FACULTAD DE INGENIERÍA Y ARQUITECTURA

ESCUELA PROFESIONAL DE INGENIERÍA CIVIL

# ANÁLISIS COMPARATIVO ENTRE TUBERÍAS DE POLIETILENO RETICULADO PEXb Y TUBERÍAS DE PVC EN INSTALACIONES DE AGUA POTABLE
# CASO: EDIFICIO MULTIFAMILIAR VITALIA EN LA AVENIDA VELASCO ASTETE 925 SAN BORJA - LIMA

PRESENTADA POR

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TESIS

PARA OPTAR EL TÍTULO PROFESIONAL DE INGENIERO CIVIL

LIMA – PERÚ

2017

USMP
UNIVERSIDAD DE SAN MARTIN DE PORRES
FACULTAD DE INGENIERÍA Y ARQUITECTURA

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**PRESENTADA POR**


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**MELÉNDEZ RODRÍGUEZ, PAUL MICHAEL**


**LIMA – PERÚ**

**2017**

**DEDICATORIA**

A Dios por la bendición de permitirnos alcanzar nuestra meta siendo guía en este arduo camino.

A nuestros padres Manuel Estacio, Pilar Natividad, Martín Oyanguren y Viany Rodriguez por sus sacrificios y consejos que nos llevaron a alcanzar nuestras metas.

A todas las amistades y familiares que confiaron en nosotros, estando en las buenas y malas.

A nuestro amigo Daniel Acosta Farfán que nos enseñó lo bello de la vida, siempre con una sonrisa y presto a ayudar a quién lo necesite.

## AGRADECIMIENTO

A los ingenieros Alexis Samohod Romero y Juan Manuel Santamaria Oblitas, por brindarnos el absoluto apoyo y guiarnos en este proceso.

A nuestra casa de estudios Universidad San Martín de Porres – Facultad de Ingeniería y Arquitectura, por la base académica que nos sirve para enfrentar el mundo laboral.

A la empresa Veneto Inversiones SAC por el apoyo brindado, dándonos facilidades en información y materiales para el óptimo desarrollo de la presente investigación.

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**RESUMEN**

El presente estudio tiene como objetivo comparar la eficiencia entre el uso en instalaciones de agua potable de tuberías de Polietileno Reticulado PEXb (en adelante tuberías PEXb) y tuberías de PVC para futuras edificaciones. El contexto teórico de la variable está sustentado principalmente con las investigaciones de Ojeda, J. (2015) y Fabián, C., & Sandoval, O. (2013), entre otros, además de la información brindada por la principal empresa distribuidora de estas tuberías en el Perú, **Inversiones Veneto SAC**.

La metodología fue de tipo mixta, nivel inicialmente descriptivo terminando siendo explicativo, con un método descriptivo comparativo, y de diseño experimental y transversal. Se empleó el cuadro de operacionalización de variables, se obtuvo como variables dependientes la **calidad, tiempo y costo** de las tuberías a comparar, el que a través de ensayos se analiza y se llega al objetivo de la investigación.

Los resultados de los datos se desarrollan a través de tablas y gráficos para comparar las diferencias según los indicadores de costo, tiempo y calidad, y así se determinó la tubería más eficiente para el uso en instalaciones de agua potable. Se concluyó que la tubería PEXb presenta mayor eficiencia con respecto a la tubería de PVC.

**Palabras claves:** Polietileno Reticulado, PEXb.

# ABSTRACT

This study the objective to compare the efficiency between using drinking water installations of reticulated polyethylene pipes PEXb (onwards PEXb pipes) and PVC pipes for future buildings. The theoretical context of this variable is mainly supported for the investigations of Ojeda, J. (2015) and Fabian, C., & Sandoval, O. (2013), and others. In addition to the information provided for the main distribution company of this pipes in Peru, **Inversiones Veneto Plc.**

The methodology was mixt, at the beginning it was descriptive and finally explicative, with a descriptive-comparative method and the experimental and transversal design. The variable operationalization table was used, the variables dependent were **quality**, **time** and **cost** of the pipes that were compared with the test that were analyzed and the objective of the investigation was reached.

The results of the data is developed through boards and graphics to compare the differences according to the indicator of **quality**, **time** and **cost** and so was determined the most efficient pipe for the use of drinking water installations. It concluded that the pipe PEXb present the highest efficiency if it is compared to PVC pipe.



**Key words:** Reticulated Polyethylene, PEXb.

# INTRODUCCIÓN

Las instalaciones sanitarias de agua potable representan una parte muy importante del proceso constructivo, tanto por los servicios que proporciona como por su costo y tiempo. En algunas construcciones su costo se eleva por las fallas de ruptura y malas instalaciones que se hace en plena obra o en la postventa que se tiene que reparar. Por lo tanto resulta conveniente la realización de este trabajo que trata los aspectos teóricos y procedimientos prácticos para las tuberías PEXb y tuberías de PVC.

El análisis comparativo entre estas dos tuberías ayuda a las empresas constructoras en el planteamiento de selección y previsión de uso de tuberías. Además, los datos obtenidos proporcionarán una idea de los costos, tiempos y calidad del uso de las tuberías para optimizar los recursos en obra, lo cual justifica el uso de las tuberías PEXb en el uso de instalaciones de agua potable.

# CAPÍTULO I: PLANTEAMIENTO DEL PROBLEMA

## 1.1. Descripción de la realidad problemática

Hoy en día tradicionalmente en las construcciones de viviendas unifamiliares y multifamiliares, para las instalaciones sanitarias de agua potable se usan las tuberías de PVC. Con el pasar de los años, algunas construcciones presentan fallas en las tuberías como, problemas con la presión del agua, roturas, micro vibraciones entre otros. Y muchos de estos problemas son por el mal manejo a la hora de instalar las tuberías de PVC.

Existen muchos sistemas para el uso en instalaciones de agua potable que podrían reemplazar al PVC, como el PPR (Polipropileno, más conocido como termofusión), cobre y PEX (Polietileno reticulado) y que ya se usan hace mucho en Europa como Italia, España, Alemania, entre otros, y en países de Sudamérica como Colombia.

Analizando los sistemas en tiempo de instalación, costo y calidad, elegimos para este estudio comparativo el PEX (Polietileno Reticulado), cuyas propiedades físicas y químicas son superiores al PVC, convirtiéndose en una excelente alternativa para el uso en las instalaciones de agua potable para dar más vida útil a las instalaciones y mejorar la calidad de la vida humana.

En esta investigación se determinará mediante los ensayos de Tracción a Tubo Completo, Presión Sostenida, Resistencia al Impacto, y Análisis de Agua con fines de Consumo Humano: Agua Potable. Ensayos que elegimos por grado de importancia con respecto a calidad de las tuberías y salud humana.

## 1.2. Identificación y formulación del problema

### 1.2.1. Problema general.

- ¿En qué medida incidirá el análisis comparativo de parámetros entre tuberías PEXb y tuberías de PVC para el eficiente uso en instalaciones de agua potable en el edificio multifamiliar Vitalia?

### 1.2.2. Problema específico.

- ¿En qué medida incidirá la realización de ensayos para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a la **calidad** entre tuberías PEXb y tuberías de PVC?

- ¿En qué medida incidirá la realización del análisis de rendimiento para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a **tiempo** entre tuberías PEXb y tuberías de PVC?

- ¿En qué medida incidirá la realización del metrado y análisis de presupuesto para la determinación del uso en instalaciones sanitarias de agua potable en el edificio multifamiliar Vitalia con respecto a **costo** entre tuberías PEXb y tuberías de PVC?

## 1.3. Objetivos de la investigación

### 1.3.1. Objetivo general.

- Evaluar incidencia del análisis comparativo de parámetros entre tuberías PEXb y tuberías de PVC para el eficiente uso en instalaciones de agua potable en el edificio multifamiliar Vitalia.

.

### 1.3.2. Objetivos específicos.

- Evaluar la incidencia de la realización de ensayos para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a la **calidad** entre tuberías PEXb y tuberías de PVC.

- Evaluar la incidencia de la realización del análisis de rendimiento para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a **tiempo** entre tuberías PEXb y tuberías de PVC.

- Evaluar la incidencia de la realización del metrado y análisis de presupuesto para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a **costo** entre tuberías PEXb y tuberías de PVC.

## 1.4. Justificación e importancia de la investigación

El presente análisis comparativo es para dar a conocer una mejor opción a la hora de elegir una tubería para la instalación de agua potable en edificaciones, se observa la necesidad de emplear sistemas de instalación sanitarias de rápida instalación, menor tiempo para la prueba de presión, que soporte mayores presiones y que presente un menor costo económico; por lo que se analizan las tuberías PEXb (comercialmente llamado TRICAPA FLEX) y tuberías de PVC, que son tuberías de forma industrializada.

La importancia de las tuberías de agua potable ha ido creciendo en los últimos años, estos influyen directamente al costo del proyecto (en ejecución y postventa), donde su inversión inicial puede ser baja por el uso de tuberías de PVC de la más económica (lo que significa que no es de buena calidad) y en adelante esto trae como consecuencia la reparación o cambio de tuberías. Siendo así, la tubería PEXb es de bajo costo, ya que al instalarlos se ahorra tiempo, se reduce el uso de accesorios y disminuye el costo del flete, y esto representa una mayor rentabilidad y garantiza una mejor calidad en salud humana.

## 1.5. Limitaciones de la investigación

La falta de estudio en el Perú de este material en el uso de instalaciones sanitarias de agua potable. Si bien es cierto hay empresas en el Perú que distribuyen tuberías PEXb pero sus principales cliente (que son pocos) son del sector privado que son extrajeras y ya conocen de estas tuberías o algunas lo usan pero de forma desconfiada, es decir que por lo mismo que las tuberías de PVC son de uso masivo ("confiable"), el usar tuberías PEXb se hace poco confiable.

La poca mano de obra especializada en instalaciones de tuberías PEXb hace que sea un limitante muy importante, porque no se arriesgan a usar una opción mucho mejor en todos sus aspectos por lo acostumbrados que están al uso del PVC, justamente ellos son los que recomiendan a los clientes de usar una mejor opción en las instalaciones sanitarias de agua potable. Siendo la instalación de tuberías PEXb más práctico, seguro y saludable que el PVC.

Otra limitación importante fue el costo elevado de los ensayos, por lo que de todos los ensayos que se hizo en esta investigación, dos se hicieron en campo (diseñando nuestro propio sistema para llegar al objetivo) y los otros dos se hizo en laboratorios de la Pontificia Universidad Católica del Perú y de la Universidad Agraria de la Molina.

### 1.6. Viabilidad de la investigación

Se han recopilado información referente a las tuberías PEXb, además de certificaciones europeas y experiencias en instalaciones ya realizadas ya en el Perú, por tal razón el presente análisis comparativo mostrará resultados que resuelvan nuestra problemática y satisfagan nuestra hipótesis.

# CAPÍTULO II: MARCO TEÓRICO

## 2.1. Antecedentes de la investigación

Al ejecutar una obra, se debe tener en cuenta que hay que elegir un método constructivo. En este punto se debe hacer énfasis debido a su importancia, ya que de esta decisión depende el proyecto. Según esta se definirá el tiempo, costo, materiales a usar y otros factores, ya que cada sistema constructivo tiene propias características. Es por esto, que constantemente se realizan comparativos para ver cual resulta ser más eficiente para diversas situaciones.

Para el desarrollo de esta investigación, se consultaron los siguientes trabajos que se resumen a continuación:

- ✓ **Ojeda, J. (2015).** *Análisis comparativo entre el método Pipe Bursting y el método tradicional en la renovación de tuberías de desagüe*, en la Universidad Peruana de Ciencias Aplicadas, Facultad de Ingeniería, Carrera de Ingeniería Civil, en el cual realiza un método para reemplazar tuberías dañadas sin excavar, Método Pipe Bursting, y el material de tubería a usar es el polietileno, dándonos detalles de este material que usaremos para el análisis comparativo con el PVC.

- ✓ **Fabián, C., & Sandoval, O. (2013).** *Análisis comparativo técnico – económico entre el sistema convencional (tuberías PVC) y el sistema de termofusión (tuberías de polipropileno) en instalaciones interiores de agua potable para edificaciones en la región de Lima*, en la Universidad Nacional de Ingeniería, Facultad de Ingeniería Ambiental, en el cual se realiza una comparación clara entre dos sistemas de tuberías para las instalaciones sanitarias, PVC vs PPR, de aquí nos basamos en los datos sobre PVC y parte de la estructura a trabajar para el marco teórico.

## 2.2. Bases teóricas

En este punto se hablará sobre las definiciones que tiene este proyecto de plan de tesis sobre el material.

### 2.2.1. Polietileno Reticulado (PEXb).

#### a. Historia del polietileno.

El polietileno fue sintetizado por primera vez por el químico alemán Hans von Pechmann quien por accidente lo preparó en 1898 mientras se calentaba en la estufa diazometano. Cuando sus compañeros Eugen Bamberger y Friedrich Tschirner investigaron la sustancia grasosa y blanca creada, descubrieron largas cadenas compuestas por $-CH_2-$ y lo llamaron polietileno.

El 27 de marzo de 1933, en Inglaterra, fue sintetizado tal como lo conocemos hoy en día, por Reginald Gibson y Eric Fawcett que trabajaban para los Laboratorios ICI. Lo lograron aplicando una presión de aproximadamente 1400 bar y una temperatura de 170 °C en un autoclave, obteniendo el material de alta viscosidad y color blanquecino que se conoce hoy en día como "polietileno de baja densidad" (PEBD o, en inglés, LDPE).

La altísima presión requerida para lograr la polimerización del etileno era un inconveniente económico. Por ello varios investigadores comenzaron a buscar catalizadores que permitiesen la polimerización a presión más reducida. Esto dio origen a los catalizadores Ziegler-Natta, por los cuales Karl Ziegler y Giulio Natta recibieron el premio Nobel de química en 1963 . (“*Polietileno*”, s.f., párr.5)

**b. Definición del Polietileno.**

El **polietileno** (PE) es un polímero termoplástico obtenido por la polimerización del etileno, empleando presiones elevadas y peróxidos como catalizadores. La polimerización es la reacción por la que los monómeros se unen entre sí para formar un polímero.

| | |
|---|---|
| $H_2C = CH_2$ | $[CH_2\text{-}CH_2]_n$ |
| Etileno | Polietileno |
| (Monómero) | (Polímero) |

***Figura 1.*** Polimerización del etileno. Ojeda, J. (2015)

Los materiales plásticos están formados por grandes moléculas agrupadas en largas cadenas, variando sus longitudes, el número de estas y sus ramificaciones, de tal modo que el grado de ramificaciones y la longitud de sus cadenas, influyen considerablemente en las propiedades del material.

Es por esto que los materiales de polietileno soportan mayores condiciones físicas de acuerdo las propiedades químicas que presentan.

Ojeda, J. (2015). *Recuperado de http://www.repositorioacademico.upc.edu.pe*

**c. Características de la materia prima usadas en las tuberías de polietileno.**

El etileno o eteno (CH2:CH2) cuyo peso molecular es de 28,05 gramos, es el hidrocarburo olefínico o insaturado más asequible. Las características que presenta este gas son incoloro e inflamable, con olor débil y agradable. Es utilizado especialmente como materia prima en la industria química orgánica sintética.

La molécula del etileno es plana y está conformada por cuatro enlaces simples C-H y un enlace doble C=C, que le imposibilita rotar excepto a elevadas temperaturas.

Las reacciones químicas del etileno pueden ser divididas en aquellas que tienen importancia en la industria comercial y por otro lado de interés investigativo. Esta división se da más importancia ya que el etileno es utilizado más en el entorno industrial, por otro lado, el interés investigativo podría ser en un futuro próximo lo primordial ya que se utilizaría como base para futuras creaciones de otros materiales. ("*Textos científicos*", 2005, párr.3)

### d. Tipos de polietileno según su densidad.

El Polietileno se puede clasificar de manera general por tres tipos de acuerdo a su densidad:

- ✓ **Polietileno de baja densidad (LDPE o PEBD)**

El polietileno de baja densidad es un homopolímero muy ramificado que tiene por unidad monomérica el etileno. El polietileno de baja densidad se obtiene a partir del etileno gaseoso, muy puro, se polimeriza en presencia de un iniciador (peróxido de benzoilo, azodi-isobutironitrilo u oxígeno), a presiones de 1,000 a 3,000 atm y temperaturas de 100 a 300°C.

Una vez polimerizado se utiliza para la creación de otros productos.

Este homopolímero (polietileno de baja densidad) se aplica para la creación de envases en el sector industrial; así como también bolsas, botellas compresibles para pulverizar fármacos, aislante para cables y conductores, tuberías de riego, sistemas de irrigación, etc. ("*Quiminet*", s.f., párr.8)

- ✓ **Polietileno de alta densidad (HDPE o PEAD)**

  Es un homopolímero con estructura lineal con pocas ramificaciones que, además son muy cortas.

  Se utilizan procesos de baja presión para su obtención y los catalizadores utilizados son los de Ziegler-Natta (compuestos organometálicos de aluminio y titanio). La reacción se lleva a cabo en condiciones de 1 a 100 kg/cm2 de presión y temperatura de 25 a 100 °C, la polimerización puede ser en suspensión o fase gaseosa.

  Se aplica el polietileno de alta densidad para la creación de diferentes tipos de materiales como bolsas para mercancía, bolsas para basura, botellas para leche y yogurt, cajas para transporte de botellas, envases para productos químicos, envases para jardinería, detergentes y limpiadores, frascos para productos cosméticos y capilares, recubrimientos de sobres para correo, sacos para comestibles, aislante de cable y alambre, contenedores de gasolina, tuberías para instalaciones de agua caliente y fría, en otros. ("*Polietileno HDPE*", 2006, párr.2)

**e. Polietileno Reticulado.**

El polietileno reticulado (en adelante PEX) es tubo plástico flexible reforzado por una reacción química que crea fibras largas para aumentar la resistencia del material. Ha sido aprobado en Europa y el Sur de los Estados Unidos durante muchos años, pero sólo recientemente recibió la aprobación para uso residencial en la mayoría de códigos de plomería. Frecuentemente es usado en casas prefabricadas y vehículos de recreación, además de sistemas de calefacción radiante.

Gracias a que es tan flexible, el polietileno reticulado es doblado fácilmente para encajar en rincones y hacer otros cambios de dirección. Desde la tubería maestra y el calentador, es conectado a múltiples uniones que redistribuyen el agua en forma similar a un sistema de riego del césped. En instalaciones residenciales estándar, el PEX es conectado con juntas y herramientas muy sencillas. ("*Arquigráfico*", 2017, párr.4)


***Figura2.*** *PEXb.* Recuperado de http://kresala.eu

**f. Proceso de Reticulación.**

Es el proceso en la cual una molécula, que viene a ser un monómero, se une mediante enlaces iguales formando cadenas tridimensionales como una especie de red donde se combinan las propiedades químicas específicas (elasticidad, porosidad, permeabilidad, entre otros), tras esto llegan a formar un polímero con diferentes propiedades químicas.

