ensayo	Temperatura	Presión	Tiempo
h	(±) °C	(±) °/o	(±) °/o
0 a 10	1	0,5	0,5
10 a 100	1	0,5	1,0
más de 100	2	1,0	2,0

8. CALCULOS

Calcular el esfuerzo circunferencial (σ) de las probetas tubulares ensayadas mediante la fórmula siguiente:

$$\sigma = \frac{p}{2} \left(\frac{D}{e} - 1 \right)$$

donde:

σ = esfuerzo circunferencial (MPa).

p = presión interna de ensayo (MPa).

D = diámetro exterior promedio (mm).

e = espesor mínimo de pared (mm).

9. INTERPRETACION DE LOS RESULTADOS

Los criterios para la evaluación de resultados se especifican en las normas de requisitos correspondientes a cada tipo de tubo bajo ensayo.

10. INFORME DE LOS RESULTADOS

El informe para la presentación de resultados debe contener los datos siguientes:

- identificación completa de cada probeta ensayada:
  - datos del marcado del producto;
- espesor mínimo de pared y diámetro exterior promedio;
- acondicionamiento y condiciones de ensayo;
- presión y tiempo de ensayo;
- tipo de falla (ver numeral 3.1);
- esfuerzo circunferencial, valores de la media y desviación estándar;
- gráfico: σ vs. tiempo;
- observaciones (tipo de tapas terminales, banco de pruebas, etc.);
- laboratorio, nombre y firma del responsable;
- fecha del ensayo;
- referencia de la presente norma.

Norma Ecuatoriana	TUBERIA PLASTICA DETERMINACION DE LA RESISTENCIA AL REVENTAMIENTO POR PRESION HIDROSTATICA INTERNA EN TIEMPO CORTO	INEN 502 1980-11

OBLIGATORIA

1. OBJETO

1.1 Esta norma establece el método de ensayo para determinar la resistencia a la rotura, en un intervalo corto de tiempo y bajo presión hidrostática interna, de los tubos y accesorios plásticos destinados al transporte de fluidos.

2. ALCANCE

2.1 Esta norma se aplica a las tuberías de materiales termoplásticos y termoestables.

3. TERMINOLOGIA

3.1 Fallas de la probeta.

3.1.1 *Fugas.* Transmisión del fluido de ensayo a través de grietas o perforaciones del cuerpo de la probeta, con la consecuente pérdida de la presión suministrada. No se considerará falla si ésta se produce a una distancia desde los extremos de la probeta menor o igual a un diámetro de la misma, más la longitud de acoplamiento.

3.1.2 *Hinchamiento.* Cualquier expansión local anormal de la probeta producida por la presión interna.

3.1.3 *Reventamiento.* Falla por rotura de la pared de la probeta.

3.1.4 *Exudación.* Filtración que ocurre a través de fisuras microscópicas en la pared de la probeta. Se evidencia en forma de manchas o gotas en la pared de la misma.

4. RESUMEN

4.1 El método consiste en someter las probetas a presión hidrostática interna uniformemente creciente, hasta que se produzca la falla de las mismas, dentro de un tiempo corto, bajo determinadas condiciones de ensayo.

5. INSTRUMENTAL

5.1 Sistema de presión. Capaz de suministrar presión hidrostática de manera gradualmente creciente y sin fluctuaciones bruscas.

5.2 Baño a temperatura constante. Sistema constituido por un recipiente que contenga agua u otro fluido que no ataque a la probeta, que se mantenga a temperatura constante y uniforme ± 1 °C.

(Continúa)

Manómetro. Con una exactitud y precisión no menor al 1°/o de toda la escala, con aguja de arrastre y ... capacidad tal que los mayores rangos de presión de ensayo estén dentro del 60°/o de la escala.

...ómetro. Con graduaciones en segundos, de preferencia accionado automáticamente.

...pas terminales de cierre para probetas tubulares. Aptas para el fácil montaje de la probeta, que ga-... la estanqueidad del conjunto, permitan la expansión longitudinal de la probeta y no sean la causa ... de la misma.

...pas terminales de cierre para accesorios y uniones. Tapas o tapones que garanticen la estanqueidad ...nto y no se extiendan más adentro de la parte de acople del accesorio.

...rtes. Que permitan colocar las probetas sin que ocurran deflexiones en las mismas y les den liber-... ...imiento circunferencial y longitudinal.

6. PREPARACION DE LAS PROBETAS

...gitud de la probeta tubular. La longitud de las probetas tubulares se obtendrá de la fórmula si-...

$$L = 250 + 3D + X$$

...

... longitud total (mm).

... diámetro exterior (mm).

... longitud total necesaria para fijar las tapas terminales (mm).

... extremos de las probetas deberán estar libres de defectos y sus planos de corte serán perpendicu-... de las mismas.

... ensayos de accesorios y uniones. Las probetas consistirán en un accesorio o unión completa sin al-...

... de probetas. Se ensayarán al menos tres probetas tubulares o tres accesorios.

...dicionamiento. Las probetas deben acondicionarse a la temperatura de ensayo ± 2°C durante ... en un baño de agua, o en un medio gaseoso durante 16 ±0,2 h, de acuerdo con la Norma INEN ...

7. PROCEDIMIENTO

...inar el espesor mínimo de pared en cada extremo de las probetas y el diámetro exterior prome-... ...tremos y en la mitad de las mismas, de acuerdo al método de ensayo INEN 499.

...ar las probetas y acoplar correctamente en sus extremos las tapas correspondientes, cuidando de ... sección del tubo y asegurando su estanqueidad.

(Continúa)

7.3 Acoplar cada probeta al sistema de presión, llenarla de agua, purgar el aire del sistema y sumergirla en el baño para su acondicionamiento de acuerdo al numeral 6.4, a la temperatura de 23 ± 2°C para tuberías de materiales termoplásticos y de 65 ± 2°C para tuberías de materiales termoestables.

7.4 Someter el conjunto a presión e incrementarla de manera uniforme y continua hasta que la probeta falle en un lapso de 60 a 70 s.

7.5 Repetir el ensayo si la probeta falla antes de 60 s o después de 70 s, disminuyendo la velocidad de aplicación de la carga, según sea el caso.

7.6 Registrar la presión y el tiempo de falla.

8. CALCULOS

8.1 Calcular el esfuerzo circunferencial (σ) de las probetas tubulares ensayadas, mediante la fórmula siguiente:

$$\sigma = \frac{p}{2}\left(\frac{D}{e} - 1\right)$$

Siendo:

σ = esfuerzo circunferencial (MPa).
p = presión interna de ensayo (MPa).
D = diámetro exterior promedio (mm).
e = espesor mínimo de pared (mm).

9. INTERPRETACION DE LOS RESULTADOS

9.1 Los criterios para la evaluación de los resultados se especifican en las normas de requisitos correspondientes a cada tipo de tubería bajo ensayo.

10. INFORME DE RESULTADOS

10.1 El informe para la presentación de resultados debe contener los datos siguientes:

a) identificación completa de cada probeta ensayada:
   – datos del marcado del producto;
b) espesor mínimo de pared y diámetro exterior promedio;
c) acondicionamiento y condiciones de ensayo;
d) presión y tiempo de falla;
e) tipo de falla (ver numeral 3.1);
f) esfuerzo circunferencial, valores de la media y desviación estándar;
g) observaciones (tipo de tapas terminales, banco de pruebas, etc.);
h) laboratorio, nombre y firma del responsable;
i) fecha de ensayo;
j) referencia a la presente norma.

CDU: 621.643.22
...: 3560

Norma Ecuatoriana Obligatoria	TUBERIA PLASTICA. ACCESORIOS DE PVC RIGIDO PARA PRESION. DIMENSIONES BASICAS.	INEN 1 328 Primera revisión 1994-09

1. OBJETO

Esta norma determina los diámetros y las dimensiones básicas de los accesorios de PVC rígido ... campana simple, para uniones por cementado solvente con tubos de PVC rígido para presión.

2. ALCANCE

... Esta norma es aplicable a accesorios de PVC rígido destinados a unirse con tubos de PVC rígido ... presión, comprendidos en la Norma INEN 1 369.

... Las longitudes Z dadas en ésta norma servirán de referencia para los diseños de moldes del ...nte y no deben usarse para propósitos de Control de Calidad.

... Esta norma no es aplicable a accesorios de PVC rígido, fabricados de tubos, y hechos por ...dura.

3. DISPOSICIONES GENERALES

... Diámetro de los accesorios

... Los diámetros interiores de las campanas de los accesorios corresponden a los diámetros ...res nominales de los tubos de PVC rígido y deben cumplir con lo indicado en la Norma INEN ...

... Los accesorios serán designados por los diámetros interiores de sus campanas.

... En el caso de accesorios del tipo reductor, serán designados por los diámetros de la superficie ..., dando la del macho en primer término.

... Angulos de los accesorios.

... Para codos los ángulos deben ser de 45° ó 90°.

... Para yee el ángulo debe ser de 45°

... Para tee el ángulo debe ser de 90°.

... Longitud de montaje

... La longitud de montaje entre los terminales de los tubos que deben ser unidos por el accesorio, ... designado como:

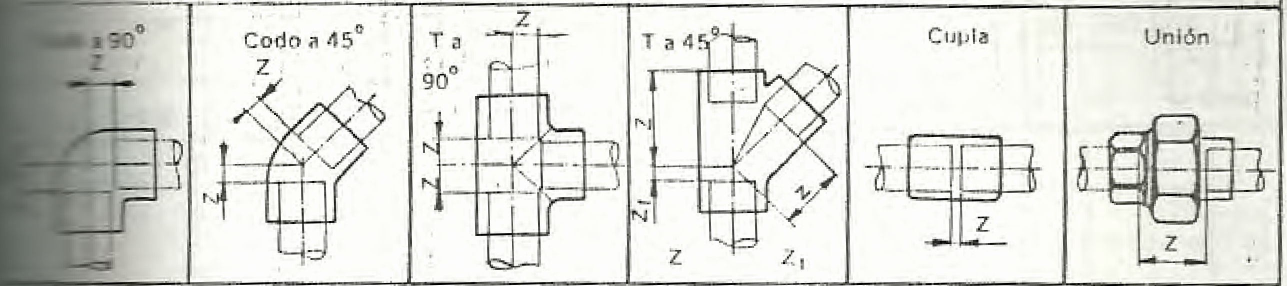
(Continúa)

...ORES: Polímeros, tubería, tubería plástica, accesorios, PVC rígido, presión, dimensiones.

ANEXO A

TABLAS. Dimensiones mínimas de las piezas de conexión (mm)

TABLA A1. Codos, Tees y Uniones



PIEZAS DE CONEXION						
[illegible] a 90°	Codo a 45°	T a 90°	T a 45° Z	Z1	Cupla	Unión
DISTANCIA Z						
[illegible]	3	6	–	–	3	13,5
[illegible]	3,5	7	–	–	3	13,5
[illegible]	4,5	9	–	–	3	13,5
[illegible]	5	11	27	6	3	13,5
[illegible]	6	13,5	33	7	3	13,5
[illegible]	7,5	17	42	8	3	13,5
[illegible]	9,5	21	51	10	3	15
[illegible]	11,5	26	63	12	3	17
[illegible]	14	32,5	79	14	3	21
[illegible]	16,5	38,5	94	17	4	–
[illegible]	19,5	46	112	20	5	–
[illegible]	23,6	56	137	24	6	–
[illegible]	27	63,5	157	27	6	–
[illegible]	30	71	175	30	8	–
[illegible]	34	81	200	35	8	–
[illegible]	34	101		–	8	–
[illegible]	48	114	–		10	–

TABLA A5. Reductor corto.

Termin. Hembra D_1	Diámetros de unión Terminales macho D_2														
	16	20	25	32	40	50	63	75	90	110	125	140	160	200	225
	Distancia Z														
10	2	4	6,5												
12	2	4	6,5	10											
16		2	4,5	8	12										
20			2,5	6	10	15									
25				3,5	7,5	12,5	19								
32					4	9	15,5	21,5							
40						5	11,5	17,5	25						
50							6,5	12,5	20	30					
63								6	13,5	23,5	31				
75									75	17,5	25	32,5			
90										10	17,5	25	35		
110											7,5	15	25	45	
125												7,5	17,5	37,5	–
140													10	30	–
160														20	33

	TUBERIA PLASTIC . TUBERIA DE PVC RIGIDO PARA P . SION. TUBOS Y ACCESORIOS CON CAMPANA PARA UN ON POR CEMENTADO SOLVENTE. DIMENSIONES.	INEN 1 330 Primera revisión 1994-09

1. OBJETO

... determina las dimensiones de la campana de los tubos y/o accesorios de PVC rígido, ... por cementado solvente.

2. DISPOSICIONES ESPECIFICAS

... de campana (L). La longitud del accesorio es de igual manera aplicable a tubos para ... diámetro y se determina mediante la siguiente fórmula:

... + 6 mm (con un valor mínimo de 12 mm)

...

... nominal del tubo.

... interior de la campana

... interior medio de la campana. El diámetro interior medio de la campana, medido como ... INEN 499, debe cumplir con los requ sitos de la tabla 1.

TABLA 1. Tolerancia para diámetro interior medio de la campana

Diámetro interior del accesorio Diámetro nominal del tubo D (mm)	Tolerancia Diámetro interior medio campana (mm)
10	+ 0,3
12	+ 0,3
16	+ 0,3
20	+ 0,3
25	+ 0,3
32	+ 0,3
40	+ 0,3
50	+ 0,3
63	+ 0,3
75	+ 0,3
90	+ 0,3
110	+ 0,4
125	+ 0,4
140	+ 0,5
160	+ 0,5
200	+ 0,6
225	+ 0,7
250	+ 0,8
280	+ 0,8
315	+ 0,9
355	+ 1,1
400	+ 1,2

...eros, tubería, tubos, plásticos, accesorios, cementado, dimensiones.

2.3 Ovalamiento de la campana. El ovalamiento de la campana no excederá el mayor de los siguientes valores:

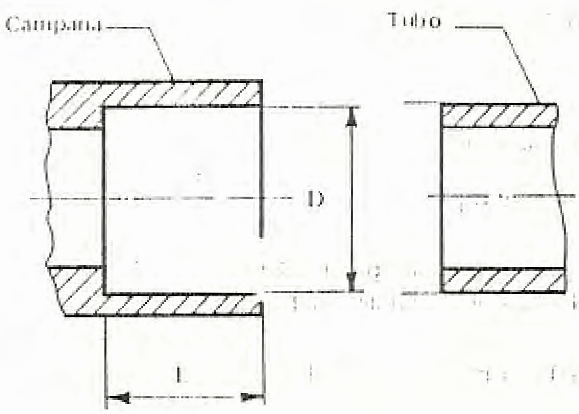
a) $t = (Dp - D) = 0,5$ mm

b) $t = (Dp - D) = 0,012\ D$ (ver nota 1)

En donde:

Dp = diámetro en un punto cualquiera

FIGURA 1. Dimensiones de la campana



NOTA 1. Cálculo redondeado al valor superior con aproxim[illegible] al 0,1 mm

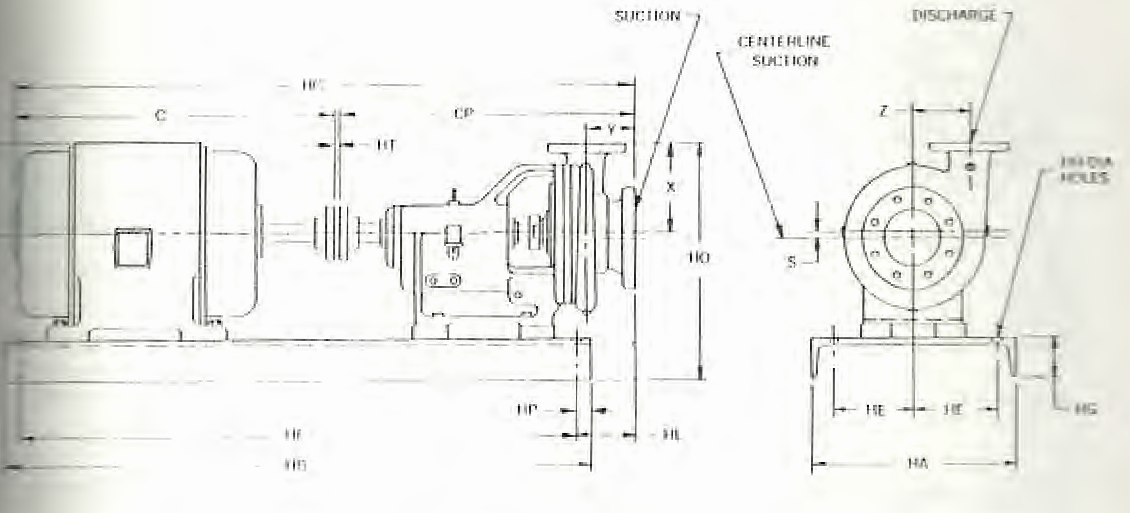
APÉNDICE J

NORMAS DE OPERACIÓN DE GRUPOS DE BOMBEO

hydraulic institute standards

for centrifugal, rotary & reciprocating pumps

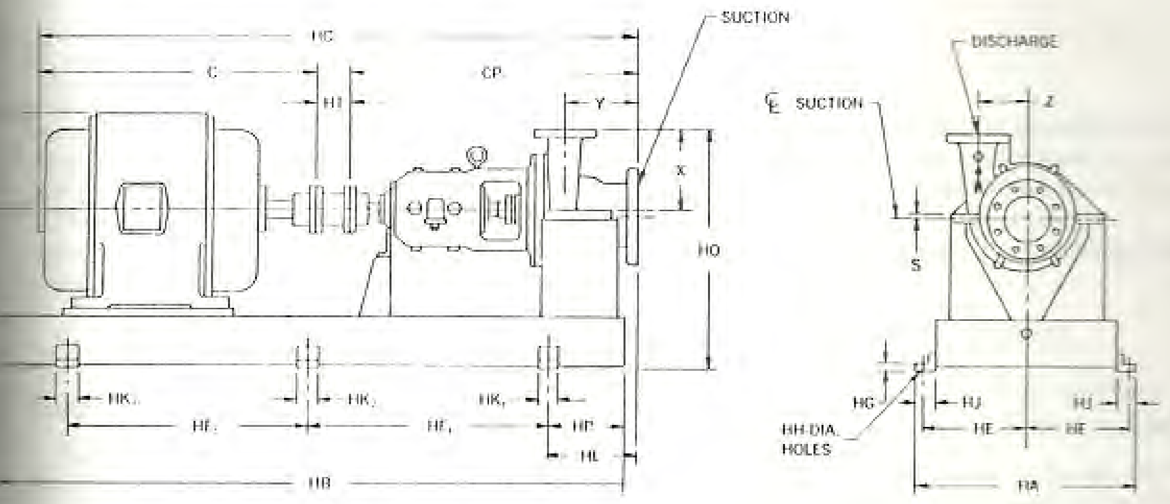
fourteenth edition



OVERHUNG IMPELLER, SEPARATELY COUPLED, SINGLE STAGE, FRAME MOUNTED PUMP ON BASEPLATE

- ...of driver.
- ...of pump.
- ...of base support.
- ...of base support.
- ...length of combined pump and driver when on base.
- ...height—bottom of base support to centerline of pump.
- ...ce from centerline pump to centerline hold-down bolts.
- ...ce from centerline to centerline of hold-down bolt holes.
- ...ness of pads on support, or height of base plate, depending on location of bolt holes.
- ...eter of hold-down bolt holes.
- ...ontal distance from suction nozzle face to centerline nearest hold-down bolt holes.
- HM— Height of unit—bottom of base to top of driver.
- HO — Vertical distance—bottom of support to discharge nozzle face or top of case on horizontally split pumps.
- HP — Length from edge of support, or base plate, to centerline of bolt holes.
- HT — Horizontal distance—between pump and driving shaft.
- S — Distance from centerline of pump to centerline of suction nozzle.
- X — Distance from discharge face to centerline of pump.
- Y — Horizontal distance—centerline discharge nozzle to suction nozzle face.
- Z — Centerline discharge nozzle to centerline of pump.

...ere multiple dimensions for similar components are required, i.e., mounting pad widths and locations, ... 1, 2, 3, et cetera should be used. Number from right to left, i.e., HE_1, HE_2, HE_3. These subscript designations ... in a view other than indicated.



33 OVERHUNG IMPELLER, SEPARATELY COUPLED, SINGLE STAGE, CENTERLINE MOUNTED PUMP ON BASEPLATE

...th of driver.
...gth of pump.
...h of base support.
...gth of base support.
...all length of combined pump and driver ...en on base.
...cal height—bottom of base support to ...nterline of pump.
...nce from centerline pump to centerline ...d-down bolts.
...nce from centerline to centerline of hold-...wn bolt holes.
...kness of pads on support, or height of ...se plate, depending on location of bolt ...es.
...eter of hold-down bolt holes.
... of pads for hold-down bolts.
...gth of support pad for hold-down bolts.
...nal distance from suction nozzle face ... centerline nearest hold-down bolt holes.

HM —Height of unit—bottom of base to top of driver.
HO —Vertical distances—bottom of support to discharge nozzle face or top of case on horizontally split pumps.
HP —Length from edge of support, or base plate, to centerline of bolt holes.
HT —Horizontal distance—between pump and driving shaft.
S —Distance from centerline of pump to centerline of suction nozzle.
X —Distance from discharge face to centerline of pump.
Y —Horizontal distance—centerline discharge nozzle to suction nozzle face.
Z —Centerline discharge nozzle to centerline of pump.

... multiple dimensions for similar components are required, i.e., mounting pad widths and locations, ... 1, 2, 3, et cetera should be used. Number from right to left, i.e., HE_1, HE_2, HE_3. These subscript designations ... a view other than indicated.

centrifugal pumps test standards

Object

This standard establishes a procedure for conducting and reporting tests on centrifugal pumps, vertical turbine pumps, mixed flow pumps and axial flow pumps, hereinafter referred to by the term, pumps.

The standard provides limiting conditions for all methods of quantitative determination of capacity, head and power input, as defined herein.

Scope

Except where specifically stated elsewhere herein, this standard shall be understood to apply to tests of pumps proper, and the terms capacity, total head, efficiency and power are to be taken as referring to the pump only, or in the case of vertical pumps of the turbine, mixed flow or axial flow type, referring to the bowl assembly only, or pump in a manner agreed upon between customer and manufacturer.

Since pumps are used to handle different liquids, or liquid-solid mixtures, it is necessary to limit this standard to the testing of pumps on clear water. For the determination of performance of centrifugal pumps handling liquids other than clear water, some methods and procedures not outlined herein may be required.

It is intended that the tests conducted under this standard shall be made and reported by qualified personnel trained in the proper application and use of the various instruments and methods involved.

Classification of Tests

Pump tests shall be classified as:

- Factory tests at the pump manufacturer's plant.
- Field tests at the place of installation.
- Model tests in accordance with pages 94–96.

In order to obtain accurate field performance test data, it is necessary to design the complete pump installation with this in mind and to provide for the use of suitable calibrated instruments.

The reliability of a field test is a function of the accuracy of the instruments used, the proper installation of same, and the skill of the test personnel.

Field tests are useful to indicate wear and/or changing conditions from initial to future tests.

Test Tolerances

In making tests under this standard no minus tolerance or margin shall be allowed with respect to capacity, total head, or efficiency at the rated or specified conditions.

Pumps shall be within the following tolerance:

At rated head:
- +10% of rated capacity, or

At rated capacity:
- +5% of rated head under 500 feet
- +3% of rated head 500 feet and over

Conformity with only one of the above tolerances is required. It should be noted that there may be an increase in horsepower at the rated condition when complying to plus tolerances for head or capacity.

Test Procedure

It is advisable to make one or more preliminary tests for the purpose of determining the adequacy of the instruments and apparatus and the training of the personnel. When conditions do not permit such preparatory runs, operations may be started and the time at which conditions may become satisfactory can be chosen later as the starting time of a test.

Fluctuations are short-time oscillations about a mean value which occur during the time that a single observation is being made. Acceptable fluctuations in test readings should not exceed those tabulated below:

Test Quantities	*Acceptable Fluctuations**
Differential across pump (Δ_H)	±2 per cent × Δ_H
Discharge (h_d)	±2 per cent × h_d
Suction (h_s)	±3 per cent × h_s
Rate of flow (Q)	±2 per cent × Q
Speed (n)	±0.3 per cent × n
Power input to pump (bhp)	±1 per cent × bhp

***Note:** The values given in this column are applicable at or near the point of best efficiency under non-cavitating conditions. It should also be noted that the above limits of fluctuation are specified only to facilitate the conduct of the test.

All pressure readings are converted into feet of the liquid being pumped.

The Datum Elevation is defined as follows:

For horizontal units it shall be the centerline of the pump shaft, Fig. 46A.

For vertical single suction pumps both volute and diffusion vane type, it shall be the entrance eye to the first stage impeller, Fig. 46, B and C.

For vertical double suction pumps it shall be the impeller discharge horizontal centerline, Fig. 46D.

The velocity head (h_v) is the kinetic energy per unit weight of the liquid at a given section. Velocity head is specifically defined by the expression:

$$h_v = \frac{V^2}{2g}$$

where

g = Acceleration due to gravity and is 32.17 feet per second per second at sea level and 45 degrees latitude

V = Velocity in the pipe in feet per second

V is obtained by dividing the discharge (cfs) by the actual area of the pipe cross-section in square feet and determined at the point of gauge connection.

If the velocity head is more than 5% of the total head, two or more pitot traverses symmetrically disposed may be required.

Note: In the following paragraphs, subscripts "s" and "d" are used to designate pump suction and discharge, respectively; thus, the velocity head at the suction would be noted as h_{v_s}.

Total suction head (h_s), as determined on test, is the reading of a gauge at the suction of the pump, converted to feet of liquid and referred to datum, plus the velocity head at the point of gauge attachment.

The gauge tap location should be close to the pump suction nozzle but such that the suction head reading will not be influenced by fluid pre-whirl, and preferably preceded by a straight run of pipe.

Thus:

$$h_s = \pm h_{g_s} + h_{v_s} \pm Z_s$$

where

h_{g_s} = Gauge head, feet, at suction
+ = Above atmospheric
− = Below atmospheric

Note: $-h_{g_s}$ indicates a suction lift.

Z = Vertical distance to gauge zero, feet.
+ = Above datum
− = Below datum

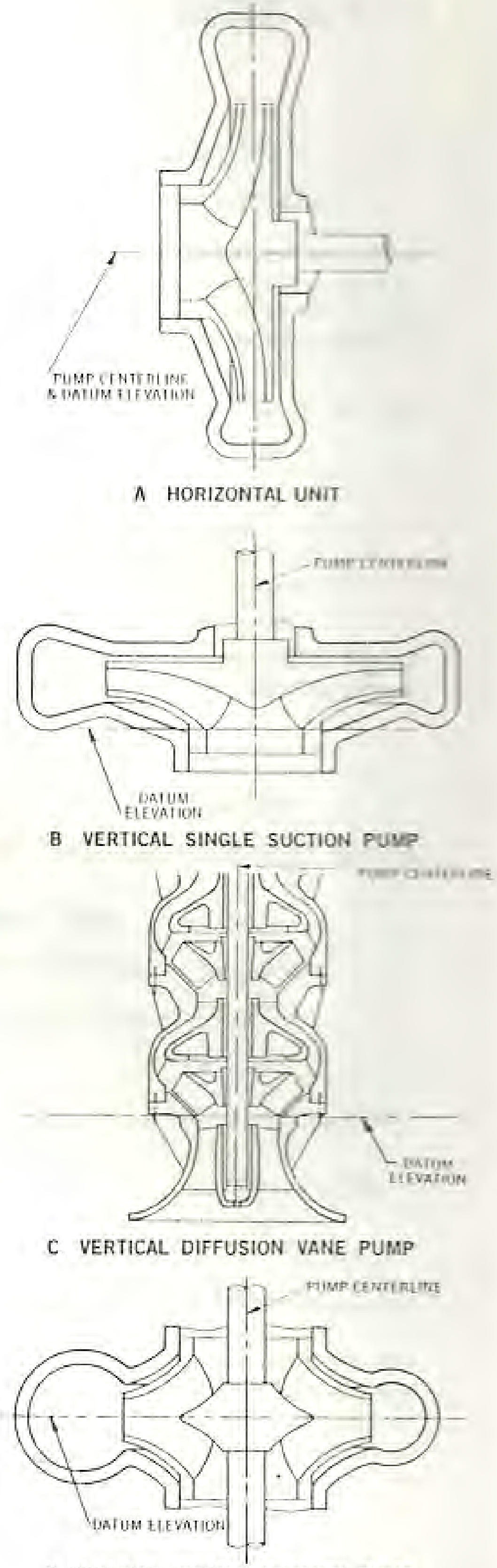


Fig. 46 DATUM ELEVATION OF VARIOUS PUMP DESIGNS

...mps submerged in a sump or wet well, where ...on piping is considered part of the pump,

$$h_s = Z_{w_s}$$

...vertical distance of sump free water surface from datum, feet.

...ischarge head (h_d) is the reading of a pres...e in the discharge pipe of the pump, con... feet of liquid and referred to datum, plus ...ead at the point of gauge attachment. ...cation of the measuring section should be ...on in the discharge pipe where the maxi...d prevails.

$$h_d = \pm h_{g_d} + h_{v_d} \pm Z_d$$

...ad or total dynamic head (H) is the mea...e energy increase per pound of the liquid ... to the liquid by the pump and is therefore ...ic difference between the total discharge ... the total suction head.

$$H = h_d - h_s$$

$$= (\pm h_{g_d} + h_{v_d} \pm Z_d) - (\pm h_{g_s} + h_{v_s} \pm Z_s)$$

$$H = (\pm h_{g_d} + h_{v_d} \pm Z_d) - Z_{w_s} \text{ for sumps.}$$

...ng terms, the general expression for total ...

$$H = (h_{g_d} - h_{g_s}) + (h_{v_d} - h_{v_s}) + (Z_d - Z_s)$$

...es of head measurement are given on ... to 88.

...receding formulas, the work accomplished ...ssing the fluid has been ignored. To eval... otal head more accurately when handling ...ible fluid, this factor should be taken into ...on. For most liquids it may be assumed ...ght line relationship exists between pres... volume. With this assumption, the above ... formula becomes:

$$\ldots - p_s)\frac{(v_d + v_s)}{2} + (h_{v_d} - h_{v_s}) + (Z_d - Z_s)$$

$$\left[\frac{\ldots - p_s)\left(\frac{1}{w_d} + \frac{1}{w_s}\right)}{2}\right] + (h_{v_d} - h_{v_s}) + (Z_d - Z_s)$$

where:

p = Unit pressure
w = Specific weight, force/unit volume
$v = \frac{1}{w}$ = Specific volume, vol./unit weight

It is suggested that either of the last two relationships be used if a significant difference exists between v_d and v_s, near best efficiency point, so as to affect the calculation of pump efficiency within the test tolerance.

EXAMPLE: Correction of total head for compressibility.

Given Water Conditions:

T_s = 350 F (suction temperature)
p_s = 200 psia (suction pressure)
T_d = 360 F (discharge temperature)
p_d = 4700 psia (discharge pressure)

Reference: ASME Steam Tables—1967, Table 3, Properties of Superheated Steam and Compressed Water.

At suction conditions:

$$p_s = 200 \text{ psia}; \quad T_s = 350 \text{ F}$$

From Table P159, $v_s = .01798$ ft^3/lb (Specific Volume)

At discharge conditions:

$$p_d = 4700 \text{ psia}; \quad T_d = 360 \text{ F}$$

From Table P193, $v_d = .01770$ ft^3/lb

then,

$$\left[\frac{(p_d - p_s)(v_d + v_s)}{2}\right] = (4700 - 200) \times 144 \times \frac{(.01770 + .01798)}{2}$$

$$= 11{,}560 \text{ ft}$$

This value should be added to the terms $(h_{v_d} - h_{v_s})$ and $(Z_d - Z_s)$ to obtain the total head.

Net positive suction head available in feet (symbol NPSHA) is the total suction head in feet of liquid absolute, determined at the suction nozzle and referred to datum, less the absolute vapor pressure of the liquid in feet of liquid pumped.

Thus:

$$NPSHA = h_{sa} - h_{vpa}$$

where

h_{sa} = Total suction head in feet absolute $= h_a + h_s$

$$NPSHA = h_a - h_{vpa} + h_s$$

= Atmospheric pressure in feet absolute
= Vapor pressure of liquid in feet absolute
= Total suction head in feet

$$NPSHA = \frac{144}{w}(p_a - p_{vp}) + h_s$$

= Atmospheric pressure in psia
= Vapor pressure in psia
= Specific weight of liquid in pounds per cubic foot

…LE: A four-stage boiler feed pump having a …side diameter suction and a 3-inch inside … discharge, is rated at a capacity of 400 …nst a total head of 900 feet handling water … F. and running at 3550 rpm. The suction …eading is 21 psig and its datum is located 0.5 …w impeller inlet datum. The pump is to be … the factory under full head and at the same … handling water at 80 F.

…s the Net Positive Suction Head Available …) to the pump in the field?

$$NPSHA = \frac{144}{w}(p_a - p_{vp}) + h_s$$

$$= 29'' \text{ of Hg} = \frac{29}{12} \times \frac{13.58}{2.31} = 14.2 \text{ psia}$$

…pecific gravity (s) of mercury = 13.58 and

$$psi = \frac{\text{ft of water} \times s}{2.31}$$

= 24.97 psia (from steam tables)
= Specific weight = 59.1 lb per cu ft

… in 4-inch inside diameter suction

$$= \frac{400 \times .321}{\frac{\pi}{4}(4)^2} = 10.2 \text{ ft/sec}$$

$$\text{Velocity head } (h_{vs}) = \frac{V^2}{2g}$$

$$h_{vs} = \frac{(10.2)^2}{2 \times 32.17} = 1.6 \text{ feet}$$

$$h_s = \pm h_{g_s} + h_{v_s} \pm Z_s$$

$$h_s = \frac{21 \times 144}{59.1} + 1.6 - 0.5 = 52.3 \text{ feet}$$

$$NPSHA = \frac{144}{59.1}(14.2 - 24.97) + 52.3 = 26.1 \text{ feet}$$

Power

The unit of power is the horsepower.

1 horsepower = 550 foot-pounds per second
= 33,000 foot-pounds per minute
= 2545 Btu per hour
= .7457 kilowatts

Motor input (ehp) is the electrical input to the driver expressed in horsepower.

Pump input or driver output (bhp) is the power delivered to the pump shaft expressed in horsepower.

Pump output (whp) is the liquid horsepower delivered by the pump, or,

$$whp = \frac{w \times cfs \times H}{550} = \frac{QHs}{3960}$$

where

s = Specific gravity of liquid referred to water at 68 F
w = Specific weight of liquid in pounds per cubic foot
H = Total head in feet
Q = Capacity in gallons per minute (gpm)
cfs = Capacity in cubic feet per second

Efficiency

Pump efficiency (η_p) is the ratio of the energy delivered by the pump to the energy supplied to the pump shaft; that is, the ratio of the liquid horsepower to the brake horsepower, or,

$$\eta_p = \frac{whp}{bhp}$$

Overall efficiency (η_o) is the ratio of the energy delivered by the pump to the energy supplied to the input side of the pump driver; for example, the overall efficiency of a motor driven pump is the ratio of the liquid horsepower to the electrical horsepower, or,

$$\eta_o = \frac{whp}{ehp}$$

In the case of vertical turbine, mixed flow and axial flow pumps, overall efficiency is based on the performance of the complete unit, including column pipe, line shafting and discharge head or elbow. See page 91 for method of calculation.

Operating Conditions

important factors affecting the opera- mp are the suction conditions, total temperature, specific weight, viscosity suspension. In some cases the condi- stallation are beyond the control of the acturer and this precludes the precise of the true head and performance. In nly a nominal performance can be factory tests are particularly needed nominal field performance.

sump for a vertical turbine, mixed ow pump is marginal, it may be advis- te the essential features of the design e factory pump test or conduct a sepa- take test. This is especially important hat will operate with limited submer- age 125, Intake Design.

Tests

al arrangements are shown for deter- avitation characteristics of pumps.

arrangement, Fig. 47, the pump is sup- constant level sump through a throttle s followed by a section of pipe contain- and straightening vanes. This arrange- ates the turbulence produced by the and makes possible an acceptable ction lift at the pump inlet.

arrangement usually is satisfactory suction lifts and smaller pumps, al- urbulence at the throttle valve tends to e release of dissolved air or gas from ch takes place as the pressure on the ed. A test made with this arrangement dicate less favorable performance than be expected under normal operating

nd arrangement, Fig. 48, the pump is a relatively deep sump in which the an be varied to establish the desired This arrangement provides an actual suc- hence more nearly duplicates average ditions. Since the release of dissolved a function of time as well as pressure, e influenced by the length of the suction test made with this arrangement may esults than can be expected with a of considerably greater length.

arrangement, Fig. 49A, the pump is a closed tank in which the level is held the suction lift or head is adjusted by varying the air or gas pressure over the liquid, or by varying the temperature of the liquid, or by a combination of these factors.

This test arrangement tends to strip the liquid of dissolved air or gas. It gives a more accurate measurement of the pump performance uninfluenced by the release of air or gas at pressures greater than the vapor pressure of the liquid. This arrangement more nearly duplicates service conditions where a pump takes its supply from a closed vessel with the liquid at or near its vapor pressure.

Tests at temperatures below that specified for the installation subject the pump to conditions which are more severe than at installation because of potentially unreleased air or gas. It is recommended, where practical, to test at the same specified temperature as the actual installation.

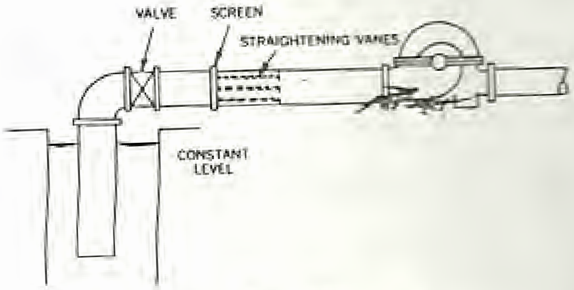


Fig. 47
CONSTANT LEVEL SUMP SUPPLY

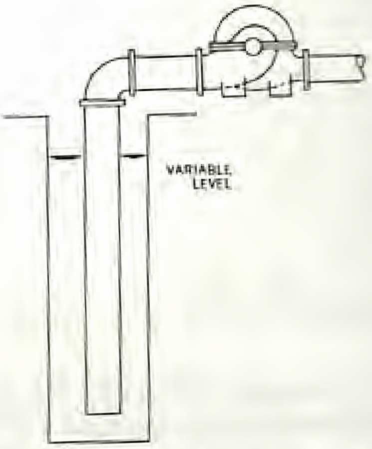


Fig. 48 DEEP SUMP SUPPLY

Cavitation Tests for Vertical Pumps

Cavitation tests for vertical turbine pumps in closed loop applications can be performed in the same manner as for other centrifugal pumps. How-

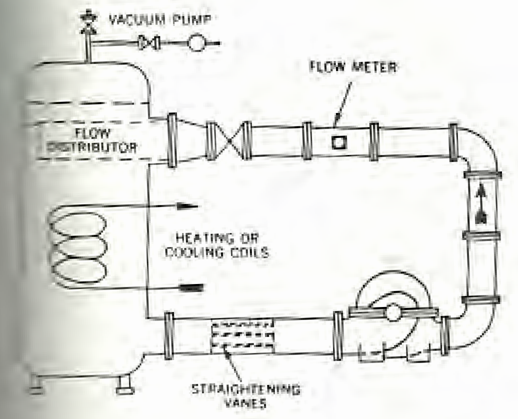


Fig. 49A
...SED LOOP SET-UP HORIZONTAL PUMP

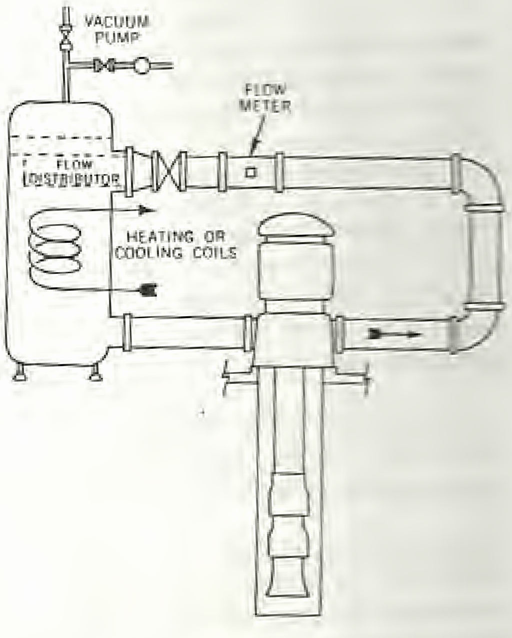


Fig. 49B
CLOSED LOOP SET-UP VERTICAL PUMP

...hen the suction condition is specified as 0 ft. ... at the suction datum elevation, the test must ...rformed by reducing the distance between the ...n at the impeller eye entrance and the datum ...n through reduction of discharge column ..., or removal of pump series stages. The test ... must then reference the difference between ...um and application datum elevation.

...cal pumps for free surface applications can, ...cal, be tested in a deep sump in which the ... evel can be varied to establish the desired ... lift or NPSH requirements. A more desirable ... is to locate the bowl assembly (first stage ... multi-stage pumps) in a suitable suction ... tank in which the pressure can be regulated ...uced to the desired level to meet the test cri... See Fig. 49B for cavitation test set-up of ver...mp.

...ge pumps cavitation testing may, for prac...sons, be performed on models. Reference is ... the section on model testing at the end of ... Standard.

...nation of Limiting Suction Requirements

...ction requirements to be met by a pump are ... by the cavitation coefficients, sigma (σ) as ...ed by the specified field conditions. Sigma ...ed as:

$$\sigma = \frac{NPSHA}{H}$$

...A = Net positive suction head available, as defined on page 71 in feet
= Total pump head per stage in feet

The cavitation characteristics of a pump can be determined by one of the following procedures:

Using one of the test arrangements shown, the pump may be run at constant capacity and speed with the suction condition varied to produce cavitation. Plots of head, efficiency, and power input shall be made as shown in Fig. 50. For the higher values of sigma (σ), the values of head (H), efficiency (η), and horsepower (bhp) should remain substantially constant. As sigma (σ) is reduced, a point is reached where the curves break away from this trend, indicating a condition under which the performance of the pump may be impaired, the degree of which will depend upon the specific speed, size and service of the pump, and the characteristics of the liquid. Fig. 51 shows results typical of tests for sigma (σ) at capacities both greater and less than normal.

One alternate technique for determining the cavitation characteristics is to hold the speed and suction pressure (p_s) constant, and to vary the capacity. For any given suction pressure, the pump head may be plotted against capacity. A series of such tests will result in a family of curves, as shown in Fig. 52. Where the curve for any suction pressure (p_s) breaks away from the envelope, cavitation occurs. Sigma (σ) may be calculated at the break-away points.

…LE: With the same field conditions as in the … example, the factory test on the same … to be made at a reduced speed of 2950 … water at 80 F. What head, capacity and …ead or lift should be used in the factory …

…g the relationships given above, the head … to be used in the factory test is:

$$\ldots H\left[\frac{N_1}{N}\right]^2 = 225\left[\frac{2950}{3550}\right]^2 = 156 \text{ feet}$$

…pacity to be used in the factory test is:

$$\ldots Q\left[\frac{N_1}{N}\right] = 400\left[\frac{2950}{3550}\right] = 333 \text{ gpm}$$

$$\ldots_s = \frac{N\sqrt{Q}}{H^{3/4}} = 3550\frac{\sqrt{400}}{225^{3/4}} = 1220$$

$$\ldots_1 = \frac{N_1\sqrt{Q_1}}{H_1^{3/4}} = 2950\frac{\sqrt{333}}{156^{3/4}} = 1220$$

… keep the specific speed the same in the … as in the field installation.
… the cavitation factor,

$$\ldots = \frac{\text{NPSHA}}{\text{Head/Stage}} = \frac{26.1}{225} = 0.116$$

… the factory test as in the field installation

$$\ldots = \sigma H$$
$$= .116 \times 156 = 18.1 \text{ feet}$$

$$\ldots = \text{NPSHA} - \frac{144}{w}(p_a - p_{vp})$$

$$= 18.1 - \frac{144}{62.2}(14.7 - .5)$$

$$= 18.1 - 32.9$$
$$= -14.8 \text{ feet}$$

… the factory test should be run with a … lift of 14.8 feet. When it is impossible … specified speed on test due to variation … the electric current or for other rea… …ons in the capacity, head and brake … correspond to the specified speed, … from test data in the manner set forth …

…mental Deviation from the Square

… relationships define the manner in … capacity, horsepower, and NPSH vary in a centrifugal or axial flow pump with respect to speed changes. If a pump operates at or near its cavitation limit, other factors also have an effect, and the critical sigma, or limiting NPSH value, may vary other than as the square of the speed. Some of these factors are: Thermodynamic effect on the vapor pressure of the fluid, change in surface tension, and test differences due to the relative air content of the liquid.

If the manufacturer can demonstrate that, with a given pump under particular conditions, an exponent different than the square of the speed exists, such exponent may be recognized and used accordingly.

Temperature

Variations in temperature of the fluid pumped cause changes in the specific weight and viscosity, with resultant changes in the performance of the pump.

Any reduction in specific weight, as caused by an increase in temperature, results in a directly proportional reduction in whp (as covered on page 72, Power) and in input power; therefore, the efficiency is not changed.

Reduced viscosity will have an influence on efficiency. For pumps in the lower range of specific speed, such as, high pressure, multi-stage boiler feed pumps and large, single stage hot water circulating pumps, reduced viscosity will:

Increase the internal leakage losses.
Reduce disc friction losses.
Reduce hydraulic skin friction or flow losses.

The net effect of a reduction in viscosity due to higher temperature will depend on specific speed and on the design details of the pump. Where substantiating data are available and where a high degree of understanding exists between the manufacturer and the user, consideration may be given to adjusting the performance data from a cold water test to hot water operating conditions on the basis of the following formula:

$$\eta_0 = 1 - (1 - \eta_t)\left[\frac{V_o}{V_t}\right]^n$$

where

η_t = Efficiency at test temperature, decimal value
η_o = Efficiency at operating temperature, decimal value
V_o = Kinematic viscosity at operating temperature
V_t = Kinematic viscosity at test temperature
n = Exponent to be established by manufacturer's data (probably in the range of 0.05 to 0.1)

...al Example of Adjustment of Efficiency for ...sed Temperature

...on water at 100 F resulted in an efficiency ...per cent. What will be the probable efficiency ... F?

$$... 1-(1-\eta_t)\left[\frac{V_o}{V_t}\right]^n$$

$$... 1-(1-.80)\left[\frac{.00000185}{.0000076}\right]^{0.1}$$

$$... 1-(.2)(.868)$$

$$... 826 = 82.6\%$$

...c Weight

...test is run with a liquid of different specific ...from that of the field installation, proper cor... shall be made.

...

...y has a very definite effect on the operat...tions of the pump with respect to head, ... efficiency and brake horsepower. Pumps ...s service, which are tested with water, will ...corrections to approximate the performance ... viscous liquid. Refer to page 111.

... Suspension

... suspension affect the operating condi... the pump in a varying degree, depending on ...ntage and nature of the solids. No definite ...s can be recommended for this condition.

...s of Capacity Measurement

...wing paragraphs present essential infor... methods of capacity measurement most ... used for testing centrifugal pumps.

... Meters

... meters may be classified into the two ... groups listed below. One group primarily ... quantity, the other primarily measures ...

- ... Meters:
  - ...ing Meters, such as:
    - ...ghing tank
    - ...ng trap
  - ...etric Meters, such as:
    - ...
    - ...procating piston
    - Rotary piston
    - Nutating disk
- Rate Meters:
  - Head (Kinetic) Meters, such as:
    - Venturi
    - Nozzle
    - Orifice plate
    - Pitot tube
  - Area (Geometric) Meters, such as:
    - Gate
    - Orifice and plug
    - Cone and disc
    - Cylinder and piston
  - Head-Area Meters, such as:
    - Weir
    - Flume
  - Velocity Meters, such as:
    - Propeller
    - Cup
    - Turbine
    - Electro-magnetic
  - Special Methods, such as:
    - Salt velocity
    - Titration
    - Ultra-sonic flow meters

All quantity meters and rate meters of the area type are primarily suitable for the measurement of relatively small rates of flow, because of the inherent size of these devices. Rate meters of the head-area type and velocity types are primarily suitable for measurement of relatively large rates of flow. Certain weirs may be used very successfully for measurement of lower flow rates. Rate meters of the head type are covered in detail in the following paragraphs and have a reasonably universal range of application. The preferred method of determining capacity is by weight or volume.

Capacity Measurement by Weight

Measurement of capacity by weight depends upon the accuracy of the scales used and the accuracy of the measurement of time. Accuracy to one-quarter of one per cent is obtainable from scales. A certification of scales shall become a part of the test record, or in the absence of certification, the scales shall be calibrated with standard weights before or after test. Time interval for the collection period must be measured to an accuracy of one-quarter of one per cent.

Measurement by Volume

...easurements of the reservoir shall be ...ablish its volume within one-half of one ...less this degree of accuracy is attain... ...servoir shall be calibrated by weighing of ...nes contained within the reservoir at a ...umber of liquid surface levels over the ...els to be measured during the test to in... ...ent of the prescribed accuracy.

...shing reservoir volume by linear mea... consideration must be given to the geo... ...arity (flatness, parallelism, roundness, ... reservoir surfaces, dimensional changes ...al expansion or contraction, or to de... ...lting from hydrostatic pressure of the

...evels shall be measured by whatever ... be required to assure determination of ... to an accuracy of one-half of one per ... means include hook gauges, floats and ...clined gauge glasses.

... measurements shall be made to an ac... ...e-quarter of one per cent.

... locations, and under some circum... ...oration and loss of liquid by spray may ..., and may be greater than the effects ...xpansion or contraction. Allowance for ...st be made, or the loss prevented.

Measurements by Head Type Rate

...ng within this classification, and ac... ...apacity determination under this stan... ...sed as prescribed herein, are Venturis, ... Orifice Plates.

... meter, compliance with this standard ... a certified curve showing the calibra... ...eter shall be obtained. This certifica... ...ate the method used in calibration and ... meter itself was calibrated, or whether ...as obtained from an exact duplicate.

... physical condition of the meter is sus... ...ng different from that existing during ..., a procedure for establishing its cur... ...istics shall be determined.

... a detailed discussion of these meters, ...on and calibration, the user is referred ...ters, Their Theory and Application," ... 1971 (a report of the ASME Research ... on Fluid Meters), and Instruments and ... PTC 19.5, 1972 (a supplement to ASME ... Codes).

Tolerances or limits of accuracy have to do with those practically unavoidable, individual differences between ostensibly duplicate meters. They do not refer to accidental errors of observation, concerning which no general predictions are possible.

For meters conforming to all physical and dimensional limitations set forth in the above referenced ASME publications, and when installed subject to limitations provided herein, tolerances applicable to measurements of rates of flows given in Table 2 may be expected. For meters not conforming to these physical and dimensional limitations, tolerances may differ from those shown in Table 2 by a significant amount, to the extent that limits of such tolerances can not be provided in this standard. Similarly, such meters may require or permit significantly different installation dimensions than those shown in Tables 3 or 4.

The accuracy of capacity measurements obtained with head type rate meters depends upon their being installed in such a manner that they will not be adversely affected by improper flow conditions in the system immediately preceding and following the meter. Non-uniform velocity distribution, or swirling or pulsating flow will affect the results obtained. Accordingly, the following sections on individual types of meters within this classification include requirements related to upstream and downstream piping which must be met to obtain the tolerances given in Table 2.

These precautions are stipulated to assure uniform flow at the meter inlet and stable flow at the downstream pressure taps. If there is a question as to whether or not uniform flow has been obtained, it shall be checked by a velocity head traverse of the pipe immediately preceding the meter to assure symmetrical velocity distribution within the pipe.

The pipe for one diameter preceding the upstream pressure taps shall be free from tubercles or other surface imperfections which would establish a local disturbance in line with these openings. Pressure tap openings shall be flush with the interior of the pipe or meter element, as appropriate, and shall be free of burrs (Figs. 53 and 54).

Manometers, pressure differential gauges, or electrical differential pressure transducer systems (not recording instruments) shall be used for measuring the differential pressure between high pressure and low pressure taps. The proper use of gauges is covered on pages 86 to 89.

The following paragraphs cover specific information related to individual forms of head type rate meters, and must be observed for the form of meter

TABLE 2

Tolerances for Discharge Coefficients and Flow Coefficients

Type of Primary Element	Pipe Size D	β (Note 1)	R_D (Note 2)	Tolerance Per Cent
Venturi Tubes Herschel-Type	4 in. & larger	0.25 to 0.75 inclusive	200,000 & over	± 0.75
			50,000 to 200,000	± 2.25 to ± 0.75 See Note 3
	less than 4 in.	as required	calibration over expected range of use	See Note 4
Modified Venturi Tubes	as required	as required	calibration over expected range of use	See Note 4
Flow Nozzles, Long-Radius with Pipe-Wall Taps at 1 D and ½ D	6 in. to 12 in. inclusive	0.30 to 0.70 inclusive	$33,000 \times D$ & over	± 0.95
		0.20 to 0.30 & 0.70 to 0.80	$3,000 \times D$ & over	± 0.95 to ± 1.50 See Note 5
(1 dia. upstream and ½ dia. downstream of inlet face)	4 in. & smaller & over 12 in.	as required	calibration over expected range of use	See Note 4
Flow Nozzles, Long-Radius or ISA Type with Corner Taps	2 in. to 8 in. inclusive	0.20 to 0.80	$10,000 \times D$ & over	± 1.5 (tentative value)
Square-Edged Concentric Orifice with Flange Taps	1½ in.	0.25 to 0.70	10,000 & over	± 1.5
	2 in. & larger	0.20 to 0.70	$7,000 \times D$ & over	± 1.0
Square-Edged Concentric Orifice with Throat Taps (1 D and ½ D)	1½ in.	0.25 to 0.70	5,000 & over	± 1.5
	2 in. & larger	0.20 to 0.70	$4,000 \times D$ & over	± 1.0
Vena Contracta Taps	1½ in. & larger	0.10 to 0.25 or 0.20 and 0.70 to 0.80	$3,000 \times D$ & over	± 1.0 to 2.5 See Note 5
Square-Edged Concentric Orifice with Pipe Taps (2½ D & 8 D)	2 in. & larger	0.25 to 0.67	$7,000 \times D$ & over	± 0.75
		0.15 to 0.25 & 0.67 to 0.75	$5,000 \times D$ & over	± 0.75 to ± 1.50 See Note 5

Note 1. β = (Diameter of throat) ÷ (Diameter of meter inlet or approach pipe)
Note 2. R_D = (Diameter of approach pipe) × (Velocity in approach pipe) ÷ (Kinematic Viscosity) (In consistent units)
Note 3. Tolerance decreases linearly as R_D increases from 50,000 to 200,000.
Note 4. Tolerance to be determined from test data by procedure described in "Fluid Meters," ASME.
Note 5. Tolerance increases linearly as β departs either way from the optimum range, or as R_D decreases below the value for minimum tolerance.

...ed in order to achieve compliance with this ...

... Measurement by Venturi Meter

...sions of this standard given under the ... sub-title covering head type rate meters ...able to capacity measurement by venturi ...

...e normal results in the measurement of ... with venturi meters, certain minimum ... straight pipe are required upstream of the ... Table 3 shows these minimum lengths, ex... terms of equivalent diameters.

...s for the venturi meter are:

$$Q = C \frac{A_2}{\sqrt{1-\beta^4}} \sqrt{2gh}$$

$$Q' = 3.118\, C \frac{A_2'}{\sqrt{1-\beta^4}} \sqrt{2gh}$$

...

...e of flow in cu ft per sec
...e of flow in gals per min
...fficient of discharge for meter
...a of throat section in sq ft
...a of throat section in sq in
...o of throat to inlet diameter $\left[\frac{D_2}{D_1}\right]$
...celeration of gravity 32.17 ft per sec per sec
...erential head between meter inlet and throat in feet of liquid being measured

... Measurement by Nozzles

...sions of this standard given under a pre... ...title covering head type rate meters are ...e to capacity measurement by nozzles. ...e normal results in the measurement of ... with nozzle type meters, a sufficient ... straight pipe is required preceding and fol... ...e nozzle inlet. Table 4 shows the length of ... pipe required, expressed in terms of equiv... ...eters.

...s for the nozzle are:

$$Q = C \frac{A_2}{\sqrt{1-\beta^4}} \sqrt{2gh}$$

$$Q' = 3.118\, C \frac{A_2'}{\sqrt{1-\beta^4}} \sqrt{2gh}$$

TABLE 3

Straight Pipe Required After Any Fitting Before Meter in Diameters of Pipe

Meter Ratio β (Throat to Inlet Diameter)	0.4	0.5	0.6	0.7	0.8
One standard short radius elbow	1	2	3	4	6
Two elbows in same plane	2	3	4	6	8
Two elbows in planes at 90 degrees and with straightening vanes	2	3	4	5	7
Standard C.I. flanged reducer	2	5	7.5	10	13
Standard C.I. flanged increaser	1	2	3	4.5	6
Globe valve—and with straightening vanes	2	4	6	9	12
Gate valve—0.2 open	2	4	6	9	12
Gate valve—0.5 open	2	3	4	6	8
Gate valve—full open	0	0.5	1	2	3

Note: A centrifugal pump pumping directly into a venturi meter should have at least 10 diameters of straight pipe between it and the meter.

where

Q = Rate of flow in cu ft per sec
Q' = Rate of flow in gpm
C = Coefficient of discharge for nozzle
A_2 = Area of nozzle throat in sq ft
A_2' = Area of nozzle throat in sq in
β = Ratio of throat to inlet diameter $\left[\frac{D_2}{D_1}\right]$
g = Acceleration of gravity 32.17 ft per sec per sec
h = Head at or across the nozzle, feet of liquid being measured.

Capacity Measurement by Thin Square Edged Orifice Plate

All provisions of this standard given under a preceding sub-title covering head type rate meters are applicable to capacity measurement by thin square edged orifice plate.

Whenever possible, the orifice plate should be calibrated in place in the piping system by weight or volume. When this is not possible, a certified curve showing the calibration of the orifice plate shall be obtained. This certification shall conform to requirements given under the section on head type rate meters, and shall, in addition, indicate the exact location and size of pressure taps, which are then to be duplicated in the test installation.

The upstream corner of the edge of the orifice must be square and sharp. The upstream face of the

TABLE 4 (Part One)

Straight Pipe Required After Any Fitting Before Meter in Diameters of Pipe

...er Ratio β (...roat to ... Diameter)	0.2	0.3	0.4	0.5	0.6	0.7	0.8
... wye within ... flow	6	6	6.5	7	8.5	10.5	14
...w, branch ... thru tee or ... flow from ... or separa-	6	6	6.5	7	9	13	20.5
... valve—wide	9	9	9.5	10.5	13	15	21
... valve—wide	6	6	6	6	7.5	9.5	13.5
... more short ... elbows or ... in the ... plane ...	7.5	7.5	8.5	10.5	13.5	18	25
... more long ... elbows or ... in the ... plane ...	6	6	6.5	8	11	16	23
... radius ... or bends ... different	14.5	16	17.5	20.5	24.5	30	40
... long radius ... or bends ... different	7	8	10	12	16	22	33

...centrifugal pump pumping directly into a nozzle or ori-... have at least 10 diameters of straight pipe between it ...meter.

TABLE 4 (Part Two)

Straight Pipe Required After Downstream Pressure Tap Before Any Fitting in Diameters of Pipe

Meter Ratio β (Throat to Inlet Diameter)	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Gate valve—wide open	0	0	0	0	0	0	0
Wye	0	0	0	0	0	0	4
Tee	0	0	0	0	0	3.5	4
Expansion joint ..	0	0	0	0	0	3.5	4
45 degree elbow .	0	0	0	0	3.5	3.5	4
Long radius elbow or bend	2	2.5	2.5	3	3.5	3.5	4
Regulators, control valves, and partly throttled gate valves ...	6	6	6	6	6	6	6

...st be smooth, flat and perpendicular to the ... of the pipe. The width of the cylindrical ... orifice shall be not more than one-fiftieth ... diameter of the pipe. The recommended co-... must not be used for pipes having inside ... less than 1.6 inches. Orifice plates less ...6 inch in thickness in any pipe, or less than ...4 inch for pipes from 4 inches to 16 inches, ... acceptable. If plates thicker than one-fiftieth ... diameter are used, the downstream face ... be beveled to an angle of 45 degrees or less ... face.

...ed orifice to pipe diameter ratios are from ... 0.60. In no case should this ratio be less ... nor more than 0.80. The pipe section into ... orifice plate is inserted must be round, ... tubercles or other surface defects, and ... per cent of published actual diameters ... orifice coefficient tables.

...e normal results in the measurement of capacities with orifice type meters, a sufficient length of straight pipe is required preceding and following the orifice plate. Table 4 shows the length of straight pipe required, expressed in terms of equivalent diameters.

If the correct coefficient is used, the differential pressure across the orifice plate may be measured at any pair of pressure taps as follows:

Flange taps, wherein the center of each of the pressure taps is 1 inch from the nearest face of the orifice plate.

Throat taps, wherein the distance from the center of the taps to the nearest face of the orifice plate is one pipe diameter for the upstream tap and one-half the pipe diameter for the downstream tap.