En el caso de los materiales plásticos que usamos para aislar y cubrir nuestros cables, el proceso de reticulación les otorga termo-estabilidad, es decir, estabilidad ante cambios de temperatura. ("*El mundo de los cables de energía*", 2008, párr.3)

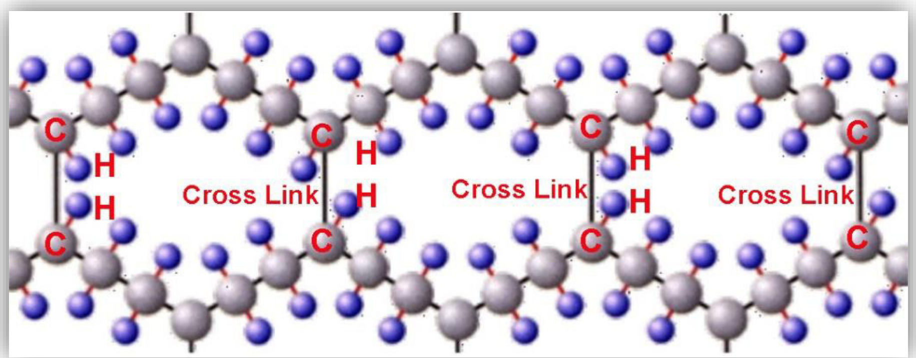



***Figura 3.*** Proceso de Reticulación. Recuperado de http://www.argpex.com

### g. Tipos de Reticulación.

- ✓ **PEXa**

El PEXa fue creado por el método Engel o método del peróxido. Este proceso es realizado por el entrecruzamiento "en caliente", llegando a superar el punto de fusión. Sin embargo, este proceso es más largo que los otros ya que este tiene que mantenerse a temperatura y presiones altas durante prolongados tiempos durante el proceso de extrusión. El entrecruzamiento es entre los átomos de carbono. ("*Tecnología de los plásticos*,", 2012, párr.3)

La reticulación se da mayor al 70%, siendo uno de los mejores tubos, debido a esto tiene como características, mayor flexibilidad que otros tubos de plástico, memoria térmica, gran capacidad de elongación.

- ✓ **PEXb**

Este método llamado silano o también conocido como método de **Curación por Humedad.** Es un método de reticulación, que se lleva a cabo por un proceso secundario de **post extrusión.** El proceso cumple con la aceleración del calor y la humedad. Por ende producen enlaces cruzados que son forados por la condensación del silanol, que son injertadas entre dos unidades de viniltrimetoxisilano (VTMS), que son conectadas con las cadenas de polietileno con puentes CC-Si-O-Si-CC.

Esta reticulacion tiene como objetivo dar un resultado mayor al 65%, obteniendo una mayor resistencia a la presión y a altas temperaturas ("*Tecnología de los plásticos*,", 2012, párr.6)

- ✓ **PEXc**

En este punto se realiza un proceso de haz de electrones, con un proceso de reticulación en un temperatura muy fría (por debajo del punto de fusión). Ofrece un resultado menos uniforme y menor grado de reticulación que el método de Engel, especialmente en diámetros de tubo de más de una pulgada (2,5 cm). Este proceso cuando no se controla adecuadamente, la capa externa del tubo tiende a ser muy frágil y reducir su resistencia. De lo contrario cuando es totalmente limpio, es un método más ecológico de los tres presentados, ya que no cuenta con productos químicos y solo se utiliza electrones de alta energía para separar los enlaces de carbono – hidrogeno y facilitar el entrecruzamiento. Reticulación mayor al 60% (“*Tecnología de los plásticos*,”, 2012, párr.7)

**h. Aplicaciones en las tuberías según su clase.**

Las tuberías de PE tienen múltiples usos debido a las excelentes propiedades que posee.

Cada vez más se utilizan con mayor frecuencia en todos los países y en diferentes aplicaciones. En Europa el 50% del uso de estas tuberías es principalmente para el transporte de agua en obras civiles (abastecimiento, saneamiento y riego).

Algunas de las principales aplicaciones de las tuberías de PE son:

- ✓ Agua potable.
- ✓ Agua residuales en el sector Industrial y complejos petroquímicos.
- ✓ En proyectos de irrigación por goteo o aspersión.
- ✓ Para alcantarillados sanitarios, pluviales, combinados y descargas industriales.
- ✓ Distribución de gas doméstico.
- ✓ Transporte de material sólido.
- ✓ Transporte de afluentes del petróleo, en la refinación y en complejos petroquímicos.
- ✓ Drenajes submarinos.
- ✓ Sistemas de dragado.
- ✓ Subconducto para cables y fibras ópticas.
- ✓ Instalaciones sin apertura de zanja.

### i. Clases según su uso.

Según la aplicación al que vayamos a destinar las tuberías se pueden diferenciar 4 clases (según la Norma ISO 10.508):

Clase 1: Tuberías para suministro de agua caliente sanitaria a 60°c.
Clase 2: Tuberías para suministro de agua caliente sanitaria a 70°c.
Clase 3: Tuberías para calefacción por suelo radiante y radiadores a baja temperatura.
Clase 4: Tuberías para calefacción por radiadores de alta temperatura
(*VENETO SAC*, 2017, párr.3)

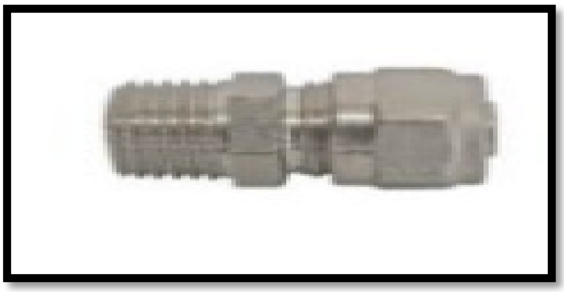
### j. Aplicaciones en los accesorios.

Los accesorios para los tubos PEX se aplican según su uso, las cuales pueden ser para instalaciones de:

- ✓ Gas
- ✓ Irrigación
- ✓ Lugares con presencia de sulfatos (casas de playas o buques)
- ✓ Agua potable (fría y caliente)

(*VENETO SAC*, 2017, párr.25)

En esta investigación nos basamos en las instalaciones para agua potable, por lo tanto los accesorios que tenemos para esto son:



Racor con fácil instalación (Multi fit), solo se ajusta con alicate.

***Figura 4.*** Racor recto macho**.** Recuperado de http:// www.veneto.com

Multi Fit con salida hembra, igual solo se usa alicate.

***Figura 5.*** Racor recto hembra. Recuperado de http:// www.veneto.com

Racor con salida hembra universal, usando llave allen.

***Figura 6.*** Adaptador Universal Hembra. Recuperado de http:// www.veneto.com

Tee con salidas Multi fit.

***Figura 7.*** Tee de Unión**.** Recuperado de http:// www.veneto.com

Tee con salida Multi fit a los laterales y punto de salida para grifería.

***Figura 8.*** Tee salida Hembra**.** Recuperado de http:// www.veneto.com

Tee con punto de salida hembra y laterales machos.

***Figura 9.*** Tee M – H – M**.** Recuperado de http:// www.veneto.com

Codo con puntos de salida hembra, aunque también hay en M-M y H-H.

***Figura 10.*** Codo 90° Salida Hembra**.** Recuperado de http:// www.veneto.com

Codo con salida Multi fit y sallida hembra.

***Figura 11.*** Codo 90° M-H Multi Fit. Recuperado de http:// www.veneto.com

**k. Definiciones y conceptos básicos.**

✓ **Tricapa Flex**

Tubo de polietileno reticulado al que se le añade una capa de aluminio soldada a tope por láser y una capa exterior de polietileno reticulado que sirve como protección contra las agresiones mecánicas de corrosión. Existiendo en el mercado nacional de ½" hasta 4" de diámetro.

Alcanzando una resistencia a la presión de 10 bar (145 PSI) a una temperatura constante de 90 ° C y 20 bar (290 PSI) a temperatura ambiente.

(*VENETO SAC*, 2017, párr.1)

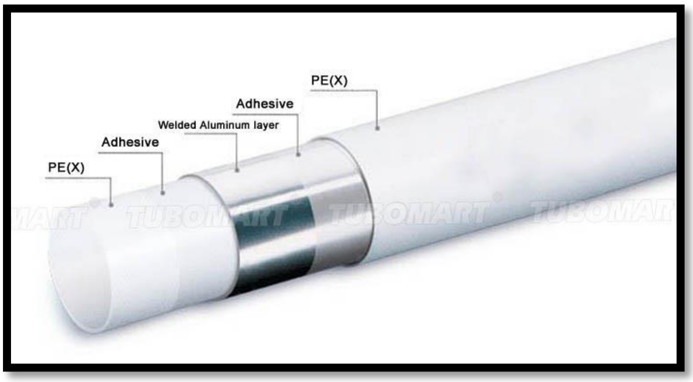
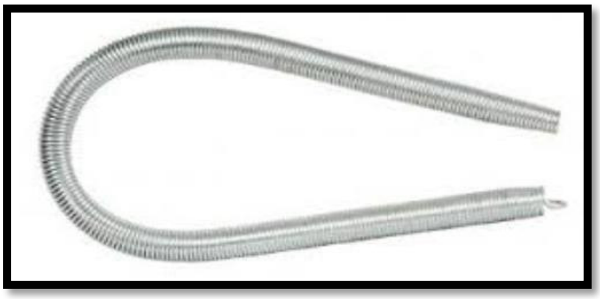



***Figura 12.*** Tricapa Flex. Recuperado de http:// www.veneto.com

**Equipos y Herramientas**

Equipo para hacer las curvas en frío de la tubería PEXb desde ½" hasta 1 ¼".

***Figura 13.*** Curvatubo. Recuperado de http:// www.veneto.com



Herramienta manual para hacer las curvas en frío de la tubería PEX desde ½" hasta ¾ ".

***Figura 14.*** Muelle doblador. Recuperado de http:// www.veneto.com

Herramienta para volver al diámetro inicial después del corte, y a la vez rebaba para la instalación de racores.

***Figura 15.*** Calibrador Desbarbador. Recuperado de http:// www.veneto.com

Ajusta los racores (uniones) a la tubería, para una correcta instalación.

***Figura 16.*** Llave inglesa o Alicate. Recuperado de http:// www.veneto.com

Ajusta correctamente los racores a las tuberías.

***Figura 17.*** Llave Allen. Recuperado de http:// www.veneto.com

Corta fácil y sin residuos a la tubería.

***Figura 18.*** Cortatubo. Recuperado de http:// www.veneto.com


Máquina de prensar, para un tipo más de instalación. Es de uso exclusivo para las instalaciones de gas, pero también se puede usar en las de agua. Solo que el costo es más elevado.

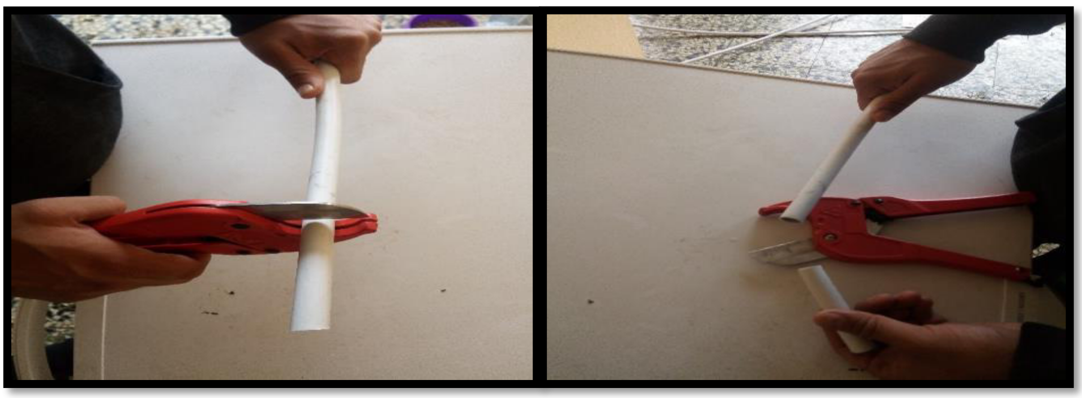
***Figura 19.*** Máquina de Prensar. Recuperado de http:// www.veneto.com

## <u>Tipos de instalación</u>

- **Instalación con Llave Allen (Racor)**

Paso 1. Cortar la tubería

***Fotografía 1.*** *Corte del PEXb*.



[Fotografía elaborada por los autores]. (Lima. 2017)

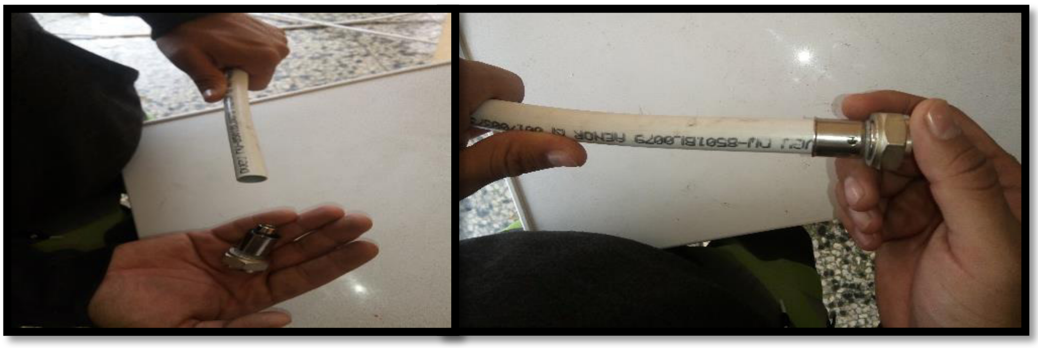
Paso 2. Calibrar y desbarbar en el corte

***Fotografía 2.*** Calibración y desbarbado en el corte.

[Fotografía elaborada por los autores]. (Lima. 2017)

Paso 3. Colocar el racor

***Fotografía 3.*** Colocación del racor.



[Fotografía elaborada por los autores]. (Lima. 2017)

Paso 4. Ajustar con Llave Allen, hasta que se note la tubería en el agujero

***Fotografía 4.*** Ajuste del racor a la tubería con la Llave Allen.

[Fotografía elaborada por los autores]. (Lima. 2017)

- **Instalación con llave inglesa o alicate (Multi Fit)**

Paso 1. Cortar la tubería

***Fotografía 5.*** Corte de tubería con el cortatubo.

[Fotografía elaborada por los autores]. (Lima. 2017)

Paso 2. Calibrar y desbarbar en el corte

***Fotografía 6.*** Calibración y desbarbado en el corte.

[Fotografía elaborada por los autores]. (Lima. 2017)

Paso 3. Colocar el Multi Fit

***Fotografía 7.*** Unión del Multi Fit al Pexb.

[Fotografía elaborada por los autores]. (Lima. 2017)

Paso 4. Ajustar con el alicate

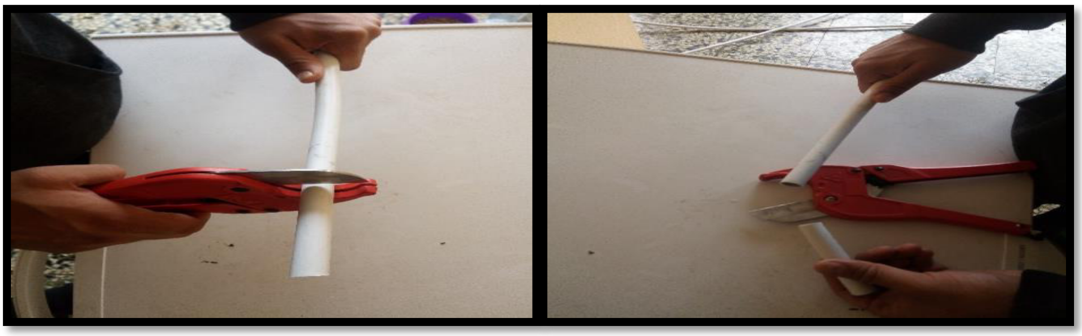
***Fotografía 8.*** Ajuste del Multi Fit con el alicate.

[Fotografía elaborada por los autores]. (Lima. 2017)

- **Instalación a Prensar**

Paso 1. Cortar la tubería

***Fotografía 9.*** Corte de tubería con el cortatubo.



[Fotografía elaborada por los autores]. (Lima. 2017)

Paso 2. Calibrar y desbarbar en el corte

***Fotografía 10.*** Calibración y desbarbado en el corte.

[Fotografía elaborada por los autores]. (Lima. 2017)

Paso 3. Colocar el racor en el corte y unirlos con la maquina prensadora

***Fotografía 11.*** Tubería Prensada.


[Fotografía elaborada por los autores]. (Lima. 2017)

**l. Ventajas del PEX**

- ✓ Precio más económico.
- ✓ Reduce el uso de accesorios, por ende reduce los errores de instalación.
- ✓ Transporte (flete) más fácil y económico, un rollo de 100 mt. De ½" tiene un diámetro de 55cm, 25cm de alto y un peso de 10.5kg.
- ✓ Garantizado para 50 años de uso.
- ✓ Es reutilizable.
- ✓ Su fácil instalación hace que se ahorre tiempo en su instalación y mano de obra.
- ✓ Es maleable, curvatura en frío que mantiene su forma una vez dada la curva.
- ✓ El riesgo que se rompa ante un sismo es casi nula, por su flexibilidad.
- ✓ No necesita pegamento para las uniones, lo que reduce los peligros a la salud humana.
- ✓ Las pruebas hidráulicas son instantáneas.

(VENETO SAC, 2017, párr.11)

### 2.2.2. Policloruro de Vinilo (PVC)

#### a. Historia del PVC

Al termino del siglo XIX, se encontró un compuesto químico que tuvo una reacción fuertemente con la luz solar que dio como resultado un material solido blanco, este compuesto químico y orgánico fue llamado cloruro de vinillo, esta reacción que tiene el compuesto se llama polimerización simple del PVC. Luego los alemanes en 1920 aproximadamente decidieron investigar e indagar más sobre el PVC y su comercialización.

Durante la segunda guerra mundial al ser destruidos todos los sistemas de agua y alcantarillados en Alemania, los científicos e ingenieros de este país decidieron crear la industria de PVC. (“Duran”, 2012, párr.2)

#### b. Definición del PVC

El policloruro de vinilo o PVC, es la unión de tres componentes químicos carbono, hidrógeno y cloro. Esta combinación de los componentes, resulta un material que bajo a los efectos del calor se reblandece, y puede así moldearse fácilmente; al enfriarse recupera la consistencia inicial y conserva la nueva forma. (*Industrias JQ SA*, 2016, párr.1)

***Figura 20.*** Tubería PVC. Recuperado de http://s2.accesoperu.com

### c. Composición del PVC

El PVC es un material que está compuesta por resina sintética más compleja, difícil de formular y procesar, pues requiere de un número importante de ingredientes y un balance adecuado de estos para poder transfórmalo al producto final deseado.

La resina de PVC está compuestos químicos por 43% de petróleo y 57% de sal común. Del refino del petróleo se obtiene una sustancia gaseosa, el etileno, una de las bases para la fabricación del PVC. Mediante la polimerización del monómero VCM en reactores, en condiciones adecuadas de presión y temperatura, se obtiene el polímero Poli cloruro de vinilo (PVC).