Vena contracta taps, wherein the upstream tap location is the same as for throat taps, but the center of the downstream tap is located at the section of minimum pressure.

Pipe taps, wherein the center of the upstream tap is two and one-half pipe diameters from the orifice plate and the center of the downstream tap is eight pipe diameters from the orifice plate.

The pressure tap openings shall be free from burrs and flush with interior surface of pipe (see Figs. 53 and 54).

Equations for the orifice plate are:

$$Q = C\frac{A_2}{\sqrt{1-\beta^4}}\sqrt{2gh}$$

$$Q' = 3.118\, C\frac{A_2'}{\sqrt{1-\beta^4}}\sqrt{2gh}$$

Rate of flow, cubic feet per second
Rate of flow, gallons per minute
Coefficient of discharge for orifice plate
Area of orifice, square feet
Area of orifice, square inches
Ratio of throat to inlet diameter $\left[\frac{D_2}{D_1}\right]$
Acceleration of gravity, 32.17 feet per second per second
Head across the orifice plate, feet of liquid being measured

...y Measurement by Weirs

...ctangular sharp crested weir with smooth ... crest wall, complete crest contraction, free ... and with end contraction suppressed, is ...ble for capacity determination under this ...d. The weir herein specified is of the same ...ns as weirs that have been calibrated by ... methods to determine their coefficients. ...ta are, therefore, applicable to this specific weir only and no other form is applicable un... standard. When properly used, the weir is a ... device for measuring reasonably steady liq... n open channels. It may be used for either ... field testing and is especially suitable for ...g relatively high rates of flow.

...ever possible, the weir should be calibrated ... in the liquid circuit. When this is not possi... construction and installation of the weir ... exactly as described and only the equations ... page 84 apply.

... The weir described herein is only one of many ... weirs. For a detailed discussion of weirs, ...struction, installation and operation, the ...eferred to "Fluid Meters, Their Theory and ...on," Sixth Edition, 1971 (a report of the ... Research Committee on Fluid Meters), and ...ents and Apparatus, PTC 19.5, 1972 (a ...ent to ASME Power Test Codes).

...nces or limits of accuracy have to do with ...actically unavoidable individual differences ... ostensibly duplicate weirs. They do not re... accidental errors of observation, concerning ... general predictions are possible.

... rectangular suppressed weirs, as specified ... standard are used, a tolerance of plus or ... 2 per cent may be expected, under the fol... limitations of flow:

...head is not smaller than 0.2 feet.

...head is not larger than one-half the height of ...e weir.

The head is not larger than one-half the length of the weir.

The weir plate preferably shall be formed of non-corrosive metal about 1/4 inch thick, with a sharp right angle corner on the upstream edge. The actual crest width shall be 1/8 inch, smooth and free from rust, grease, algae, etc., during all testing. The plate shall be beveled at an angle of 45 degrees from the crest on the downstream face.

The weir plate must be mounted in a vertical plane at right angles to the line of liquid flow, and the crest must be absolutely level. Complete aeration of the nappe is required and observations before and during test are necessary to provide against adhering nappe, disturbed or turbulent flow, or surging. The side walls of the channel shall be smooth and parallel and shall extend downstream beyond the overfall above the level of the crest.

The depth of the channel of approach below the weir crest shall not be less than three and preferably four times the maximum head for which the weir is to be used. The weir shall be located on the discharge side of the pump being tested, but sufficiently far downstream from the pump to be sure that smooth flow, free from eddies, surface disturbance, or excessive air in suspension, is maintained at all flow rates.

Proper baffling is very important. Small variations from the proper arrangement may cause appreciable variation of the quantity indicated by the weir. The baffles or racks should be arranged to give approximately uniform velocity across the channel of approach. The channel of approach shall be of uniform cross section, straight and free from stilling racks or other obstructions for a length equal to at least fifteen times the maximum head on the weir. If the channel is out of doors protection should be provided against surface disturbance from wind.

The head on the weir shall be measured by the use of a hook gauge, securely placed in stilling boxes located at the sides of the channel of approach, upstream from the weir at a distance of not less than four nor more than ten times the maximum head on the weir. These stilling boxes shall communicate with the approach channel by a pipe approximately 1 1/2 inches in diameter, terminating in an opening located in the side of the channel approximately 1 foot below the level of the crest and flush with the side of the channel. If stilling boxes are located outdoors, protection against wind pressure is desirable and covers should be used to exclude dirt or other contaminants which might alter surface tension and cause erroneous hook gauge readings.

The flow shall be computed by the Rehbock formula as follows:

$$Q = \left[3.228 + 0.435 \frac{h_e}{Z} \right] B h_e^{3/2}$$

where

Q = Capacity, cubic feet per second

h_e = h + 0.0036, feet

h = Observed Head on crest, feet, without correction for velocity of approach

Z = Height of weir crest above bottom of channel of approach, feet

B = length of weir crest, feet

If desired, the value of (h_e) may be read directly by setting the point of the hook gauge 0.0036 feet below the edge of the weir.

Capacity Measurement by Pitot Tubes

Where it is impossible to employ one of the methods described above, the pitot tube is often used. When the flow conditions are steady during the time required to make a traverse, and when used by a qualified person, the flow may be determined with a fair degree of accuracy.

The procedure set forth in the ASME Test Code on Hydraulic Prime Movers (1949) is recommended.

Other Methods of Measurement

When the methods of quantity measurement described above are not applicable, there are other methods not included in this standard which may be utilized, subject to agreement by the interested parties in advance of a performance test. Some of these methods are:

Tagging Methods
- a. Salt Velocity
- b. Dye Dilution
- c. Thermal Pulse
- d. Neutral Density Immiscible Particles
- e. Hydrogen Bubble Technique

Head Meters
- a. Elbow Meter
- b. Conical Entrance Orifice Plate
- c. Cylinder Nozzle
- d. Other Weirs than described above
- e. Dahl Tube

Acoustic Methods
- a. Doppler Velocimeter
- b. Turbulence noise calibration

Electromagnetic Methods
- a. Magnetic Induction Velocimeter
- b. Laser Doppler Velocimeter

Hydrodynamic Oscillators
- a. Swirlmeter
- b. Vortex Shedding Flowmeter
- c. Vortex Flowmeter
- d. Fluidic Flow Measurement
- e. Hydrodynamic Oscillator Flowmeter

Drag Force Meters
- a. Calibrated drag body

Methods of Head Measurement

The units of head and the definition of total head and its component parts are covered on page 66.

It is important that steady flow conditions exist at the point of instrument connection. For this reason, it is necessary that pressure or head measurement be taken on a section of pipe where the cross-section is constant and straight. Five to ten diameters of straight pipe of unvarying cross-section following any elbow or curved member, valve, or other obstruction, are necessary to insure steady flow conditions.

If the pipe friction loss between the pump discharge flange and the point of instrument connection is significant, it should be added to the total discharge head (h_d). The friction factor used for the calculation should be based on the appropriate roughness ratios for the actual pipe section. (See page 66 for definition of the Total Discharge Head).

The following precautions shall be taken in forming orifices for pressure measuring instruments and for making connections:

The orifice in the pipe shall be flush with and normal to the wall of the water passage.

The wall of the water passage shall be smooth and of unvarying cross-section. For a distance of at least 12 inches preceding the orifice, all tubercles and roughness shall be removed with a file or emery cloth, if necessary.

The orifice shall be of a diameter from 1/8 inch to 1/4 inch and of a length equal to twice the diameter.

The edges of the orifice shall be provided with a suitable radius tangential to the wall of the water passage, and shall be free from burrs or irregularities. Figs. 53 and 54 show two suggested arrangements of taps or orifices in conformity with the above.

Where more than one tap or orifice is required at a given measuring section, separate connections, properly valved, shall be made. As an alternative, separate instruments shall be provided.

Multiple orifices shall not be connected to an in-

TABLE 5

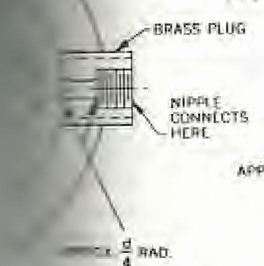
Values of $\left[3.228 + 0.435 \frac{h_e}{z} \right]$ in the Formula for Weir Discharge

Height of Crest (z) in Feet (Above Bottom of Channel of Approach)

1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.2	2.4	2.6	2.8	3.0
3.273	3.269	3.266	3.263	3.260	3.258	3.256	3.255	3.253	3.252	3.251	3.248	3.245	3.245	3.244	3.243
3.317	3.309	3.302	3.296	3.291	3.287	3.283	3.280	3.277	3.275	3.272	3.268	3.265	3.262	3.260	3.258
3.360	3.348	3.338	3.330	3.322	3.316	3.311	3.306	3.301	3.298	3.294	3.288	3.283	3.279	3.275	3.272
3.404	3.388	3.374	3.363	3.353	3.345	3.338	3.331	3.326	3.320	3.316	3.308	3.301	3.296	3.291	3.287
3.447	3.427	3.411	3.397	3.384	3.374	3.365	3.357	3.350	3.343	3.338	3.328	3.319	3.312	3.306	3.301
3.491	3.467	3.447	3.430	3.416	3.403	3.392	3.382	3.374	3.366	3.359	3.347	3.337	3.329	3.322	3.316
3.534	3.506	3.483	3.463	3.447	3.432	3.419	3.408	3.398	3.389	3.381	3.367	3.356	3.346	3.337	3.330
3.578	3.546	3.519	3.497	3.478	3.461	3.446	3.434	3.422	3.412	3.403	3.387	3.374	3.362	3.353	3.345
3.621	3.585	3.556	3.530	3.509	3.490	3.474	3.459	3.446	3.435	3.425	3.407	3.392	3.379	3.368	3.359
3.665	3.625	3.592	3.564	3.540	3.519	3.501	3.485	3.471	3.458	3.446	3.426	3.410	3.396	3.384	3.374

Height of Crest (z) in Feet (Above Bottom of Channel of Approach)

4	5	6	7	8	9	10	12	14	16	18	20
3.337	3.315	3.301	3.290	3.283	3.277	3.272	3.264	3.259	3.255	3.252	3.250
3.458	3.324	3.308	3.297	3.288	3.281	3.276	3.268	3.262	3.258	3.255	3.252
3.359	3.333	3.315	3.303	3.293	3.286	3.280	3.272	3.265	3.261	3.257	3.254
3.370	3.341	3.323	3.309	3.299	3.291	3.285	3.275	3.269	3.264	3.260	3.256
3.381	3.350	3.330	3.315	3.304	3.296	3.289	3.279	3.272	3.266	3.262	3.259
3.392	3.359	3.337	3.321	3.310	3.230	3.293	3.283	3.275	3.269	3.264	3.261
3.402	3.368	3.344	3.328	3.315	3.306	3.298	3.286	3.278	3.272	3.267	3.263
3.413	3.376	3.352	3.334	3.321	3.310	3.302	3.290	3.281	3.274	3.269	3.265
3.424	3.385	3.359	3.340	3.326	3.315	3.307	3.293	3.284	3.277	3.272	3.267
3.435	3.394	3.366	3.346	3.332	3.320	3.311	3.297	3.287	3.280	3.274	3.269
3.446	3.402	3.373	3.353	3.337	3.325	3.315	3.301	3.290	3.283	3.276	3.272



PRESSURE
OPENING

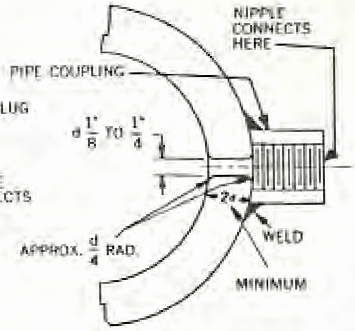


Fig. 54 WELDED ON PRESSURE TAP OPENING

except on those metering devices such as ...ters, etc., where proper calibrations have ... on an instrument of this form.

...ections or leads from the orifice tap shall ... These leads shall be as short and direct as ... For the dry-tube type of leads, suitable ... shall be provided and a loop shall be ... sufficient height to keep the pumped liq... entering the leads. For the wet-tube type of leads, vent cocks for flushing shall be provided at any high point or loop crest to assure that tubes do not become air-bound.

All instrument hose, piping and fittings shall be checked under pressure prior to test to assure that there are no leaks.

Suitable damping devices may be used in the leads.

If the conditions specified above cannot be satisfied at the point of measurement, it is recommended that four separate pressure taps be installed, equally spaced about the pipe, and the pressure or head at that section be taken as the average of the four separate values of head. If the separate readings show a difference of static pressure, such as to affect head beyond the contract tolerances, the installation shall be corrected or an acceptable tolerance determined.

Pages 86 to 89 show the suitable arrangements for various types of instruments, formulae for transforming instrument readings into feet of the liquid pumped, for expressing instrument head as elevation over a common datum, and correcting same for the velocity head existing in the suction and discharge pipes.

centrifugal pumps test standards

…atum shall be taken as the centerline of the …for horizontal shaft pumps, as the entrance …e impeller for vertical single suction pumps …mpeller discharge horizontal centerline for … double suction pumps.

…nstruments shall, when practical, be water …or manometers, and for high pressures shall …ury manometers, bourdon gauges, electrical …transducers or dead weight gauge testers. …ater columns are used, care shall be taken …errors due to the difference between the …ure of the water in the gauge and that of …r in the pump.

…le Measurement of Head by Means of …s

…ollowing definitions apply to Figs. 55–61 …mperature effects are negligible.

- …scharge gauge reading in ft of water
- …uction gauge reading in ft of water
- …levation of discharge gauge zero above datum elevation in ft
- …levation of suction gauge zero above datum elevation in ft

…uantities (Z_d) and (Z_s) are negative if the …ero is below the datum elevation.

- …Elevation of discharge gauge connection to discharge pipe above datum elevation in ft
- …Elevation of suction gauge connection to suction pipe above datum elevation in ft

…uantities (Y_d) and (Y_s) are negative if the …onnection to the pipe lies below the datum …

- …Average water velocity in discharge pipe at discharge gauge connection in ft per sec
- …Average water velocity in suction pipe at suction gauge connection in ft per sec
- …Total discharge head above atmospheric pressure at datum elevation in ft
- …Total suction head above atmospheric pressure at datum elevation in ft
- …Total pump head in ft
- $= h_d - h_s$

…uantities (h_d) and (h_s) are negative if the …onding values at the datum elevation are …atmospheric pressure.

…LE: If the pressure at the gauge connection …bove the atmospheric pressure, use arrange-…shown in Fig. 55 with line between discharge …on pipe and the corresponding gauge filled …ely with water.

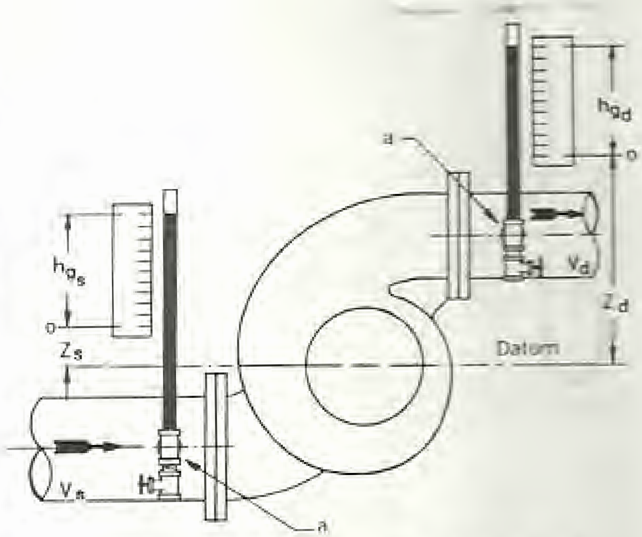


Fig. 55 GAUGES ABOVE ATMOSPHERIC PRESSURE

In this example:

$$h_d = h_{g_d} + Z_d + \frac{V_d^2}{2g}$$

$$h_s = h_{g_s} + Z_s + \frac{V_s^2}{2g}$$

EXAMPLE: If the pressure at gauge connection (a) is below atmospheric pressure, use arrangement shown in Fig. 56 showing suction gauge.

In this example:

$$h_s = h_{g_s} - Z_s + \frac{V_s^2}{2g}$$

The negative sign of (Z_s) indicates that the gauge zero is located below the datum.

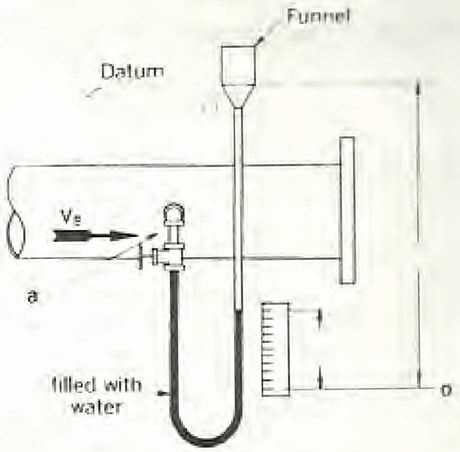


Fig. 56 GAUGE BELOW ATMOSPHERIC PRESSURE

...E: If the pressure at the gauge connection ... the atmospheric pressure, use arrangement ...n in Fig. 57 with line between the dis... suction pipe and the corresponding gauge ...pletely with air.

... example:

$$h_d = -h_{g_d} + Y_d + \frac{V_s^2}{2g}$$

$$h_s = -h_{g_s} - Y_s + \frac{V_s^2}{2g}$$

... installations, either (h_d) or (h_s) may be ... by various types of gauges. Pages 86–88 ... various methods with (h_g) representing ... the gauge reading applicable to either the ... gauge reading (h_{g_d}) or the suction reading

... word "water" is used on these pages to ... the liquid being pumped. The provisions ...ble to the pumping of other liquids, such ... provided the gauges and connecting lines ... the liquid being pumped.

... connecting pipe is air filled, it must be ... before reading is made. Water cannot be ... "U" tube if either (h_{g_s}) or (h_{g_d}) exceeds ... rising loop.

...ment of Head by Means of Mercury

... gauge pressure is above the atmospheric ... and the connecting line is completely filled ... then the head (h) is calculated as

$$h = \frac{w_m}{w} h_g + Z + \frac{V^2}{2g}$$

...ecific weight of mercury in lbs per cu ft
...ecific weight of liquid pumped in lbs per cu ft
...ction or discharge gauge reading in ft of mercury.

...antities (h), (Z), (Y) and (V) without sub... apply equally to suction and discharge head ...ments.

... the gauge pressure is below the atmospheric ... and the connecting line is completely filled ... with a rising loop to prevent water from

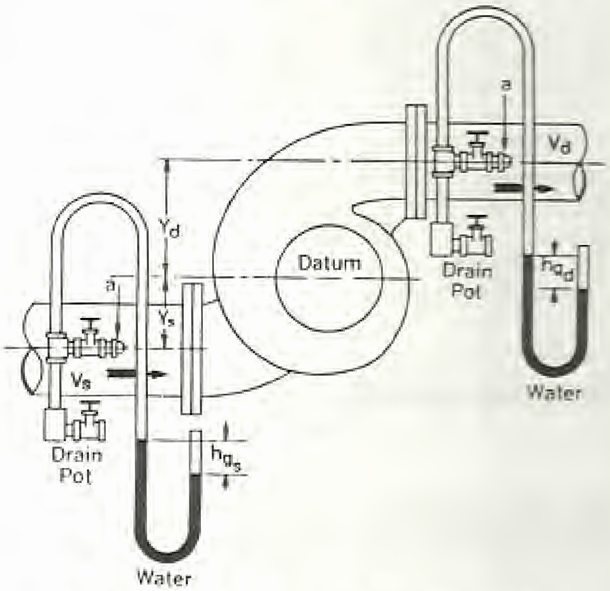


Fig. 57 GAUGES BELOW ATMOSPHERIC PRESSURE

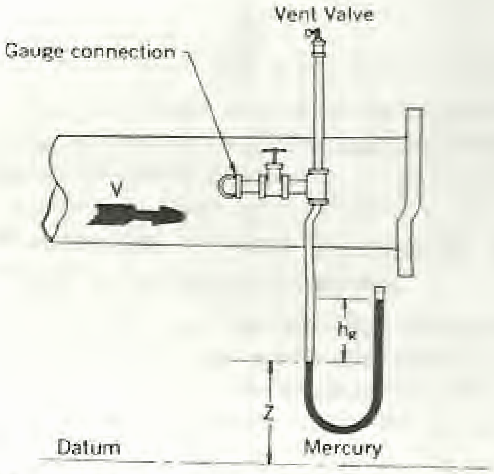


Fig. 58 MERCURY GAUGE WITH WATER LEG

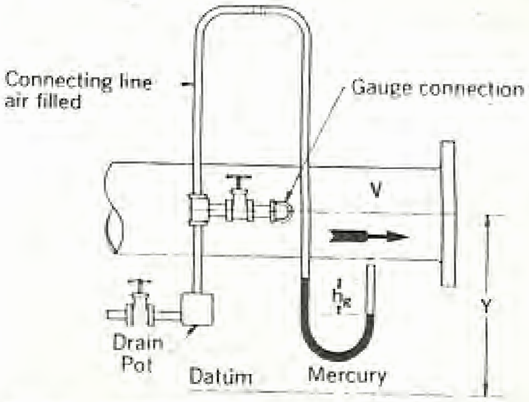


Fig. 59 MERCURY GAUGE WITH AIR LEG

...g to the mercury column, then (h) is calcu-
...ed as follows:

$$h = -\frac{w_m}{w} h_g + Y + \frac{V^2}{2g}$$

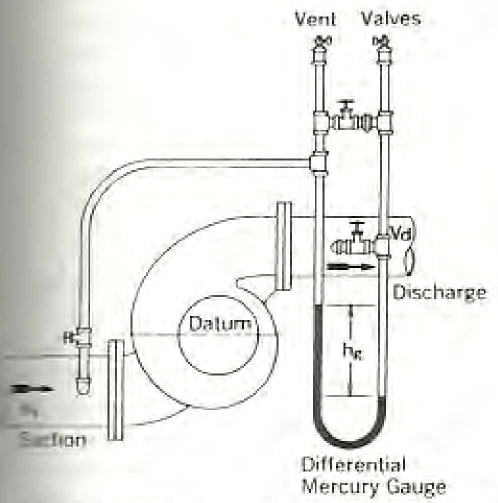
...rement of Head by Means of Differential ...ury Gauges

...reading a differential mercury gauge in feet ...ury (h_g) and with the connecting lines com-...filled with water, then

$$H = \left[\frac{w_m}{w} - 1\right] h_g + \frac{V_d^2}{2g} - \frac{V_s^2}{2g}$$

...dition to the differential gauge, use a sepa-...ction gauge as shown in Fig. 56,

$$h_s = -h_{g_s} - Z_s + \frac{v_s^2}{2g}$$



...60 USE OF DIFFERENTIAL MERCURY GAUGE

...rement of Head by Means of Calibrated ...ges

...y types of pressure indicators may be used. ...e applicable types are:

...ssure transducers—strain gauge and magnetic ...pe
...hragm—activated magnetic linkage type
...ows—actuated torque to transfer type
...rdon Tube—actuated gear type

... gauges shall be calibrated before and after ... series of tests.

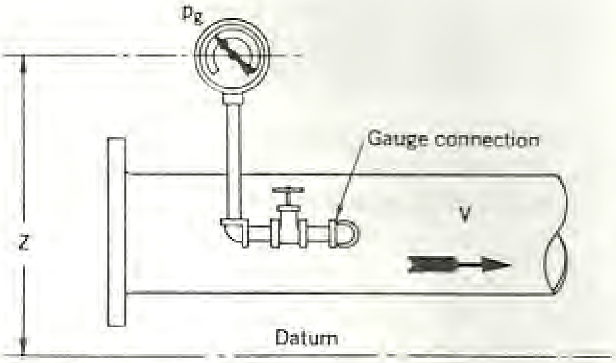


Fig. 61 USE OF CALIBRATED BOURDON GAUGE

When gauge pressure is above atmospheric pressure and the connecting line is completely filled with water, then

$$h = \frac{144\ p_g}{w} + Z + \frac{V^2}{2g}$$

where

p_g = Pressure, in psig
w = Specific Weight of the liquid in lbs per cu ft

The quantity (Z) is measured to the center of the gauge and is negative if the center of the gauge lies below the datum line.

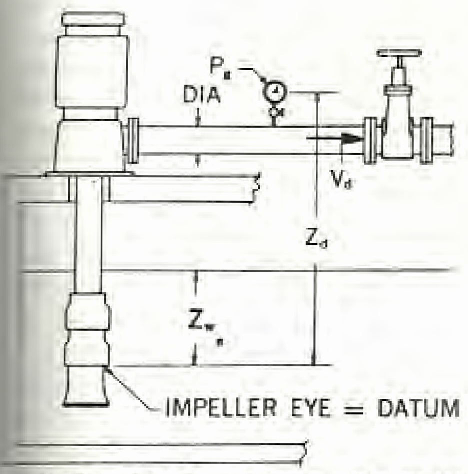
Measurement of Head on Vertical Suction Pumps in Sumps and Channels

In installations of vertical shaft pumps drawing water from large open sumps and having short inlet passages of a length not exceeding about three diameters of the inlet opening, such inlet pieces having been furnished as part of the pump, the total head shall be the reading of the discharge gauge in feet, plus the velocity head in the pipe at the gauge connection in feet, plus the vertical distance from the gauge center to the free water level in the sump in ft. ($Z_d - Z_{w_s}$) (Fig. 62).

Power Measurements

Pump input horsepower may be determined by transmission dynamometers, torsion dynamometers, strain gauge type torque measuring devices, or by the use of calibrated drivers.

When pump input horsepower is to be determined by transmission dynamometers, the unloaded and unlocked dynamometer must be properly balanced, prior to the test, at the same speed at which the test is to be run. The scales should be checked against



HEAD MEASUREMENT FOR VERTICAL PUMPS IN SUMPS

weights. After the test, the balance must ...ked to assure that no change has taken ... the event of an appreciable change, the ... be rerun. An accurate measurement of ... essential. Power input is calculated as ... page 90.

...mp input horsepower is to be determined ... dynamometers, the unloaded dynamom- ...e statically calibrated prior to the test by ... the angular deflection for a given torque, ...eading on the dynamometer scale being ...ated speed with the pump disconnected. ...st, the calibrations shall be rechecked to ... no change has taken place. In the event ...eciable change, the test shall be rerun. An ...easurement of speed is essential.

...ain gauge type torque measuring devices ... measure pump input horsepower, they ...librated, with their accompanying instru-..., at regular intervals. After the test, the ...rumentation balance shall be rechecked ... that no appreciable change has taken ...e event of an appreciable change, the ...e rerun.

...d laboratory type electric meters and ...s shall be used to measure power input ...

...mp input horsepower is to be determined ... of a calibrated motor, measurements of ... shall be made at the terminals of the ... exclude any line losses that may occur ... switchboard and the driver itself. Certi-...ation curves of the motor must be ob-... calibration shall be conducted on the ...otor in question, and not on a similar machine. Such calibrations must indicate the true input-output value of motor efficiency and not some conventional method of determining an arbitrary efficiency.

For motors other than calibrated test motors the efficiency may be determined by dynamometer test or by segregated losses methods, or as agreed upon.

METHODS FOR ROTARY SPEED MEASUREMENT

The succeeding paragraphs discuss the various methods and instruments suitable for measuring the speed of rotation of centrifugal pumps. Test speeds for such pumps may be in the range of a few hundred to some thousands of revolutions per minute. Since the pump test data will be taken under steady state conditions, the maximum permissible short term speed fluctuation shall be no more than 0.3 per cent. The speed measuring methods described, therefore, are those which, at moderate speeds, will give a measure of the average speed over an interval of from less than one second up to one or two minutes, depending on the type of instrumentation.

Speed measurement instruments fall into four main categories:

Revolution counter and timer

Tachometers, such as:
- Chronometric
- Centrifugal
- Eddy current drag
- Electric generation (either a-c or d-c)
- Electronic

Frequency responsive devices, such as:
- Vibrating reed
- Electronic
- Photocell

Stroboscopes

Note: The various methods and instrumentation are discussed in detail in Instruments and Apparatus Part 13, Measurement of Rotary Speed 1961, PTC 19.13 (a supplement to ASME Power Test Codes).

The revolution counter and timer method, as its name implies, involves the counting of the number of revolutions over an interval of time. A major source of error is inexact synchronization of counter and timer. In cases where this is automatic (e.g., a tachoscope), sufficient accuracy is achieved over a time interval of a few seconds. In the usual case, where a hand held counter and stopwatch are used, the timing interval should be about two minutes. During this time the speed must, of course, be constant, and slippage of the counter on the shaft must be avoided. The stopwatch should be periodically checked against a standard timer. This method can be very accurate, to ±0.25 per cent of pump speed, or better.

Tachometers provide a direct reading of speed averaged over a fixed time interval. Some types automatically repeat the reading process, while the standard, hand held unit must be reset manually. The above comments regarding uniform speed and slippage pertain here also. A tachometer should be checked periodically against a counter and stopwatch. Accuracy of tachometers varies widely, from ±0.25 per cent to ±3.5 per cent, the latter limit being unacceptably high for test purposes.

Frequency responsive devices have the advantage of not requiring direct contact with the motor or pump shaft, and hence impose no additional load on the motor. The vibrating reed type is of use only when the shaft is completely inaccessible. Electronic units may be converted to read RPM directly using a shaft mounted gear, and a non-contacting magnetic pickup. Since normally the line frequency (which determines the timing interval) is 60 Hz ± 0.1 per cent, the method is accurate to the nearest RPM, as read on a digital readout. The timing interval may be set as short as 0.1 second, thus making any speed fluctuations readily discernible.

Most stroboscopes are limited in accuracy due to uncertainty in the precision of the strobe frequency. The only approach suitable for pump test purposes is to use the strobe to determine motor slip under load relative to synchronous speed, using a stopwatch to time the slippage while driving the strobe at line frequency (which is known to the accuracy given above, and can be determined with even greater precision for the time and location of the test).

CALCULATION OF OUTPUT

The liquid horsepower (whp) is computed by the following formula:

$$whp = \frac{\text{pounds of liquid pumped per min.} \times \text{total head in feet of liquid}}{33{,}000}$$

When the specific weight of the liquid is 62.3 pounds per cubic foot, which is the value for water at standard temperature of 68 F, then

$$whp = \frac{QH}{3960}$$

where

Q = Capacity in gpm
H = Total head in ft

If the pump is handling a liquid with different specific weight, or water at a temperature resulting in a specific weight per cubic foot other than 62.3 pounds, the above formula must be corrected so that

$$whp = \frac{QH\,(s)}{3960}$$

If the total head is expressed in pounds per square inch, the formula for liquid horsepower, irrespective of the specific weight of the liquid, becomes

$$whp = \frac{Q\Delta p}{1714}$$

CALCULATION OF INPUT

The input horsepower (bhp), when measured by transmission dynamometer is calculated from the following formula:

$$bhp = \frac{2\pi LWN}{33{,}000}$$

where

L = Length of lever arm in ft
W = Net weight in lbs
N = Speed in rpm
π = 3.1416

The electrical horsepower input to an electric motor is given by

$$ehp = \frac{kw}{.746}$$

where

kw = kilowatt input

The input horsepower to a pump driven by an electric motor is

$$bhp = ehp \times \eta_m$$

where

η_m = true efficiency of motor

...ON OF EFFICIENCY

...efficiency is calculated by

$$\eta_p = \frac{\text{output}}{\text{input}} = \frac{\text{whp}}{\text{bhp}}$$

... efficiency of a motor driven unit is ...

$$\eta_o = \frac{\text{whp}}{\text{ehp}}$$

$$\eta_o = \eta_p \times \eta_m$$

...of Efficiency (Vertical Pumps)

...mps which include Propeller or Axial ...ed Flow type units all have similar ...which require consideration when effi-...nation is made. For sectional draw-...units see pages 41 to 45 and 47.