("*Composición del PVC*", 2005, párr.4)

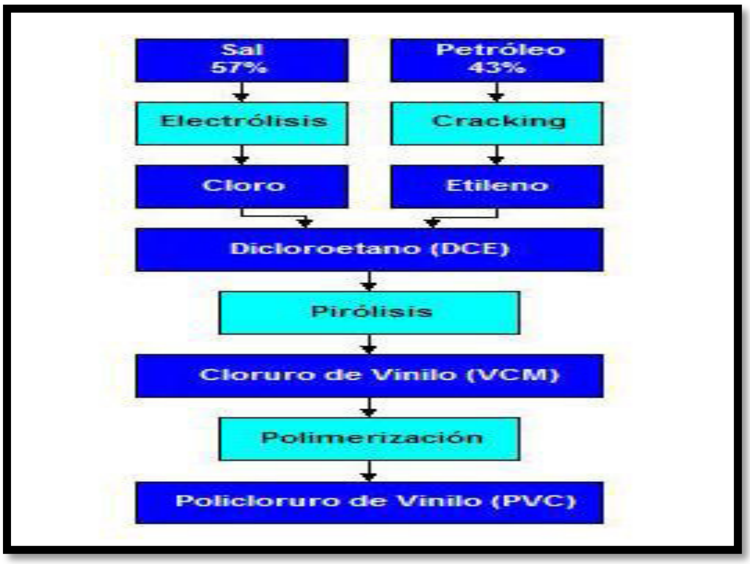



***Figura 21.*** Proceso y composición del PV. Recuperado de http://plomyplas.com

### d. Características de PVC

- ✓ Rango de temperatura de trabajo -15ºC +60ºC.
- ✓ Resistencia, rigidez y dureza mecánicas elevadas.
- ✓ Buen aislante eléctrico.
- ✓ Elevada resistencia a sustancias químicas.
- ✓ Autoextingible.
- ✓ Impermeable a gases y líquidos.
- ✓ Mínima absorción de agua.
- ✓ Resistente a la acción de hongos, bacterias, insectos y roedores.
- ✓ Fácil de pegar y soldar Resistente a la intemperie (sol, lluvia, viento y aire marino).
- ✓ Resistente al fuego.

(*Industrias JQ SA*, 2016, párr.7)

### e. Principales accesorios del PVC

Entre los accesorios básicos de PVC encontramos:

- ✓ Tees: Permite la unión de tres tuberías en forma de Tee.
- ✓ Tee doble: Permite la unión de cuatro tuberías en forma de cruz.
- ✓ Tees reducidas: Permite la unión de tres tuberías, una de estas de menos diámetro, en forma de Tee.
- ✓ Codos 90°: Permite la unión de dos tuberías en una posición de 90°.
- ✓ Codos 45°: Permite la unión de dos tuberías en una posición de 45°
- ✓ Uniones: Permite la unión de dos tuberías que están en la misma posición.
- ✓ Adaptadores Macho y hembra: Permite la unión de dos tuberías de diferente tipo de compatibilidad sea lisa y roscados o viceversa.
- ✓ Unión universal
- ✓ Reducciones: Permite la reducción un diámetro de tubería a otro.

(*Pavco*, 2016, párr.9)

#### f. Tuberías de PVC según su clase

Las tuberías para conducción de fluidos de PVC se fabrican de cuatro tipos de acuerdo a la norma técnica peruana 399.002 que soportan presiones nominales que son:

- ✓ Clase 5 (C5), o presión nominal 5 (PN5), lo que significa que soporta 5 bar o su equivalente a 72.5 PSI.
- ✓ Clase 7.5 (C7.5), o presión nominal 7.5 (PN7.5), lo que significa que soporta 7.5 bar o su equivalente a 108.8 PSI.
- ✓ Clase 10 (C10), o presión nominal 10 (PN10), lo que significa que soporta 10 bar o su equivalente a 145 PSI. Siendo esta clase la que se utiliza en las instalaciones de agua potable, por lo tanto es la clase con la que realizamos los ensayos en esta investigación.
- ✓ Clase 15 (C15), o presión nominal 15 (PN15), lo que significa que soporta 15 bar o su equivalente a 217.5 PSI.

## 2.3. Términos básicos

- ✓ **PEX - AL - PEX**, Polietileno Reticulado – Aluminio- Polietileno Reticulado.
- ✓ **Polietileno reticulado,** El polietileno reticulado, conocido por sus abreviaturas como PEX o XLPE, es una forma de polietileno con reticulaciones. Se utiliza para fabricar tubos y mangueras, y es sumamente utilizado en la construcción de sistemas de calefacción radiante que utilizan agua, cañerías de agua domésticas y aislamiento para cables eléctricos de alta tensión.
- ✓ **Reticulación,** es una reacción química por la que los polímeros se unen en cadenas tridimensionalmente formando una especie de red. Tras esta reacción, las propiedades químicas del polímero inicial cambian.

  En el caso de los materiales plásticos que usamos para aislar y cubrir nuestros cables, el proceso de reticulación les otorga termoestabilidad**.**

- ✓ **Termoplástico,** es un adjetivo que permite calificar al material que resulta maleable ante el calor. En otras palabras: un termoplástico, al encontrarse a una temperatura elevada, pierde su estado rígido y se deforma.

- ✓ **Termoestable,** Que no se altera fácilmente por la acción del calor.
- ✓ **Aluminio,** El aluminio es un elemento químico, de símbolo Al y número atómico 13. Se trata de un metal no ferromagnético.
- ✓ **PVC,** Material termoplástico obtenido del cloruro de vinilo, cuyo residuo presenta problemas de contaminación.
- ✓ **Rugosidad,** Es un coeficiente adimensional que depende de la rugosidad, grado de suciedad y diámetro de la tubería.

## 2.4. Formulación de hipótesis

### 2.4.1. Hipótesis general

- El análisis comparativo de parámetros entre tuberías PEXb y tuberías de PVC incide para el eficiente uso en instalaciones de agua potable en el edificio multifamiliar Vitalia.

### 2.4.2. Hipótesis específica

- La realización de ensayos incide para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a la **calidad** entre tuberías PEXb y tuberías de PVC.

- La realización del análisis de rendimiento incide para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a **tiempo** entre tuberías PEXb y tuberías de PVC.

- La realización del metrado y análisis de presupuesto incide para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a **costo** entre tuberías PEXb y tuberías de PVC.

# CAPÍTULO III: METODOLOGÍA

## 3.1. Tipo de investigación

Nuestra investigación es ***mixta***, con el fin de cuantificar resultados de laboratorio y analizar las características de cada material según la calidad.

## 3.2. Nivel de investigación

Inicialmente será descriptiva (por el objetivo de la misma) y explicativa posteriormente.

## 3.3. Diseño de la investigación

***Experimental***, porque realizamos ensayos para llegar al objetivo principal.

***Transversal***, se aplica en un solo caso de estudio.

## 3.4. Método de la investigación

La investigación es descriptiva comparativa, se describirán los procesos (ensayos de laboratorio) de cada variable dependiente y análisis comparativo de las variables independientes.

## 3.5. Operacionalización de las variables

### 3.5.1. Variable Independiente.

**Tipo de tubería**, es de tipo cualitativo nominal. Es independiente porque podemos hacer una instalación de agua potable y podemos usar cualquiera de los dos tubos (PEXb y PVC) y la función principal al final es el fluido del agua.

### 3.5.2. Operacionalización de la V.I.

**Tabla 1.** *Operacionalización de la V.I.*

| Variable | Definición conceptual | Categoría | Indicadores | Medición |
|---|---|---|---|---|
| Tipo de Tubería | Describir las características y comportamiento de cada tipo de tubería | Estudio Comparativo | Calidad | Nominal |
| | | | Tiempo | |
| | | | Costo | |

***Fuente***. *Elaborado por los autores.*

### 3.5.3. Variable Dependiente

**Calidad, tiempo y costo**, son de tipo cualitativo ordinal, dependiente porque dependen del tipo tubería que usemos para la instalación de agua potable.

### 3.5.4. Operacionalización de la V.D.

**Tabla 2.** *Operacionalización de la V.D.*

| Variable | Definición conceptual | Categoría | Indicadores | Medición |
|---|---|---|---|---|
| Calidad | Comparar mediante ensayos la resistecia y salubridad de cada tubería. | Estudio Comparativo | Ensayo de Presión<br>Ensayo de Impacto<br>Ensayo de Tracción<br>Analisis de agua para consumo humano: agua potable | Ordinal |
| Tiempo | Medir el tiempo usado en cada instalación por cada tubería. | Estudio Comparativo | Flexibilidad<br>Cantidad de usos<br>Instalación | Ordinal |
| Costo | Analizar el beneficio costo, llegando a saber quien produce más ahorro. | Estudio Comparativo | Mano de Obra<br>Material<br>Mantenimiento<br>Transporte (flete) | Ordinal |

***Fuente***. *Elaborado por los autores.*

### 3.6. Caso de investigación

Para la presente investigación se tomara el caso de Edificio Multifamiliar Vitalia. El edificio multifamiliar Vitalia se encuentra ubicado en la Avenida Velasco Astete N° 295, distrito de San Borja y provincia y departamento de Lima.
El terreno figura inscrito con un área total de 837 m2.
Consta de una azotea, 4 pisos (4 departamentos por piso), un semisótano (3 departamentos), tres sótanos (cocheras).


*Figura 22.* Edificio Multifamiliar Vitalia. Recuperado de http://inarco.com

### 3.7. Instrumentos de recolección de datos

Para recolectar datos y poder hacer el estudio comparativo, nos basamos en tres parámetros (calidad, tiempo y costo) para lo cual se trabajó de la siguiente manera:

Para **calidad**, se realizó ensayos, los cuales se mencionan a continuación:

**Tabla 3.** *Ensayos y Análisis*

| Ensayo | Lugar de realización |
|---|---|
| **De Presión Sostenida** | Campo |
| **De Tracción a Tubo Completo** | Pontificia Universidad Católica del Perú |
| **De Resistencia al Impacto** | Campo |
| **Análisis del agua, con fines de consumo humano: Agua Potable** | Universidad Agraria La Molina |

***Fuente***. *Elaborado por los autores.*

Para ***costo***, se realizó el presupuesto de la partida de instalaciones sanitarias (Metrados y Análisis de Precios Unitario) del edificio multifamiliar VITALIA, ubicado en Av Velasco Astete 925, San Borja – Lima, para lo cual usamos los planos de Instalaciones Sanitarios que consta de:

- 1 azotea
- 4 pisos (4 departamentos por piso)
- 1 semisótano (3 departamentos)
- 3 sótanos (cochera)
- Área total: 837m2 (18m x 46.5 m)

Para **tiempo,** se analizó el rendimiento (tiempo de instalación, cantidad de puntos de salida en un tiempo determinado), del edificio multifamiliar VITALIA, y también el tiempo con el que se terminó de instalar el ejemplo de una instalación de un baño completo que se realizó para el ensayo de Presión Sostenida.

# CAPÍTULO IV: PRESENTACIÓN DE RESULTADOS

## 4.1. Contrastación de hipótesis

### 4.1.1. Hipótesis general

**Hipótesis alterna (Ha)**

- El análisis comparativo de parámetros entre tuberías PEXb y tuberías de PVC **incide** para el eficiente uso en instalaciones de agua potable en el edificio multifamiliar Vitalia.

**Hipótesis nula (H0)**

- El análisis comparativo de parámetros entre tuberías PEXb y tuberías de PVC **no incide** para el eficiente uso en instalaciones de agua potable en el edificio multifamiliar Vitalia.

### 4.1.2. Hipótesis específicas

**Hipótesis específica 1:**

Hipótesis alterna 1 (H1)

- La realización de ensayos **incide** para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a la calidad entre tuberías PEXb y tuberías de PVC.

Hipótesis nula 1 (H0)

- La realización de ensayos **no incide** para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a la calidad entre tuberías PEXb y tuberías de PVC.

**Hipótesis específica 2:**

Hipótesis alterna 2 (H2)

- La realización del análisis de rendimiento **incide** para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a tiempo entre tuberías PEXb y tuberías de PVC.

Hipótesis nula 2 (H0)

- La realización del análisis de rendimiento **no incide** para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a tiempo entre tuberías PEXb y tuberías de PVC.

**Hipótesis específica 3**

Hipótesis alterna 3 (H3)

- La realización del metrado y análisis de presupuesto **incide** para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a costo entre tuberías PEXb y tuberías de PVC.

Hipótesis nula 3 (H0)

- La realización del metrado y análisis de presupuesto **no incide** para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a costo entre tuberías PEXb y tuberías de PVC.

### 4.2. Análisis e interpretación de los resultados

#### 4.2.1. Ensayo de Presión sostenida

En este ensayo, lo que se halló es la presión que pueden resistir las tuberías en un tiempo de 4 horas, viendo si esa presión se mantiene al final de las 4 horas.

Para el desarrollo de este ensayo se utilizó una Bomba Hidráulica, para lo cual simuló un baño completo (ducha, lavamano e inodoro), para cada tipo de tubería. Este ensayo se realizó en campo.

***Figura 23.*** *Bomba Hidráulica. Elaborado por los autores.*

Esta bomba hidráulica tiene una capacidad máxima de 20 bar o su equivalente que es 290 PSI.

## Ensayo de Presión Sostenida con PVC

### Materiales usados

*Figura 24.* Tubería PVC. *Elaborado por los autores.*

Tubería PVC ½” – Clase 10

*Figura 25.* Accesorios PVC. *Elaborado por los autores.*

Accesorios de PVC:

- Tee ½”
- Codo ½”
- Tapones Hembra ½”


*Figura 26.* Herramientas. *Elaborado por los autores.*

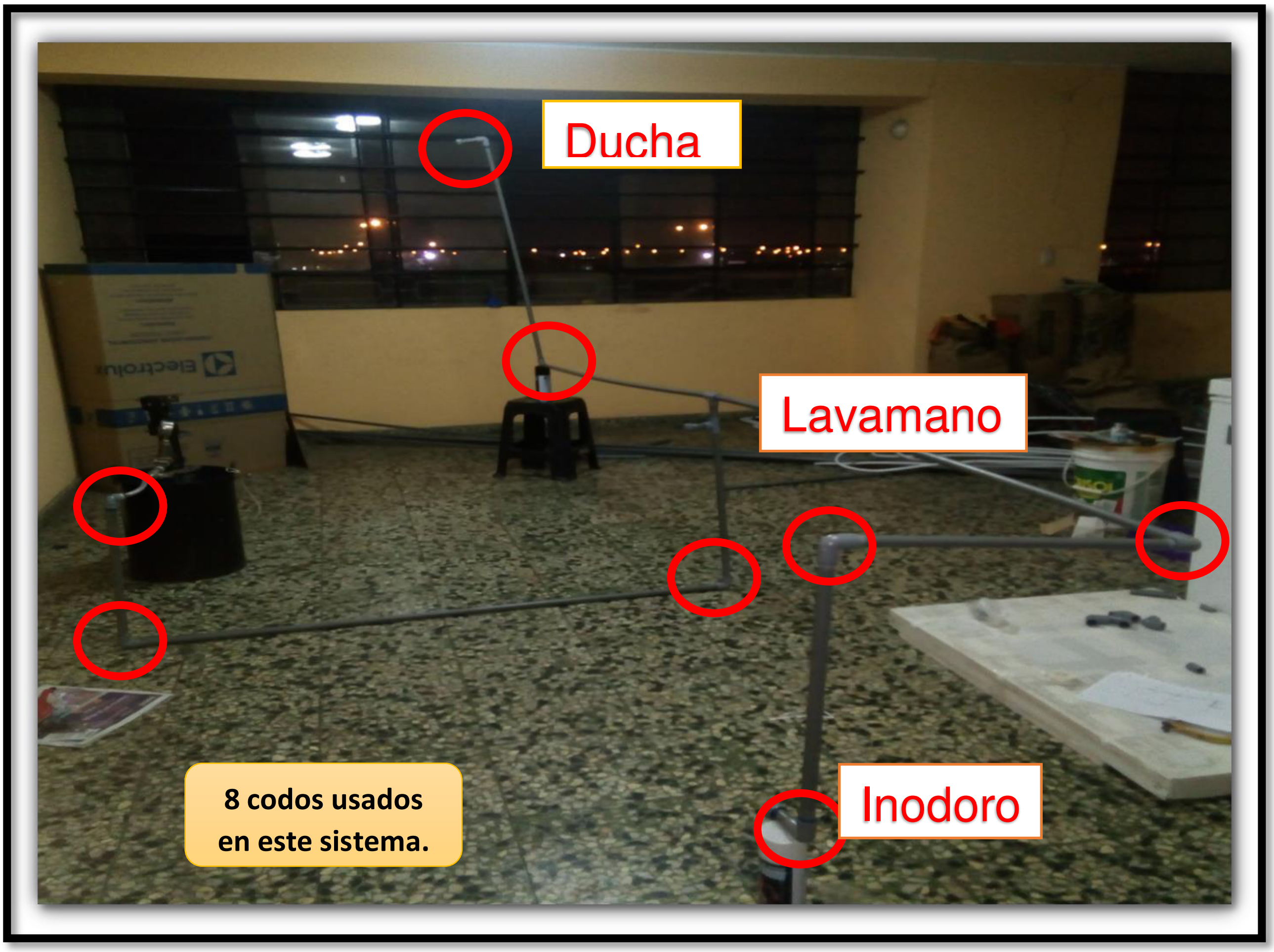
- Hoja de sierra
- Wincha
- Lija

- Pegamento
- Teflón

***Figura 27.*** Selladores. *Elaborado por los autores.*

## Simulación de Baño Completo

***Fotografía 12.*** Isométrico de baño completo (PVC).




[Fotografía elaborada por los autores]. (Lima. 2017)

En la simulación de este baño el tiempo que se empleó para la instalación fue de 38.45 minutos, mostrado a continuación:

***Fotografía 13.*** Tiempo inicio y final de la instalación del baño completo (PVC).


[Fotografía elaborada por los autores]. (Lima. 2017)

**Resultados**

Acabada la instalación del baño completo, se procede a bombear el agua mediante la bomba hidráulica a través del sistema simulado, con una Presión Inicial igual a cero.

***Fotografía 14.*** Bomba hidráulica con Presión igual a 0 bar.

**Pi = 0 bar = 0 PSI**

[Fotografía elaborada por los autores]. (Lima. 2017)

Una vez llegada a la presión máxima se deja de bombear, y se espera un tiempo de 4 horas para observar si la presión dada en ese momento varía.

***Fotografía 15.*** Bomba hidráulica con Presión igual a 11 bar.


**P1 = 11 bar = 159.5 PSI**

[Fotografía elaborada por los autores]. (Lima. 2017)

Pasada las 4 horas se puede observar que la presión ha disminuido, por lo tanto se puede decir que ha tenido una pérdida de presión.