...bly Head in Feet (h_b)

...bly head is the difference between ...harge head, measured in the column ...d to the top of the bowl assembly, and ...on head.

...bly Efficiency

...efficiency obtained from the bowl as-...es not include reduction in efficiency ...thin the remaining pump components.

...ency

...e bowl assembly efficiency minus effi-...on due to the following losses:

...osses (in feet) for flow through suction ...trainer, column pipe, and surface dis-...ead or discharge elbow.
... Losses (in horsepower). Line shaft ...osses due to rotational friction of shaft ...s and other losses such as shaft seal-...

...ciency

...p efficiency minus efficiency reduction ...such as, but not limited to, driver losses ...rust bearing losses and gear losses ...able.

Total Head in feet (H)—Bowl assembly head (h_b) in feet, minus the sum of all hydraulic losses in feet.

Pump Input (bhp)—Bowl assembly input (hp_b) plus the sum of lineshaft bearing losses in horsepower.

$$\text{Bowl Assembly Efficiency} = \frac{Q \times h_b \times s}{3960 \times hp_b}$$

$$\text{Pump Efficiency} = \frac{Q \times H \times s}{3960 \times \text{bhp}}$$

Overall Efficiency—Pump efficiency × driver efficiency × gear efficiency (if applicable) minus efficiency reduction due to thrust bearing losses. For calculation purposes, all efficiencies must be in decimal form. Electric motor efficiencies for vertical motors generally do not include thrust bearing losses.

Note: Refer to the Hydraulic Institute Engineering Data Book for column pipe friction losses and lineshaft bearing friction losses.

CORRECTION TO RATED SPEED

For purposes of plotting, the capacity, head and power shall be corrected from the test values at test speed to the rated speed of the pump. The corrections are made as follows:

Capacity:

$$Q = \frac{N}{N_1} \times Q_1$$

where

Q_1 = Capacity at test speed in gpm
Q = Capacity at rated speed in gpm
N_1 = Test speed in rpm
N = Rated speed in rpm

Head:

$$H = \left[\frac{N}{N_1}\right]^2 \times H_1$$

where

H_1 = Head at test speed in ft
H = Head at rated speed in ft

Horsepower:

$$hp = \left[\frac{N}{N_1}\right]^3 \times hp_1$$

where

hp_1 = horsepower at test speed
hp = horsepower at rated speed

Net Positive Suction Head (NPSH):

$$NPSH = \left[\frac{N}{N_1}\right]^2 \times NPSH_1$$

where

$NPSH_1$ = Net positive suction head at test speed in feet

NPSH = Net positive suction head at rated speed in feet.

Note: Refer to page 77, "NPSH-Experimental Deviation from the Square Law" for discussion of other factors which may affect this relationship.

PLOTTING RESULTS

The total head, efficiency, and brake horsepower are usually plotted as ordinates on the same sheet with capacity as the abscissa as shown on Fig. 63.

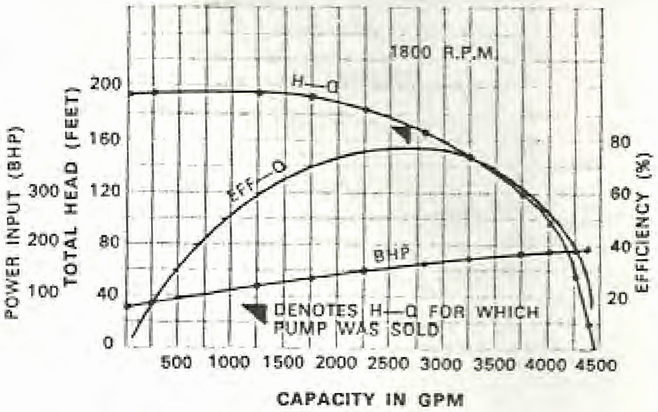


Fig. 63 PLOTTED TEST RESULTS

Note: For effect of compressibility of the fluid on the calculation of efficiency, see page 71.

...MARY OF NECESSARY DATA ON ...PS TO BE TESTED

...following information should be furnished on ... to be tested:

Ge...

- Owner's name ______
- Plant location ______
- Elevation above sea level ______
- Type of service ______

- Manufactured by ______
- Manufacturer's designation ______
- Manufacturer's serial number ______
- Arrangement: horizontal ___ vertical ___
- Inlet: ___ single ___ double ___
- Number of stages ______
- Size suction: nominal ______ in.
  actual ______ in.
- Size discharge: nominal ______ in.
  actual ______ in.

...ediate Transmission:

- Manufactured by ______
- Type ______
- Serial number ______
- Speed ratio ______
- Efficiency ______

- Manufactured by ______
- Serial number ______
- Type: motor ___ turbine ___ other ___
- Rated horsepower ______
- Rated speed ______
- Characteristics (voltage, frequency, etc.) ______
- Calibration data ______

...ing Rated Conditions

...following information is necessary in specify... ...ed conditions:

- Liquid pumped (water, oil, etc.) ______
- Specific weight ______
- Viscosity at pumping temperature ______
- Temperature ______ F
- Vapor pressure ______ psia
- Capacity ______ gpm

7. Total suction lift (h_s) ______ ft
   head (h_s) ______ ft
8. Net positive suction head (NPSH) ______ ft
9. Total discharge head (h_d) ______ ft
10. Total head (H) ______ ft
11. Liquid horsepower (whp) ______ hp
12. Efficiency (η_p) ______ per cent
13. Brake horsepower (bhp) ______ hp
14. Speed ______ rpm

TEST INFORMATION

Test information should be listed substantially as follows:

General:

1. Where tested ______
2. Date ______
3. Tested by ______
4. Test witnessed by ______

Capacity:

1. Method of measurement ______
2. Meter—Make and serial number ______
3. Calibration data ______

Head:

1. Suction gauge—Make and serial number ______
2. Calibration curve ______
3. Discharge gauge—Make and serial number ______
4. Calibration data ______

Power:

1. Method of measurement ______
2. Make and serial number of instrument ______
3. Calibration data ______

Speed:

1. Method of measurement ______
2. Make and serial number of instrument ______
3. Calibration data ______

Test Performance Corrected to Specified Conditions

Test performance of pumps handling non-viscous liquids shall be corrected to rated speed and rated specific weight. For correction values applying to centrifugal pumps handling viscous liquid, refer to page 111.

Model Tests

In many installations involving units of large size, model tests are of great utility. Even when it might be feasible to test the large unit in the factory, a model may often be tested with greater accuracy and thoroughness. By adopting a standard size of model for various pumps, properly comparable performances can be obtained. The model impeller should be not less than 12 inches outside diameter. The exact model to prototype ratio shall be selected by the pump builder. Comparisons between model tests are valid only when the model to prototype ratios are substantially the same.

Testing models in advance of final design and installation of a large unit not only provides advance assurance of performance but makes alterations possible in time for incorporation in the prototype unit.

Not all installations lend themselves to a practical model investigation. The pumping of water carrying considerable quantities of sand or other foreign material is not readily reproduced in model operation. This standard, therefore, is limited to the pumping of clear water, free from abnormal quantities of air or solids, both in field installations and factory tests. The effects of wear and deterioration, the effects of free surface disturbances in open channel sumps, interference between neighboring units, and peculiar problems caused by abnormal settings are covered by model sump tests (See page 129).

It is recommended that when model tests are to be conducted, the performance characteristics be specified for the model. It is not, in general, essential that the model test head be the same as that of the prototype. A model pump should be tested at such conditions that complete turbulent flow will be maintained in all flow passages at all times. In general, this means that the model head will be the same as that of the prototype.

The model should have complete geometric similarity with the prototype, not only in the pump proper, but also in the intake and discharge conduits as specified above for tests on full sized pumps. The model should be run at such speed that the specific speed remains the same as that of the prototype unit. If cavitation tests are not available, the suction head or lift should be such as to give the same sigma value as in the prototype. As previously explained, if the prototype sigma is known to be safely in excess of the critical sigma, then a higher sigma can be used for the model tests, although it is preferable to maintain the same value.

There is danger of air separation destroying similarity relationships if the absolute pressure is reduced too low. Consequently, condensate pumps should not be modeled.

If corresponding diameters of model and prototype are (D_1) and (D) respectively, then the model speed (N_1) and model capacity (Q_1), under the test head (H_1), must agree with the relationships:

$$\frac{N_1}{N} = \left[\frac{D}{D_1}\right]\sqrt{\frac{H_1}{H}}$$

and

$$\frac{Q_1}{Q} = \left[\frac{D_1}{D}\right]^2\sqrt{\frac{H_1}{H}}$$

If a model vertical wet pit pump is tested in its corresponding model intake structure, it should be remembered that the conditions to satisfy the pump model relationship and the Froude sump model relationship (see page 129) cannot exist simultaneously. The velocities derived by the Froude law will be considerably less. The model system should be designed so that performance can be observed and measured through the entire range of velocities.

The efficiency of the model should not, in general, be assumed to be exactly equal to that of the prototype. In testing a model of reduced-size, the above conditions being observed, complete hydraulic similarity may not be attained because of certain influences. For example, complete geometric similarity will not be obtained unless the relative roughness of the impeller and pump casing surfaces are the same. With the same surface texture in both model and prototype, the model efficiency will be lower than that of the larger unit. Further, it is generally not practical to model running clearances or bearing sizes. When such is the case, the model efficiency will be reduced. To approximate prototype efficiency with a model, the impeller and diffuser surfaces must be considerably smoother on the model than on the prototype.

When a high degree of understanding exists between manufacturer and user relative to the comparison limitations encountered going from model to prototype, thought may be given to the practicability of increasing the prototype efficiency on the

...f model test results. However, this should be ...nly by mutual agreement before the job is let, ...basis of all the available test data of a similar ...e.

...erous comparisons of prototype and model ...cies, with consistent surface finish of models ...ototypes, are necessary for a given factory to ...sh a basis for stepping up model performance ...d performance. This stepping up can be ap... conveniently according to the formula in use ...bines; namely

$$\frac{1-\eta_1}{1-\eta} = \left[\frac{D}{D_1}\right]^n$$

...xponent (n) is to be determined from actual ...s described above.

...alues for the exponent (n) have been found ... between zero and 0.26, depending on rela...face roughness of model and prototype and ...actors.

...ossible adjustment of a cold water test to hot ... conditions see page 77.

...cal Example of Model Test

...gle stage pump designed to deliver 90,000 ...gainst a head of 400 feet at 450 rpm and with ... suction head of 10 feet has an impeller ...er of 6.8 feet. This pump is too large for a ... test and, in place of such test on the actual ... a model is to be tested at a reduced head of ...eet. The model impeller is to be 18 inches, or ...et in diameter.

...PLE: Determine speed, capacity and suction ... for the above model test.

...ying the above relationships:

$$\frac{N_1}{N} = \left[\frac{D}{D_1}\right]\sqrt{\frac{H_1}{H}}$$

$$N_1 = N\left[\frac{D}{D_1}\right]\sqrt{\frac{H_1}{H}}$$

$$= 450\left[\frac{6.8}{1.5}\right]\sqrt{\frac{320}{400}}$$

$$= 1825 \text{ rpm}$$

$$\frac{Q_1}{Q} = \left[\frac{D_1}{D}\right]^2\sqrt{\frac{H_1}{H}}$$

or

$$Q_1 = Q\left[\frac{D_1}{D}\right]^2\sqrt{\frac{H_1}{H}}$$

$$= 90{,}000\left[\frac{1.5}{6.8}\right]^2\sqrt{\frac{320}{400}}$$

$$= 3920 \text{ gpm}$$

The model pump should therefore be run at a speed of 1825 rpm delivering 3920 gpm against a head of 320 feet.

To check these results it will be noted that the specific speed of the prototype is:

$$N_s = N\frac{\sqrt{Q}}{H^{3/4}} = 450\frac{\sqrt{90{,}000}}{(400)^{3/4}} = 1510$$

and the specific speed of the model will be

$$N_s = 1825\frac{\sqrt{3920}}{(320)^{3/4}} = 1510$$

Therefore, the specific speeds are the same as required.

The cavitation factor sigma for the field installation, which should be the same as in the test, assuming the usual water temperature of 80 F as a maximum probable value, will be

$$\sigma = \frac{NPSHA}{H}$$

where

$$NPSHA = \frac{144}{w}(p_a - p_{vp}) + h_s$$

$$= \frac{144}{62.3}(14.7 - .5) + 10$$

$$= 32.8 + 10 = 42.8 \text{ feet}$$

therefore

$$\sigma = \frac{42.8}{400} = 0.107$$

With the water temperature of model and prototype approximately the same

$$\sigma = \frac{NPSHA_1}{H_1}$$

Thus:

$$NPSHA_1 = \sigma H_1$$

$$= 0.107 \times 320$$

$$= 34.25 \text{ feet}$$

$$h_s = 34.25 - 32.80$$
$$= 1.45 \text{ feet}$$

...del should therefore be tested with a total ...ead of 1.45 feet to reproduce the field ...

... Models at Increased Head

... special and unusual circumstances, it may ...le to carry out factory tests at higher heads ... prototype head. This may be due, for ex... the limitations of available test motors or ... frequency. In this case, all of the above ...ions continue to apply.

...d be pointed out, however, that with a re...ze model, coupled with an increase in ...e increase in speed corresponding to the ...ease tends to minimize the change in Rey...ber; that is, the product of flow velocity ... dimensions of the model tends to ap...uality with the same product in the proto...s effect tends to restore dynamic similarity ...and prototype and to approach equality of ...es and other performance factors. With in...ead, however, the preservation of the ...a value in the model as in the prototype ... be observed, and this factor will assume ... importance, requiring an increase in sub... or reduction in suction lift in the factory ...

...t mentioned requirement may result in ...eason for the use of an increased head in ...y test. Cases may arise in which the limi... the factory test set-up may preclude the ... of sufficient suction lift to reproduce the ... sigma. In such cases, the required sigma ...ained by an increase in the pumping head ... by a reduction in suction head or increase ... lift.

... of Self-Priming Pumps

...on to the standard performance tests, as ... preceding paragraphs, it is recommended ...riming pumps be tested to determine the ...me. For this test, the suction line shall be ...ally the same as that shown in Fig. 64. ... between the eye of the impeller and the ...el shall not be less than ten feet. No check ...ve shall be installed in the suction piping. ...ng this test, proceed as follows:

...ming chamber with liquid, or turn on the sealing water line to the vacuum pump if a wet-type vacuum pump is used.

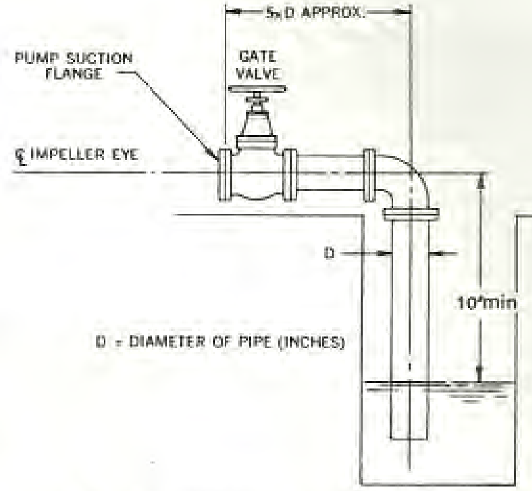


Fig. 64 SUCTION LINE FOR STATIC LIFT TEST

Start the unit. The priming time then shall be the total elapsed time between starting the unit and the time required to obtain a steady discharge gauge reading, or full flow through the discharge nozzle. During this phase of the test, the discharge pipe must be vented if the priming system is of the recirculating type. This will prevent a back pressure being developed as the result of the accumulation of gas. If the unit is equipped with a priming pump of the separate type, it will be necessary that the discharge pipe be sealed with a column of water that will prevent air being drawn from the discharge side of the unit.

Determination of Maximum Developed Vacuum by Means of Dry Vacuum Test

The test procedure is:

With the unit in operation and delivering full flow, close gate valve in the suction line.

The reading on the vacuum gauge will then be the maximum developed vacuum.

Priming Time Conversion Factors

If a suction line is used which is larger in size than is normal for the pump being tested, it is necessary to compute the performance for the normal size of pipe. Referring to Table 6, select the size of suction pipe actually used in the test. Follow this line horizontally to the right, to the vertical column

...er the heading representing the normal suction ...e size of the pump. The figure shown at the point ... intersection is the conversion factor. Divide the ... time (in seconds) by this factor and then divide the resultant by the total length of empty test suction line in feet. The resultant will then be the average time in seconds for air removal from a suction line of normal size, per foot of length.

TABLE 6
Priming Time Conversion Table

Size of Std. Pipe Actually Used	3/8"	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"	2-1/2"	3"
1/2	1.59	—	—	—	—	—	—	—	—
3/4	2.79	1.75	—	—	—	—	—	—	—
1	4.53	2.85	1.62	—	—	—	—	—	—
1-1/4	7.85	4.93	2.81	1.73	—	—	—	—	—
1-1/2	10.7	6.70	3.82	2.35	1.36	—	—	—	—
2	17.6	11.0	6.29	3.88	2.24	1.64	—	—	—
2-1/2	25.1	15.8	8.98	5.53	3.20	2.35	1.42	—	—
3	38.7	24.3	13.9	8.55	4.94	3.62	2.20	1.54	—
3-1/2	—	32.6	18.6	11.4	6.61	4.85	2.95	2.07	1.34
4	—	41.8	23.9	14.7	8.50	6.25	3.79	2.66	1.72
5	—	66.0	37.5	23.2	13.4	9.83	5.96	4.18	2.70
6	—	—	54.2	33.4	19.3	14.2	8.61	6.03	3.90
7	—	—	72.6	44.8	25.9	19.0	11.5	8.10	5.24
8	—	—	93.8	57.9	33.4	24.5	14.9	10.4	6.77
9	—	—	—	72.6	41.9	30.8	18.7	13.1	8.49
10	—	—	—	91.3	52.7	38.7	23.5	16.5	10.7
11	—	—	—	—	63.5	46.6	28.3	19.8	12.9
12	—	—	—	—	75.5	55.5	33.7	23.6	15.3

Size of Std. Pipe Actually Used	3-1/2"	4"	5"	6"	7"	8"	9"	10"	11"
1/2	—	—	—	—	—	—	—	—	—
3/4	—	—	—	—	—	—	—	—	—
1	—	—	—	—	—	—	—	—	—
1-1/4	—	—	—	—	—	—	—	—	—
1-1/2	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—
2-1/2	—	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—	—
3-1/2	—	—	—	—	—	—	—	—	—
4	1.29	—	—	—	—	—	—	—	—
5	2.02	1.57	—	—	—	—	—	—	—
6	2.92	2.27	1.44	—	—	—	—	—	—
7	3.92	3.04	1.94	1.34	—	—	—	—	—
8	5.06	3.93	2.50	1.73	1.29	—	—	—	—
9	6.34	4.93	3.14	2.17	1.62	1.25	—	—	—
10	7.98	6.20	3.94	2.73	2.04	1.58	1.26	—	—
11	9.62	7.46	4.75	3.29	2.45	1.90	1.51	1.20	—
12	11.4	8.88	5.65	3.91	2.92	2.26	1.80	1.43	1.19

centrifugal pumps
instructions for installation, operation and maintenance

General

Centrifugal pumps, when properly installed and when given reasonable care and maintenance, should operate satisfactorily for a long period of time. The following paragraphs discuss the general principles that must be considered to insure trouble free pump operation.

Centrifugal pumps are built in a wide variety of designs and for many different services. The manufacturer's instruction book should be studied carefully and followed as there may be specific requirements for a particular machine or application which cannot be covered in a general discussion.

Location of Unit

The pump should be as near the liquid source as practical, either submerged or so that a short, direct suction pipe may be used. The pump should be located so that a short, direct discharge pipe, with the least number of elbows and fittings, may be used to minimize head loss from friction. If practical it should be placed so that it will be accessible for inspection during operation. Head room should be provided where it is necessary to use lifting devices. The equipment selected should be compatible with the environment. Pumps and drivers, other than submersible types, should be protected against flooding.

Foundation

The foundation should be sufficiently substantial to absorb vibration and to form a permanent, rigid support for the base plate. This is important in maintaining the alignment of a direct connected unit. A concrete foundation on a solid base should be satisfactory. Foundation bolts of the proper size should be embedded in the concrete, located by a drawing or template. A pipe sleeve larger than the bolt should be used to allow movement for final positioning of the bolts. (See Fig. 86.)

Well Pumps and Well Quality

When vertical pumps, either of the line-shaft or submersible type, are installed in wells, consideration must be given to the well before application and installation.

Installing a unit in a crooked well may bind and distort the pump column or pump-motor assembly with potential resulting malfunction. Well straightness should be within one inch per hundred feet and without double bend. If straightness is in doubt, the well should be "caged" prior to installation, lowering a dummy assembly, slightly longer and larger on the diameter than the actual pump or pump motor assembly, on a cable.

Wells that have not been properly constructed or developed, or which produce sand, can be detrimental to a pump. If a well is suspected of producing an excessive amount of sand, a unit other than the production pump should be used to clear the well.

Installation

It is recommended that the services of a manufacturer's erecting engineer be employed in installing and starting pump equipment which is of appreciable value or of a precision type. This is to assure that the machinery is properly installed. The purchaser then is also afforded the opportunity of receiving adequate and authoritative instructions.

Alignment

The following discussion of alignment applies primarily to horizontal, general service, centrifugal pumps driven by an independent driver through a flexible coupling and with pump and driver mounted on a common base plate.

Vertical line-shaft and submersible pumps will be automatically aligned through registered fits. However on line-shaft pumps, it is recommended to check the alignment of the head shaft to the driver at the time the latter is mounted.

Pumps and drivers that are received from the factory with both machines mounted on a common base plate, were accurately aligned before shipment. All base plates are flexible to some extent and, therefore, must not be relied upon to maintain the factory alignment. Realignment is necessary after the complete unit has been leveled on the foundation and again after the grout has set and foundation bolts have been tightened. The alignment must be checked after the unit is piped and rechecked periodically as outlined in the following paragraphs. To facilitate accurate field alignment, most manufacturers either do not dowel the pumps or drivers on the base plates before shipment, or at most, dowel the pump only.

When the driver is to be mounted at the place of installation, the base plate is machined at the factory and the pump is positioned, but the bolt holes for fastening the driver may not be drilled and tapped.

Leveling the Unit

When the unit is received with the pump and the driver mounted on the base plate, it should be placed

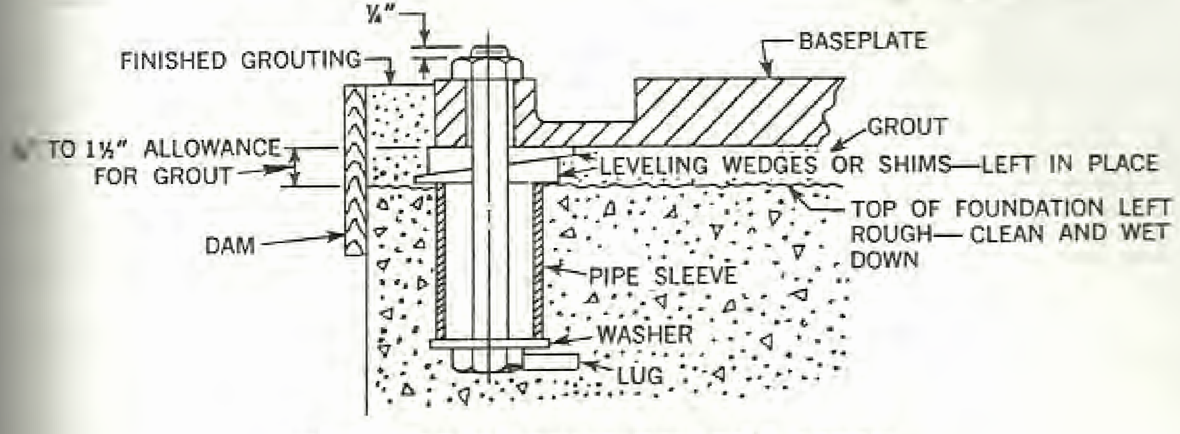


Fig. 86 TYPICAL FOUNDATION BOLT DESIGN

foundation and the coupling halves discon-nected. The coupling should not be reconnected un-til alignment operations have been completed. The base plate should be supported on rectangular blocks and shims or on metal wedges having a small taper. The support pieces should be placed close to the foundation bolts. (Fig. 87). On large units, small jacks made of cap screws and nuts are convenient. In each case the supports should be directly under the part of the base plate carrying the greatest weight and spaced closely enough to give uniform support. A spacing of 24 inches is sug-gested on medium size units. A gap of about ¾ to 1½ inches should be allowed between the base plate and the foundation for grouting.

Adjust the metal supports or wedges until the shafts of the pump and driver are level. Check the coupling faces as well as the suction and discharge flanges of the pump for horizontal or vertical posi-tion by means of a level. Correct the positions, if necessary, by adjusting the supports or wedges under the base plate as required.

Flexible Couplings

A flexible coupling should not be used to com-pensate for misalignment of the pump and driver shafts. The purpose of the flexible coupling is to compensate for temperature changes and to permit end movement of the shafts without interference with each other while transmitting power from the driver to the pump.

Types of Misalignment

There are two forms of misalignment between the pump shaft and the driver shaft, as follows:

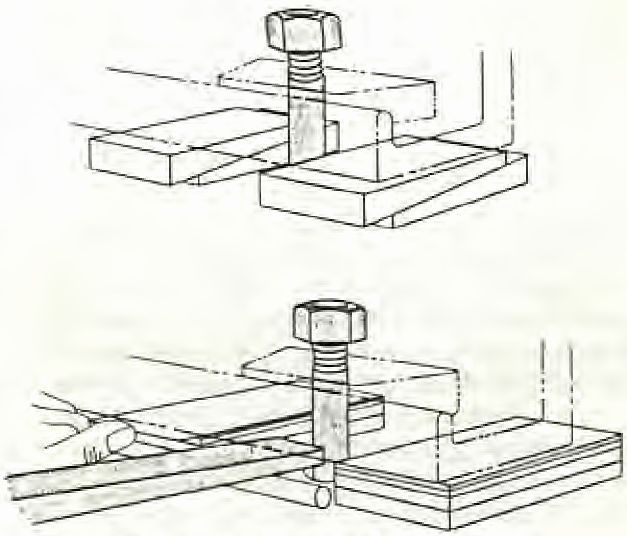


Fig. 87 METHOD OF LEVELING

Angular misalignment—shafts with axes concen-tric but not parallel.

Parallel misalignment—shafts with axes parallel but not concentric.

Coupling Alignment

The faces of the coupling halves should be spaced far enough apart so that they cannot strike each other when the driver rotor is moved hard over toward the pump. Due allowance should be made for wear of the thrust bearings. A minimum dimension for the sep-aration of the coupling halves is usually specified by the manufacturer. The necessary tools for approxi-mately checking the alignment of a flexible coupling are a straight edge and a taper gauge or a set of feeler gauges.

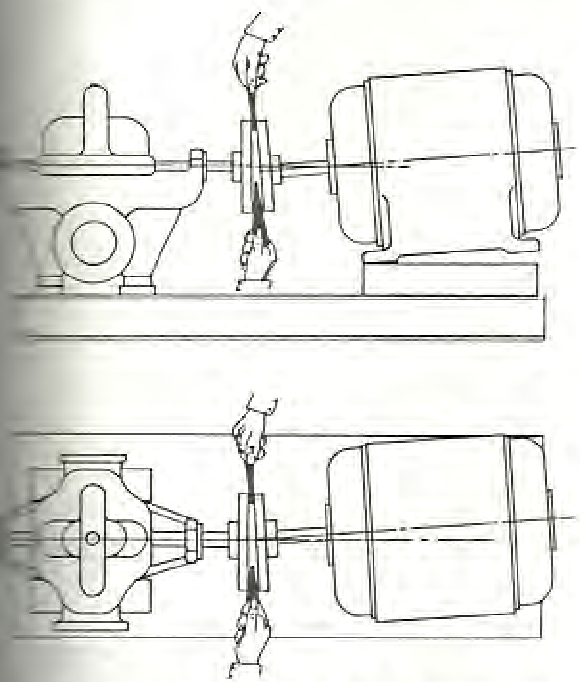


Fig. 88 CHECKING ANGULAR ALIGNMENT

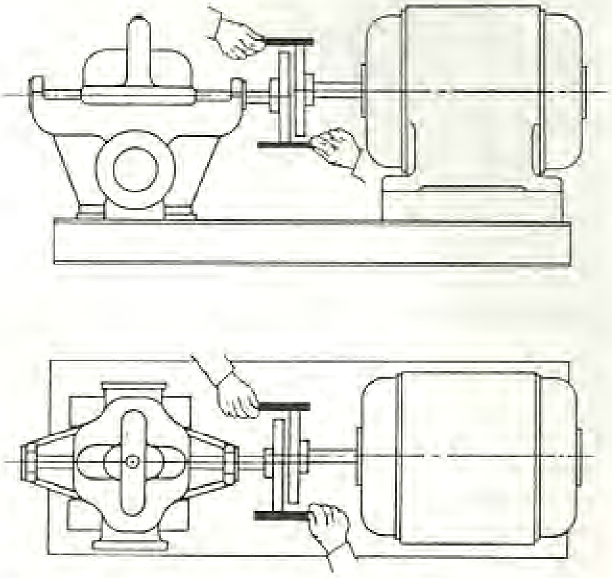


Fig. 89 CHECKING PARALLEL ALIGNMENT

On certain large units, limited end float cou- ... are used and the instruction book furnished ... ch units should be consulted for the special ... ent instructions that apply to such couplings.

... nnect coupling halves before proceeding ... gnment. Proceed with checks for angular ... allel alignment by the immediately following ... d only if satisfied that faces and outside di- ... s of the coupling halves are square and con- ... with the bores. If this condition does not ... e Alternate Method of Alignment described ... e 137 is recommended.

... eck for angular alignment is made by insert- ... taper gauge or feelers at four points between ... upling faces and comparing the distance be- ... e faces at four points spaced at 90-degree ... s around the coupling. The unit will be in ... alignment when the measurements show ... coupling faces are the same distance apart ... oints. (Fig. 88).