***Fotografía 16.*** Bomba hidráulica con Presión igual a 10 bar.

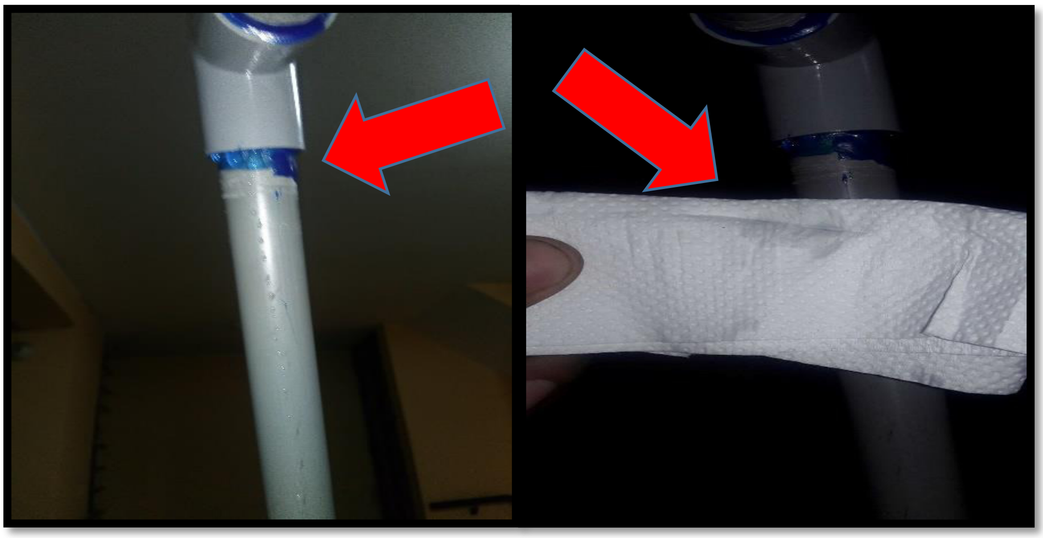

**P2 = 10 bar = 145 PSI**

[Fotografía elaborada por los autores]. (Lima. 2017)

**Falla**

En el transcurso de las 4 horas (tiempo en que se produce la pérdida de carga) se observa que en el codo del punto salida de la ducha se produce goteos.

***Fotografía 17.*** Falla por goteo en el punto de salida de la ducha.



[Fotografía elaborada por los autores]. (Lima. 2017)

## Ensayo de Presión Sostenida con PEXb

### Materiales usados

*Figura 28.* Tubería PEXb. *Elaborado por los autores.*

Tubería PEXb ½” – Clase 5

*Figura 29.* Accesorios PEXb. *Elaborado por los autores.*

Accesorios:

- Tee ½”
- Racor ½”
- Tapones Macho ½”

*Figura 30.* Herramientas para PEXb. *Elaborado por los autores.*

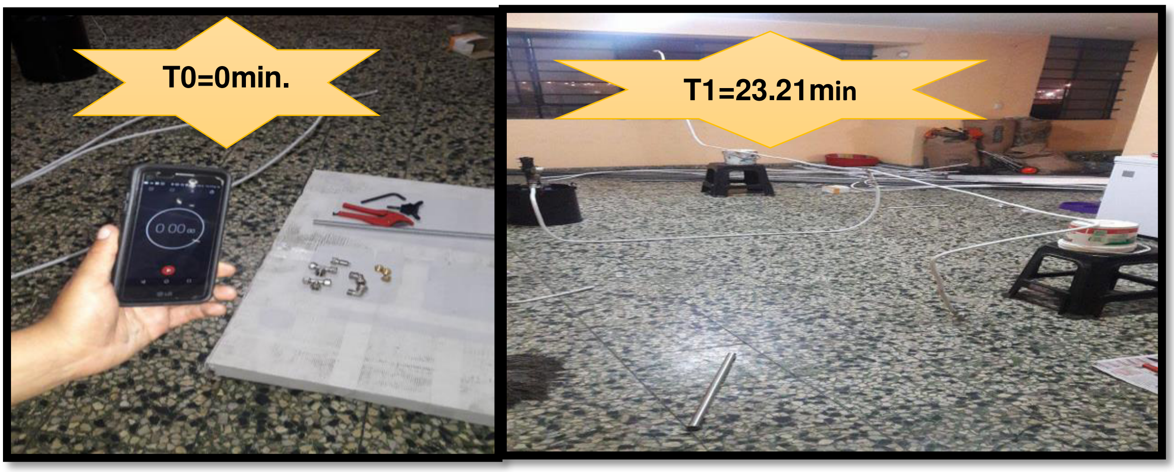
- Cortatubo
- Calibrador y Desbarbador
- Llave Allen
- Muelle doblador 1/2”

**Simulación de Baño Completo**

***Fotografía 18.*** Isométrico de baño completo (PEXb).


En la simulación de este baño el tiempo que se empleó para la instalación fue de 23.21 minutos, mostrado a continuación:

***Fotografía 19.*** Tiempo inicio y final de la instalación del baño completo (PEXb).




[Fotografía elaborada por los autores]. (Lima. 2017)

**Resultados**

Acabada la instalación del baño completo, se procede a bombear el agua mediante la bomba hidráulica a través del sistema simulado, con una Presión Inicial igual a cero.

***Fotografía 20.*** Bomba hidráulica con Presión igual a 0 bar.

**Pi = 0 bar = 0 PSI**

[Fotografía elaborada por los autores]. (Lima. 2017)

Una vez llegada a la presión máxima se deja de bombear, y se espera un tiempo de 4 horas para observar si la presión dada en ese momento varía.

***Fotografía 21.*** Bomba hidráulica con Presión igual a 20 bar.

**P1 = 20 bar = 290 PSI**

[Fotografía elaborada por los autores]. (Lima. 2017)

Pasada las 4 horas se puede observar que la presión se mantiene constante, por lo tanto se puede decir que no ha tenido pérdida de presión.

***Fotografía 22.*** Bomba hidráulica con Presión igual a 20 bar.


**P2 = 20 bar = 290 PSI**

[Fotografía elaborada por los autores]. (Lima. 2017)

### 4.2.2. Ensayo de Tracción a tubo Completo

En este ensayo se determinó la resistencia mecánica de la tubería de PVC y la tubería PEXb, las muestras son sometidas a esfuerzo de tracción mono axial hasta llegar a la rotura. En esta prueba se utilizó la norma ASTM D638 - Standard Test Method for Tensile Properties of Plastics y fue realizada por el Laboratorio de Materiales (LabMat) de la Facultad de Ingeniería Mecánica de la Pontificia Universidad Católica del Perú.

Se entregaron 4 muestras a disposición (2 muestras de PEXb y 2 muestras de PVC).

***Fotografía 23.*** Muestras de tuberías enviadas al LabMat - PUCP.

[Fotografía elaborada por los autores]. (Lima. 2017)

**Resultados**

Los resultados que dieron las pruebas de laboratorio son el promedio de las 2 muestras de cada tipo de tubería que se mostrará a continuación.

**PEXb**

| MUESTRA | | PROMEDIO | DESVIACIÓN ESTÁNDAR |
|---|---|---|---|
| Módulo elástico (MPa) | | --- | --- |
| Esfuerzos (MPa) | Fluencia | 32,3 | 1,9 |
| | Rotura | 31,9 | 1,5 |
| Alargamiento (%) | Fluencia | 12 | 0,0 |
| | Rotura | 15 | 4 |

***Figura 31.*** Resultados Promedios (PEXb). Elaborado por el Laboratorio de la PUCP

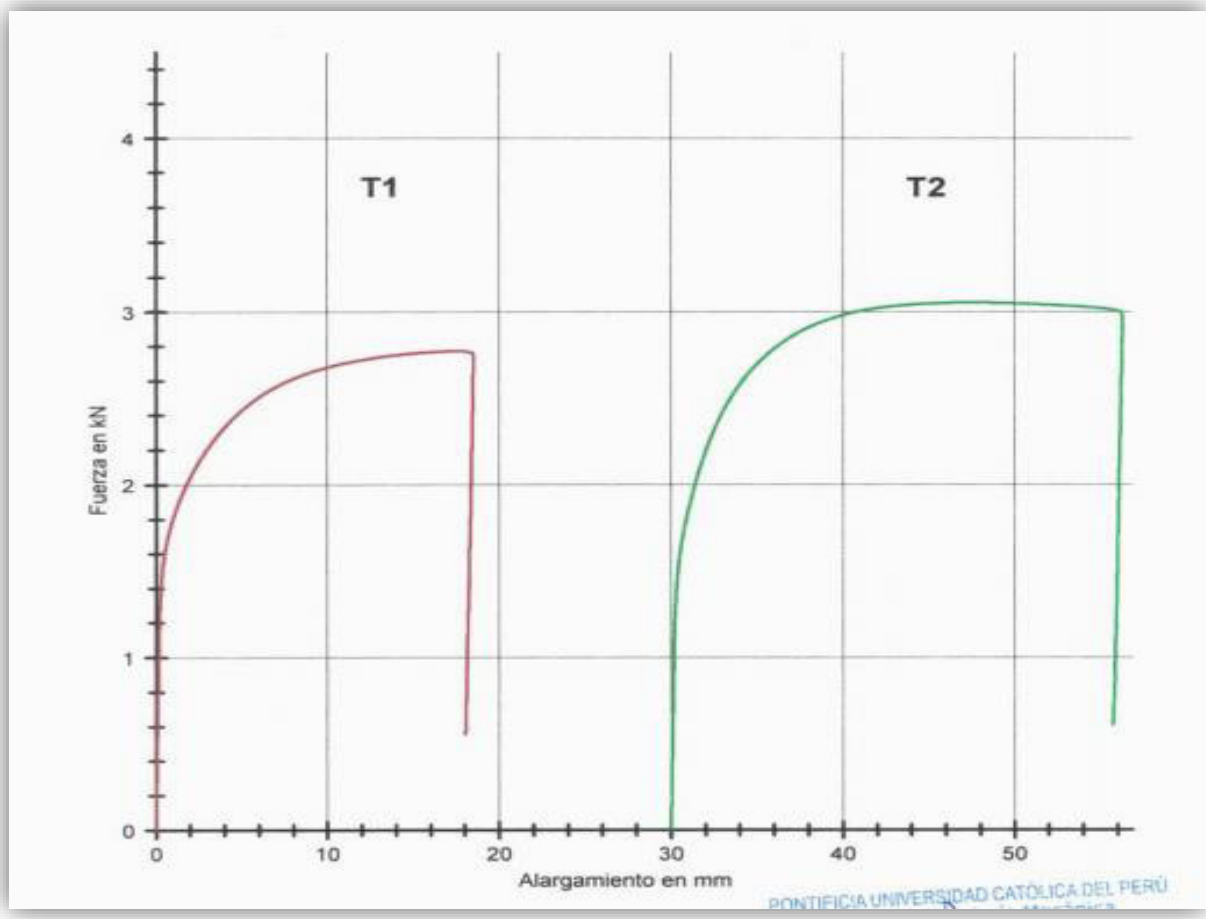



***Figura 32.*** Diagrama Fuerza vs Alargamiento (PEXb). Elaborado por el Laboratorio de la PUCP.

**PVC**

| MUESTRA | | PROMEDIO | DESVIACIÓN ESTÁNDAR |
|---|---|---|---|
| Módulo elástico (MPa) | | --- | --- |
| Esfuerzos (MPa) | Fluencia | 39,2 | 3,9 |
| | Rotura | 38,8 | 0,5 |
| Alargamiento (%) | Fluencia | 2,9 | 0,1 |
| | Rotura | 52 | 66 |

***Figura 33.*** Resultados Promedios (PVC). Elaborado por el Laboratorio de la PUCP.

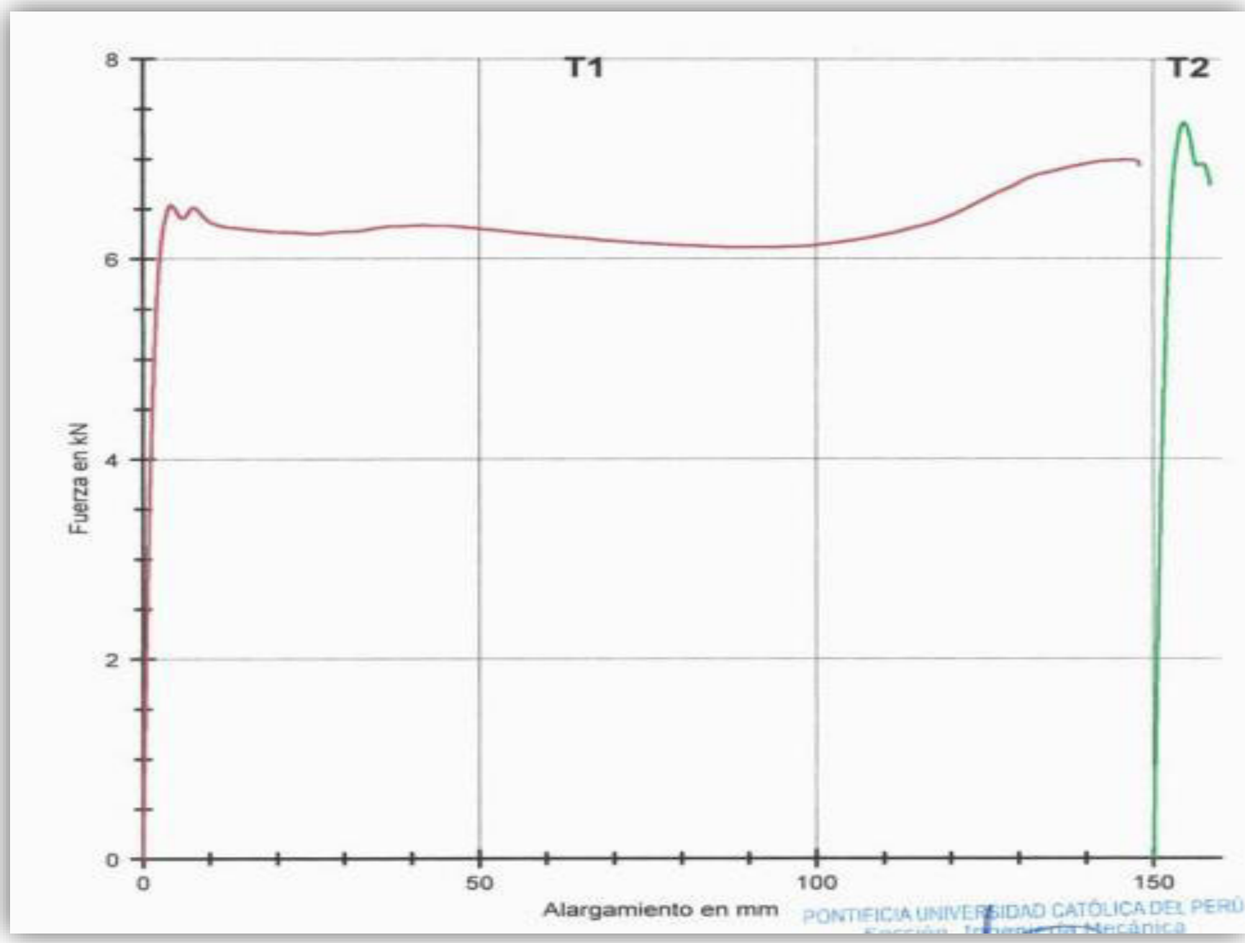



**Figura 34.** Diagrama Fuerza vs Alargamiento (PVC). Elaborado por el Laboratorio de la PUCP.

#### 4.2.3. Ensayo de Resistencia al Impacto

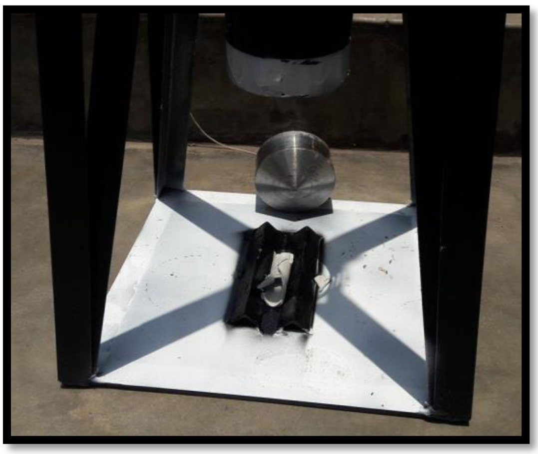
En este ensayo lo que se busca es hallar es el valor de la fuerza cinética con que se rompe la tubería de PVC y PEXb al ser sometidas a dos masas y alturas diferentes. Por limitaciones económicas mencionadas anteriormente lo realizamos en campo, diseñando un sistema similar y respetando lo normado en el ASTM D2444.

***Fotografía 24.*** Sistema para hallar Resistencia al impacto.

* Altura: 1.70 mt.
* Tubo cilíndrico de acero
* Base de caída: 30cm x 30 cm

[Fotografía elaborada por los autores]. (Lima. 2017)

***Fotografía 25.*** Base del sistema.



[Fotografía elaborada por los autores]. (Lima. 2017)

**Masas**

***Fotografía 26.*** Masa 1 de 2.70kg.


[Fotografía elaborada por los autores]. (Lima. 2017)

***Fotografía 27.*** Masa 2 de 5.40kg.


[Fotografía elaborada por los autores]. (Lima. 2017)

## Fórmulas

Como lo que se desea hallar es la Energía con la que se rompen las tuberías, entonces lo hallamos mediante las siguientes fórmulas:

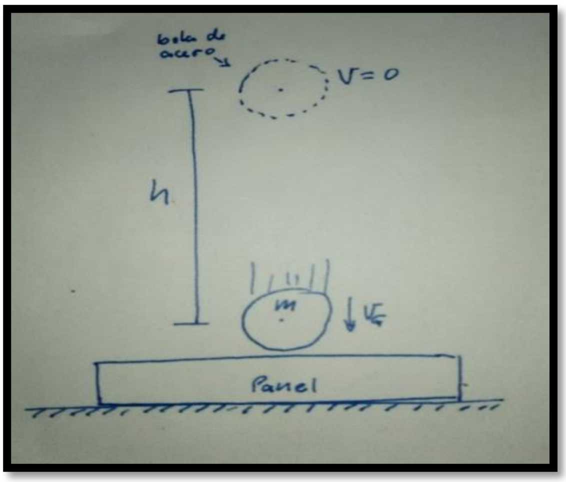



***Figura 35.*** Diseño del sistema. *Elaborado por los autores.*

Primero se halla la velocidad, con la que cae la masa sobre el material, y con este valor se halla la Energía con la que impacta al material (Energía Cinética).

$$V = \sqrt{2 \, x \, g \, x \, h}$$

$$Ek = \frac{1}{2} x \, m \, x \; V^2$$

Donde:

V: Velocidad (m/s)

g: Gravedad (m/s2)

h: Altura (m)

m: Masa (kg)

Ek: Energía cinética (J)

**Resultados**

**Masa 1 (2.70 kg.)**

***Tabla 4.*** *Resultados de PVC con masa 1.*

| | m1 | | | |
|---|---|---|---|---|
| | H (m) | V (m/s) | Ek (J) | |
| PVC | 0.30 | 2.43 | 7.95 | √ |
| | 0.50 | 3.13 | 13.24 | √ |
| | 0.70 | 3.71 | 18.54 | √ |
| | 1.00 | 4.43 | 26.49 | √ |
| | 1.15 | 4.75 | 30.46 | √ |
| | 1.16 | 4.77 | 30.72 | √ |
| | 1.17 | 4.79 | 30.99 | √ |
| | 1.18 | 4.81 | 31.25 | X |
| | 1.20 | 4.85 | 31.78 | X |
| | 1.25 | 4.95 | 33.11 | X |
| | 1.35 | 5.15 | 35.76 | X |
| | 1.40 | 5.24 | 37.08 | X |
| | 1.45 | 5.33 | 38.41 | X |
| | 1.50 | 5.42 | 39.73 | X |

***Fuente****. Elaborado por los autores.*

***Tabla 5.*** *Resultados de PEXb con masa 1.*

| | m1 | | | |
|---|---|---|---|---|
| | H (m) | V (m/s) | Ek (J) | |
| PEX | 1.18 | 4.81 | 31.25 | √ |
| | 1.25 | 4.95 | 33.11 | √ |
| | 1.50 | 5.42 | 39.73 | √ |
| | 1.60 | 5.60 | 42.38 | √ |
| | 1.70 | 5.78 | 45.03 | √ |

**Fuente**. Elaborado por los autores.

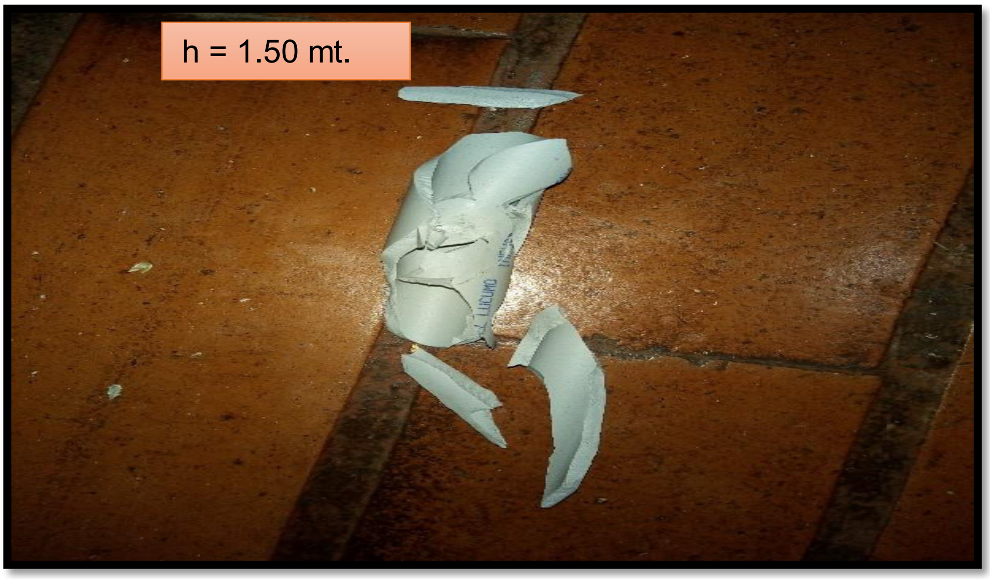
***Fotografía 28.*** Muestra de PVC (h=1.18mt).


[Fotografía elaborada por los autores]. (Lima. 2017)

***Fotografía 29.*** Muestra de PEXb (h=1.18mt).


[Fotografía elaborada por los autores]. (Lima. 2017)

***Fotografía 30.*** Muestra de PVC (h=1.50mt).




[Fotografía elaborada por los autores]. (Lima. 2017)

***Fotografía 31.*** Muestra de PEXb (h=1.70mt).


[Fotografía elaborada por los autores]. (Lima. 2017)

**Masa 2 (5.40 kg.)**

**Tabla 6.** *Resultados de PVC con masa 2.*

| | m2 | | | |
|---|---|---|---|---|
| PVC | H (m) | V (m/s) | Ek (J) | |
| | 0.20 | 1.98 | 10.59 | √ |
| | 0.30 | 2.43 | 15.89 | √ |
| | 0.40 | 2.80 | 21.19 | √ |
| | 0.45 | 2.97 | 23.84 | √ |
| | 0.50 | 3.13 | 26.49 | √ |
| | 0.51 | 3.16 | 27.02 | X |
| | 0.52 | 3.19 | 27.55 | X |
| | 0.55 | 3.28 | 29.14 | X |
| | 0.60 | 3.43 | 31.78 | X |
| | 0.80 | 3.96 | 42.38 | X |

**Fuente**. Elaborado por los autores.

**Tabla 7.** *Resultados de PEXb con masa 2.*

| | m2 | | | |
|---|---|---|---|---|
| PEX | H (m) | V (m/s) | Ek (J) | √ |
| | 0.51 | 3.16 | 23.01 | √ |
| | 0.80 | 3.96 | 36.10 | √ |
| | 1.00 | 4.43 | 45.13 | √ |
| | 1.50 | 5.42 | 67.69 | √ |
| | 1.70 | 5.78 | 76.71 | √ |

**Fuente**. Elaborado por los autores.

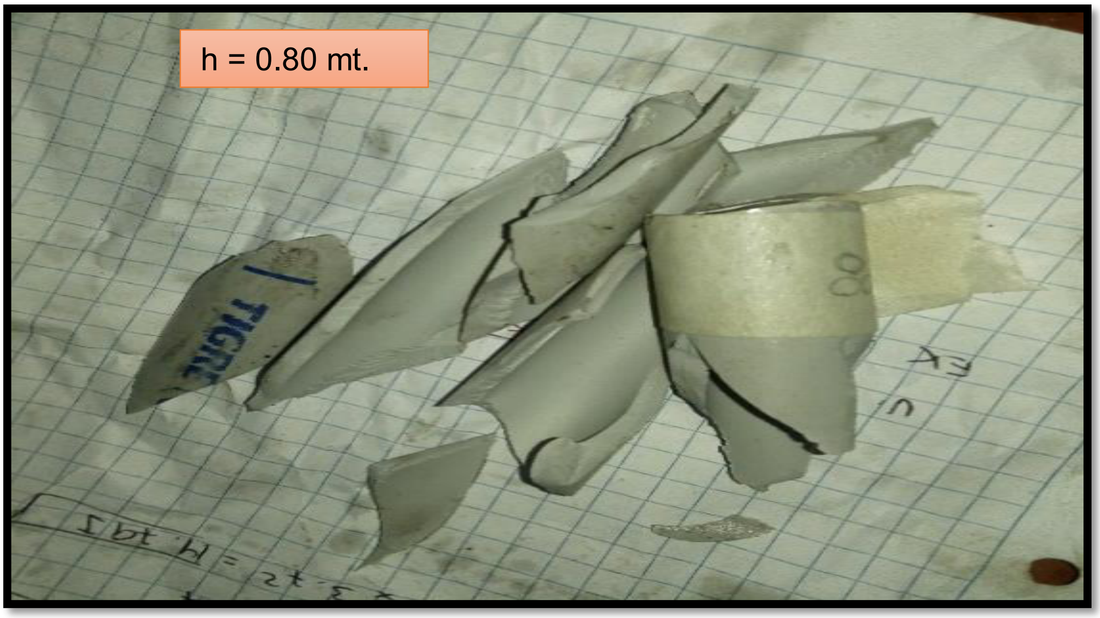
***Fotografía 32***. Muestra de PVC (h=0.51mt).


[Fotografía elaborada por los autores]. (Lima. 2017)

***Fotografía 33***. Muestra de PEXb (h=0.51mt).


[Fotografía elaborada por los autores]. (Lima. 2017)

***Fotografía 34***. Muestra de PVC (h=0.80mt).




[Fotografía elaborada por los autores]. (Lima. 2017)

***Fotografía 35***. Muestra de PEXb (h=1.70mt).


[Fotografía elaborada por los autores]. (Lima. 2017)

#### 4.2.4. Análisis del agua, con fines de consumo humano: Agua Potable

Se mandó a analizar 3 muestras de agua de 1 litro cada una al Laboratorio de Agua, Suelo, Medio Ambiente y Fertirriego de la Facultad de Ingeniería Agrícola de la Universidad Nacional Agraria La Molina para determinar si el agua que fluye a través de sistema de tuberías de cada material a temperatura de ebullición (100 °c) durante media hora es apta para el consumo humano.

Estas muestras son: muestra 1(antes de ingresar por las tuberías), muestra 2 (agua que fluyó por la red de tuberías PEXb) y la muestra 3 (agua que fluyó por la red de tuberías de PVC), cada red tiene 45 metros de longitud con sus respectivos accesorios que se verán a continuación.

**<u>Red de agua de PEXb</u>**

***Fotografía 36.*** Red de agua con tubería PEXb


[Fotografía elaborada por los autores]. (Lima. 2017)

## Red de agua de PVC

***Fotografía 37*****.** Red de agua con tubería PVC.


[Fotografía elaborada por los autores]. (Lima. 2017)

**Resultados**

**Tabla 8.** Muestra 1 (Antes del ingreso a las tuberías).

| **Nº LABORATORIO** | | **3793** |
|---|---|---|
| **N° DE CAMPO** | | **Muestra 1** |
| **Turbiedad** | **NTU** | **0.72** |
| **Sólidos Totales** | **mg/L** | **443.50** |
| **Hierro** | **mg/L** | **<0.08** |
| **Plomo** | **mg/L** | **0.020** |
| **Cobre** | **mg/L** | **<0.035** |
| **Cadmio** | **mg/L** | **<0.005** |
| **Manganeso** | **mg/L** | **<0.03** |
| **Zinc** | **mg/L** | **0.09** |
| **Boro** | **mg/L** | **0.30** |
| **Magnesio** | **mg/L** | **9.30** |
| **Sulfatos** | **mg/L** | **127.91** |
| **Cloruros** | **mg/L** | **48.01** |
| **Dureza Total** | **mg/$CaCO_3$/L** | **260.82** |
| **Alcalinidad Total** | **mg/$CaCO_3$/L** | **105.50** |
| **pH** | | **7.49** |
| **Nitratos** | **mg/L** | **1.33** |
| **Sodio** | **mg/L** | **27.30** |

***Fuente***. *Elaborado por el Laboratorio de Agua, Suelo, Medio Ambiente y Fertirriego de la Universidad Agraria La Molina*

**Tabla 9.** Muestra 2 (Salida de la tubería PEXb).

| Nº LABORATORIO | | 3794 |
|---|---|---|
| **N° DE CAMPO** | | **Muestra 2** |
| **Turbiedad** | **NTU** | **3.96** |
| **Sólidos Totales** | **mg/L** | **467.50** |
| **Hierro** | **mg/L** | **<0.08** |
| **Plomo** | **mg/L** | **0.021** |
| **Cobre** | **mg/L** | **<0.035** |
| **Cadmio** | **mg/L** | **<0.005** |
| **Manganeso** | **mg/L** | **<0.03** |
| **Zinc** | **mg/L** | **0.06** |
| **Boro** | **mg/L** | **0.32** |
| **Magnesio** | **mg/L** | **12.10** |
| **Sulfatos** | **mg/L** | **133.39** |
| **Cloruros** | **mg/L** | **43.90** |
| **Dureza Total** | **mg/$CaCO_3$/L** | **237.35** |
| **Alcalinidad Total** | **mg/$CaCO_3$/L** | **95.05** |
| **pH** | | **8.32** |
| **Nitratos** | **mg/L** | **1.64** |
| **Sodio** | **mg/L** | **28.40** |

***Fuente***. *Elaborado por el Laboratorio de Agua, Suelo, Medio Ambiente y Fertirriego de la Universidad Agraria La Molina*

**Tabla 10.** Muestra 3 (Salida de la tubería de PVC).

| **Nº LABORATORIO** | **3795** |
|---|---|
| **N° DE CAMPO** | **Muestra 3** |
| **Turbiedad NTU** | 3.15 |
| **Sólidos Totales mg/L** | 524.00 |
| **Hierro mg/L** | <0.08 |
| **Plomo mg/L** | 0.022 |
| **Cobre mg/L** | <0.035 |
| **Cadmio mg/L** | <0.005 |
| **Manganeso mg/L** | <0.03 |
| **Zinc mg/L** | 0.06 |
| **Boro mg/L** | 0.28 |
| **Magnesio mg/L** | 11.24 |
| **Sulfatos mg/L** | 107.82 |
| **Cloruros mg/L** | 49.38 |
| **Dureza Total mg/$CaCO_3$/L** | 241.31 |
| **Alcalinidad Total mg/$CaCO_3$/L** | 106.93 |
| **pH** | 8.34 |
| **Nitratos mg/L** | 1.69 |
| **Sodio mg/L** | 24.90 |

***Fuente***. *Elaborado por el Laboratorio de Agua, Suelo, Medio Ambiente y Fertirriego de la Universidad Agraria La Molina*

### 4.2.5. Metrado y Análisis de Precios Unitarios

**Tabla 11.** Presupuesto PVC

| Item | Descripción | Und. | Metrado | Precio S/. | Parcial S/. |
|---|---|---|---|---|---|
| 1 | **INSTALACIONES SANITARIAS** | | | | |
| 1.1 | **AGUA FRIA PVC** | | | | **S/49,963.78** |
| 1.1.1 | PUNTOS DE SALIDA | PTO | 304.00 | S/37.31 | S/11,342.24 |
| 1.1.2 | TUBERÍA PVC 1/2" SAP | ML | 861.33 | S/11.57 | S/9,965.59 |
| 1.1.3 | TUBERÍA PVC 3/4" SAP | ML | 264.00 | S/12.87 | S/3,397.68 |
| 1.1.4 | TUBERÍA PVC 1" SAP | ML | 191.16 | S/15.43 | S/2,949.60 |
| 1.1.5 | TUBERÍA PVC 1 1/4" SAP | ML | 51.34 | S/18.92 | S/971.35 |
| 1.1.6 | TUBERÍA PVC 3" SAP | ML | 5.15 | S/18.36 | S/94.55 |
| 1.1.7 | CODOS DE 1/2" SAP | UND | 1007.00 | S/12.73 | S/12,819.11 |
| 1.1.8 | CODOS DE 3/4" SAP | UND | 57.00 | S/13.33 | S/759.81 |
| 1.1.9 | CODOS DE 1" SAP | UND | 130.00 | S/16.23 | S/2,109.90 |
| 1.1.10 | CODOS DE 1 1/4" SAP | UND | 29.00 | S/19.76 | S/573.04 |
| 1.1.11 | CODOS DE 3" SAP | UND | 6.00 | S/60.36 | S/362.16 |
| 1.1.12 | TEE DE 1/2" SAP | UND | 158.00 | S/13.13 | S/2,074.54 |
| 1.1.13 | TEE DE 3/4" SAP | UND | 105.00 | S/13.37 | S/1,403.85 |
| 1.1.14 | TEE DE 1 1/4" SAP | UND | 8.00 | S/25.18 | S/201.44 |
| 1.1.15 | REDUCCION 3/4" A 1/2" | UND | 40.00 | S/13.26 | S/530.40 |
| 1.1.16 | REDUCCION 1" A 3/4" | UND | 13.00 | S/14.59 | S/189.67 |
| 1.1.17 | REDUCCION 1"A 1/2" | UND | 15.00 | S/14.59 | S/218.85 |
| | | | | | |
| **1.2** | **AGUA CALIENTE CPVC** | | | | **S/33,829.56** |
| 1.2.1 | PUNTOS DE SALIDA | PTO | 178.00 | S/41.23 | S/7,338.94 |
| 1.2.2 | TUBERÍA CPVC 1/2" CPVC | ML | 568.78 | S/16.35 | S/9,299.55 |
| 1.2.3 | TUBERÍA CPVC 3/4" CPVC | ML | 298.63 | S/16.65 | S/4,972.19 |
| 1.2.4 | CODOS DE 1/2" CPVC | UND | 590.00 | S/13.02 | S/7,681.80 |
| 1.2.5 | CODOS DE 3/4" CPVC | UND | 113.00 | S/13.64 | S/1,541.32 |
| 1.2.6 | TEE DE 1/2" CPVC | UND | 73.00 | S/14.30 | S/1,043.90 |
| 1.2.7 | TEE DE 3/4" AGUA FRIA | UND | 77.00 | S/14.04 | S/1,081.08 |
| 1.2.8 | REDUCCION 1" A 3/4" | UND | 69.00 | S/12.62 | S/870.78 |
| | | | | TOTAL | S/83,793.35 |

***Fuente****. Elaborado por los autores.*

**Tabla 12.** Presupuesto PEXb

| Item | Descripción | Und. | Metrado | Precio S/. | Parcial S/. |
|---|---|---|---|---|---|
| **1.3** | **AGUA FRIA PEXb** | | | | S/29,414.13 |
| 1.3.1 | PUNTOS DE SALIDA | PTO | 304 | 39.26 | S/11,935.04 |
| 1.3.2 | TUBERÍA PEXb 1/2" | ML | 689.49 | 11.61 | S/8,004.98 |
| 1.3.3 | TUBERÍA PEXb 3/4" | ML | 211.12 | 12.9 | S/2,723.45 |
| 1.3.4 | TUBERÍA PEXb 1" | ML | 150.8 | 15.29 | S/2,305.73 |
| 1.3.5 | TUBERÍA PEXb 1 1/4" | ML | 41.07 | 18.66 | S/766.37 |
| 1.3.6 | TUBERÍA PEXb 3" | ML | 5.15 | 25.1 | S/129.27 |
| 1.3.7 | TEE DE 1/2" | UND | 158 | 11.8 | S/1,864.40 |
| 1.3.8 | TEE DE 3/4" | UND | 105 | 14.5 | S/1,522.50 |
| 1.3.9 | TEE DE 1 1/4"" | UND | 8 | 20.3 | S/162.40 |
| | | | | | |
| **1.4** | **AGUA CALIENTE PEXb** | | | | S/17,331.02 |
| 1.4.1 | PUNTOS DE SALIDA | PTO | 178 | 39.26 | S/6,988.28 |
| 1.4.2 | TUBERÍA PEXb 1/2" | ML | 455.03 | 11.61 | S/5,282.90 |
| 1.4.3 | TUBERÍA PEXb 3/4" | ML | 238.91 | 12.9 | S/3,081.94 |
| 1.4.4 | TEE DE 1/2" | UND | 73 | 11.8 | S/861.40 |
| 1.4.5 | TEE DE 3/4" | UND | 77 | 14.5 | S/1,116.50 |
| | | | | Total | S/46,745.15 |

***Fuente***. *Elaborado por los autores.*

# CAPITULO V: DISCUSIÓN

## 5.1. Discusión de resultados

### 5.1.1. Comparación de las tuberías PEXb y PVC desde el parámetro de calidad

Habiendo concluido los ensayos de calidad (ensayo de Presión sostenida, Tracción a Tubo Completo, Resistencia al Impacto) podemos deducir que los resultados del PEXb fueron superiores con respecto a las del PVC. A continuación se detallarán los resultados:

En el Ensayo de Presión Sostenida, la tubería de PVC genera una pérdida de carga al llegar a los 11 bar, que después de 4 horas llega a los 10 bar mientras que la del PEXb llega a los 20 bar y pasado las 4 horas se mantiene en 20 bar, la cual no genera ninguna pérdida de carga. Esto resolvería muchos problemas en casas donde la presión no es constante ni llega con la fuerza necesaria para ser distribuida a toda la casa.