... eck for parallel alignment is made by placing ... t edge across both coupling rims at the top, ... and at both sides. The unit will be in parallel ... ent when the straight edge rests evenly on ... upling rim at all positions. Allowance may be ... ary for temperature changes and for coupling ... that are not of the same outside diameter.

Care must be taken to have the straight edge parallel to the axis of the shafts (Fig. 89).

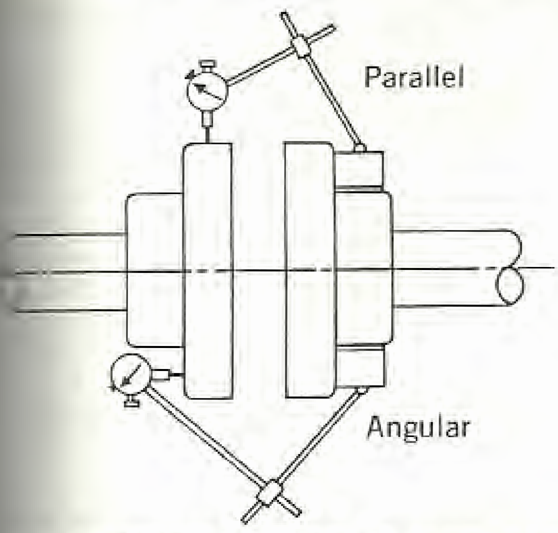
Angular and parallel misalignment are corrected by means of shims under the motor mounting feet. After each change, it is necessary to recheck the alignment of the coupling halves. Adjustment in one direction may disturb adjustments already made in another direction. It should not be necessary to adjust the shims, if used, under the pump.

The permissible amount of misalignment will vary with the type of pump and driver. The manufacturer's recommendations should be obtained and followed.

When the driver is to be mounted on the base plate in the field, it is necessary to place the base plate with pump on the foundation, to level the pump shaft, to check the coupling faces, the suction and discharge flanges for horizontal or vertical position, and to make any necessary corrective adjustments.

When the units are lined up cold, it may be necessary to make an allowance for the vertical rise of the driver and/or pump caused by heating. The manufacturer's recommendations should be obtained and followed.

The pads provided on the base plate for the driver should be coated with chalk to facilitate marking the location of the bolt holes. Place the driver on the base plate so that the distance between the coupling halves is in accordance with the dimensions indicated on the outline elevation of the complete unit by adjusting the position of the driver and by placing shims as required under the driver feet.



...90 ALTERNATE METHOD OF ALIGNMENT

...alignment of pump and driver coupling halves ...should be checked and corrected. Scribe on ...ase plate pads the circumference of the bolt ...in the driver feet. Remove the driver and de...e size of bolts. Drill and tap for bolts. Replace ...on the base plate, insert the bolts and align ...iver before tightening. The subsequent proce...s are the same as for factory aligned units.

...nate Method of Alignment

... approved method for putting the coupling ...s in final accurate alignment is by the use of a ... indicator. Check alignment by straight edge, ... gauge or feelers as accurately as possible by ...edure indicated previously.

...sten the indicator to the pump half of the cou...g with the indicator button resting on the other ... coupling periphery (Fig. 90). Set the dial to ... and chalk mark the coupling half beside where ... button rests. For any check, top or bottom or ...s, rotate both shafts by the same amount, i.e., ... readings on the dial must be made with button ...e the chalk mark.

...e dial readings will indicate whether the driver ...to be raised or lowered or moved to either side. ... each movement, check to see that coupling ...s remain parallel to one another.

...h this method accurate alignment of shaft ...ers can be obtained even where faces or outside ...meters of the coupling halves are not square or ...centric with the bores, provided all measure...ts for angular alignment are made between the ...e two points on the faces and all measurements

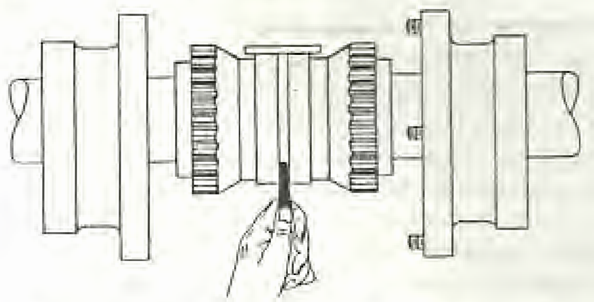


Fig. 91 ALIGNMENT OF GEAR TYPE COUPLING

for parallel alignment are made between the same two points on the outside diameters. Gross deviations in squareness or concentricity, however, may cause problems due to coupling unbalance or abnormal coupling wear and may need to be corrected for reasons other than accomplishment of shaft alignment.

EXAMPLE: If the dial reading at the starting point (either top or one side) is set to zero and the diametrically opposite reading at the bottom or other side shows a plus or minus reading of .020 inch, the driver must be raised or lowered by the use of suitable shims, or moved to one side or the other by half of this reading.

Note: For all checks, including that for parallelism of coupling faces, keep both shafts pressed hard over to one side when taking readings.

Alignment of Gear Type Couplings

Gear type couplings are aligned in the same manner as outlined above. However, the coupling covers must be moved back out of the way and measurements made on the coupling hubs as shown on Fig. 91.

Alignment of Spacer Type Couplings

Where a spacer type coupling is used between the pump and driver, it is not possible to align the couplings to the pump and driver exactly as described above. To align units with a floating coupling, remove the spacer between the pump and driver. Make a bracket, as shown in Fig. 92, which can be fastened to one of the coupling halves and which is long enough to reach the other coupling half. Fasten this bracket to one coupling half and a dial-type indicator to the bracket arm so that the indicator button is in contact with the other coupling half as

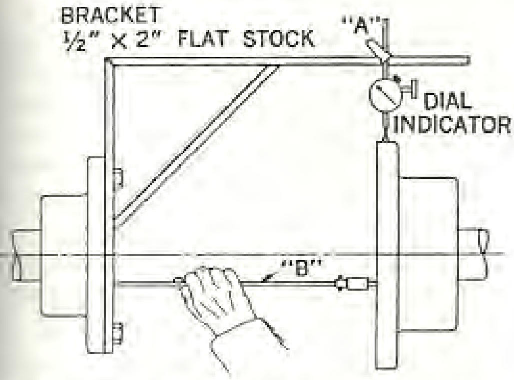


Fig. 92 ALIGNMENT OF SPACER TYPE COUPLINGS

shown at A, Fig. 92. Make a chalk mark on the coupling half beside where the button rests and set the dial to zero. To check for parallel alignment, rotate both shafts by the same amount, i.e., all readings are made with the button beside the chalk mark.

After parallel alignment has been obtained, change the indicator so it bears against the face of the same coupling half and follow the same procedure to check for angular alignment that were used for parallel alignment. If the shafts have end play, it is preferable to make this check of angular alignment by using inside micrometers as shown at B, Fig. 92.

After final alignment is obtained, insert the spacer and bolt the coupling halves.

Grouting

When the alignment is correct, the foundation bolts should be tightened evenly but not too firmly. The unit can then be grouted to the foundation. The base plate should be completely filled with grout, and it is desirable to grout the leveling pieces, shims or wedges in place. Foundation bolts should not be fully tightened until the grout is hardened, usually about 48 hours after pouring.

Final Check of Alignment

After the grout has set and the foundation bolts have been properly tightened, the unit should be checked for parallel and angular alignment and, if necessary, corrective measures taken. After the piping of the unit has been connected, the alignment should be checked again.

The direction of rotation of the driver should be checked to make certain that it matches that of the pump. The corresponding direction of rotation of the pump is usually indicated by a direction arrow on the pump casing.

The coupling halves can then be reconnected. With the pump properly primed, the unit then should be operated under normal operating conditions until temperatures have stabilized. It then should be shut down and immediately checked again for alignment of the coupling. All alignment checks must be made with the coupling halves disconnected.

It should be emphasized that attempts to correct alignment in one direction may alter the alignment in the other direction; therefore, it is necessary to check in all directions after making any adjustments.

Dowelling

After the unit has been running for about one week, the coupling halves should be given a final check for misalignment caused by pipe strains or temperature strains. If the alignment is correct, both pump and driver should be dowelled to the base plate. The location of the dowels is very important and the manufacturer's instructions should be obtained, especially if the unit is subject to temperature changes.

Factors That May Disturb Alignment

The unit should be checked periodically for alignment. If the unit does not stay in line after being properly installed, the following are possible causes:

Settling, seasoning or springing of the foundation.
Pipe strains distorting or shifting the machine.
Wear of the bearings.
Springing of the base plate by heat from an adjacent steam pipe or from a steam turbine.
Shifting of the building structure due to variable loading or other causes.
Loose nuts or bolts on the pump or driver assembly.

It may be necessary to slightly readjust the alignment, from time to time, while the unit and foundation are new.

Piping

It is desirable to support and restrain both the suction and discharge pipes near the pump to avoid application of forces and moments to the pump casing.

In installations involving large temperature variations, expansion of the connected piping may subject the pump nozzles to significant forces and moments. If this condition is unavoidable, each such application should be referred to the pump manufacturer for approval.

If an expansion joint is installed in the piping between the pump and the nearest point of anchor in

...ng, it should be noted that a force equal to ...a of the expansion joint (which may be con... ...y larger than the normal pipe size) times the ...e in the pipe will be transmitted to the pump ... Pipe couplings which do not provide an axi... ...d connection have the same effect. This re... ...force can be of such magnitude that it would ...actical to design adequate baseplates, bolts ...casings, and other components to withstand ...e. If an expansion joint or non-rigid coupling ...e used, it is recommended that a pipe anchor ...lled between it and the pump. If properly in... ..., this will eliminate the objectionable force ...ned above.

...usually advisable to increase the size of both ... and discharge pipes at the pump nozzle in ... decrease the head loss from friction. For ...e reason piping should be arranged with as ...ends as possible and even then should be ...ith a long radius wherever possible.

...es on Cast Iron Pumps for High Pressures

... the increasing use of high tensile strength ...n for pump casings for operation at relatively ...essures, the pump flanges are generally made ...t faces. When steel discharge piping is used, ...e flange should also have a flat face. A full ...asket must be used.

...arge Piping

...eck valve and a stop valve should be installed ... discharge line. The check valve, placed be... ...the pump and the stop valve, is to protect the ...from reverse flow and excessive back pressure. ...op valve is used in priming, starting and when ...g down the pump. Except on axial flow and ... flow pumps, it is advisable to close the stop ...before stopping the pump. This is especially ...tant when the pump is operated against a high ...head. If increasers are used on the discharge ... increase the size of discharge piping, they ... be placed between the check valve and .... If expansion joints are used, they should be ...d between the check valve and pump.

...on Piping

...e suction pipe must be kept free of air leaks. ...s particularly important when the suction line ...ng one or the static suction lift is high. (Figs. ...95.)

...uble is often caused by the use of bell and ... pipe in the suction line. Screwed or flanged pipe for the smaller sizes and flanged pipe for the larger sizes or for high suction lifts are recommended.

Water Hammer

Water hammer is an increase in pressure due to rapid changes in the velocity of a liquid flowing through a pipe line. This dynamic pressure change is the result of the transformation of the kinetic energy of the moving mass of liquid into pressure energy. When the velocity is changed by closing a valve or by some other means, the magnitude of the pressure produced is frequently much greater than the static pressure on the line, and may cause rupture or damage to the pump, piping or fittings. This applies both to horizontal and vertical pump installations.

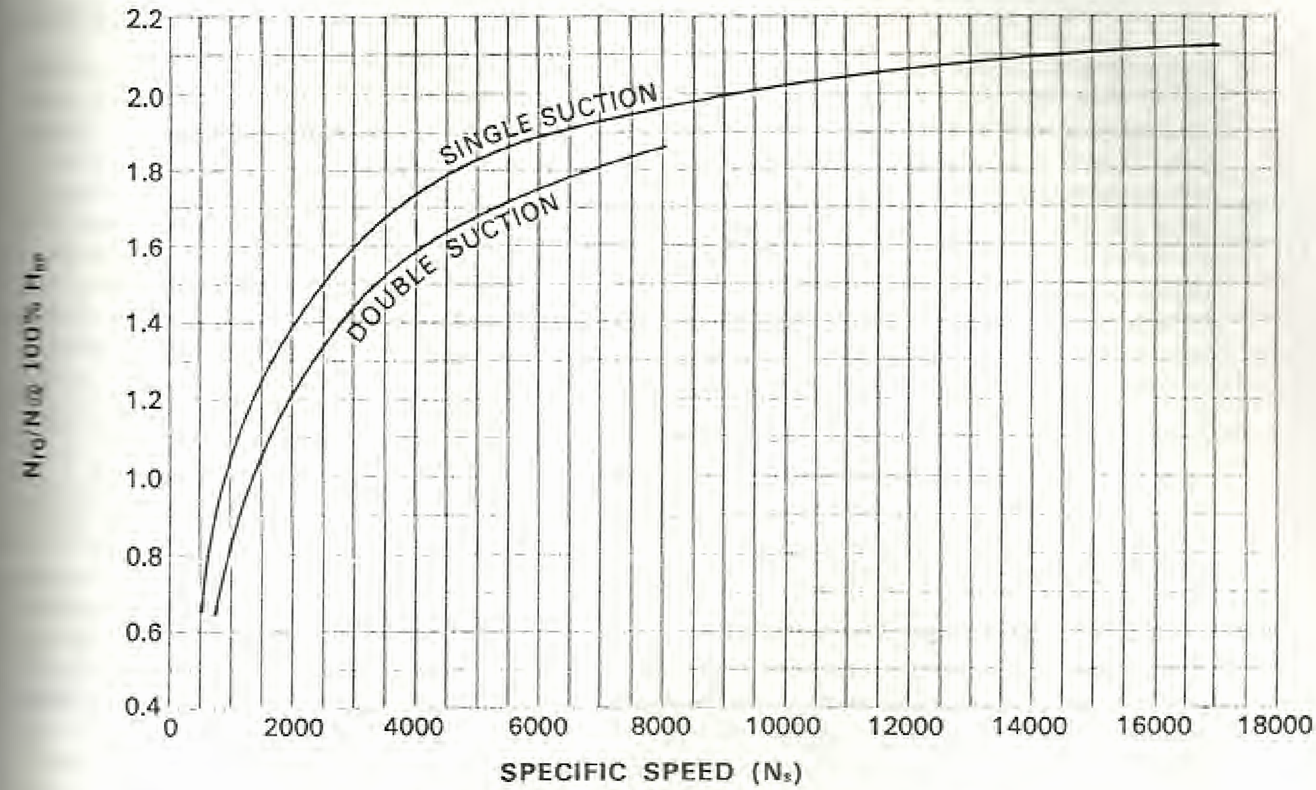
Starting at the closed valve, a wave of increased pressure is transmitted back through the pipe with constant velocity and intensity. When the pressure wave has travelled upstream to the end of the pipe where there is a reservoir or large main, the elasticity of the compressed liquid and of the expanded pipe reverse the flow and a wave of normal pressure travels downstream, the flow being progressively reversed as the liquid expands.

If the liquid were incompressible and the pipe inelastic, the instantaneous closure of the valve would create an infinite pressure. Since it is impossible to close a valve instantaneously, it is apparent that a series of pressure waves is created, thus causing an increased pressure at the valve. If the valve is completely closed before the first pressure wave has time to return to the valve as a wave of low pressure, the pressure increases continuously up to the time of complete closure, and the resulting pressure is the same as if the valve had been closed instantaneously. The velocity of the pressure wave depends upon the ratio of the wall thickness to the inside pipe diameter, on the modulus of elasticity of the pipe material, and on the modulus of elasticity of the liquid.

The head due to water hammer in excess of normal static head is a function of the destroyed velocity, the time of closure and the velocity of pressure wave along the pipe. The value of water hammer can be calculated with a fair degree of accuracy by an engineer thoroughly experienced in this work, providing all of the factors influencing water hammer are known.

Water hammer may be controlled by regulating valve closure time, relief valves, surge chambers and other means.

It is recommended that specialized engineering



Note: Curve Fitted to the Highest Reported Values of N_{ro}/N @ 100% H_{BP} where:
N_{ro} = Reverse runaway speed (rpm)
N_s = Specific speed
N = Pump operating speed (rpm)
H_{BP} = Pump head at best efficiency point

Fig. 93 REVERSE RUNAWAY SPEED RATIO VS SPECIFIC SPEED

services be engaged for such calculations, since few pump users or pump manufacturers have the knowledge and experience necessary for this work.

The following is a brief list of references which may be consulted on this subject:

"Symposium on Water Hammer"—American Society of Mechanical Engineers, 1933 (Reprinted 1949)

"Symposium on Water Hammer"—Transactions A.S.M.E. 59:651 (1937)

"Water Hammer Control"—S. L. Kerr—Journal of American Water Works Association 43:985 (December, 1951)

"Water Hammer"—J. Stevens—AWWA—Vol. 37, (1945)

"Water Hammer in Compound and Branched Pipes"—R. Angus—Transaction of the ASCE, (1939)

"Basic Theory of Water Hammer"—L. Allievi—Typography Riccardo & Garroni, Rome, Italy, (1925)

"Elements of Graphical Solution of Water Hammer Problems in Centrifugal Pump Systems"—A. J. Stepanoff—Transactions A.S.M.E. 71: 515 (1949)

"Practical Aspects of Water Hammer"—S. L. Kerr—Journal of American Water Works Association 40:599 (June, 1948)

"Water Hammer Analysis"—J. Parmakian—Dover Publications, New York (1955)

...se Runaway Speed

...dden power and check valve failure during ... operation against a static head will result in a ... versal, and the pump will operate as a hy... turbine in the direction of rotation opposite ... consistent with normal pump operation.

...al pump drivers can be equipped with non... ratchets to prevent reverse rotation. How... their application is not always desirable and a ... should always be made with the manufacturer.

... pump is driven by a prime mover offering lit... tance while running backwards, the reverse ... may approach its maximum consistent with ...que. This speed is called runaway speed. If ...d, under which such operation may occur, is ... greater than that developed by the pump at ... efficiency point during normal operation, ...way speed will exceed that corresponding to ... pump operation. This excess speed may im...h mechanical stresses on the rotating parts ... the pump and the prime mover and, there... knowledge of this speed is essential to safe... equipment from possible damage.

... been found practical to express the runaway ... a percentage of that during normal opera... The head consistent with the runaway speed is ... case assumed to be equal to that developed ... pump at the best efficiency point.

...e ratio between the maximum expected head ... turbining operation to the head at the best ...cy point during normal pumping operation is ... the runaway speed is determined from the ... laws.

... ratio of runaway speed to normal speed for ... and double suction pumps varies with specific ... This relationship is shown by Fig. 93. The ...wn should be used as a guide, it being rec... that variations can be experienced with in... designs.

... be pointed out that transient conditions, ... which runaway speed may take place, often ... considerable head variations due to surging ... pressure line. Since most pumping units have ... little inertia, surging can cause rapid ...ctuations. The runaway speed may, in such ... be consistent with the highest head resulting ...rging. Therefore, knowledge of the surging ...eristic of the pipeline is essential for deter... the runaway speed. This is particularly im... in case of long lines.

Slope of Suction Pipe

A horizontal suction line should have a gradual rise to the pump (Fig. 94.) Any high point in the suction line will become filled with air and thus prevent proper operation of the pump. *A straight taper reducer should not be used in a horizontal suction line* as an air pocket is formed in the top of the reducer and the pipe. An eccentric reducer should be used instead. (Fig. 95.) If an air pocket remains in the suction pipe when the pump has been primed and started, it is likely that the entrapped air will be drawn into the pump and may cause the pump to lose its prime. This is particularly true when the pump is primed by means of a foot valve. Even when the pump is primed by an ejector or vacuum pump, a small quantity of air is left in the pocket and to this is added air from the water released by the partial vacuum in the suction pipe as well as air admitted through minute leaks in the pipe connections. Small air pockets that may cause trouble are formed in the top of any valves installed in the suction line in such manner that the valve stems are vertical. It is recommended that gate valves in the suction line be installed so that the stems are horizontal. Trouble caused by an air pocket in the suction line can usually be stopped temporarily by priming and starting the pump several times. This will draw out enough of the air in the pocket so that the pump will operate properly; but, the trouble is liable to recur and therefore it is important such pockets should be eliminated.

Check Valves

Ordinarily, check valves should not be used in the suction line, although they are sometimes used in series-parallel connections to reduce the number of valves which must be operated when changing from series to parallel operation.

Elbow on Suction

Suction piping, for double suction pumps, should not be installed so that there is an elbow close to the suction nozzle of the pump except when this elbow is in a plane at right angles to the pump shaft. (See Fig. 96.) There is always uneven flow in an elbow and when it is installed in any position other than in a plane at right angles to the pump shaft, this unequal flow causes more water to enter one side of the impeller than enters the other side. This causes

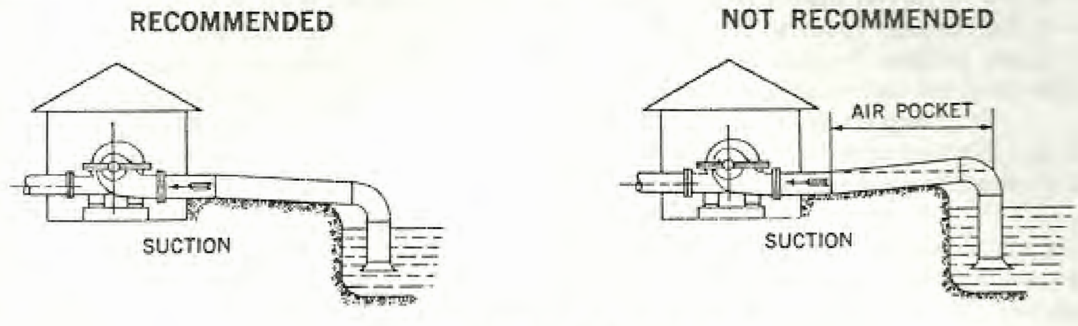


Fig. 94 SUCTION PIPE DESIGN

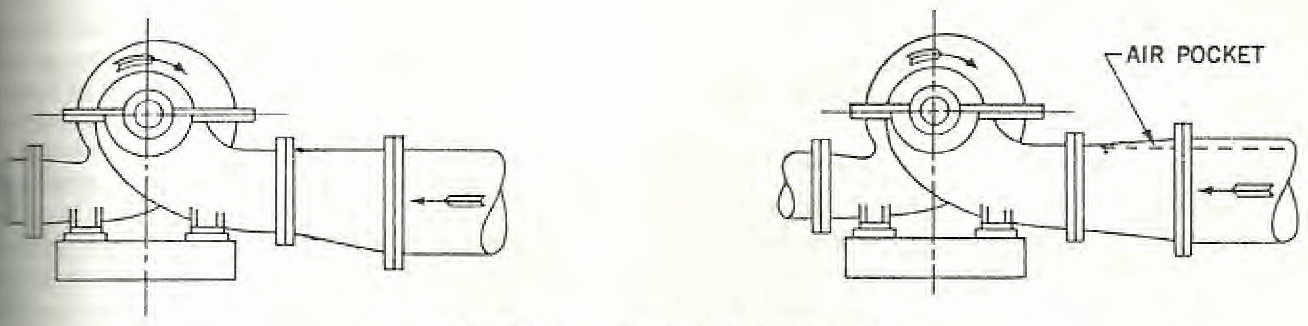


Fig. 95 REDUCER AT PUMP SUCTION

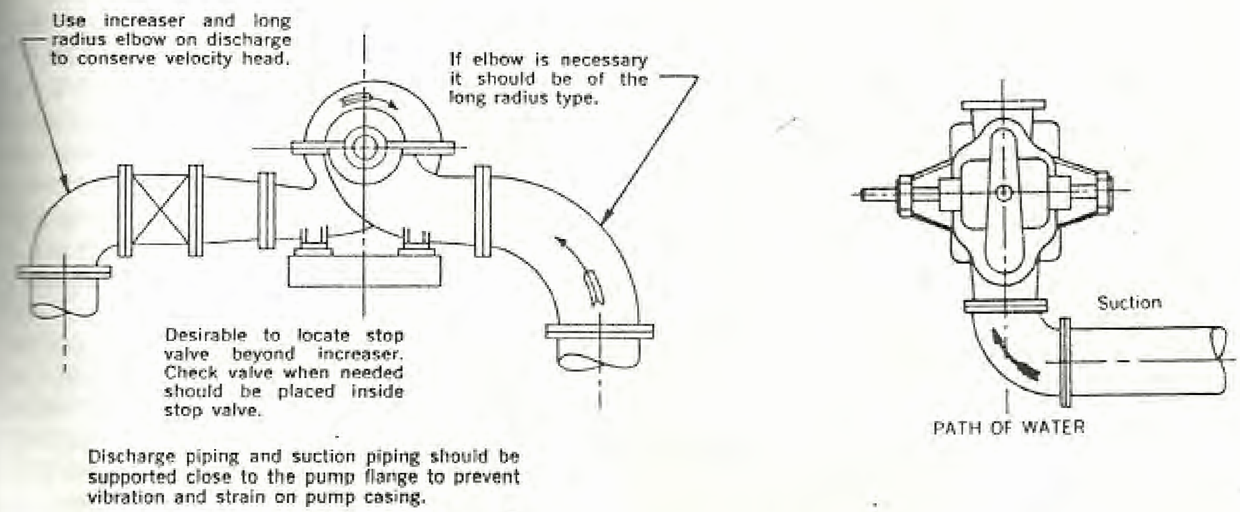


Fig. 96 SUCTION ELBOW ON DOUBLE SUCTION PUMP

...tion in capacity and efficiency and a thrust ...may heat the thrust bearing and possibly ...apid wear of that bearing. The unequal flow ...ion may also cause impeller damage due to ...n and/or flow separation.

...alve

...the suction lift is not very high, it is fre... advisable to install a foot valve to facilitate ... Foot valves should not be used when the ...s operating against a high static head, as fail... the driver would allow the water to rush back ...y causing a heavy water hammer. This is par... true for vertical turbine and submersible ... which, as a rule, are not designed for use ... foot valve.

...foot valves are used, they should be of the ...s flap type rather than of the multiple spring ...d have a clear passage for water at least of ...e area as that of the suction pipe. Care must ...en to prevent foreign substances from being ...nto the pump or choking the foot valve. For ...pose an effective strainer should be provided. ...there is any refuse such as sticks, twigs, ... etc., in the water, a larger outside screen ... be placed around the suction inlet to prevent ...g of the strainer. This screen should have ...nt openings so that the flow velocity does ...ceed two feet per second.

...ng Boxes and Packing

...stuffing box may or may not be packed before ...ent. Where the stuffing box is not packed, it ... be carefully cleaned and packed when the ... is put into operation. Instructions will usually ...nd with the box of packing. If not, the follow... may be used as a guide:

...re a lantern ring is required, be sure that suf... packing is placed back of the lantern ring so ...e liquid for sealing is brought in at the lantern ...d not at the packing. The pipe supplying the ... liquid should be fitted tightly so that no air ... On suction lifts, a small quantity of air en... the pump at this point may result in loss of ...

...*e liquid to be pumped is dirty, gritty or is acid, ...g liquid should be piped to the stuffing boxes ... a clean outside source of supply* in order to pre... damage to the packing and shaft sleeves. Seal... liquid should be at a pressure sufficient to insure ... of clean liquid into pump but not so high as to ...e excessive tightening of the packing.

Each packing ring should be cut to the proper length so that the ends come together but do not overlap. Succeeding rings of packing should be placed in the stuffing box so that the joints of the several rings of packing are staggered.

Packing should not be pressed too tightly, as this may result in burning the packing and scoring the shaft or shaft sleeve.

When a pump is first put into operation, the stuffing box packing should be left quite loose. After the pump has been found to operate properly, the stuffing box gland may be tightened very slowly if the leakage is excessive. A slight flow of liquid from the stuffing box is necessary to provide lubrication and cooling.

When the leakage can no longer be controlled by adjusting the gland, all rings of packing should be replaced. The addition of a single ring to restore gland adjustment is not recommended.

If the pump is to be left idle for a long period of time, it is recommended that the packing be removed from the stuffing box.

Mechanical Seals

Pumps handling hazardous or expensive liquids, or liquids where the necessary leakage from the stuffing box is objectionable, are often furnished with mechanical seals.

A mechanical seal consists of a rotating element and a stationary element. The sealing faces are highly lapped surfaces on materials selected for their low coefficient of friction and their resistance to corrosion by the liquid being pumped. The faces have a minute running clearance and normally run with a very thin film of liquid. In addition, there must be a means of loading the seal and providing flexibility. This is accomplished either with a spring (or springs) and shaft packing, or with a flexible member of some organic material.

Since mechanical seals are made in a wide variety of designs, the instructions for the specific seal must be carefully studied and followed exactly. A mechanical seal is a precision device and must be treated accordingly.

When the pump is equipped with a mechanical seal, no attention or adjustment to the seal is normally required. Except for possible slight initial leakage, the seal should operate with negligible leakage.

Oil Lubricated Sleeve Bearings

Before starting the pump, make certain that bearings and bearing housings are free of dirt and foreign stances which may have entered during shipment installation. The bearings should then be filled with the lubricant, as recommended by the manufacturer. The lubricant should be changed when it becomes dirty, or at recommended intervals, and the bearings cleaned out at the same time. Bearings should be examined periodically for wear.

When the pump is first started, the operator should make sure that the oil rings (where used) are turning freely. They may be inspected through the oil holes in the bearing caps.

If the pump is equipped with a forced-feed lubrication system, check the sight glasses to assure oil is flowing.

The bearings should be checked for overheating. *For special instructions see manufacturer's instruction book.*

Anti-Friction Bearings—Lubrication

It is impossible to overemphasize the importance of proper lubrication of anti-friction bearings in pumps.

Oil lubricated bearings should be lubricated with the grade of lubricant recommended by the manufacturer.

For grease lubrication it is recommended that the grade of anti-friction bearing grease be used. *Graphite should not be used.*

Heating of anti-friction bearings often is caused by too much instead of too little grease or oil, and careful inspection to determine the cause of trouble should be made before more lubricant is added. It is impossible to say how often the bearings should be greased or cleaned; this must be determined by experience with the installation and the service.

Anti-friction bearings should be cleaned by flushing with a low volatility petroleum solvent. Use clean pans and cloths. Great care should be exercised to keep the housing clean, and only clean grease should be used. Foreign solids or liquids within the bearing housing can completely ruin the bearings in a short time.

Freezing

When handling water, care should be taken to prevent the pump from freezing during cold weather when the pump is not in operation. It may be necessary, when there is any possibility of freezing, to drain the pump casing on dry pit applications during shut-down periods by removing the bottom drain plug. In some pumps draining of suction line is sufficient. For vertical wet pit pumps, removal of the unit is required.

Priming

The pump must not be run unless it is completely filled with liquid or, for vertical line-shaft and submersible units, are provided with the minimum required submergence, as there is danger of damaging some of the pump components. Typically wearing rings, bushing and internal sleeve bearings depend on liquid for their lubrication and may seize if the pump is run dry.