En el Ensayo de Tracción a Tubo Completo, la tubería de PEXb sufre una rotura recién cuando el alargamiento llega a los 12% de fluencia con un esfuerzo de 32.3 Mpa, representado un 15 % de rotura, mientras el PVC sufre una rotura cuando el alargamiento llega apenas a los 2.9% de fluencia con un esfuerzo de 39.2 Mpa, representando una rotura de 52% sobre la muestra inicial. Dando por confirmado que ante factores externos como sismos, esfuerzos humanos, etc. la tubería PEXb tiene una resistencia mucho mayor que el de PVC. Lo que al final reduce los daños de reparación, tanto económicos como vidas humanas.

En el Ensayo de Resistencia al Impacto, observamos que para la masa 1 (2.70 kg) con una altura de 1.18 mt. el PVC se rompe parcialmente y en 1.50 mt. ya se hace trizas, mientras que el PEXb a una altura de 1.18mt. solo se aplasta un mínimo y a 1.70mt. el aplastamiento en un poco mayor pero no en ningún caso llega a la ruptura. Lo mismo para la masa 2 (5.40kg) el PVC experimenta una ruptura parcial a una altura de 0.51 mt y una ruptura total a una altura de 0.80 mt, mientras el PEXb a la misma altura de 0.51mt. solo se aplasta insignificantemente y al 1.70mt. el aplastamiento solo se profundiza, pero tampoco llega a la ruptura. Esto nos permite una ventaja en obra, ya que las tuberías están expuestas y puede ocurrir que un operario puede soltar un elemento (comba, martillo, ladrillo, etc.) que puede dañar las tuberías de PVC, pero si usamos el PEXb no ocurrirá los daños mencionados.

Y con respecto al Análisis de agua con fines de consumo humano: Agua Potable, hechos en la Universidad Agraria La Molina, después de haber hecho fluir agua a temperatura de ebullición (100°C) por un tiempo de 30 minutos , lo que nos arroja las muestra 1 y 2 (PEXb y PVC respectivamente) nos dan resultados parecidos y todos dentro del rango permitido, lo que significa que el PEXb cumple con las normas, las mismas que le permiten al PVC ser utilizadas para el fluido de agua potable. Pero según artículo de GreenPeace al ser continuo el paso de agua a esas temperaturas hace que se desprendan elementos cancerígenos, motivo por la cual ellos recomiendan el uso de tuberías de Polietileno (PEXb).

### 5.1.2. <u>Comparación de las tuberías PEXb y PVC desde el parámetro de costo</u>

En comparación de costos, nos podemos dar cuenta que para el mismo plano sanitario, pero con el metrado tanto para el PVC y el PEXb los presupuestos salen con una diferencia notable.

El presupuesto del PVC nos da un valor de s/. 83, 793.35 y para el PEXb nos da s/. 46,745.15, por tanto este análisis nos hace dar cuenta que el hecho de ahorrar en codos, pegamentos, y sobre todo que se pueda realizar más instalaciones en menor tiempo se vea reflejado en el presupuesto final de la obra.

### 5.1.3. Comparación de las tuberías PEXb y PVC desde el parámetro de tiempo

Con respecto a tiempo, lo que nos ofrece el PEXb es un ahorro enorme de tiempo frente al PVC, al momento de hacer la instalación por puntos de salida y uniones, y también al realizar las pruebas hidráulicas. Al momento de realizar el Ensayo de Presión sostenida el tiempo que tomó hacer la instalación del baño completo con PVC fue de 38.45 minutos, mientras que con PEXb solo fue de 23.21 minutos. Esto pasa porque para el PVC, se tiene que usar pegamento para cada unión, dicho de paso el pegamento es malo para la salud humana, luego de esto esperar que seque para seguir con las demás uniones, mientras en el PEXb solo se presiona y se utiliza bien la Llave Allen o algún alicate para el ajuste dependiendo el tipo de unión que se desee usar. También el ahorro de tiempo se da porque en vez de colocar un codo en PVC, en el PEXb solo se doble en frío, utilizando menos de la mitad del tiempo.

Luego de realizar todo la instalación se tiene que realizar el ensayo de Presión instantánea, que mientras para el PVC se tiene que esperar un tiempo (de secado) en el PEXb se puede realizar apenas acabado la instalación.

Todo esto hace posible un mejor trabajo, en un menor tiempo y mayor avance, en conclusión aumenta la productividad.

# CONCLUSIONES

1. Los ensayos de calidad (ensayo de Presión sostenida, tracción a tubo Completo y Resistencia al Impacto) evidencian que PEXb fueron superiores con respecto a las del PVC. Y el análisis de agua con fines de consumo humano evidenció que tanto PEXb y PVC cumplen los requisitos para el consumo humano.

2. Los análisis de costo evidencian un ahorro significativo de 44.21 % cuando se utiliza PEXb en comparación con PVC si se hubiese utilizado en el edificio multifamiliar Vitalia.

3. Las evaluaciones del parámetro del tiempo en el modelo de instalación de baño evidencian que el PEXb presenta un ahorro en tiempo 39.64%.

4. El PEXb al venir en rollos y ser más liviano, hace que el flete (transporte) sea más barato, lo que permite ahorrar más en tiempo y costo.

5. La flexibilidad hace que el PEXb sea más trabajable y moldeable, pudiendo ser reutilizado.

6. La empresa brinda los equipos a disposición de sus clientes para un mejor trabajo y aminorar gastos, así como capacitación al personal que trabajará con el PEXb.

7. El PEXb al soportar más presión puede ser aplicado en otras aplicaciones que necesiten de más presión.

8. El aluminio que forma la Tricapa Flex hace que la tubería PEXb pueda ser instalado al intemperie. Soportando climas con temperaturas altas y bajas.

9. Las uniones no sufren daño alguno, ni se desprenden ante movimientos sísmicos, mientras el PVC se seca el pegamento y si se desprende.

10. Al no emitir humo hace más beneficioso a la salud.

11. Al ser termoestable, demora más en ser afectado por temperaturas altas.

12. El PEXb al usar menos accesorios hace que la pérdida sea casi nula.

13. El agua tiene mayor fluidez ya que el coeficiente de rugosidad es mucho menor al de PVC.

## RECOMENDACIONES

1. Para el uso de este sistema, recomendamos contratar un técnico especializado, así evitamos malas maniobras, y gastos en vano.

2. Una buena programación antes de iniciar la obra con la aplicación de este sistema.

3. Otras investigaciones que se pueden realizar referentes a las tuberías de polietileno son:

- Empleo de las tuberías de polietileno en climas extremos.
- Empleo de las tuberías de polietileno en sistemas de aire acondicionado.
- Análisis comparativo entre las tuberías de polietileno y las tuberías de Cobre.
- Empleo de las tuberías de polietileno en sistemas de gas.
- Empleo de las tuberías de polietileno en sistemas de irrigación y viveros.
- Empleo de las tuberías de polietileno en sistemas de calefacción.
- Instalaciones donde las tuberías estén total o parcialmente expuestas a la acción de los factores externos.

4. Se puede usar esta investigación para aplicar la tubería PEXb en lugares donde hayan casas estructuralmente débiles (ejemplo Barrios Altos) y aún vivan personas. Ya que en vez de picar la pared se puede colocar externamente a la pared.

5. También puede usarse como tubo de abasto, reduciendo costos.

6. Se puede doblar y desdoblar varias veces, pero se recomienda un máximo de 3 veces.

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# ANEXOS

1. **Matriz de consistencia**

2. **Normas**

3. **Documentos técnicos**

4. **Planos**

5. **Análisis de Precios Unitarios (APU)**

## MATRIZ DE CONSISTENCIA

### ANÁLISIS COMPARATIVO ENTRE TUBERÍAS DE POLIETILENO RETICULADO PEXb Y TUBERÍAS DE PVC EN INSTALACIONES DE AGUA POTABLE
### CASO: EDIFICIO MULTAFAMILIAR VITALIA
### EN LA AVENIDA VELASCO ASTETE 925
### SAN BORJA - LIMA

| PROBLEMA | OBJETIVO | HIPÓTESIS | OPERACIONALIZACIÓN DE VARIABLES | | MEDICIÓN | METODOLOGÍA |
|---|---|---|---|---|---|---|
| General | General | General | VARIABLES | INDICADORES | | |
| • ¿En qué medida incidirá el análisis comparativo de parámetros entre tuberías PEXb y tuberías de PVC para el eficiente uso en instalaciones de agua potable en el edificio multifamiliar Vitalia? | • Evaluar incidencia del análisis comparativo de parámetros entre tuberías PEXb y tuberías de PVC para el eficiente uso en instalaciones de agua potable en el edificio multifamiliar Vitalia. | • El análisis comparativo de parámetros entre tuberías PEXb y tuberías de PVC incide para el eficiente uso en instalaciones de agua potable en el edificio multifamiliar Vitalia. | **VI**<br>Tipo de tuberías | Costo<br>Tiempo<br>Calidad | Nominal | **1. Tipo**<br>Nuestra investigación es mixta, con el fin de cuantificar resultados de laboratorio y analizar las caraterísticas de cada material según la calidad.<br><br>**2. Nivel de investigación**<br>Inicialmente será descriptiva (por el objetivo de la misma) y explicativa posteriormente.<br><br>**3. Método**<br>La investigacón es descriptiva comparativa, se describiran los procesos(ensayos de laboratorio) de cada variable dependiente y análisis comparativo de las variables independientes.<br><br>**4. Diseño de la investigación**<br>**Experimental,** porque realizamos ensayos para llegar al objetivo principal.<br>**Transversal,** se aplica en un solo caso de estudio.<br><br>**5. Instrumentos de Recolección de Datos.**<br>Ensayos de laboratorio.<br>Los resultados serán presentados como informaciones en forma de figuras, gráficos, cuadros o resúmenes.<br>Análisis de precios unitarios para cada metrado existente de las instalaciones sanitarias y presupesto para cada material. |
| Específicos | Específicos | Específicos | | | | |
| . • ¿En qué medida incidirá la realización de ensayos para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a la **calidad** entre tuberías PEXb y tuberías de PVC? | • Evaluar la incidencia de la realización de ensayos para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a la **calidad** entre tuberías PEXb y tuberías de PVC. | • La realización de ensayos incide para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a la **calidad** entre tuberías PEXb y tuberías de PVC. | **VD**<br>Calidad | Ensayo de presión<br>Ensayo de impacto<br>Ensayo de tracción<br>Análisis de agua para consumo humano: agua potable | Ordinal | |
| • ¿En qué medida incidirá la realización del análisis de rendimiento para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a **tiempo** entre tuberías PEXb y tuberías de PVC? | • Evaluar la incidencia de la realización del análisis de rendimiento para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a **tiempo** entre tuberías PEXb y tuberías de PVC. | • La realización del análisis de rendimiento incide para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a **tiempo** entre tuberías PEXb y tuberías de PVC. | **VD**<br>tiempo | Flexibilidad<br>Cantidad de Usos<br>Instalación | Ordinal | |
| • ¿En qué medida incidirá la realización del metrado y análisis de presupuesto para la determinación del uso en instalaciones sanitarias de agua potable en el edificio multifamiliar Vitalia con respecto a **costo** entre tuberías PEXb y tuberías de PVC? | • Evaluar la incidencia de la realización del metrado y análisis de presupuesto para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a **costo** entre tuberías PEXb y tuberías de PVC. | • La realización del metrado y análisis de presupuesto incide para la determinación del uso en instalaciones de agua potable en el edificio multifamiliar Vitalia con respecto a **costo** entre tuberías PEXb y tuberías de PVC. | **VD**<br>costo | Mano de obra<br>Material<br>Mantenimiento y limpieza<br>Flete | Ordinal | |

**Fuente: Elaborado por los autores.**

# Standard Test Method for Tensile Properties of Plastics[1]

This standard is issued under the fixed designation D638; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the U.S. Department of Defense.*

## 1. Scope*

1.1 This test method covers the determination of the tensile properties of unreinforced and reinforced plastics in the form of standard dumbbell-shaped test specimens when tested under defined conditions of pretreatment, temperature, humidity, and testing machine speed.

1.2 This test method is applicable for testing materials of any thickness up to 14 mm (0.55 in.). However, for testing specimens in the form of thin sheeting, including film less than 1.0 mm (0.04 in.) in thickness, ASTM standard D882 is the preferred test method. Materials with a thickness greater than 14 mm (0.55 in.) shall be reduced by machining.

1.3 This test method includes the option of determining Poisson's ratio at room temperature.

NOTE 1—This standard and ISO 527-1 address the same subject matter, but differ in technical content.

NOTE 2—This test method is not intended to cover precise physical procedures. It is recognized that the constant rate of crosshead movement type of test leaves much to be desired from a theoretical standpoint, that wide differences may exist between rate of crosshead movement and rate of strain between gage marks on the specimen, and that the testing speeds specified disguise important effects characteristic of materials in the plastic state. Further, it is realized that variations in the thicknesses of test specimens, which are permitted by these procedures, produce variations in the surface-volume ratios of such specimens, and that these variations may influence the test results. Hence, where directly comparable results are desired, all samples should be of equal thickness. Special additional tests should be used where more precise physical data are needed.

NOTE 3—This test method may be used for testing phenolic molded resin or laminated materials. However, where these materials are used as electrical insulation, such materials should be tested in accordance with Test Methods D229 and Test Method D651.

NOTE 4—For tensile properties of resin-matrix composites reinforced with oriented continuous or discontinuous high modulus >20-GPa (>$3.0 \times 10^6$-psi) fibers, tests shall be made in accordance with Test Method D3039/D3039M.

1.4 Test data obtained by this test method have been found to be useful in engineering design. However, it is important to consider the precautions and limitations of this method found in Note 2 and Section 4 before considering these data for engineering design.

1.5 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

D229 Test Methods for Rigid Sheet and Plate Materials Used for Electrical Insulation

D412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension

D618 Practice for Conditioning Plastics for Testing

D651 Test Method for Test for Tensile Strength of Molded Electrical Insulating Materials (Withdrawn 1989)[3]

D882 Test Method for Tensile Properties of Thin Plastic Sheeting

D883 Terminology Relating to Plastics

D1822 Test Method for Tensile-Impact Energy to Break Plastics and Electrical Insulating Materials

D3039/D3039M Test Method for Tensile Properties of Polymer Matrix Composite Materials

D4000 Classification System for Specifying Plastic Materials

D4066 Classification System for Nylon Injection and Extrusion Materials (PA)

D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens

E4 Practices for Force Verification of Testing Machines

[1] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.10 on Mechanical Properties.

Current edition approved Dec. 15, 2014. Published March 2015. Originally approved in 1941. Last previous edition approved in 2010 as D638 - 10. DOI: 10.1520/D0638-14.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

***A Summary of Changes section appears at the end of this standard**

Designation: D638 – 14

# Standard Test Method for Tensile Properties of Plastics[1]

This standard is issued under the fixed designation D638; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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## 1. Scope*

1.1 This test method covers the determination of the tensile properties of unreinforced and reinforced plastics in the form of standard dumbbell-shaped test specimens when tested under defined conditions of pretreatment, temperature, humidity, and testing machine speed.

1.2 This test method is applicable for testing materials of any thickness up to 14 mm (0.55 in.). However, for testing specimens in the form of thin sheeting, including film less than 1.0 mm (0.04 in.) in thickness, ASTM standard D882 is the preferred test method. Materials with a thickness greater than 14 mm (0.55 in.) shall be reduced by machining.

1.3 This test method includes the option of determining Poisson's ratio at room temperature.

NOTE 1—This standard and ISO 527-1 address the same subject matter, but differ in technical content.

NOTE 2—This test method is not intended to cover precise physical procedures. It is recognized that the constant rate of crosshead movement type of test leaves much to be desired from a theoretical standpoint, that wide differences may exist between rate of crosshead movement and rate of strain between gage marks on the specimen, and that the testing speeds specified disguise important effects characteristic of materials in the plastic state. Further, it is realized that variations in the thicknesses of test specimens, which are permitted by these procedures, produce variations in the surface-volume ratios of such specimens, and that these variations may influence the test results. Hence, where directly comparable results are desired, all samples should be of equal thickness. Special additional tests should be used where more precise physical data are needed.

NOTE 3—This test method may be used for testing phenolic molded resin or laminated materials. However, where these materials are used as electrical insulation, such materials should be tested in accordance with Test Methods D229 and Test Method D651.

NOTE 4—For tensile properties of resin-matrix composites reinforced with oriented continuous or discontinuous high modulus >20-GPa (>$3.0 \times 10^6$-psi) fibers, tests shall be made in accordance with Test Method D3039/D3039M.

1.4 Test data obtained by this test method have been found to be useful in engineering design. However, it is important to consider the precautions and limitations of this method found in Note 2 and Section 4 before considering these data for engineering design.

1.5 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

D229 Test Methods for Rigid Sheet and Plate Materials Used for Electrical Insulation

D412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension

D618 Practice for Conditioning Plastics for Testing

D651 Test Method for Test for Tensile Strength of Molded Electrical Insulating Materials (Withdrawn 1989)[3]

D882 Test Method for Tensile Properties of Thin Plastic Sheeting

D883 Terminology Relating to Plastics

D1822 Test Method for Tensile-Impact Energy to Break Plastics and Electrical Insulating Materials

D3039/D3039M Test Method for Tensile Properties of Polymer Matrix Composite Materials

D4000 Classification System for Specifying Plastic Materials

D4066 Classification System for Nylon Injection and Extrusion Materials (PA)

D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens

E4 Practices for Force Verification of Testing Machines

[1] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.10 on Mechanical Properties.

Current edition approved Dec. 15, 2014. Published March 2015. Originally approved in 1941. Last previous edition approved in 2010 as D638 - 10. DOI: 10.1520/D0638-14.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

***A Summary of Changes section appears at the end of this standard**

E83 Practice for Verification and Classification of Extensometer Systems
E132 Test Method for Poisson's Ratio at Room Temperature
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *ISO Standard:*[4]

ISO 527-1 Determination of Tensile Properties

## 3. Terminology

3.1 *Definitions*—Definitions of terms applying to this test method appear in Terminology D883 and Annex A2.

## 4. Significance and Use

4.1 This test method is designed to produce tensile property data for the control and specification of plastic materials. These data are also useful for qualitative characterization and for research and development.

4.2 Some material specifications that require the use of this test method, but with some procedural modifications that take precedence when adhering to the specification. Therefore, it is advisable to refer to that material specification before using this test method. Table 1 in Classification D4000 lists the ASTM materials standards that currently exist.

4.3 Tensile properties are known to vary with specimen preparation and with speed and environment of testing. Consequently, where precise comparative results are desired, these factors must be carefully controlled.