When the required submergence is provided, all submersible units and most vertical turbine pumps can be started without concern for the non-submerged part of the pump. For vertical line-shaft pumps this will, however, depend on the column length and bearing construction. The manufacturer's instructions should be checked for pre-lubrication requirements.

When required, the pump may be primed by one of the following methods, as may best be suited to the conditions.

Priming By Ejector or Exhauster

When steam, high pressure water, or compressed air is available, the pump may be primed by attaching an air ejector to the highest points in the pump casing. This will remove the air from the pump and suction line, provided a tight valve is located in the discharge line close to the pump. As soon as the ejector waste pipe throws water continuously, the pump may be started. After starting, a steady stream of water from the waste pipe indicates that the pump is primed. If this stream of water is not obtained, the pump must be stopped at once and the process of priming repeated. A foot valve is unnecessary when this kind of device is used.

Priming With Foot Valve

When it is not practicable to prime by ejector or exhauster, a foot valve in the suction inlet will prevent liquid running out through the suction inlet and the pump can be completely filled with liquid from some outside source. Pet cocks on top of the pump should be opened during filling to allow the air to escape. A tight foot valve will keep the pump constantly primed so that the pump may be used for automatic operation. The valve must be inspected frequently, however, to see that it does not develop leaks and thus allow the pump to be started dry.

Priming By Vacuum Pumps

When neither of the above methods of priming are practicable, the pump may be primed by the use a vacuum pump to exhaust the air from the pump ...ng and suction line. A wet vacuum pump is pref...ble, as it will not be injured if water enters it. ...en a dry vacuum pump is to be used, the instal...n must be such as to prevent liquid being taken ... the air pump. The manufacturer's instructions ...uld be followed.

...e: Careful attention to the priming method at the ...e of installation may save later annoyance be...se of improper equipment or procedure.

...arting

...efore starting the pump, check the direction of ...tion. The proper direction is usually indicated ... a direction arrow on the pump casing, bearing ...ing or discharge head. When electric motors are ...d as drivers, the rotation should be checked with ...motor disconnected from the pump. The rotating ...ent in vertical turbine pumps must be raised ...y before start-up. An adjustable pump-to-motor ... coupling is provided for this purpose, and the ... shaft must be raised per the manufacturer's ...ctions.

...e rotation of submersible units can normally be ...ed by observation. Check the manufacturer's ...up instructions.

...UTION: Before starting the pump, adequate ...ergence must be provided for vertical turbine ... submersible pumps, and casing and suction ... must be filled with liquid for horizontal pumps.

...d-Torque Curves

...ot of speed versus torque requirements during ... starting phase of a centrifugal pump is some... checked against the speed versus torque curve ... driving motor. The driver must be capable of ...ing more torque at each speed than required ... pump in order to bring the pump up to rated .... This condition is generally easily attainable ... standard induction or synchronous motors but ... certain conditions, such as high specific ... pumps or reduced voltage starting, a motor ...gh pull-in torque may be required.

...e centrifugal pumps, in the low to medium ... speed range (under 3500), are started with ...ischarge valve closed, the procedure used to ...ate the minimum torque requirements at vari...eeds under this condition is as follows:

...rmine the maximum pump power input re... at rated speed under shut-off conditions. ...t this power to torque (in ft lbs) by using the ...a:

$$T = \frac{5250 \times HP}{rpm}$$

Torque varies as the square of the speed; therefore, to obtain torque at:

¾ Speed—multiply full speed torque by 0.563
½ Speed—multiply full speed torque by 0.250
¼ Speed—multiply full speed torque by 0.063
⅛ Speed—multiply full speed torque by 0.016

At zero speed the torque would theoretically be zero, but the driver must overcome stuffing box friction, rotating element inertia and bearing friction in order to start the shaft turning. This requires a torque at zero speed of from 2½ per cent to 15 per cent of the maximum.

Speed torque requirements for starting conditions other than closed discharge will vary depending on the percentage of static head to total head; the cubic content of the discharge line; the condition of the discharge line, that is full, partly full, or empty; and conditions which may change during the starting period, such as the opening or closing of bypass valves. Each of these conditions determines a different torque requirement at any specified speed which should be obtained from the pump manufacturer when necessary.

Position of Discharge Valve on Starting—High or Medium Head Centrifugal Pumps

A high or medium head centrifugal pump, when primed and operated at full speed with the discharge stop valve closed, requires much less power input than when it is operated at its rated capacity and head with the discharge stop valve open. For this reason, it is advantageous to have the stop valve closed when the pump is being started, except as noted below. It is to be noted, however, that with a pump of higher specific speeds, closing of the discharge valve at starting is less effective. Where the design approaches the mixed flow type of pump, the input power required at "shut-off" may equal or exceed the power required with the discharge valve open.

Position of Discharge Valve on Starting—Mixed Flow and Axial Flow Type Pumps

Pumps of the mixed flow type frequently require greater input power with the discharge valve closed than with it open. Axial flow type pumps nearly always require a great deal more power at shut-off than at rating and must be started with the discharge valve open. The manufacturer's instructions should be consulted for the characteristics of such pumps.

Warning Against Operating Pumps with Suction and/or Discharge Valves Closed

Brief shut-off operation of most centrifugal pumps is often necessary. The necessity may arise from system start-up or shut-down requirements and is normally met by closure of the discharge valve for minimum possible time. Prolonged operation of the pump under this condition may prove harmful to the structural integrity of the pump mainly because of:

Increased vibration level affecting the bearings, stuffing boxes, or mechanical seals.

Increased radial thrust and resultant stresses in the shafts and bearings of centrifugal volute type pumps.

Heat build up resulting in a dangerous temperature rise of the liquid being handled and pump elements in contact with it.

Excessive cavitation and accompanying damage resulting from internal recirculation.

Operation of a centrifugal pump with the suction valve closed (discharge valve open) may cause serious damage and should not be attempted unless absolutely required by unusual circumstances. In addition to the above conditions, such operation may lead to loss of lubricant to the stuffing box and any bearings lubricated by the pump fluid.

Operation of a centrifugal pump with both valves closed for even brief periods of time is an unacceptable and dangerous practice. It can rapidly lead to a violent pump failure.

Reduced Voltage Starting

Except in the case of axial flow and mixed flow pumps, pumps using squirrel cage induction motors having reduced voltage starting control should always be started with the stop valve closed.

Across-the-Line Starting

When squirrel cage induction motors having line starting controls are used, it is permissible to have the stop valve open when the pump is being started. However, the length of time of the electrical disturbance on the line, due to the starting cycle, may be shortened if the stop valve remains closed or partially closed until the pump comes up to full speed.

Synchronous Motors

Synchronous motors of the general purpose sizes up to and including 500 horsepower at 80 per cent power factor and at unity power-factor, having speeds of 500 rpm or higher, are usually designed with sufficient pull-in torque to start pumps with discharge valve open. Above these horsepower ratings, and for speeds below 500 rpm, standard motors are not usually designed with sufficient pull-in torque to start pumps with discharge valve open. Most manufacturers can modify their design to meet this requirement, but such motors must be specially built. Sometimes it is necessary to consider the total hydraulic system, especially for high specific speed pumps to insure that sufficient pull-in torque is available. The comments given in the two previous paragraphs for squirrel cage motors also apply to the synchronous type.

Wound Rotor and Direct Current Motors

If the pump must be started with the discharge valve open, and the starting current must be kept to a minimum, a wound rotor induction motor should be used as this type of motor will develop full load torque without requiring excessive line current, or, if direct current is available, a motor of the direct current type will also develop full load torque without taking line current in excess of 125 per cent to 200 per cent of normal full load current.

Wearing Rings

Wearing rings are commonly fitted in the casing (casing wearing rings) and possibly on the impeller (impeller wearing rings). These wearing rings provide a close running, renewable clearance, to reduce the quantity of liquid leaking from the high pressure side to the suction side. These rings depend on the liquid in the pump for lubrication. They will eventually wear so that the clearance becomes greater and more liquid passes into the suction. This rate of wear depends on the character of the liquid pumped. Badly worn wearing rings will result in severe degradation of pump performance, particularly on small pumps.

Vibration in Centrifugal Pumping Machinery Installations

There are a number of factors which may cause vibration. Refer to "Radial Vibration of Centrifugal Pumps" on page 117.

Noise in Centrifugal Pumping Machinery Installations

Sound is energy and may be produced by movement within machinery. This is also true for centrifpumps. Sound is produced by liquid flowing n the pump casing, the bearings within the ping units, the couplings, and the unit drivers. all sound is objectionable. Sound which is ob- nable is defined as noise.

und may be transmitted in three manners:

-borne within the machinery room.
uid-borne by the liquid being pumped.
ucture-borne through the attached piping and support system.

nce sound is much more readily transmitted gh incompressible structures, structure-borne ds are generally most objectionable. Two of the important factors in minimizing sound in a installation are the correct selection of the type for the operating conditions and the ll installation. To insure minimum sound, the should be chosen for operation near the point st efficiency and proper suction conditions d be provided.

e prevention of noise is greatly dependent upon ump installation. Proper alignment of the pump driver is essential, as well as the support of the on and discharge piping. The manner in which pump is installed and in which the piping is sup- d may contribute to objectionable harmonics. ater degree of noise prevention may be obtained the pumping unit is supported free of building ures by the use of vibration isolators and flex- piping and conduit connectors. Noise emanat- from the motion of high velocity liquids within ping system, particularly from partly opened , should not mistakenly be attributed to the ing unit.

ATING TROUBLE

en investigating pump trouble at the job-site, effort must first be made to eliminate all out- influences. If the performance is suspect, the t use and accuracy of instruments should first ecked. In addition, note that pump performance bstantially affected by such fluid characteris- as temperature, specific gravity and viscosity.

Discharge

ck of discharge from a pump may be caused by of the following conditions:

Pump not primed
*Speed too low
System head too high
Suction lift higher than that for which pump is designed
Impeller completely plugged
Impeller installed backwards
Wrong direction of rotation
Air leak in the suction line
Air leak through stuffing box
Well draw-down below minumum submergence
Pump damaged during installation (wells)
Broken line shaft or coupling
Impeller(s) loose on shaft
Closed suction valve

Insufficient Discharge

Insufficient discharge from a pump may be caused by any of the following conditions:

Air leaks in suction or stuffing boxes
*Speed too low
System head higher than anticipated
Insufficient NPSHA:
- Suction lift too high. Check with gauges. Check also for clogged suction line or screen
- Not enough suction head for hot or volatile liquids
- Foot valve too small

Impeller partially plugged
Mechanical defects:
- Wearing rings worn
- Impeller damaged

Impeller(s) loose on shaft
Excessive lift on rotor element
Suction valve partially closed
Leaking joints (well application)
Foot valve of suction opening not submerged enough
Impeller installed backwards
Wrong direction rotation

Insufficient Pressure

Insufficient pressure from a pump may be caused by any of the following conditions:

*Speed too low
System head less than anticipated
Air or gas in liquid
Mechanical defects:
- Wearing rings worn
- Impeller damaged

Impeller diameter too small

Impeller installed backwards
Wrong direction of rotation
Excessive lift on rotor element
Leaking joints (well application)

Loss of Suction Following Period of Satisfactory Operation

Loss of suction under these conditions may be caused by any of the following conditions:

Leaky suction line
Waterseal plugged
Suction lift too high or insufficient NPSHA
Air or gas in liquid
Casing gasket defective
Clogging of strainer
Excessive well draw-down

Excessive Power Consumption

Excessive power consumption may be caused by any of the following conditions:

Speed too high
System head lower than rating, pumps too much liquid (radial and mixed flow pumps)
System head higher than rating, pumps too little liquid (axial flow pumps)
Specific gravity or viscosity of liquid pumped is too high
Mechanical defects:
- Shaft bent
- Rotating element binds
- Stuffing boxes too tight
- Wearing rings worn

Electrical or mechanical defect in submerged motor
Undersized submersible cable
Incorrect lubrication of driver
Lubricant in shaft enclosing tube too heavy (vertical turbine)

*When direct connected to electric motors, determine whether or not motor is across the line and receives full voltage. When direct connected to steam turbines, make sure that turbine receives full steam pressure.

APÉNDICE K

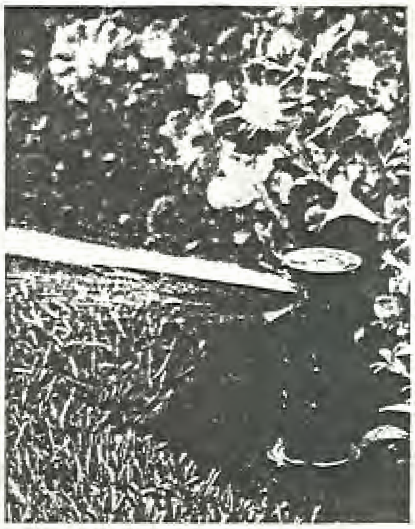
TABLAS DE RENDIMIENTO DE LOS ASPERSORES

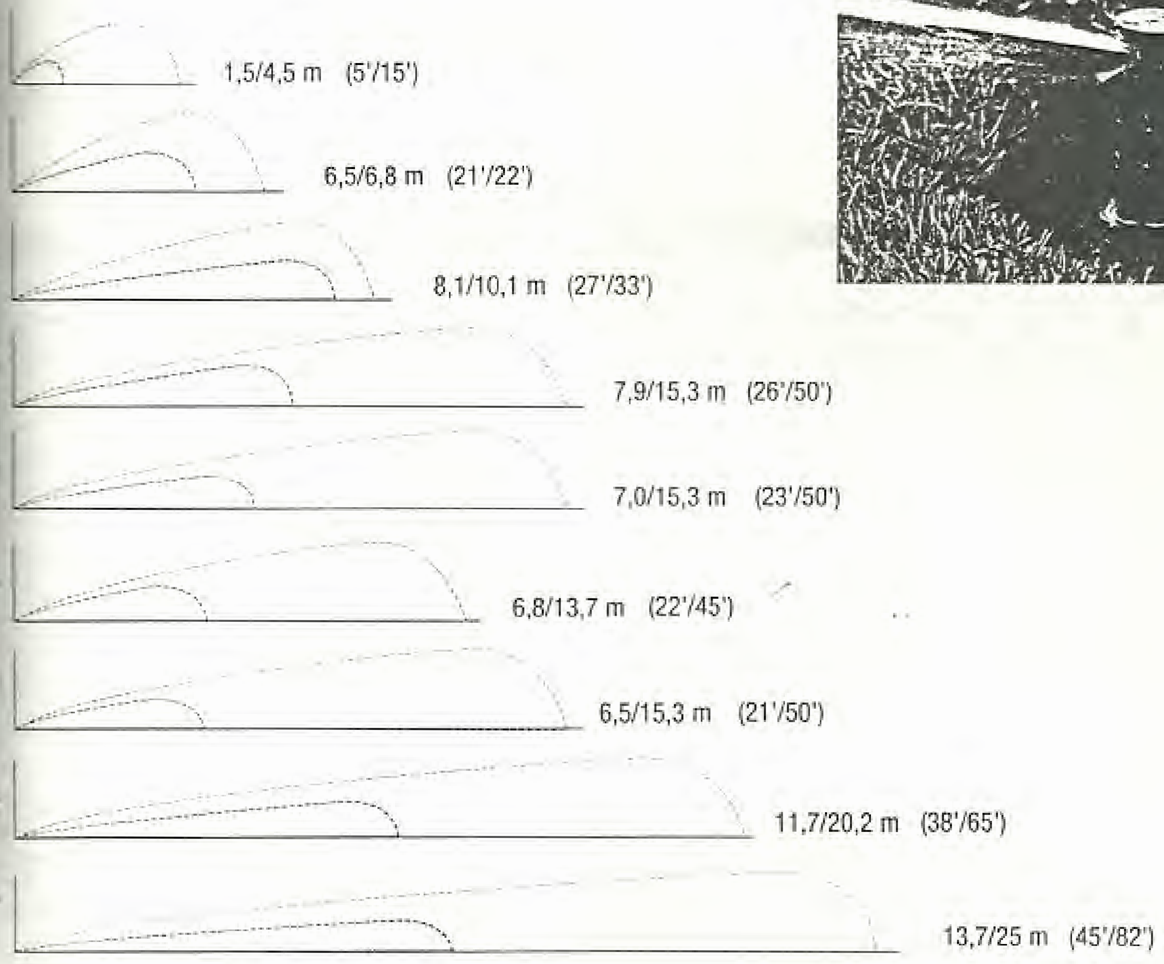
[…]ara Escolha de Aspersores Emergentes / *Guía de Selección de Aspersores Retráctiles*

[…]ersor é geralmente o primeiro critério da sua […]a seguinte permitirá uma rápida pré-seleção […] aspersores da Rain Bird. Ele indica para cada tipo […] são os alcances com velocidade de vento zero: […] o bocal menor e a pressão mínima […] com o bocal maior e a pressão máxima.

El criterio más importante para seleccionar un aspersor generalmente es el alcance. La tabla siguiente le ayudará a iniciar el proceso de selección de uno de los muchos modelos de aspersores de Rain Bird. En esta tabla se indica el alcance máximo de cada uno de los tipos de aspersores, en condiciones sin viento. Los datos presentados corresponden a las combinaciones siguientes:

- la boquilla más pequeña con la menor presión permitida
- la boquilla más grande con la mayor presión permitida





...R para Série 1800 e UNI-Spray™/ *Boquillas MPR para las Series 1800 y UNI-Spray™*

...rceptação do jato para
...cance
...nal à superfície a ser

...o por baixo do bocal,
...sível

...rviço: 1,0 a 2,1 bars
... 1,5 a 4,5 m

...hadores
...zado

...s distintos
...s distintos

Características

- *Tornillo de ajuste de caudal y alcance*
- *Tasas de precipitación equivalentes*
- *Filtro de fácil acceso, localizado debajo de la boquilla (filtro entregado con la boquilla)*

Especificaciones

- *Presión: 1 a 2 bars (15 a 30 psi)*
- *Espaciamiento: 1,5 a 4,5 m (5 a 15 pies)*

Modelos

- *Serie 5* **Nuevo**
- *Serie 5 - Burbujeadores*
- *Serie 8* **Mejorado**
- *Serie 10*
- *Serie 12*
- *Serie 15*
- *Serie 15 Strip*
- *Serie 16 - Salida de chorro*
- *Serie 22 - Salida de chorro*

Bocal MPR e filtro
Boquilla MPR y filtro

...5 MPR

	Vazão Fluxo (m³/h)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
	0,02	52	60
	0,05	47	55
	0,08	41	48
	0,09	40	45
	0,01	52	60
	0,02	47	55
	0,04	41	48
	0,05	40	46
	0,01	52	60
	0,02	47	55
	0,03	41	48
	0,03	40	46
	0,01	52	60
	0,01	47	55
	0,02	41	48
	0,02	40	46

SISTEMA NORTEAMERICANO

Bocal Boquilla	Pressão Presión (PSI)	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
5F	15	2	0.09	2.07	2.39
	20	3	0.19	2.01	2.32
	25	4	0.27	1.62	1.87
	30	5	0.41	1.58	1.83
5H	15	2	0.04	2.07	2.39
	20	3	0.09	2.01	2.32
	25	4	0.13	1.62	1.87
	30	5	0.20	1.58	1.83
5T	15	2	0.03	2.07	2.39
	20	3	0.06	2.01	2.32
	25	4	0.09	1.62	1.87
	30	5	0.13	1.58	1.83
5Q	15	2	0.02	2.07	2.39
	20	3	0.05	2.01	2.32
	25	4	0.07	1.62	1.87
	30	5	0.10	1.58	1.83

...MPR são testados em aspersores de 10 cm.
... baseado em 50% do diâmetro de alcance.
... baseado em 50% do diâmetro de alcance.
...testes em condições sem vento.
...corpos dos aspersores e os bocais separadamente. Refira-se à Lista de Preços para
...
...vel reduzir o alcance de um aspersor mais de 25%.

Série 8 MPR/*Serie 8 MPR*

SISTEMA MÉTRICO

Trajetória / *Trayectoria de 10°*

Bocal Boquilla	Pressão Presión (Bars)	Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
8F	1,0	1,5	0,12	0,03	52	60
	1,5	1,9	0,16	0,05	47	55
	2,0	2,3	0,22	0,06	41	48
	2,1	2,4	0,23	0,06	40	46
8H	1,0	1,5	0,06	0,02	52	60
	1,5	1,9	0,09	0,02	47	55
	2,0	2,3	0,11	0,03	41	48
	2,1	2,4	0,12	0,03	40	46
8T	1,0	1,5	0,04	0,01	52	60
	1,5	1,9	0,06	0,02	47	55
	2,0	2,3	0,07	0,02	41	48
	2,1	2,4	0,08	0,02	40	46
8Q	1,0	1,5	0,03	0,01	52	60
	1,5	1,9	0,04	0,01	47	55
	2,0	2,3	0,05	0,02	41	48
	2,1	2,4	0,06	0,02	40	46

SISTEMA NORTEAMERICANO

Bocal Boquilla	Pressão Presión (PSI)	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
8F	15	5	0.54	2.07	2.39
	20	6	0.75	2.01	2.32
	25	7	0.82	1.62	1.87
	30	8	1.05	1.58	1.83
8H	15	5	0.27	2.07	2.39
	20	6	0.38	2.01	2.32
	25	7	0.41	1.62	1.87
	30	8	0.52	1.58	1.83
8T	15	5	0.18	2.07	2.39
	20	6	0.25	2.01	2.32
	25	7	0.27	1.62	1.87
	30	8	0.35	1.58	1.83
8Q	15	5	0.13	2.07	2.39
	20	6	0.19	2.01	2.32
	25	7	0.21	1.62	1.87
	30	8	0.26	1.58	1.83

Nota: *Todos las boquillas MPR han sido probadas en los rociadores emergentes de 10 cm (4").*
■ *Espaciamiento cuadrado en base a un diámetro de alcance de 50%.*
▲ *Espaciamiento triangular en base a un diámetro de alcance de 50%.*
Datos del rendimiento obtenidos sin viento.
Nota: *Especifique los cuerpos de los aspersores y las boquillas separadamente. Verifique la Lista de Precios para quantidad de entrega.*
Nota: *No es recomendable reducir el alcance de la boquilla en más del 25%.*

... MPR/Serie 10 MPR

...TRICO | SISTEMA NORTEAMERICANO

...toria de 15°

Pressão Presión (Bars)	Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
[illegible]	2,1	0,26	0,07	58	67
[illegible]	2,4	0,29	0,08	50	58
[illegible]	3,0	0,35	0,10	39	45
[illegible]	3,1	0,36	0,10	37	43
[illegible]	2,1	0,13	0,04	58	67
[illegible]	2,4	0,14	0,04	50	58
[illegible]	3,0	0,18	0,05	39	45
[illegible]	3,1	0,18	0,05	37	43
[illegible]	2,1	0,09	0,03	58	67
[illegible]	2,4	0,10	0,03	50	58
[illegible]	3,0	0,12	0,03	39	45
[illegible]	3,1	0,12	0,03	37	43
[illegible]	2,1	0,06	0,02	58	67
[illegible]	2,4	0,07	0,02	50	58
[illegible]	3,0	0,09	0,03	39	45
[illegible]	3,1	0,09	0,03	37	43

Bocal Boquilla	Pressão Presión (PSI)	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
10F	15	7	1.16	2.28	2.63
	20	8	1.37	1.96	2.26
	25	9	1.44	1.71	1.98
	30	10	1.58	1.52	1.75
10H	15	7	0.58	2.28	2.63
	20	8	0.65	1.96	2.26
	25	9	0.72	1.71	1.98
	30	10	0.79	1.52	1.75
10T	15	7	0.39	2.28	2.63
	20	8	0.43	1.96	2.26
	25	9	0.48	1.71	1.98
	30	10	0.53	1.52	1.75
10Q	15	7	0.29	2.28	2.63
	20	8	0.33	1.96	2.26
	25	9	0.36	1.71	1.98
	30	10	0.39	1.52	1.75

... MPR/Serie 12 MPR

...TRICO | SISTEMA NORTEAMERICANO

...yectoria de 30°

Pressão Presión (Bars)	Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
1,0	2,7	0,40	0,11	55	63
1,5	3,2	0,48	0,14	47	54
2,0	3,6	0,59	0,16	46	53
2,1	3,7	0,60	0,16	44	51
1,0	2,7	0,30	0,09	55	63
1,5	3,2	0,36	0,10	47	54
2,0	3,6	0,45	0,12	46	53
2,1	3,7	0,45	0,12	44	51
1,0	2,7	0,26	0,08	55	63
1,5	3,2	0,32	0,09	47	54
2,0	3,6	0,40	0,11	46	53
2,1	3,7	0,40	0,11	44	51
1,0	2,7	0,20	0,06	55	63
1,5	3,2	0,24	0,07	47	54
2,0	3,6	0,30	0,08	46	53
2,1	3,7	0,30	0,08	44	51
1,0	2,7	0,13	0,04	55	63
1,5	3,2	0,16	0,05	47	54
2,0	3,6	0,20	0,05	46	53
2,1	3,7	0,20	0,05	44	51
1,0	2,7	0,10	0,03	55	63
1,5	3,2	0,12	0,03	47	54
2,0	3,6	0,15	0,04	46	53
2,1	3,7	0,15	0,04	44	51

Bocal Boquilla	Pressão Presión (PSI)	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
12F	15	9	1.80	2.14	2.47
	20	10	2.10	2.02	2.34
	25	11	2.40	1.91	2.21
	30	12	2.60	1.74	2.01
12TQ	15	9	1.35	2.14	2.47
	20	10	1.58	2.02	2.34
	25	11	1.80	1.91	2.21
	30	12	1.95	1.74	2.01
12TT	15	9	1.20	2.14	2.47
	20	10	1.40	2.02	2.34
	25	11	1.60	1.91	2.21
	30	12	1.74	1.74	2.01
12H	15	9	0.90	2.14	2.47
	20	10	1.05	2.02	2.34
	25	11	1.20	1.91	2.21
	30	12	1.30	1.74	2.01
12T	15	9	0.60	2.14	2.47
	20	10	0.70	2.02	2.34
	25	11	0.80	1.91	2.21
	30	12	0.87	1.74	2.01
12Q	15	9	0.45	2.14	2.47
	20	10	0.53	2.02	2.34
	25	11	0.60	1.91	2.21
	30	12	0.65	1.74	2.01

Todos os bocais MPR são testados em aspersores de 10 cm.
...ento quadricular baseado em 50% do diâmetro de alcance.
...ento triangular baseado em 50% do diâmetro de alcance.
...ados obtidos com testes em condições sem vento.
Especifique os corpos dos aspersores e os bocais separadamente. Refira-se à Lista de Preços para ...des de entrega.
Não é aconselhável reduzir o alcance de um aspersor mais de 25%.

Todas las boquillas MPR han sido probadas en los rociadores emergentes de 10 cm (4").
...miento cuadrado en base a un diámetro de alcance de 50%.
...miento triangular en base a un diámetro de alcance de 50%.
...del rendimiento obtenidos sin viento.
Especifique los cuerpos de los aspersores y las boquillas separadamente. Verifique la Lista de Precios ...cantidad de entrega.
No es recomendable reducir el alcance de la boquilla en más del 25%.

Série 15 MPR/Serie 15 MPR

SISTEMA MÉTRICO | SISTEMA NORTEAMERICANO

Trajetória / Trayectoria de 30°

Bocal Boquilla	Pressão Presión (Bars)	Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
15F	1,0	3,4	0,60	0,16	52	60
	1,5	3,9	0,72	0,19	47	55
	2,0	4,5	0,84	0,23	41	48
	2,1	4,6	0,84	0,23	40	46
15TQ	1,0	3,4	0,45	0,12	52	60
	1,5	3,9	0,54	0,15	47	55
	2,0	4,5	0,63	0,17	41	48
	2,1	4,6	0,63	0,16	40	46
15TT	1,0	3,4	0,40	0,11	52	60
	1,5	3,9	0,48	0,13	47	55
	2,0	4,5	0,55	0,15	41	48
	2,1	4,6	0,56	0,16	40	46
15H	1,0	3,4	0,30	0,08	52	60
	1,5	3,9	0,36	0,10	47	55
	2,0	4,5	0,42	0,11	41	48
	2,1	4,6	0,42	0,12	40	46
15T	1,0	3,4	0,20	0,05	52	60
	1,5	3,9	0,24	0,07	47	55
	2,0	4,5	0,28	0,08	41	48
	2,1	4,6	0,28	0,08	40	46
15Q	1,0	3,4	0,15	0,04	52	60
	1,5	3,9	0,18	0,05	47	55
	2,0	4,5	0,21	0,06	41	48
	2,1	4,6	0,21	0,06	40	46

Bocal Boquilla	Pressão Presión (PSI)	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
15F	15	11	2.60	2.07	2.39
	20	12	3.00	2.01	2.32
	25	14	3.30	1.62	1.87
	30	15	3.70	1.58	1.83
15TQ	15	11	1.95	2.07	2.39
	20	12	2.25	2.01	2.32
	25	14	2.48	1.62	1.87
	30	15	2.78	1.58	1.83
15TT	15	11	1.74	2.07	2.39
	20	12	2.01	2.01	2.32
	25	14	2.21	1.62	1.87
	30	15	2.48	1.58	1.83
15H	15	11	1.30	2.07	2.39
	20	12	1.50	2.01	2.32
	25	14	1.65	1.62	1.87
	30	15	1.85	1.58	1.83
15T	15	11	0.87	2.07	2.39
	20	12	1.00	2.01	2.32
	25	14	1.10	1.62	1.87
	30	15	1.23	1.58	1.83
15Q	15	11	0.65	2.07	2.39
	20	12	0.75	2.01	2.32
	25	14	0.82	1.62	1.87
	30	15	0.92	1.58	1.83

Série 15 - Strip/Serie 15 - Strip

SISTEMA MÉTRICO | SISTEMA NORTEAMERICANO

Trajetória / Trayectoria de 30°

Bocal Boquilla	Pressão Presión (Bars)	L x C A x L m	Vazão Flujo (m³/h)	Vazão Flujo (l/s)
15SQ	1,0	5,5 x 5,5	0.61	0.17
	1,5	5,8 x 5,8	0.69	0.19
	2,0	6,4 x 6,4	0.78	0.22
	2,1	7,0 x 7,0	0.85	0.23
15EST	1,0	1,2 x 4,0	0,10	0.03
	1,5	1,2 x 4,3	0,11	0.03
	2,0	1,2 x 4,3	0,13	0.04
	2,1	1,2 x 4,6	0,14	0.04
15CST	1,0	1,2 x 7,9	0.20	0.06
	1,5	1,2 x 8,5	0.23	0.06
	2,0	1,2 x 8,5	0.25	0.07
	2,1	1,2 x 9,2	0.27	0.08
15SST	1,0	1,2 x 7,9	0.20	0.06
	1,5	1,2 x 8,5	0.23	0.06
	2,0	1,2 x 8,5	0.25	0.07
	2,1	1,2 x 9,2	0.27	0.08
9SST	1,0	2,7 x 4,6	0.30	0.08
	1,5	2,7 x 4,9	0.33	0.09
	2,0	2,7 x 5,5	0.36	0.10
	2,1	2,7 x 5,5	0.39	0.11

Bocal Boquilla	Pressão Presión (Bars)	L x C A x L (pies)	Vazão Flujo (GPM)
15SQ	15	18 x 18	2.68
	20	19 x 19	3.06
	25	21 x 21	3.42
	30	23 x 23	3.73
15EST	15	4 x 13	0.45
	20	4 x 14	0.50
	25	4 x 14	0.56
	30	4 x 15	0.61
15CST	15	4 x 26	0.89
	20	4 x28	1.00
	25	4x 28	1.11
	30	4 x 30	1.21
15SST	15	4 x 26	0.89
	20	4 x 28	1.00
	25	4 x 28	1.11
	30	4 x 30	1.21
9SST	15	9 x 15	1.34
	20	9 x 16	1.47
	25	9 x 18	1.60
	30	9 x 18	1.73

L x C = largura x comprimento da cobertura
A x L *= ancho x largo de la cobertura*

*Espaçamento do bocal quadrado baseado em cobertura total de um aspersor a outro (head-to-head)
**Espaciamento de la boquilla cuadrada en base de alcance total de un rociador a otro (head-to-head)*

ie VAN / *Serie VAN*

de setor ajustável para Séries 1800 e UNI-Spray /
as con Arco de Cobertura Variable para Rociadores de las Series 1800 y UNI-Spray

ições

ocais são ideais para superfícies
res porque são ajustáveis com
o em qualquer ângulo.

teristicas

r facilmente ajustável:
AN/6-VAN/8-VAN: de 0° a 330°
VAN/12-VAN/15-VAN/18-VAN:
0° a 360°
de ajuste para aumentar ou reduzir
co do setor
ensa ferramentas
afuso interceptor de jato para
lagem de vazão e alcance
posicionado por baixo do bocal,
mente acessível, incluído no
ecimento do bocal

Técnicos

ão de serviço: 1,0 a 2,1 bars
çamento: 0,9 a 5,5 m
o de trajetória
N: 0°
N: 0°
N: 5°
N: 10°
N: 15°
N: 23°
N: 26°

Aplicaciones

- *Estas boquillas son ideales para el riego de zonas de forma irregular que tengan césped o arbustos, gracias al ajuste preciso del sector de cobertura.*

Características

- *Ajuste sencillo del arco de cobertura:*
  -4-VAN/6-VAN/8-VAN: 0° a 330°
  -10-VAN/12-VAN/15-VAN/18-VAN: 0° a 360°
- *Anillo de control para aumentar o disminuir el arco de cobertura*
- *No se necesitan herramientas*
- *ornillo de ajuste de caudal y alcance*
- *Filtro de fácil acceso, localizado debajo de la boquilla (el filtro se entrega con la boquilla)*

Especificaciones

- *Presión: 1,0 a 2,1 bars (15 to 30 psi)*
- *Alcance: 0,9 a 5,5 m (3 a 18 pies)*
- *Ángulo de trayectoria:*
  4-VAN: 0°
  6-VAN: 0°
  8-VAN: 5°
  10-VAN: 10°
  12-VAN: 15°
  15-VAN: 23°
  18-VAN: 26°

Modelos

- *4-VAN*
- *6-VAN*
- *8-VAN*
- *10-VAN*
- *12-VAN*
- *15-VAN*
- *18-VAN* Novo/Nuevo

AN/Série 4 VAN

TRICO

ectoria de 0°

Pressão Presión (Bars)	Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
0	0,9	0,14	0,04	189	218
5	1,0	0,17	0,05	183	215
0	1,2	0,20	0,06	152	176
1	1,2	0,20	0,06	152	176
0	0,9	0,12	0,03	198	229
5	1,0	0,14	0,04	187	216
0	1,2	0,16	0,04	148	171
1	1,2	0,17	0,05	157	181
0	0,9	0,07	0,02	173	200
5	1,0	0,09	0,03	180	208
0	1,2	0,10	0,03	139	161
21	1,2	0,10	0,03	139	161
0	0,9	0,05	0,01	247	285
5	1,0	0,06	0,02	240	277
0	1,2	0,06	0,02	167	193
1	1,2	0,07	0,02	194	224

SISTEMA NORTEAMERICANO

Bocal Boquilla	Pressão Presión (PSI)	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pul./h)	▲ Pluvio. Precip. (pul./h)
330° Arco	15	3	0.62	7.23	8.35
	20	3	0.70	8.17	9.43
	25	4	0.80	5.25	6.06
	30	4	0.88	5.78	6.67
270° Arco	15	3	0.52	7.42	8.57
	20	3	0.58	8.27	9.55
	25	4	0.66	5.29	6.11
	30	4	0.73	5.86	6.77
180° Arco	15	3	0.32	6.84	7.90
	20	3	0.37	7.91	9.13
	25	4	0.41	4.93	5.69
	30	4	0.45	5.41	6.25
90° Arco	15	3	0.21	8.98	10.37
	20	3	0.24	10.27	11.86
	25	4	0.26	6.26	7.23
	30	4	0.29	6.98	8.06

lo quadricular baseado em 50% do diâmetro de alcance.
ento triangular baseado em 50% do diâmetro de alcance.
obtidos com testes em condições sem vento.
ecifique os corpos dos asperores e os bocais separadamente. Refira-se à Lista de Preços para
s de entrega.
é aconselhável reduzir o alcance de um aspersor mais de 25%.
caso do setor não estar aberto no limite, utilize o parafuso de redução de alcance para conseguir as
es e alcances indicados nas tabelas acima.

Série 6 VAN/Serie 6 VAN

SISTEMA MÉTRICO

Trajetória / *Trayectoria de 0°*

Bocal Boquilla	Pressão Presión (Bars)	Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
330° Arco	1,0	1,2	0,19	0,05	144	166
	1,5	1,5	0,23	0,06	112	129
	2,0	1,8	0,27	0,08	91	105
	2,1	1,8	0,27	0,08	91	105
270° Arco	1,0	1,2	0,18	0,05	167	193
	1,5	1,5	0,21	0,06	124	143
	2,0	1,8	0,24	0,07	99	114
	2,1	1,8	0,25	0,07	103	119
180° Arco	1,0	1,2	0,10	0,03	139	161
	1,5	1,5	0,11	0,03	98	113
	2,0	1,8	0,13	0,04	80	92
	2,1	1,8	0,14	0,04	86	99
90° Arco	1,0	1,2	0,06	0,025	167	193
	1,5	1,5	0,07	0,02	124	143
	2,0	1,8	0,08	0,02	99	114
	2,1	1,8	0,08	0,02	99	114

SISTEMA NORTEAMERICANO

Bocal Boquilla	Pressão Presión (PSI)	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pul./h)	▲ Pluvio. Precip. (pul./h)
330° Arco	15	4	0.85	5.58	6.44
	20	5	0.96	4.03	4.65
	25	5	1.09	4.58	5.29
	30	6	1.20	3.50	4.04
270° Arco	15	4	0.79	6.34	7.32
	20	5	0.88	4.52	5.22
	25	5	1.00	5.13	5.92
	30	6	1.10	3.92	4.53
180° Arco	15	4	0.42	5.05	5.83
	20	5	0.49	3.77	4.35
	25	5	0.55	4.24	4.90
	30	6	0.60	3.21	3.71
90° Arco	15	4	0.26	6.26	7.23
	20	5	0.30	4.62	5.33
	25	5	0.34	5.24	6.05
	30	6	0.37	3.96	4.57

■ *Espaciamiento cuadrado en base a un diámetro de alcance de 50%.*
▲ *Espaciamiento triangular en base a un diámetro de alcance de 50%.*
Datos del rendimiento obtenidos sin viento.
***Nota:** Especifique los cuerpos de los aspersores y las boquillas separadamente. Verifique la Lista de Precios para quantidad de entrega.*
***Nota:** No es recomendable reducir el alcance de la boquilla en más del 25%.*
***Nota:** En caso que el arco de cobertura no esté regulado en el máximo, posiblemente sea necesario utilizar el tornillo de reducción de alcance para obtener el caudal y el alcance indicados en las tablas.*

… VAN

SISTEMA NORTEAMERICANO

Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
…27	0,08	91	105
[illegible]	0,09	79	91
…30	0,11	78	90
…39	0,11	74	85
…25	0,07	103	119
…30	0,08	91	105
…34	0,09	86	99
…35	0,10	81	94
…19	0,05	117	135
…23	0,06	104	120
…26	0,07	98	113
…27	0,08	94	109
…12	0,03	148	171
…14	0,04	127	147
…16	0,04	121	140
…16	0,04	111	128

Bocal Boquilla	Pressão Presión (PSI)	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
330° Arco	15	6	1.21	3.53	4.07
	20	7	1.36	2.91	3.36
	25	7	1.55	3.32	3.83
	30	8	1.70	2.79	3.22
270° Arco	15	6	1.11	3.95	4.55
	20	7	1.24	3.24	3.74
	25	7	1.41	3.69	4.25
	30	8	1.55	3.10	3.58
180° Arco	15	6	0.84	4.49	5.18
	20	7	0.97	3.81	4.40
	25	7	1.09	4.28	4.94
	30	8	1.19	3.58	4.13
90° Arco	15	6	0.51	5.46	6.29
	20	7	0.59	4.64	5.35
	25	7	0.66	5.19	5.98
	30	8	0.72	4.33	5.00

Série 10 VAN/*Serie 10 VAN*

SISTEMA MÉTRICO

Trajetória / *Trayectoria de 10°*

Bocal Boquilla	Pressão Presión (Bars)	Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
360° Arco	1,0	2,1	0.44	0.12	96	111
	1,5	2,4	0.53	0.15	89	103
	2,0	2,7	0.57	0.16	76	88
	2,1	3,1	0.59	0.16	63	73
270° Arco	1,0	2,1	0.33	0.09	96	111
	1,5	2,4	0.40	0.11	89	103
	2,0	2,7	0.43	0.12	76	89
	2,1	3,1	0.48	0.13	68	79
180° Arco	1,0	2,1	0.22	0.06	97	112
	1,5	2,4	0.27	0.08	92	106
	2,0	2,7	0.29	0.08	76	88
	2,1	3,1	0.33	0.09	71	82
90° Arco	1,0	2,1	0.11	0.03	96	110
	1,5	2,4	0.13	0.04	89	103
	2,0	2,7	0.14	0.04	76	88
	2,1	3,1	0.17	0.05	73	85

SISTEMA NORTEAMERICANO

Bocal Boquilla	Pressão Presión (PSI)	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
360° Arco	15	7	1.93	3.80	4.39
	20	8	2.32	3.50	4.04
	25	9	2.52	3.00	3.46
	30	10	2.60	2.50	2.89
270° Arco	15	7	1.45	3.80	4.39
	20	8	1.75	3.50	4.04
	25	9	1.89	3.00	3.46
	30	10	2.10	2.70	3.12
180° Arco	15	7	0.97	3.80	4.39
	20	8	1.20	3.50	4.04
	25	9	1.26	3.00	3.46
	30	10	1.45	2.80	3.23
90° Arco	15	7	0.48	3.80	4.39
	20	8	0.58	3.50	4.04
	25	9	0.63	3.00	3.46
	30	10	0.75	2.90	3.35

… 12 VAN

SISTEMA NORTEAMERICANO

…15°

Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
0,40	0,11	55	63
0,48	0,14	47	54
0,59	0,16	46	53
0,60	0,16	44	51
0,30	0,09	55	63
0,36	0,10	47	54
0,45	0,12	46	53
0,45	0,12	44	51
0,20	0,06	55	63
0,24	0,07	47	54
0,30	0,08	46	53
0,30	0,08	44	51
0,10	0,03	55	63
0,12	0,03	47	54
0,15	0,04	46	53
0,15	0,04	44	51

Bocal Boquilla	Pressão Presión (PSI)	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
360° Arco	15	9	1.80	2.14	2.47
	20	10	2.10	2.02	2.34
	25	11	2.40	1.91	2.21
	30	12	2.60	1.74	2.01
270° Arco	15	9	1.35	2.14	2.47
	20	10	1.58	2.02	2.34
	25	11	1.80	1.91	2.21
	30	12	1.95	1.74	2.01
180° Arco	15	9	0.90	2.14	2.47
	20	10	1.05	2.02	2.34
	25	11	1.20	1.91	2.21
	30	12	1.30	1.74	2.01
90° Arco	15	9	0.45	2.14	2.47
	20	10	0.53	2.02	2.34
	25	11	0.60	1.91	2.21
	30	12	0.65	1.74	2.01

Série 15 VAN/*Serie 15 VAN*

SISTEMA MÉTRICO

Trajetória / *Trayectoria de 23°*

Bocal Boquilla	Pressão Presión (Bars)	Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
360° Arco	1,0	3,4	0,60	0,16	52	60
	1,5	3,9	0,72	0,19	47	55
	2,0	4,5	0,84	0,23	41	48
	2,1	4,6	0,84	0,23	40	46
270° Arco	1,0	3,4	0,45	0,12	52	60
	1,5	3,9	0,54	0,15	47	55
	2,0	4,5	0,63	0,17	41	48
	2,1	4,6	0,63	0,18	40	46
180° Arco	1,0	3,4	0,30	0,08	52	60
	1,5	3,9	0,36	0,10	47	55
	2,0	4,5	0,42	0,11	41	48
	2,1	4,6	0,42	0,12	40	46
90° Arco	1,0	3,4	0,15	0,04	52	60
	1,5	3,9	0,18	0,05	47	55
	2,0	4,5	0,21	0,06	41	48
	2,1	4,6	0,21	0,06	40	46

SISTEMA NORTEAMERICANO

Bocal Boquilla	Pressão Presión (PSI)	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
360° Arco	15	11	2.60	2.07	2.39
	20	12	3.00	2.01	2.32
	25	14	3.30	1.62	1.87
	30	15	3.70	1.58	1.83
270° Arco	15	11	1.95	2.07	2.39
	20	12	2.25	2.01	2.32
	25	14	2.48	1.62	1.87
	30	15	2.78	1.58	1.83
180° Arco	15	11	1.30	2.07	2.39
	20	12	1.50	2.01	2.32
	25	14	1.65	1.62	1.87
	30	15	1.85	1.58	1.83
90° Arco	15	11	0.65	2.07	2.39
	20	12	0.75	2.01	2.32
	25	14	0.82	1.62	1.87
	30	15	0.92	1.58	1.83

■ Espaçamento quadricular baseado em 50% do diâmetro de alcance.

▲ Espaçamento triangular baseado em 50% do diâmetro de alcance.

Resultados obtidos com testes em condições sem vento.

Nota: Especifique os corpos dos asperores e os bocais separadamente. Refira-se à Lista de Preços para quantidades de entrega.

Nota: Não é aconselhável reduzir o alcance de um aspersor mais de 25%.

Nota: Em caso do setor não estar aberto no limite, utilize o parafuso de redução de alcance para conseguir as vazões e alcances indicados nas tabelas acima.

■ *Espaciamento cuadrado en base a un diámetro de alcance de 50%.*

▲ *Espaciamento triangular en base a un diámetro de alcance de 50%.*

Datos del rendimiento obtenidos sin viento.

***Nota:** Especifique los cuerpos de los aspersores y las boquillas separadamente. Verifique la Lista de Precios para quantidad de entrega.*

***Nota:** No es recomendable reducir el alcance de la boquilla en más del 25%.*

***Nota:** En caso que el arco de cobertura no esté regulado en el máximo, posiblemente sea necesario utilizar el tornillo de reducción de alcance para obtener el caudal y el alcance indicados en las tablas.*

… 18 VAN

SISTEMA NORTEAMERICANO

…23°

Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
0,96	0,27	52	60
1,07	0,30	47	55
1,20	0,33	41	48
1,21	0,34	40	46
0,72	0,20	52	60
0,80	0,22	47	55
0,90	0,25	41	48
0,91	0,25	40	46
0,48	0,13	52	60
0,54	0,15	47	55
0,60	0,17	41	48
0,61	0,17	40	46
0,24	0,07	52	60
0,27	0,08	47	55
0,30	0,08	41	48
0,30	0,08	40	46

Bocal Boquilla	Pressão Presión (PSI)	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
360° Arco	15	14	4.21	2.07	2.39
	20	15	4.70	2.01	2.32
	25	17	4.86	1.62	1.87
	30	18	5.32	1.58	1.83
270° Arco	15	14	3.16	2.07	2.39
	20	15	3.52	2.01	2.32
	25	17	3.65	1.62	1.87
	30	18	3.99	1.58	1.83
180° Arco	15	14	2.11	2.07	2.39
	20	15	2.35	2.01	2.32
	25	17	2.43	1.62	1.87
	30	18	2.66	1.58	1.83
90° Arco	15	14	1.05	2.07	2.39
	20	15	1.17	2.01	2.32
	25	17	1.22	1.62	1.87
	30	18	1.33	1.58	1.83

...rie T-Bird™ / *Serie T-Bird™*

...rsores do tipo rotor / *Rotores*

...cações

...s aspersores com alcance de 5 a 15 m ...apropriados para instalações de ...ção em jardins e espaços verdes de ...nho médio.

...cterísticas

- ...cance de 5 a 15 m
- ...ura de elevação: 3 modelos com 10, ...5 e 30 cm respectivamente
- ...cais com diâmetro identificáveis pela ...a cor
- ...ande variedade de bocais: Bocais ...mpensadores de pressão T-22 e T-30, ...ocais T-40 Rain Curtain e Radius+
- ...nta de limpeza e de vedação
- ...ecanismo da turbina lubrificado a água
- ...bo de elevação desmontável
- ...ola de retração forte, em aço inóx
- ...rafuso interceptor de jato em aço inóx
- ...nel anti-vandalismo
- ...rafuso de fixação do bocal anti-...ndalismo
- ...odelo completo ou de setor
- ...ocais disponíveis com trajetória de jato ...5° e jato baixo de 15°
- ...ácil ajuste do ângulo, sem ferramentas
- ...egunda entrada lateral nos modelos ...-6 e T-12 (¾")
- ...inco anos de garantia

...dos Técnicos

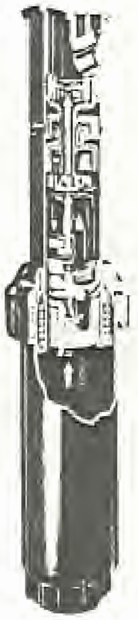
- ...lcance: de 5 a 15 m
- ...ressão de serviço: 1,7 a 4,5 bars
- ...azão: 0,11 a 2,07 m³/h
- ...rajetória do jato: Bocais T-30 e T-40: bocal padrão 25°
- ...ocais T-22: Bocais de angulo baixo 15°
- ...etorial: de 30° a 350° para os modelos T-4 PC, T-6 PC e T-12 PC
- ...ntrada: ¾" rosca fêmea

...mensões

- ...ltura do corpo
  T-4: 18 cm (7")
  T-6: 23,5 cm (9")
  T-12: 42 cm (16½")
  T-S: 18 cm (7")
- Diâmetro visível: 4,5 cm (1¾")

Modelos

- T-4 PC: Setorial - Elevação 10 cm
- T-4 FC: Circulo completo - Elevação 10 cm
- T-6 PC: Setorial, 15 cm de elevação
- T-6 FC: Circulo completo de 15 cm de elevação
- T-12 PC: Setorial - Elevação 30 cm
- T-12 FC: Circulo completo - Elevação 30 cm
- T-S PC: Setorial - modelo para arbustos
- T-S FC: Circulo completo - modelo para arbustos



Aplicaciones

Aspersores con alcance de 5 a 15 metros, concebidos para áreas de césped medianas, tales como instalaciones residenciales de riego automático.

Características

- *Alcance de 5 a 15 metros (16 a 50 pies)*
- *Tres alturas de elevación: 10 cm, 15 cm y 30 cm (4", 6" y 12")*
- *Boquillas codificadas por colores*
- *Amplia gama de boquillas: T-22 y T-30 con compensación de presión; T-40 con Rain Curtain o Radius+*
- *Junta limpiadora multifuncional*
- *Mecanismo de turbina lubricado por agua*
- *Aspersor con sistema de embrague*
- *Muelle de retracción de acero inoxidable*
- *Tornillo de ajuste de alcance, de acero inoxidable*
- *Collar antivandálico*
- *Tornillo de sujeción antivandálico para las boquillas*
- *2 modelos: círculo completo y sectorial*
- *Boquillas disponibles con ángulo de trayectoria estándar de 25° o ángulo bajo de 15°*
- *Fácil ajuste del arco de cobertura sin necesidad de herramientas*
- *Entrada lateral de 3/4" en los modelos T-6 y T-12*
- *Modelo T-S para arbustos*
- *5 años de garantía*

Especificaciones

- *Alcance: 5 a 15 metros (16 a 50 pies)*
- *Presión operativa: 1,7 a 4,5 bars (25-65 psi)*
- *Caudal: 0,11 a 2,07 m³/h (0.49 a 9.1 GPM)*
- *Ángulo de trayectoria: Ángulo estándar: 25° (boquillas T-30 y T-40)*
  Ángulo bajo: 15° (boquilla T-22)
- *Ajuste de cobertura de 30° a 350° en los modelos T-4 PC, T-6 PC y T-12 PC*
- *Entrada roscada hembra de ¾"*

Dimensiones

- *Altura de cuerpo: T-4: 18 cm (7"); T-6: 23,5 cm (9"); T-12: 42 cm (16½"); T-S: 18 cm (7")*
- *Diámetro expuesto: 4,5 cm (1¾")*

Modelos

- *T-4 PC: sectorial, altura extendida de 10 cm*
- *T-4 FC: círculo completo, altura extendida de 10 cm*
- *T-6 PC: sectorial, altura extendida de 15 cm*
- *T-6 FC: círculo completo, altura extendida de 15 cm*
- *T-12 PC: sectorial, altura extendida de 30 cm*
- *T-12 FC: círculo completo, altura extendid... de 30 cm*
- *T-S FC: círculo completo, modelo para arbustos*
- *T-S PC: sectorial, modelo para arbustos*

... / Boquillas T-22

		Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
		6,4	0,14	0,04	7	8
		6,4	0,20	0,06	10	11
		6,4	0,27	0,08	13	15
		6,4	0,43	0,12	21	24
		6,4	0,54	0,15	26	30
		5,8	0,77	0,21	46	53
		6,5	0,14	0,04	7	8
		6,5	0,21	0,06	10	11
		6,5	0,28	0,06	13	15
		6,5	0,43	0,12	20	24
		6,5	0,56	0,15	27	31
		6,2	0,81	0,22	42	49
		6,5	0,15	0,04	7	8
		6,6	0,22	0,06	10	12
		6,6	0,29	0,08	13	15
		6,6	0,42	0,12	19	22
		6,6	0,57	0,16	26	30
		6,4	0,82	0,23	40	46
		6,7	0,15	0,04	7	8
		6,7	0,22	0,06	10	11
		6,7	0,30	0,08	13	15
		6,7	0,42	0,12	19	22
		6,7	0,59	0,16	26	30
		6,6	0,83	0,23	38	44
		6,7	0,15	0,04	7	8
		6,7	0,23	0,06	10	12
		6,7	0,30	0,09	13	15
		6,7	0,41	0,11	18	21
		6,7	0,61	0,17	27	31
		6,8	0,84	0,23	36	42
		6,7	0,15	0,04	7	8
		6,7	0,23	0,06	10	12
		6,7	0,31	0,09	14	16
		6,7	0,41	0,11	18	21
		6,7	0,61	0,17	27	31
		6,7	0,82	0,23	37	42

SISTEMA NORTEAMERICANO

Pressão Presión (PSI)		Bocal Boquilla	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pul./h)	▲ Pluvio. Precip. (pul./h)
25	●	T22-0.65	21	0.53	0.28	0.32
	●	T22-1.0	21	0.90	0.39	0.45
	●	T22-1.3	21	1.20	0.52	0.61
	●	T22-2.0	21	1.90	0.83	0.96
	●	T22-2.5	21	2.40	1.05	1.21
	▲	T22-4.0	19	3.40	1.81	2.09
35	●	T22-0.65	22	0.65	0.26	0.30
	●	T22-1.0	22	1.00	0.40	0.46
	●	T22-1,3	22	1.30	0.52	0.60
	●	T22-2.0	22	1.90	0.76	0.87
	●	T22-2.5	22	2.50	0.99	1.15
	▲	T22-4.0	22	3.80	1.51	1.75
45	●	T22-0.65	22	0.65	0.26	0.30
	●	T22-1,0	22	1.00	0.40	0.46
	●	T22-1.3	22	1.32	0.53	0.61
	●	T22-2.0	22	1.80	0.72	0.83
	●	T22-2.5	22	2.65	1.05	1.22
	▲	T22-4.0	22	3.70	1.47	1.70
55	●	T22-0.65	22	0.67	0.27	0.31
	●	T22-1.0	22	1.00	0.40	0.46
	●	T22-1.3	22	1.35	0.54	0.62
	●	T22-2.0	22	1.80	0.72	0.83
	●	T22-2.5	22	2.70	1.07	1.24
	▲	T22-4.0	22	3.60	1.43	1.65

Bocais T-30 / Boquillas T-30

SISTEMA METRICO

Pressão Presión (Bars)		Bocal Boquilla	Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
1,7	●	T30-1,0	8,2	0,20	0,06	6	7
	●	T30-1,3	8,5	0,27	0,08	7	9
	●	T30-2,0	8,8	0,38	0,11	10	11
	●	T30-2,5	8,8	0,50	0,14	13	15
	▲	T30-4,0	8,8	0,63	0,17	16	19
	●	T30-5,0	9,5	0,95	0,26	21	24
2,0	●	T30-1,0	8,2	0,21	0,06	6	7
	●	T30-1,3	8,6	0,28	0,08	7	8
	●	T30-2,0	9,0	0,41	0,11	10	12
	●	T30-2,5	9,0	0,54	0,15	13	15
	▲	T30-4,0	9,0	0,68	0,19	17	19
	●	T30-5,0	9,7	1,03	0,29	22	25
2,5	●	T30-1,0	8,2	0,22	0,06	7	8
	●	T30-1,3	8,9	0,29	0,08	7	8
	●	T30-2,0	9,1	0,42	0,12	10	12
	●	T30-2,5	9,1	0,58	0,16	14	16
	▲	T30-4,0	9,3	0,75	0,21	17	20
	●	T30-5,0	9,8	1,12	0,31	23	27
3,0	●	T30-1,0	8,2	0,22	0,06	7	8
	●	T30-1,3	9,1	0,30	0,08	7	8
	●	T30-2,0	9,3	0,43	0,12	10	11
	●	T30-2,5	9,3	0,63	0,17	15	17
	▲	T30-4,0	9,5	0,82	0,23	18	21
	●	T30-5,0	10,0	1,21	0,33	24	28
3,5	●	T30-1,0	8,2	0,23	0,06	7	8
	●	T30-1,3	9,2	0,31	0,09	7	8
	●	T30-2,0	9,5	0,44	0,12	10	11
	●	T30-2,5	9,5	0,67	0,19	15	17
	▲	T30-4,0	9,7	0,89	0,25	19	22
	●	T30-5,0	10,1	1,29	0,36	25	29
3,8	●	T30-1,0	8,2	0,23	0,06	7	8
	●	T30-1,3	9.2	0,34	0,09	8	9
	●	T30-2,0	9,5	0,42	0,12	9	11
	●	T30-2,5	9,5	0,68	0,19	15	17
	▲	T30-4,0	9,8	0,91	0,25	19	22
	●	T30-5,0	10,1	1,32	0,37	25	30

SISTEMA NORTEAMERICANO

Pressão Presión (PSI)		Bocal Boquilla	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pul./h)	▲ Pluvio. Precip. (pul./h)
25	●	T30-1.0	27	0.95	0.24	0.27
	●	T30-1.3	28	1.20	0.29	0.34
	●	T30-2.0	29	1.68	0.38	0.44
	●	T30-2.5	29	2.20	0.50	0.58
	▲	T30-4.0	29	2.77	0.63	0.73
	●	T30-5.0	31	4.20	0.84	0.97
35	●	T30-1.0	27	1.00	0.26	0.31
	●	T30-1.3	30	1.30	0.28	0.32
	●	T30-2.0	30	1.99	0.43	0.49
	●	T30-2.5	30	2.60	0.56	0.64
	▲	T30-4.0	30	3.31	0.71	0.82
	●	T30-5.0	33	5.00	0.88	1.02
45	●	T30-1.0	27	1.00	0.26	0.31
	●	T30-1.3	30	1.40	0.30	0.35
	●	T30-2.0	31	2.00	0.40	0.46
	●	T30-2.5	31	2.90	0.58	0.67
	▲	T30-4.0	32	3.75	0.71	0.81
	●	T30-5.0	33	5.50	0.97	1.12
55	●	T30-1.0	27	1.00	0.26	0.31
	●	T30-1.3	30	1.50	0.32	0.37
	●	T30-2.0	31	1.85	0.37	0.43
	●	T30-2.5	31	3.00	0.60	0.69
	▲	T30-4.0	32	4.02	0.76	0.87
	●	T30-5.0	33	5.80	1.03	1.18

... baseada com o aspersor operando em meio-círculo
... baseado em 50% do diâmetro de alcance
... baseado em 50% do diâmetro de alcance.
... testes em condições sem vento

... ación basada en cobertura de semicírculo
... en base a un diámetro de alcance de 50%
... en base a un diámetro de alcance de 50%
... obtenidos sin viento