4.4 It is realized that a material cannot be tested without also testing the method of preparation of that material. Hence, when comparative tests of materials per se are desired, exercise great care to ensure that all samples are prepared in exactly the same way, unless the test is to include the effects of sample preparation. Similarly, for referee purposes or comparisons within any given series of specimens, care shall be taken to secure the maximum degree of uniformity in details of preparation, treatment, and handling.

4.5 Tensile properties provide useful data for plastics engineering design purposes. However, because of the high degree of sensitivity exhibited by many plastics to rate of straining and environmental conditions, data obtained by this test method cannot be considered valid for applications involving load-time scales or environments widely different from those of this test method. In cases of such dissimilarity, no reliable estimation of the limit of usefulness can be made for most plastics. This sensitivity to rate of straining and environment necessitates testing over a broad load-time scale (including impact and creep) and range of environmental conditions if tensile properties are to suffice for engineering design purposes.

NOTE 5—Since the existence of a true elastic limit in plastics (as in many other organic materials and in many metals) is debatable, the propriety of applying the term "elastic modulus" in its quoted, generally accepted definition to describe the "stiffness" or "rigidity" of a plastic has been seriously questioned. The exact stress-strain characteristics of plastic materials are highly dependent on such factors as rate of application of stress, temperature, previous history of specimen, etc. However, stress-strain curves for plastics, determined as described in this test method, almost always show a linear region at low stresses, and a straight line drawn tangent to this portion of the curve permits calculation of an elastic modulus of the usually defined type. Such a constant is useful if its arbitrary nature and dependence on time, temperature, and similar factors are realized.

## 5. Apparatus

5.1 *Testing Machine*—A testing machine of the constant-rate-of-crosshead-movement type and comprising essentially the following:

5.1.1 *Fixed Member*—A fixed or essentially stationary member carrying one grip.

5.1.2 *Movable Member*—A movable member carrying a second grip.

5.1.3 *Grips*—Grips for holding the test specimen between the fixed member and the movable member of the testing machine can be either the fixed or self-aligning type.

5.1.3.1 Fixed grips are rigidly attached to the fixed and movable members of the testing machine. When this type of grip is used take extreme care to ensure that the test specimen is inserted and clamped so that the long axis of the test specimen coincides with the direction of pull through the center line of the grip assembly.

5.1.3.2 Self-aligning grips are attached to the fixed and movable members of the testing machine in such a manner that they will move freely into alignment as soon as any load is applied so that the long axis of the test specimen will coincide with the direction of the applied pull through the center line of the grip assembly. Align the specimens as perfectly as possible with the direction of pull so that no rotary motion that may induce slippage will occur in the grips; there is a limit to the amount of misalignment self-aligning grips will accommodate.

5.1.3.3 The test specimen shall be held in such a way that slippage relative to the grips is prevented insofar as possible. Grip surfaces that are deeply scored or serrated with a pattern similar to those of a coarse single-cut file, serrations about 2.4 mm (0.09 in.) apart and about 1.6 mm (0.06 in.) deep, have been found satisfactory for most thermoplastics. Finer serrations have been found to be more satisfactory for harder plastics, such as the thermosetting materials. It is important that the serrations be kept clean and sharp. Should breaking in the grips occur, even when deep serrations or abraded specimen surfaces are used, other techniques shall be used. Other techniques that have been found useful, particularly with smooth-faced grips, are abrading that portion of the surface of the specimen that will be in the grips, and interposing thin pieces of abrasive cloth, abrasive paper, or plastic, or rubber-coated fabric, commonly called hospital sheeting, between the specimen and the grip surface. No. 80 double-sided abrasive paper has been found effective in many cases. An open-mesh fabric, in which the threads are coated with abrasive, has also been effective. Reducing the cross-sectional area of the specimen may also be effective. The use of special types of grips is sometimes necessary to eliminate slippage and breakage in the grips.

5.1.4 *Drive Mechanism*—A drive mechanism for imparting a uniform, controlled velocity to the movable member with

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

respect to the stationary member. This velocity is to be regulated as specified in Section 8.

5.1.5 *Load Indicator*—A suitable load-indicating mechanism capable of showing the total tensile load carried by the test specimen when held by the grips. This mechanism shall be essentially free of inertia lag at the specified rate of testing and shall indicate the load with an accuracy of ±1 % of the indicated value, or better. The accuracy of the testing machine shall be verified in accordance with Practices E4.

NOTE 6—Experience has shown that many testing machines now in use are incapable of maintaining accuracy for as long as the periods between inspection recommended in Practices E4. Hence, it is recommended that each machine be studied individually and verified as often as may be found necessary. It frequently will be necessary to perform this function daily.

5.1.6 The fixed member, movable member, drive mechanism, and grips shall be constructed of such materials and in such proportions that the total elastic longitudinal strain of the system constituted by these parts does not exceed 1 % of the total longitudinal strain between the two gage marks on the test specimen at any time during the test and at any load up to the rated capacity of the machine.

5.1.7 *Crosshead Extension Indicator*—A suitable extension indicating mechanism capable of showing the amount of change in the separation of the grips, that is, crosshead movement. This mechanism shall be essentially free of inertial lag at the specified rate of testing and shall indicate the crosshead movement with an accuracy of ±10 % of the indicated value.

5.2 *Extension Indicator* (extensometer)—A suitable instrument shall be used for determining the distance between two designated points within the gauge length of the test specimen as the specimen is stretched. For referee purposes, the extensometer must be set at the full gage length of the specimen, as shown in Fig. 1. It is desirable, but not essential, that this instrument automatically record this distance, or any change in it, as a function of the load on the test specimen or of the elapsed time from the start of the test, or both. If only the latter is obtained, load-time data must also be taken. This instrument shall be essentially free of inertia at the specified speed of testing. Extensometers shall be classified and their calibration periodically verified in accordance with Practice E83.

5.2.1 *Modulus-of-Elasticity Measurements*—For modulus-of-elasticity measurements, an extensometer with a maximum strain error of 0.0002 mm/mm (in./in.) that automatically and continuously records shall be used. An extensometer classified by Practice E83 as fulfilling the requirements of a B-2 classification within the range of use for modulus measurements meets this requirement.

5.2.2 *Low-Extension Measurements*—For elongation-at-yield and low-extension measurements (nominally 20 % or less), the same above extensometer, attenuated to 20 % extension, is acceptable. In any case, the extensometer system must meet at least Class C (Practice E83) requirements, which include a fixed strain error of 0.001 strain or ±1.0 % of the indicated strain, whichever is greater.

5.2.3 *High-Extension Measurements*—For making measurements at elongations greater than 20 %, measuring techniques with error no greater than ±10 % of the measured value are acceptable.

5.3 *Micrometers*—Apparatus for measuring the width and thickness of the test specimen shall comply with the requirements of Test Method D5947.

## 6. Test Specimens

6.1 *Sheet, Plate, and Molded Plastics:*

6.1.1 *Rigid and Semirigid Plastics*—The test specimen shall conform to the dimensions shown in Fig. 1. The Type I specimen is the preferred specimen and shall be used where sufficient material having a thickness of 7 mm (0.28 in.) or less is available. The Type II specimen is recommended when a material does not break in the narrow section with the preferred Type I specimen. The Type V specimen shall be used where only limited material having a thickness of 4 mm (0.16 in.) or less is available for evaluation, or where a large number of specimens are to be exposed in a limited space (thermal and environmental stability tests, etc.). The Type IV specimen is generally used when direct comparisons are required between materials in different rigidity cases (that is, nonrigid and semirigid). The Type III specimen must be used for all materials with a thickness of greater than 7 mm (0.28 in.) but not more than 14 mm (0.55 in.).

6.1.2 *Nonrigid Plastics*—The test specimen shall conform to the dimensions shown in Fig. 1. The Type IV specimen shall be used for testing nonrigid plastics with a thickness of 4 mm (0.16 in.) or less. The Type III specimen must be used for all materials with a thickness greater than 7 mm (0.28 in.) but not more than 14 mm (0.55 in.).

6.1.3 *Reinforced Composites*—The test specimen for reinforced composites, including highly orthotropic laminates, shall conform to the dimensions of the Type I specimen shown in Fig. 1.

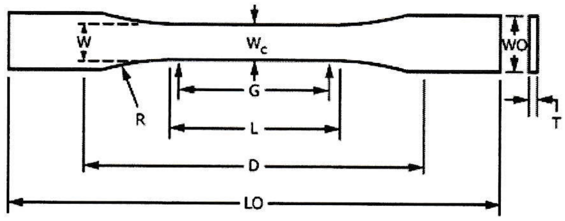
6.1.4 *Preparation*—Methods of preparing test specimens include injection molding, machining operations, or die cutting, from materials in sheet, plate, slab, or similar form. Materials thicker than 14 mm (0.55 in.) shall be machined to 14 mm (0.55 in.) for use as Type III specimens.

NOTE 7—Test results have shown that for some materials such as glass cloth, SMC, and BMC laminates, other specimen types should be considered to ensure breakage within the gage length of the specimen, as mandated by 7.3.

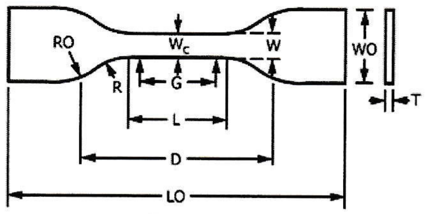
NOTE 8—When preparing specimens from certain composite laminates such as woven roving, or glass cloth, exercise care in cutting the specimens parallel to the reinforcement. The reinforcement will be significantly weakened by cutting on a bias, resulting in lower laminate properties, unless testing of specimens in a direction other than parallel with the reinforcement constitutes a variable being studied.

NOTE 9—Specimens prepared by injection molding may have different tensile properties than specimens prepared by machining or die-cutting because of the orientation induced. This effect may be more pronounced in specimens with narrow sections.

6.2 *Rigid Tubes*—The test specimen for rigid tubes shall be as shown in Fig. 2. The length, *L*, shall be as shown in the table in Fig. 2. A groove shall be machined around the outside of the specimen at the center of its length so that the wall section after




TYPES I, II, III & V




TYPE IV

Specimen Dimensions for Thickness, *T*, mm (in.)$^{A}$

| Dimensions (see drawings) | 7 (0.28) or under | | Over 7 to 14 (0.28 to 0.55), incl | 4 (0.16) or under | | Tolerances |
|---|---|---|---|---|---|---|
| | Type I | Type II | Type III | Type IV$^{B}$ | Type V$^{C,D}$ | |
| *W*—Width of narrow section$^{E,F}$ | 13 (0.50) | 6 (0.25) | 19 (0.75) | 6 (0.25) | 3.18 (0.125) | ±0.5 (±0.02)$^{B,C}$ |
| *L*—Length of narrow section | 57 (2.25) | 57 (2.25) | 57 (2.25) | 33 (1.30) | 9.53 (0.375) | ±0.5 (±0.02)$^{C}$ |
| *WO*—Width overall, min$^{G}$ | 19 (0.75) | 19 (0.75) | 29 (1.13) | 19 (0.75) | ... | + 6.4 ( + 0.25) |
| *WO*—Width overall, min$^{G}$ | ... | ... | ... | ... | 9.53 (0.375) | + 3.18 ( + 0.125) |
| *LO*—Length overall, min$^{H}$ | 165 (6.5) | 183 (7.2) | 246 (9.7) | 115 (4.5) | 63.5 (2.5) | no max (no max) |
| *G*—Gage length$^{I}$ | 50 (2.00) | 50 (2.00) | 50 (2.00) | ... | 7.62 (0.300) | ±0.25 (±0.010)$^{C}$ |
| *G*—Gage length$^{I}$ | ... | ... | ... | 25 (1.00) | ... | ±0.13 (±0.005) |
| *D*—Distance between grips | 115 (4.5) | 135 (5.3) | 115 (4.5) | 65 (2.5)$^{J}$ | 25.4 (1.0) | ±5 (±0.2) |
| *R*—Radius of fillet | 76 (3.00) | 76 (3.00) | 76 (3.00) | 14 (0.56) | 12.7 (0.5) | ±1 (±0.04)$^{C}$ |
| *RO*—Outer radius (Type IV) | ... | ... | ... | 25 (1.00) | ... | ±1 (±0.04) |

$^{A}$Thickness, *T*, shall be 3.2± 0.4 mm (0.13 ± 0.02 in.) for all types of molded specimens, and for other Types I and II specimens where possible. If specimens are machined from sheets or plates, thickness, *T*, shall be the thickness of the sheet or plate provided this does not exceed the range stated for the intended specimen type. For sheets of nominal thickness greater than 14 mm (0.55 in.) the specimens shall be machined to 14 ± 0.4 mm (0.55 ± 0.02 in.) in thickness, for use with the Type III specimen. For sheets of nominal thickness between 14 and 51 mm (0.55 and 2 in.) approximately equal amounts shall be machined from each surface. For thicker sheets both surfaces of the specimen shall be machined, and the location of the specimen with reference to the original thickness of the sheet shall be noted. Tolerances on thickness less than 14 mm (0.55 in.) shall be those standard for the grade of material tested.

$^{B}$For the Type IV specimen, the internal width of the narrow section of the die shall be 6.00 ± 0.05 mm (0.250 ± 0.002 in.). The dimensions are essentially those of Die C in Test Methods D412.

$^{C}$The Type V specimen shall be machined or die cut to the dimensions shown, or molded in a mold whose cavity has these dimensions. The dimensions shall be:

$W$ = 3.18 ± 0.03 mm (0.125 ± 0.001 in.),
$L$ = 9.53 ± 0.08 mm (0.375 ± 0.003 in.),
$G$ = 7.62 ± 0.02 mm (0.300 ± 0.001 in.), and
$R$ = 12.7 ± 0.08 mm (0.500 ± 0.003 in.).

The other tolerances are those in the table.

$^{D}$Supporting data on the introduction of the L specimen of Test Method D1822 as the Type V specimen are available from ASTM Headquarters. Request RR:D20-1038.

$^{E}$The tolerances of the width at the center $W_c$ shall be +0.00 mm, −0.10 mm ( +0.000 in., −0.004 in.) compared with width *W* at other parts of the reduced section. Any reduction in *W* at the center shall be gradual, equally on each side so that no abrupt changes in dimension result.

$^{F}$For molded specimens, a draft of not over 0.13 mm (0.005 in.) is allowed for either Type I or II specimens 3.2 mm (0.13 in.) in thickness. See diagram below and this shall be taken into account when calculating width of the specimen. Thus a typical section of a molded Type I specimen, having the maximum allowable draft, could be as follows:

$^{G}$Overall widths greater than the minimum indicated are used for some materials in order to avoid breaking in the grips.

$^{H}$Overall lengths greater than the minimum indicated are used for some materials to avoid breaking in the grips or to satisfy special test requirements.

$^{I}$Test marks or initial extensometer span.

$^{J}$When self-tightening grips are used, for highly extensible polymers, the distance between grips will depend upon the types of grips used and may not be critical if maintained uniform once chosen.

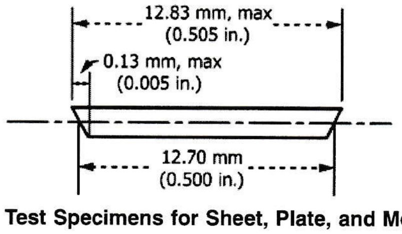
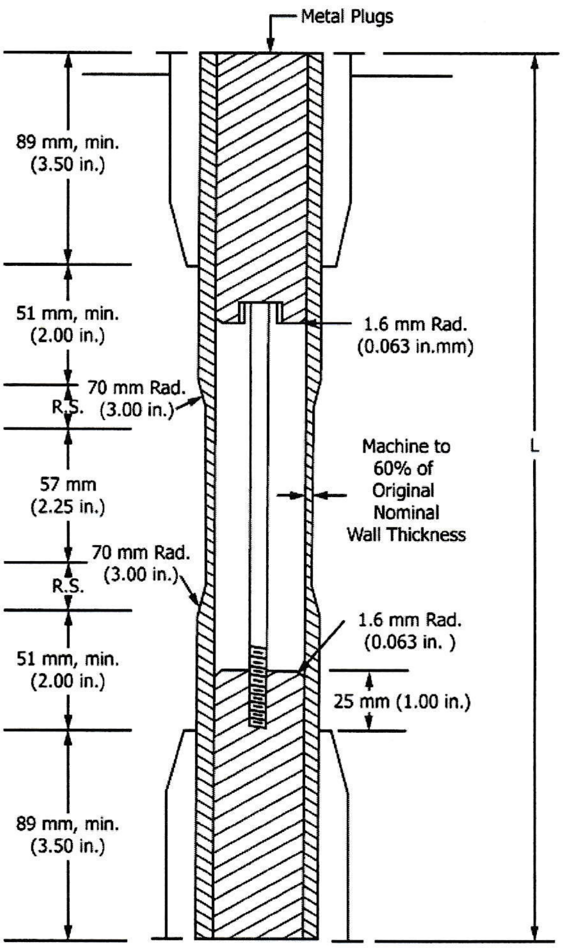



**FIG. 1 Tension Test Specimens for Sheet, Plate, and Molded Plastics**




DIMENSIONS OF TUBE SPECIMENS

| Nominal Wall Thickness | Length of Radial Sections, 2R.S. | Total Calculated Minimum Length of Specimen | Standard Length, *L*, of Specimen to Be Used for 89-mm (3.5-in.) Jaws[A] |
|---|---|---|---|
| | mm (in.) | | |
| 0.79 (1⁄32) | 13.9 (0.547) | 350 (13.80) | 381 (15) |
| 1.2 (3⁄64) | 17.0 (0.670) | 354 (13.92) | 381 (15) |
| 1.6 (1⁄16) | 19.6 (0.773) | 356 (14.02) | 381 (15) |
| 2.4 (3⁄32) | 24.0 (0.946) | 361 (14.20) | 381 (15) |
| 3.2 (1⁄8) | 27.7 (1.091) | 364 (14.34) | 381 (15) |
| 4.8 (3⁄16) | 33.9 (1.333) | 370 (14.58) | 381 (15) |
| 6.4 (1⁄4) | 39.0 (1.536) | 376 (14.79) | 400 (15.75) |
| 7.9 (5⁄16) | 43.5 (1.714) | 380 (14.96) | 400 (15.75) |
| 9.5 (3⁄8) | 47.6 (1.873) | 384 (15.12) | 400 (15.75) |
| 11.1 (7⁄16 ) | 51.3 (2.019) | 388 (15.27) | 400 (15.75) |
| 12.7 (1⁄2 ) | 54.7 (2.154) | 391 (15.40) | 419 (16.5) |

[A]For jaws greater than 89 mm (3.5 in.), the standard length shall be increased by twice the length of the jaws minus 178 mm (7 in.). The standard length permits a slippage of approximately 6.4 to 12.7 mm (0.25 to 0.50 in.) in each jaw while maintaining the maximum length of the jaw grip.