Bocais T-22
Boquillas T-22

Bocais T-30
Boquillas T-30

RAIN BIRD

T-40 com Rain Curtain / *T-40 con Rain Curtain*

SISTEMA MÉTRICO

Pressão Presión (Bars)	Bocal Boquilla	Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
	T40-1,0	7,9	0,20	0,06	6	7
	T40-1,5	8,5	0,36	0,10	10	12
	T40-2,0	9,8	0,43	0,12	9	10
	T40-3,0	10,4	0,64	0,18	12	14
	T40-4,0	10,7	0,86	0,24	15	17
	T40-6,0	10,7	1,16	0,32	20	23
	T40-1,0	8,0	0,22	0,06	7	8
	T40-1,5	8,9	0,39	0,11	10	11
	T40-2,0	9,9	0,46	0,13	9	11
	T40-3,0	10,6	0,69	0,19	12	14
	T40-4,0	11,0	0,93	0,26	15	18
	T40-6,0	11,0	1,27	0,35	21	24
	T40-1,0	8,1	0,25	0,07	8	9
	T40-1,5	9,0	0,44	0,12	11	13
	T40-2,0	10,1	0,51	0,14	10	12
	T40-3,0	10,7	0,76	0,21	13	15
	T40-4,0	11,3	1,03	0,29	16	19
	T40-6,0	11,4	1,41	0,39	22	25
	T40-1,0	8,3	0,27	0,08	8	9
	T40-1,5	9,2	0,48	0,13	11	13
	T40-2,0	10,2	0,57	0,16	11	13
	T40-3,0	10,8	0,83	0,23	14	16
	T40-4,0	11,6	1,14	0,32	17	20
	T40-6,0	11,8	1,55	0,43	22	25
	T40-1,0	8,4	0,30	0,08	9	10
	T40-1,5	9,3	0,53	0,15	12	14
	T40-2,0	10,3	0,62	0,17	12	13
	T40-3,0	10,9	0,89	0,25	15	17
	T40-4,0	11,9	1,24	0,34	18	20
	T40-6,0	12,3	1,70	0,47	22	26
	T40-1,0	8,5	0,33	0,09	9	11
	T40-1,5	9,5	0,57	0,16	13	15
	T40-2,0	10,4	0,68	0,19	13	15
	T40-3,0	11,0	0,97	0,27	16	19
	T40-4,0	12,2	1,35	0,37	18	21
	T40-6,0	12,8	1,87	0,52	23	26
	T40-1,0	8,5	0,34	0,09	9	11
	T40-1,5	9,5	0,61	0,17	14	16
	T40-2,0	10,4	0,70	0,20	13	15
	T40-3,0	11,0	1,02	0,28	17	19
	T40-4,0	12,2	1,43	0,40	19	22
	T40-6,0	12,8	1,95	0,54	24	27

SISTEMA NORTEAMERICANO

Pressão Presión (PSI)	Bocal Boquilla	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
25	T40-1.0	26	0.90	0.26	0.30
	T40-1.5	28	1.60	0.39	0.45
	T40-2.0	32	1.90	0.36	0.41
	T40-3.0	34	2.80	0.47	0.54
	T40-4.0	35	3.00	0.60	0.69
	T40-6.0	35	5.10	0.80	0.93
35	T40-1.0	26	1.10	0.31	0.36
	T40-1.5	30	1.90	0.41	0.47
	T40-2.0	33	2.20	0.39	0.45
	T40-3.0	35	3.30	0.52	0.60
	T40-4.0	37	4.50	0.63	0.73
	T40-6.0	37	6.20	0.87	1.01
45	T40-1.0	27	1.20	0.32	0.37
	T40-1.5	31	2.20	0.44	0.51
	T40-2.0	34	2.60	0.43	0.50
	T40-3.0	36	3.90	0.56	0.65
	T40-4.0	39	5.20	0.66	0.76
	T40-6.0	40	7.10	0.85	0.99
55	T40-1.0	27	1.40	0.37	0.43
	T40-1.5	31	2.40	0.48	0.56
	T40-2.0	34	2.90	0.48	0.56
	T40-3.0	36	4.10	0.61	0.70
	T40-4.0	40	5.70	0.69	0.79
	T40-6.0	42	7.90	0.86	1.00
65	T40-1.0	26	1.50	0.43	0.49
	T40-1.5	31	2.70	0.54	0.62
	T40-2.0	34	3.10	0.52	0.60
	T40-3.0	36	4.50	0.67	0.77
	T40-4.0	40	6.30	0.76	0.88
	T40-6.0	42	8.60	0.94	1.08

T-40 com Radius+ / *T-40 con Radius+*

SISTEMA MÉTRICO

Pressão Presión (Bars)	Bocal Boquilla	Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
1,7	T40-1,5	8,8	0,34	0,09	9	10
	T40-2,0	11,0	0,50	0,14	8	10
	T40-3,0	11,0	0,73	0,20	12	14
	T40-4,0	11,3	0,93	0,26	15	17
	T40-6,0	11,3	1,23	0,34	19	22
2,0	T40-1,5	9,7	0,37	0,10	8	9
	T40-2,0	11,3	0,53	0,15	8	10
	T40-3,0	11,7	0,80	0,22	12	13
	T40-4,0	12,2	1,01	0,28	14	16
	T40-6,0	12,2	1,36	0,38	18	21
2,5	T40-1,5	10,0	0,41	0,11	8	9
	T40-2,0	11,6	0,58	0,16	9	10
	T40-3,0	12,0	0,89	0,25	12	14
	T40-4,0	12,7	1,13	0,31	14	16
	T40-6,0	12,9	1,51	0,42	18	21
3,0	T40-1,5	10,3	0,44	0,12	8	10
	T40-2,0	11,8	0,64	0,18	9	11
	T40-3,0	12,4	0,98	0,27	13	15
	T40-4,0	13,2	1,24	0,34	14	16
	T40-6,0	13,6	1,66	0,46	18	21
3,5	T40-1,5	10,5	0,48	0,13	9	10
	T40-2,0	12,0	0,69	0,19	10	11
	T40-3,0	12,7	1,07	0,30	13	15
	T40-4,0	13,8	1,36	0,38	14	16
	T40-6,0	14,3	1,81	0,50	18	20
4,0	T40-1,5	10,7	0,52	0,14	9	10
	T40-2,0	12,2	0,75	0,12	10	12
	T40-3,0	13,1	1,19	0,33	14	16
	T40-4,0	14,3	1,49	0,41	15	17
	T40-6,0	15,3	2,00	0,55	17	20
4,5	T40-1,5	10,7	0,54	0,15	9	11
	T40-2,0	12,5	0,79	0,22	10	12
	T40-3,0	13,1	1,23	0,34	14	17
	T40-4,0	14,3	1,57	0,43	15	18
	T40-6,0	15,3	2,07	0,57	18	20

SISTEMA NORTEAMERICANO

Pressão Presión (PSI)	Bocal Boquilla	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
25	T40-1.5	29	1.5	0.34	0.40
	T40-2.0	36	2.2	0.33	0.38
	T40-3.0	36	3.2	0.48	0.55
	T40-4.0	37	4.1	0.58	0.67
	T40-6.0	37	5.4	0.76	0.88
35	T40-1.5	35	1.8	0.28	0.33
	T40-2.0	39	2.5	0.32	0.37
	T40-3.0	41	3.9	0.45	0.52
	T40-4.0	43	4.9	0.51	0.59
	T40-6.0	43	6.7	0.70	0.81
45	T40-1.5	35	2.0	0.31	0.36
	T40-2.0	39	2.9	0.37	0.42
	T40-3.0	41	4.5	0.52	0.60
	T40-4.0	45	5.7	0.54	0.63
	T40-6.0	47	7.6	0.66	0.77
55	T40-1.5	35	2.2	0.35	0.40
	T40-2.0	39	3.2	0.41	0.47
	T40-3.0	43	5.0	0.52	0.60
	T40-4.0	47	6.3	0.55	0.63
	T40-6.0	49	8.4	0.67	0.78
65	T40-1.5	35	2.4	0.38	0.44
	T40-2.0	41	3.5	0.40	0.46
	T40-3.0	43	5.4	0.56	0.65
	T40-4.0	47	6.9	0.60	0.69
	T40-6.0	50	9.1	0.70	0.81

Nota: Pluviometria baseada com o aspersor operando em meio-círculo.
■ Espaçamento quadricular baseado em 50% do diâmetro de alcance.
▲ Espaçamento triangular baseado em 50% do diâmetro de alcance.
Resultados obtidos com testes em condições sem vento.

Nota: *Tasa de precipitación basada en cobertura de semicírculo.*
■ *Espaciamento cuadrado en base a un diámetro de alcance de 50%.*
▲ *Espaciamento triangular en base a un diámetro de alcance de 50%.*
Datos del rendimiento obtenidos sin viento.

T-40 com bocais Rain Curtain
T-40 con boquillas Rain Curtain

T-40 com bocais Radius+
T-40 con boquillas Radius+

...essórios A49119, A49400 / *R-50 - Accesorios A49119, A49400*

...eção adicionais (R-50 e
...a atender às necessidades
...ada local

...as
...orracha de duas peças
...ra maior segurança; ideal
...de tráfego intenso e campos

... advertência "Do not
... beber!"(A49400) em inglês
...ndicativa de ser água não

...as tampas de borracha
...mpa de cor roxa com
...dvertência".

Memory-Arc™: Este dispositivo de memória mantém a direção programada do jato de água mesmo que vândalos tentem forçar uma mudança na direção do jato

Memory-Arc™: La función de memoria de arco siempre devuelve el rotor al arco de cobertura establecido, aunque se altere indebidamente durante el funcionamiento

Aplicaciones

Cubiertas de protección adicionales para rotores R-50 y R-50 SAM, que satisfacen las necesidades especiales de cada sitio

Características

- *Cubierta de caucho de dos piezas (A49119) para mayor seguridad; ideal para lugares muy transitados o campos deportivos*
- *"Do Not Drink! / ¡No Beber!" (A49400) Advertencia al público que permite identificar fácilmente los rotores que usan agua no potable*

Modelos

- *A49119: Cubierta de caucho de dos piezas*
- *A49400: Cubierta morada de advertencia para rotores que usan agua no potable*

... com Rain Curtain / *R-50/R-50 SAM con Rain Curtain*

Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
,2	0,36	0,10	11	12
,5	0,43	0,12	12	14
,8	0,64	0,18	13	15
,1	0,86	0,24	17	19
,0	1,23	0,34	20	23
,4	0,39	0,11	11	13
,7	0,46	0,13	12	14
,9	0,68	0,19	14	16
,2	0,92	0,25	18	20
,5	1,33	0,37	21	24
,4	0,44	0,12	12	14
,9	0,52	0,14	13	15
,1	0,76	0,21	15	17
,3	1,02	0,28	19	22
,6	1,47	0,41	22	25
,5	0,48	0,13	13	15
,1	0,57	0,16	14	16
10,2	0,83	0,23	16	18
10,3	1,13	0,31	21	25
11,9	1,62	0,45	23	26
,5	0,53	0,15	15	17
,2	0,63	0,18	15	17
10,4	0,90	0,25	17	19
10,4	1,24	0,34	23	27
12,2	1,76	0,49	24	27
,5	0,56	0,16	15	18
,2	0,67	0,19	16	18
10,4	0,96	0,27	18	21
10,4	1,35	0,37	25	29
12,2	1,89	0,53	25	29
,5	0,57	0,16	16	18
,2	0,68	0,19	16	19
10,4	0,98	0,27	18	21
10,4	1,38	0,38	26	29
12,2	1,93	0,54	26	30

SISTEMA NORTEAMERICANO

Pressão Presión (PSI)	Bocal Boquilla	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
25	● 1.5	27	1.60	0.42	0.49
	● 2.0	28	1.90	0.47	0.54
	● 3.0	32	2.80	0.53	0.61
	◒ 4.0	33	3.80	0.67	0.78
	● 6.0	36	5.40	0.80	0.93
35	● 1.5	28	1.90	0.47	0.54
	● 2.0	30	2.20	0.47	0.54
	● 3.0	33	3.30	0.58	0.67
	◒ 4.0	34	4.40	0.73	0.85
	● 6.0	38	6.50	0.87	1.00
45	● 1.5	28	2.20	0.54	0.62
	● 2.0	30	2.60	0.56	0.64
	● 3.0	34	3.80	0.63	0.73
	◒ 4.0	34	5.10	0.85	0.98
	● 6.0	40	7.30	0.88	1.01
55	● 1.5	28	2.40	0.59	0.68
	● 2.0	30	2.90	0.62	0.72
	● 3.0	34	4.10	0.68	0.79
	◒ 4.0	34	5.70	0.95	1.10
	● 6.0	40	8.10	0.98	1.13
60	● 1.5	28	2.50	0.61	0.71
	● 2.0	30	3.00	0.64	0.74
	● 3.0	34	4.30	0.72	0.83
	◒ 4.0	34	6.10	1.02	1.17
	● 6.0	40	8.50	1.02	1.18

Nota: Pluviometria baseada com o aspersor operando em meio-círculo.

■ Espaçamento quadricular baseado em 50% do diâmetro de alcance.

▲ Espaçamento triangular baseado em 50% do diâmetro de alcance.

Resultados obtidos com testes em condições sem vento.

R-50/R-50 SAM com Radius+ / *R-50/R-50 SAM con Radius+*

SISTEMA MÉTRICO

Pressão Presión (Bars)	Bocal Boquilla	Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
1,7	● 1,5	10,0	0,34	0,09	7	8
	● 2,0	11,3	0,50	0,14	8	9
	● 3,0	11,6	0,70	0,20	10	12
	◒ 4,0	-	-	-	-	-
	● 6,0	-	-	-	-	-
2,0	● 1,5	10,2	0,36	0,10	7	8
	● 2,0	11,4	0,53	0,15	8	9
	● 3,0	11,7	0,75	0,21	11	13
	◒ 4,0	-	-	-	-	-
	● 6,0	-	-	-	-	-
2,5	● 1,5	10,3	0,40	0,11	8	9
	● 2,0	11,6	0,58	0,16	9	10
	● 3,0	11,9	0,83	0,23	12	14
	◒ 4,0	11,9	1,11	0,31	16	18
	● 6,0	13,9	1,63	0,45	17	19
3,0	● 1,5	10,3	0,43	0,12	8	9
	● 2,0	11,7	0,63	0,17	9	11
	● 3,0	12,0	0,91	0,25	13	15
	◒ 4,0	12,2	1,21	0,33	16	19
	● 6,0	14,3	1,78	0,49	17	20
3,5	● 1,5	10,4	0,47	0,13	9	10
	● 2,0	11,9	0,68	0,19	10	11
	● 3,0	12,2	0,99	0,28	13	15
	◒ 4,0	12,4	1,31	0,36	17	20
	● 6,0	14,8	1,95	0,54	18	21
4,0	● 1,5	10,4	0,50	0,14	9	11
	● 2,0	11,9	0,73	0,20	10	12
	● 3,0	12,2	1,08	0,30	15	17
	◒ 4,0	12,5	1,39	0,39	18	21
	● 6,0	15,1	2,09	0,58	18	21
4,1	● 1,5	10,4	0,52	0,14	10	11
	● 2,0	11,9	0,75	0,21	11	12
	● 3,0	12,2	1,11	0,31	15	17
	◒ 4,0	12,5	1,41	0,39	18	21
	● 6,0	15,2	2,13	0,59	18	21

SISTEMA NORTEAMERICANO

Pressão Presión (PSI)	Bocal Boquilla	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
25	● 1.5	33	1.5	0.27	0.31
	● 2.0	37	2.2	0.31	0.36
	● 3.0	38	3.1	0.41	0.48
	◒ 4.0	-	-	-	-
	● 6.0	-	-	-	-
35	● 1.5	34	1.7	0.28	0.33
	● 2.0	38	2.5	0.33	0.39
	● 3.0	39	3.5	0.44	0.51
	◒ 4.0	39	4.8	0.61	0.70
	● 6.0	45	7.0	0.67	0.77
45	● 1.5	34	2.0	0.33	0.38
	● 2.0	39	2.8	0.35	0.41
	● 3.0	40	4.2	0.51	0.58
	◒ 4.0	40	5.4	0.65	0.75
	● 6.0	46	8.1	0.68	0.78
55	● 1.5	34	2.1	0.35	0.40
	● 2.0	39	3.1	0.39	0.45
	● 3.0	40	4.5	0.54	0.63
	◒ 4.0	41	6.0	0.69	0.79
	● 6.0	49	8.9	0.71	0.82
60	● 1.5	34	2.3	0.38	0.44
	● 2.0	39	3.3	0.42	0.48
	● 3.0	40	4.9	0.59	0.68
	◒ 4.0	41	6.2	0.71	0.82
	● 6.0	50	9.4	0.72	0.84

***Nota:** Tasa de precipitación basada en cobertura de semicírculo*

■ Espaciamento cuadrado en base a un diámetro de alcance de 50%

▲ Espaciamento triangular en base a un diámetro de alcance de 50%

Datos del rendimiento obtenidos sin viento

-50/R-50 SAM com bocal Rain Curtain de Ângulo Baixo /
-50/R-50 SAM con boquilla Rain Curtain de Angulo Bajo

-EMA MÉTRICO

	Bocal Boquilla	Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
	● 1,5	6,4	0,34	0,09	17	19
	● 2,0	7,9	0,43	0,12	14	16
	● 3,0	6,5	0,61	0,17	17	19
	● 4,0	8,5	0,86	0,24	24	27
	● 6,0	9,2	1,16	0,32	27	32
	● 1,5	6,7	0,37	0,10	16	19
	● 2,0	8,1	0,46	0,13	14	16
	● 3,0	8,7	0,65	0,18	17	20
	● 4,0	8,7	0,92	0,26	24	28
	● 6,0	9,4	1,24	0,34	28	32
	● 1,5	6,8	0,41	0,11	18	20
	● 2,0	8,1	0,51	0,14	16	18
	● 3,0	8,7	0,72	0,20	19	22
	● 4,0	8,8	1,02	0,28	26	30
	● 6,0	9,7	1,38	0,38	29	34
	● 1,5	6,8	0,44	0,12	19	22
	● 2,0	8,2	0,56	0,15	17	19
	● 3,0	8,8	0,79	0,22	20	24
	● 4,0	9,0	1,12	0,31	28	32
	● 6,0	10,1	1,52	0,42	30	34
	● 1,5	6,8	0,48	0,13	21	24
	● 2,0	8,2	0,61	0,17	18	21
	● 3,0	8,8	0,86	0,24	22	25
	● 4,0	9,2	1,22	0,34	29	34
	● 6,0	10,4	1,65	0,46	30	35
	● 1,5	6,7	0,52	0,14	23	27
	● 2,0	8,1	0,65	0,18	20	23
	● 3,0	8,8	0,92	0,25	24	27
	● 4,0	9,2	1,31	0,36	31	36
	● 6,0	10,4	1,77	0,49	33	39
	● 1,5	6,7	0,52	0,14	23	27
	● 2,0	8,2	0,66	0,18	20	23
	● 3,0	8,8	0,93	0,26	24	28
	● 4,0	9,2	1,34	0,37	32	37
	● 6,0	10,4	1,79	0,50	33	38

SISTEMA NORTEAMERICANO

Bocal Boquilla	Pressão Presión (PSI)	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
25	● 1.5	21	1.5	0.66	0.76
	● 2.0	26	1.9	0.54	0.63
	● 3.0	28	2.7	0.66	0.77
	● 4.0	28	3.8	0.93	1.08
	● 6.0	30	5.1	1.09	1.26
35	● 1.5	23	1.8	0.66	0.76
	● 2.0	27	2.2	0.58	0.67
	● 3.0	29	3.1	0.71	0.82
	● 4.0	29	4.4	1.01	1.16
	● 6.0	32	6.0	1.13	1.30
45	● 1.5	23	2.0	0.73	0.84
	● 2.0	28	2.5	0.61	0.71
	● 3.0	29	3.6	0.82	0.95
	● 4.0	30	5.1	1.09	1.26
	● 6.0	33	6.9	1.22	1.41
55	● 1.5	22	2.2	0.88	1.01
	● 2.0	26	2.8	0.80	0.92
	● 3.0	29	3.9	0.89	1.03
	● 4.0	30	5.6	1.20	1.39
	● 6.0	35	7.6	1.19	1.38
60	● 1.5	22	2.3	0.92	1.06
	● 2.0	27	2.9	0.77	0.89
	● 3.0	29	4.1	0.94	1.08
	● 4.0	30	5.9	1.26	1.46
	● 6.0	34	7.9	1.32	1.52

Nota: Pluviometria baseada com o aspersor operando em meio-círculo.
■ Espaçamento quadricular baseado em 50% do diâmetro de alcance.
▲ Espaçamento triangular baseado em 50% do diâmetro de alcance.
Resultados obtidos com testes em condições sem vento.

R-50/R-50 SAM com bocal Radius+ de Ângulo Baixo /
R-50/R-50 SAM con boquilla Radius+ de Angulo Bajo

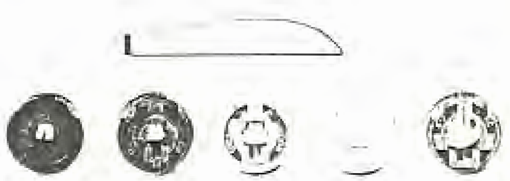
SISTEMA MÉTRICO

Pressão Presión (Bars)	Bocal Boquilla	Alcance Alcance (m)	Vazão Flujo (m³/h)	Vazão Flujo (l/s)	■ Pluvio. Precip. (mm/h)	▲ Pluvio. Precip. (mm/h)
1,7	● 1,5	7,9	0,36	0,10	12	13
	● 2,0	8,5	0,43	0,12	12	14
	● 3,0	8,5	0,64	0,18	18	20
	● 4,0	9,2	0,86	0,24	20	23
	● 6,0	10,4	1,23	0,34	23	26
2,0	● 1,5	7,9	0,39	0,11	12	14
	● 2,0	8,7	0,46	0,13	12	14
	● 3,0	8,8	0,68	0,19	18	20
	● 4,0	9,3	0,92	0,25	21	25
	● 6,0	10,4	1,33	0,37	25	28
2,5	● 1,5	7,9	0,44	0,12	14	16
	● 2,0	8,8	0,52	0,14	13	16
	● 3,0	8,9	0,76	0,21	19	22
	● 4,0	9,4	1,02	0,28	23	27
	● 6,0	10,6	1,47	0,41	26	30
3,0	● 1,5	7,9	0,48	0,13	15	18
	● 2,0	9,0	0,57	0,16	14	16
	● 3,0	9,1	0,83	0,23	20	23
	● 4,0	9,5	1,13	0,31	25	29
	● 6,0	10,8	1,62	0,45	28	32
3,5	● 1,5	7,9	0,53	0,15	17	20
	● 2,0	9,2	0,63	0,18	15	17
	● 3,0	9,2	0,90	0,25	21	25
	● 4,0	9,5	1,24	0,34	27	32
	● 6,0	11,0	1,75	0,49	29	34
4,0	● 1,5	7,9	0,56	0,16	18	21
	● 2,0	9,2	0,67	0,19	16	18
	● 3,0	9,2	0,96	0,27	23	26
	● 4,0	9,8	1,35	0,37	28	33
	● 6,0	11,0	1,89	0,53	31	36
4,1	● 1,5	7,9	0,57	0,16	18	21
	● 2,0	9,2	0,68	0,19	16	19
	● 3,0	9,2	0,98	0,27	23	27
	● 4,0	9,8	1,38	0,38	29	33
	● 6,0	11,0	1,93	0,54	32	37

SISTEMA NORTEAMERICANO

Bocal Boquilla	Pressão Presión (PSI)	Alcance Alcance (pies)	Vazão Flujo (GPM)	■ Pluvio. Precip. (pol./h)	▲ Pluvio. Precip. (pol./h)
25	● 1.5	26	1.60	0.46	0.53
	● 2.0	28	1.90	0.47	0.54
	● 3.0	28	2.80	0.69	0.79
	● 4.0	30	3.60	0.81	0.94
	● 6.0	34	5.40	0.90	1.04
35	● 1.5	26	1.90	0.54	0.63
	● 2.0	29	2.20	0.50	0.58
	● 3.0	30	3.30	0.71	0.82
	● 4.0	32	4.40	0.83	0.96
	● 6.0	34	6.50	1.08	1.25
45	● 1.5	26	2.20	0.63	0.72
	● 2.0	30	2.60	0.56	0.64
	● 3.0	30	3.80	0.81	0.94
	● 4.0	30	5.10	1.09	1.26
	● 6.0	36	7.30	1.08	1.25
55	● 1.5	26	2.40	0.68	0.79
	● 2.0	30	2.90	0.62	0.72
	● 3.0	30	4.10	0.88	1.01
	● 4.0	32	5.70	1.07	1.24
	● 6.0	36	8.10	1.20	1.39
60	● 1.5	26	2.50	0.71	0.82
	● 2.0	30	3.00	0.64	0.74
	● 3.0	30	4.30	0.92	1.06
	● 4.0	32	6.10	1.15	1.32
	● 6.0	36	8.50	1.26	1.46

***Nota:** Tasa de precipitación basada en cobertura de semicírculo.*
■ *Espaciamento cuadrado en base a un diámetro de alcance de 50%.*
▲ *Espaciamento triangular en base a un diámetro de alcance de 50%.*
Datos del rendimiento obtenidos sin viento.



Bocais Rain Curtain oferecem distribuição melhor da água, especialmente nas proximidades.

Las boquillas Rain Curtain ofrecem la mejor uniformidad de riego, especialmente en distancias más cortas.

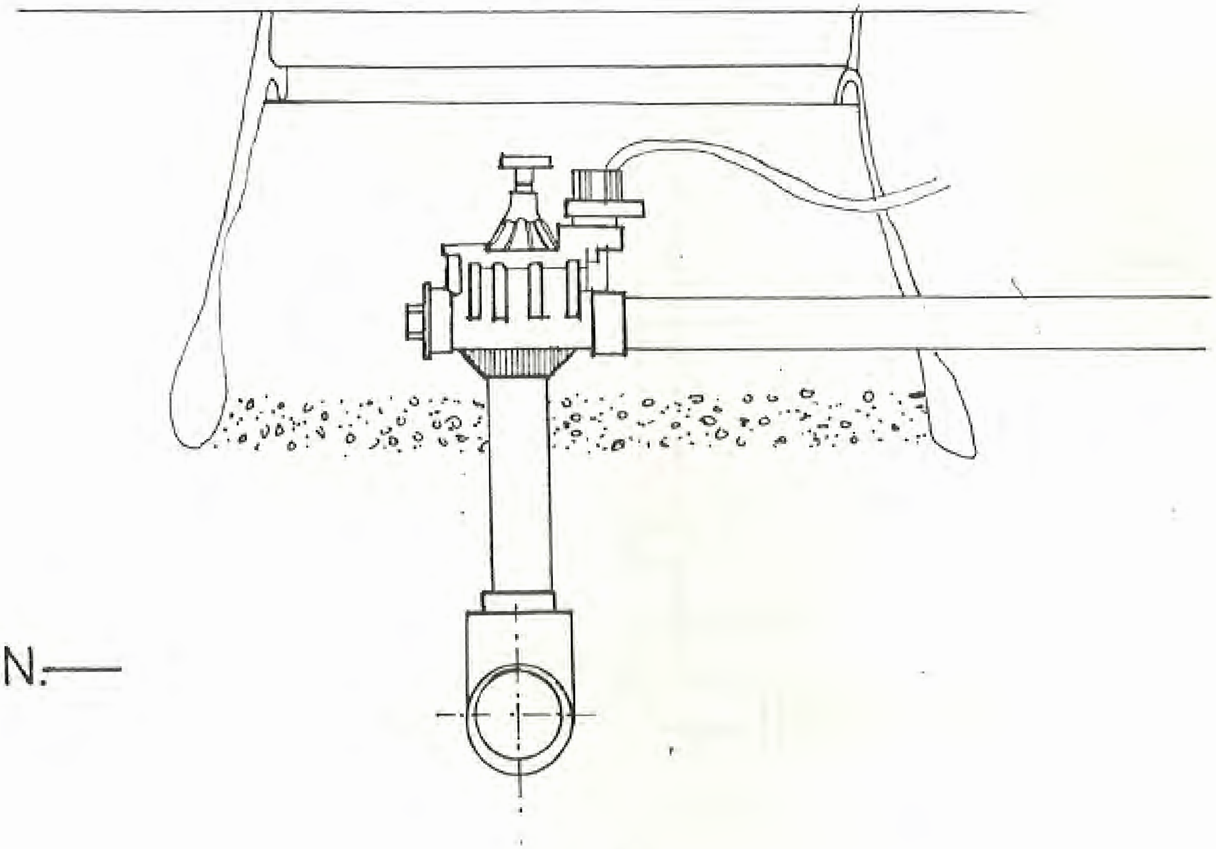
Bocais Radius+ oferecem o maior alcance possível com distribuição eficiente de água.

Las boquillas Radius+ ofrecem el mayor alcance posible con distribución eficiente de agua.

APÉNDICE L

PLANOS

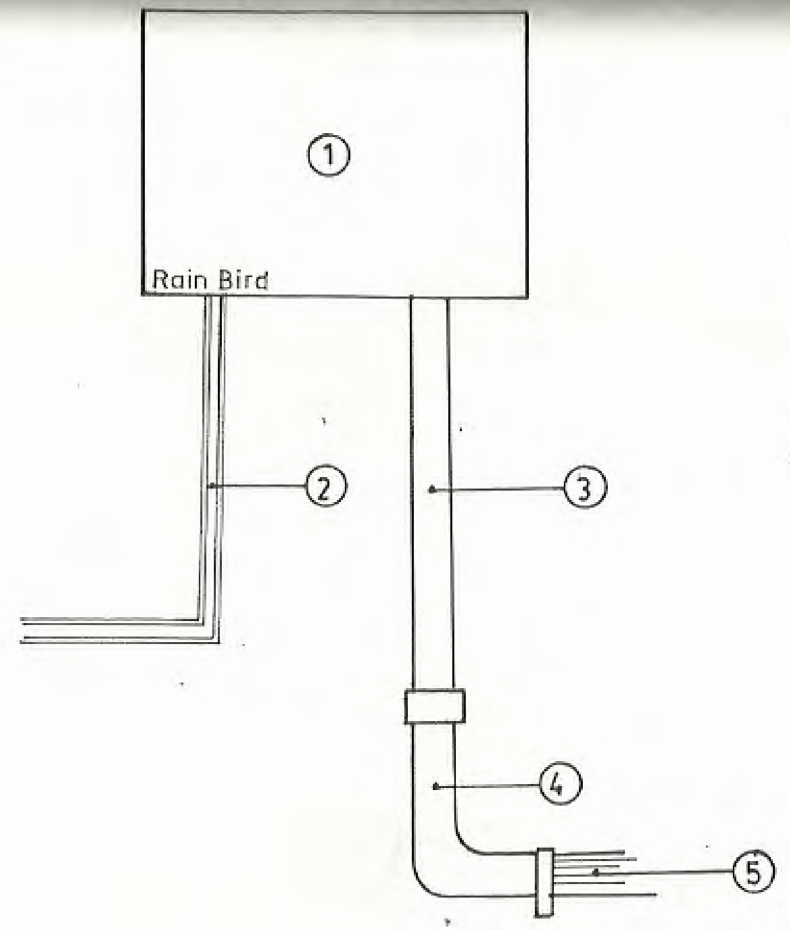
INSTALACION DE VALVULA SOLENOIDE



SECCION.—

SIN ESCALA

FIMCP - ESPOL			FECHA Dib. L. MEZA Rev. Ing. E. Martínez
PROYECTO SISTEMA DE RIEGO			PLANO Nº 4
	ESCALA	CONTIENE INSTALACION DE VALVULA	
		MATERIALES	MASA Kg



1. CONTROLADOR
2. ACOMÈTIDA 110 Vo
3. TUBERIA CONDOIT
4. CODO
5. CABLES

SIN ESCALA

FIMCP- ESPOL			Fecha Dib. L. MEZA Rev. Ing.E.Martínez
RROYECTO SISTEMA DE RIEGO			PLANO N° 1
	Escala	CONTIENE TABLERO DE CONTROL	
		MATERIALES	MASA Kg.