**FIG. 2 Diagram Showing Location of Tube Tension Test Specimens in Testing Machine**

machining shall be 60 % of the original nominal wall thickness. This groove shall consist of a straight section 57.2 mm (2.25 in.) in length with a radius of 76 mm (3 in.) at each end joining it to the outside diameter. Steel or brass plugs having diameters such that they will fit snugly inside the tube and having a length equal to the full jaw length plus 25 mm (1 in.) shall be placed in the ends of the specimens to prevent crushing. They can be located conveniently in the tube by separating and supporting them on a threaded metal rod. Details of plugs and test assembly are shown in Fig. 2.

6.3 *Rigid Rods*—The test specimen for rigid rods shall be as shown in Fig. 3. The length, *L*, shall be as shown in the table in Fig. 3. A groove shall be machined around the specimen at the center of its length so that the diameter of the machined portion shall be 60 % of the original nominal diameter. This groove shall consist of a straight section 57.2 mm (2.25 in.) in length with a radius of 76 mm (3 in.) at each end joining it to the outside diameter.

6.4 All surfaces of the specimen shall be free of visible flaws, scratches, or imperfections. Marks left by coarse machining operations shall be carefully removed with a fine file or abrasive, and the filed surfaces shall then be smoothed with abrasive paper (No. 00 or finer). The finishing sanding strokes shall be made in a direction parallel to the long axis of the test specimen. All flash shall be removed from a molded specimen, taking great care not to disturb the molded surfaces. In machining a specimen, undercuts that would exceed the dimensional tolerances shown in Fig. 1 shall be scrupulously avoided. Care shall also be taken to avoid other common machining errors.

6.5 If it is necessary to place gage marks on the specimen, this shall be done with a wax crayon or India ink that will not affect the material being tested. Gage marks shall not be scratched, punched, or impressed on the specimen.

6.6 When testing materials that are suspected of anisotropy, duplicate sets of test specimens shall be prepared, having their long axes respectively parallel with, and normal to, the suspected direction of anisotropy.

## 7. Number of Test Specimens

7.1 Test at least five specimens for each sample in the case of isotropic materials.

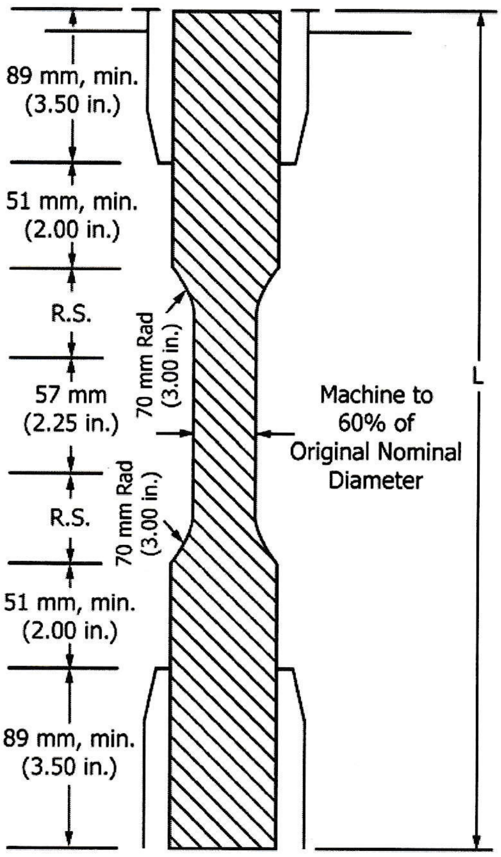
7.2 For anisotropic materials, when applicable, test five specimens, normal to, and five parallel with, the principle axis of anisotropy.

7.3 Discard specimens that break at some flaw, or that break outside of the narrow cross-sectional test section (Fig. 1, dimension "L"), and make retests, unless such flaws constitute a variable to be studied.

NOTE 10—Before testing, all transparent specimens should be inspected in a polariscope. Those which show atypical or concentrated strain patterns should be rejected, unless the effects of these residual strains constitute a variable to be studied.

## 8. Speed of Testing

8.1 Speed of testing shall be the relative rate of motion of the grips or test fixtures during the test. The rate of motion of the driven grip or fixture when the testing machine is running




DIMENSIONS OF ROD SPECIMENS

| Nominal Diameter | Length of Radial Sections, 2R.S. | Total Calculated Minimum Length of Specimen | Standard Length, *L*, of Specimen to Be Used for 89-mm (3.5-in.) Jaws[A] |
|---|---|---|---|
| | | mm (in.) | |
| 3.2 (1/8) | 19.6 (0.773) | 356 (14.02) | 381 (15) |
| 4.7 (3/16) | 24.0 (0.946) | 361 (14.20) | 381 (15) |
| 6.4 (1/4) | 27.7 (1.091) | 364 (14.34) | 381 (15) |
| 9.5 (3/8) | 33.9 (1.333) | 370 (14.58) | 381 (15) |
| 12.7 (1/2) | 39.0 (1.536) | 376 (14.79) | 400 (15.75) |
| 15.9 (5/8) | 43.5 (1.714) | 380 (14.96) | 400 (15.75) |
| 19.0 (3/4) | 47.6 (1.873) | 384 (15.12) | 400 (15.75) |
| 22.2 (7/8) | 51.5 (2.019) | 388 (15.27) | 400 (15.75) |
| 25.4 (1) | 54.7 (2.154) | 391 (15.40) | 419 (16.5) |
| 31.8 (1 1/4) | 60.9 (2.398) | 398 (15.65) | 419 (16.5) |
| 38.1 (1 1/2) | 66.4 (2.615) | 403 (15.87) | 419 (16.5) |
| 42.5 (1 3/4) | 71.4 (2.812) | 408 (16.06) | 419 (16.5) |
| 50.8 (2) | 76.0 (2.993) | 412 (16.24) | 432 (17) |

[A]For jaws greater than 89 mm (3.5 in.), the standard length shall be increased by twice the length of the jaws minus 178 mm (7 in.). The standard length permits a slippage of approximately 6.4 to 12.7 mm (0.25 to 0.50 in.) in each jaw while maintaining the maximum length of the jaw grip.

**FIG. 3 Diagram Showing Location of Rod Tension Test Specimen in Testing Machine**

idle may be used, if it can be shown that the resulting speed of testing is within the limits of variation allowed.

8.2 Choose the speed of testing from Table 1. Determine this chosen speed of testing by the specification for the material being tested, or by agreement between those concerned. When the speed is not specified, use the lowest speed shown in Table 1 for the specimen geometry being used, which gives rupture within 0.5 to 5-min testing time.

**TABLE 1 Designations for Speed of Testing[A]**

| Classification[B] | Specimen Type | Speed of Testing, mm/min (in./min) | Nominal Strain[C] Rate at Start of Test, mm/mm· min (in./in.·min) |
|---|---|---|---|
| Rigid and Semirigid | I, II, III rods and tubes | 5 (0.2) ± 25 % | 0.1 |
| | | 50 (2) ± 10 % | 1 |
| | | 500 (20) ± 10 % | 10 |
| | IV | 5 (0.2) ± 25 % | 0.15 |
| | | 50 (2) ± 10 % | 1.5 |
| | | 500 (20) ± 10 % | 15 |
| | V | 1 (0.05) ± 25 % | 0.1 |
| | | 10 (0.5) ± 25 % | 1 |
| | | 100 (5)± 25 % | 10 |
| Nonrigid | III | 50 (2) ± 10 % | 1 |
| | | 500 (20) ± 10 % | 10 |
| | IV | 50 (2) ± 10 % | 1.5 |
| | | 500 (20) ± 10 % | 15 |

[A]Select the lowest speed that produces rupture in 0.5 to 5 min for the specimen geometry being used (see 8.2).
[B]See Terminology D883 for definitions.
[C]The initial rate of straining cannot be calculated exactly for dumbbell-shaped specimens because of extension, both in the reduced section outside the gage length and in the fillets. This initial strain rate can be measured from the initial slope of the tensile strain-versus-time diagram.

8.3 Make modulus determinations at the speed selected for the other tensile properties when the recorder response and resolution are adequate.

## 9. Conditioning

9.1 *Conditioning*—Condition the test specimens in accordance with Procedure A of Practice D618, unless otherwise specified by contract or the relevant ASTM material specification. Conditioning time is specified as a minimum. Temperature and humidity tolerances shall be in accordance with Section 7 of Practice D618 unless specified differently by contract or material specification.

9.2 *Test Conditions*—Conduct the tests at the same temperature and humidity used for conditioning with tolerances in accordance with Section 7 of Practice D618, unless otherwise specified by contract or the relevant ASTM material specification.

## 10. Procedure

10.1 Measure the width and thickness of each specimen to the nearest 0.025 mm (0.001 in.) using the applicable test methods in D5947.

10.1.1 Measure the width and thickness of flat specimens at the center of each specimen and within 5 mm of each end of the gage length.

10.1.2 For injection molded specimens, the actual measurement of only one specimen from each sample will suffice when it has previously been demonstrated that the specimen-to-specimen variation in width and thickness is less than 1 %.

10.1.3 For thin sheeting, including film less than 1.0 mm (0.04 in.), take the width of specimens produced by a Type IV die as the distance between the cutting edges of the die in the narrow section. For all other specimens, measure the actual width of the center portion of the specimen to be tested, unless it can be shown that the actual width of the specimen is the same as that of the die within the specimen dimension tolerances given in Fig. 1.

10.1.4 Measure the diameter of rod specimens, and the inside and outside diameters of tube specimens, to the nearest 0.025 mm (0.001 in.) at a minimum of two points 90° apart; make these measurements along the groove for specimens so constructed. Use plugs in testing tube specimens, as shown in Fig. 2.

10.2 Place the specimen in the grips of the testing machine, taking care to align the long axis of the specimen and the grips with an imaginary line joining the points of attachment of the grips to the machine. The distance between the ends of the gripping surfaces, when using flat specimens, shall be as indicated in Fig. 1. On tube and rod specimens, the location for the grips shall be as shown in Fig. 2 and Fig. 3. Tighten the grips evenly and firmly to the degree necessary to prevent slippage of the specimen during the test, but not to the point where the specimen would be crushed.

10.3 Attach the extension indicator. When modulus is being determined, a Class B-2 or better extensometer is required (see 5.2.1).

NOTE 11—Modulus of materials is determined from the slope of the linear portion of the stress-strain curve. For most plastics, this linear portion is very small, occurs very rapidly, and must be recorded automatically. The change in jaw separation is never to be used for calculating modulus or elongation.

10.4 Set the speed of testing at the proper rate as required in Section 8, and start the machine.

10.5 Record the load-extension curve of the specimen.

10.6 Record the load and extension at the yield point (if one exists) and the load and extension at the moment of rupture.

NOTE 12—If it is desired to measure both modulus and failure properties (yield or break, or both), it may be necessary, in the case of highly extensible materials, to run two independent tests. The high magnification extensometer normally used to determine properties up to the yield point may not be suitable for tests involving high extensibility. If allowed to remain attached to the specimen, the extensometer could be permanently damaged. A broad-range incremental extensometer or hand-rule technique may be needed when such materials are taken to rupture.

## 11. Calculation

11.1 Toe compensation shall be made in accordance with Annex A1, unless it can be shown that the toe region of the curve is not due to the take-up of slack, seating of the specimen, or other artifact, but rather is an authentic material response.

11.2 *Tensile Strength*—Calculate the tensile strength by dividing the maximum load sustained by the specimen in newtons (pounds-force) by the average original cross-sectional area in the gage length segment of the specimen in square metres (square inches). Express the result in pascals (pounds-force per square inch) and report it to three significant figures as tensile strength at yield or tensile strength at break, whichever term is applicable. When a nominal yield or break load less than the maximum is present and applicable, it is often desirable to also calculate, in a similar manner, the corresponding tensile stress at yield or tensile stress at break and report it to three significant figures (see Note A2.8).

11.3 Elongation values are valid and are reported in cases where uniformity of deformation within the specimen gage length is present. Elongation values are quantitatively relevant and appropriate for engineering design. When non-uniform deformation (such as necking) occurs within the specimen gage length nominal strain values are reported. Nominal strain values are of qualitative utility only.

11.3.1 *Percent Elongation*—Percent elongation is the change in gage length relative to the original specimen gage length, expressed as a percent. Percent elongation is calculated using the apparatus described in 5.2.

11.3.1.1 *Percent Elongation at Yield*—Calculate the percent elongation at yield by reading the extension (change in gage length) at the yield point. Divide that extension by the original gage length and multiply by 100.

11.3.1.2 *Percent Elongation at Break*—Calculate the percent elongation at break by reading the extension (change in gage length) at the point of specimen rupture. Divide that extension by the original gage length and multiply by 100.

11.3.2 *Nominal Strain*—Nominal strain is the change in grip separation relative to the original grip separation expressed as a percent. Nominal strain is calculated using the apparatus described in 5.1.7.

11.3.2.1 *Nominal strain at break*—Calculate the nominal strain at break by reading the extension (change in grip separation) at the point of rupture. Divide that extension by the original grip separation and multiply by 100.

11.4 *Modulus of Elasticity*—Calculate the modulus of elasticity by extending the initial linear portion of the load-extension curve and dividing the difference in stress corresponding to any segment of section on this straight line by the corresponding difference in strain. All elastic modulus values shall be computed using the average original cross-sectional area in the gage length segment of the specimen in the calculations. The result shall be expressed in pascals (pounds-force per square inch) and reported to three significant figures.

11.5 *Secant Modulus*—At a designated strain, this shall be calculated by dividing the corresponding stress (nominal) by the designated strain. Elastic modulus values are preferable and shall be calculated whenever possible. However, for materials where no proportionality is evident, the secant value shall be calculated. Draw the tangent as directed in A1.3 and Fig. A1.2, and mark off the designated strain from the yield point where the tangent line goes through zero stress. The stress to be used in the calculation is then determined by dividing the load-extension curve by the original average cross-sectional area of the specimen.

11.6 For each series of tests, calculate the arithmetic mean of all values obtained and report it as the "average value" for the particular property in question.

11.7 Calculate the standard deviation (estimated) as follows and report it to two significant figures:

$$s = \sqrt{\left(\sum X^2 - n\bar{X}^2\right)/(n-1)} \tag{1}$$

where:

$s$ = estimated standard deviation,
$X$ = value of single observation,
$n$ = number of observations, and
$\bar{X}$ = arithmetic mean of the set of observations.

11.8 See Annex A1 for information on toe compensation.

11.9 See Annex A3 for the determination of Poisson's Ratio.

## 12. Report

12.1 Report the following information:

12.1.1 Complete identification of the material tested, including type, source, manufacturer's code numbers, form, principal dimensions, previous history, etc.,

12.1.2 Method of preparing test specimens,

12.1.3 Type of test specimen and dimensions,

12.1.4 Conditioning procedure used,

12.1.5 Atmospheric conditions in test room,

12.1.6 Number of specimens tested; for anisotropic materials, the number of specimens tested and the direction in which they were tested,

12.1.7 Speed of testing,

12.1.8 Classification of extensometers used. A description of measuring technique and calculations employed instead of a minimum Class-C extensometer system,

12.1.9 Tensile strength at yield or break, average value, and standard deviation,

12.1.10 Tensile stress at yield or break, if applicable, average value, and standard deviation,

12.1.11 Percent elongation at yield, or break, or nominal strain at break, or all three, as applicable, average value, and standard deviation,

12.1.12 Modulus of elasticity or secant modulus, average value, and standard deviation,

12.1.13 If measured, Poisson's ratio, average value, standard deviation, and statement of whether there was proportionality within the strain range,

12.1.14 Date of test, and

12.1.15 Revision date of Test Method D638.

## 13. Precision and Bias[5]

13.1 *Precision*—Tables 2-4 are based on a round-robin test conducted in 1984, involving five materials tested by eight laboratories using the Type I specimen, all of nominal 0.125-in. thickness. Each test result was based on five individual determinations. Each laboratory obtained two test results for each material.

[5] Supporting data are available from ASTM Headquarters. Request RR:D20-1125 for the 1984 round robin and RR:D20-1170 for the 1988 round robin.

**TABLE 2 Modulus, $10^6$ psi, for Eight Laboratories, Five Materials**

| | Mean | $S_r$ | $S_R$ | $I_r$ | $I_R$ |
|---|---|---|---|---|---|
| Polypropylene | 0.210 | 0.0089 | 0.071 | 0.025 | 0.201 |
| Cellulose acetate butyrate | 0.246 | 0.0179 | 0.035 | 0.051 | 0.144 |
| Acrylic | 0.481 | 0.0179 | 0.063 | 0.051 | 0.144 |
| Glass-reinforced nylon | 1.17 | 0.0537 | 0.217 | 0.152 | 0.614 |
| Glass-reinforced polyester | 1.39 | 0.0894 | 0.266 | 0.253 | 0.753 |

**TABLE 3 Tensile Stress at Break, $10^3$ psi, for Eight Laboratories, Five Materials[A]**

| | Mean | $S_r$ | $S_R$ | $I_r$ | $I_R$ |
|---|---|---|---|---|---|
| Polypropylene | 2.97 | 1.54 | 1.65 | 4.37 | 4.66 |
| Cellulose acetate butyrate | 4.82 | 0.058 | 0.180 | 0.164 | 0.509 |
| Acrylic | 9.09 | 0.452 | 0.751 | 1.27 | 2.13 |
| Glass-reinforced polyester | 20.8 | 0.233 | 0.437 | 0.659 | 1.24 |
| Glass-reinforced nylon | 23.6 | 0.277 | 0.698 | 0.784 | 1.98 |

[A] Tensile strength and elongation at break values obtained for unreinforced propylene plastics generally are highly variable due to inconsistencies in necking or "drawing" of the center section of the test bar. Since tensile strength and elongation at yield are more reproducible and relate in most cases to the practical usefulness of a molded part, they are generally recommended for specification purposes.

**TABLE 4 Elongation at Break, %, for Eight Laboratories, Five Materials[A]**

| | Mean | $S_r$ | $S_R$ | $I_r$ | $I_R$ |
|---|---|---|---|---|---|
| Glass-reinforced polyester | 3.68 | 0.20 | 2.33 | 0.570 | 6.59 |
| Glass-reinforced nylon | 3.87 | 0.10 | 2.13 | 0.283 | 6.03 |
| Acrylic | 13.2 | 2.05 | 3.65 | 5.80 | 10.3 |
| Cellulose acetate butyrate | 14.1 | 1.87 | 6.62 | 5.29 | 18.7 |
| Polypropylene | 293.0 | 50.9 | 119.0 | 144.0 | 337.0 |

[A] Tensile strength and elongation at break values obtained for unreinforced propylene plastics generally are highly variable due to inconsistencies in necking or "drawing" of the center section of the test bar. Since tensile strength and elongation at yield are more reproducible and relate in most cases to the practical usefulness of a molded part, they are generally recommended for specification purposes.

13.1.1 Tables 5-8 are based on a round-robin test conducted by the polyolefin subcommittee in 1988, involving eight polyethylene materials tested in ten laboratories. For each material, all samples were molded at one source, but the individual specimens were prepared at the laboratories that tested them. Each test result was the average of five individual determinations. Each laboratory obtained three test results for each material. Data from some laboratories could not be used for various reasons, and this is noted in each table.

13.1.2 Tables 9 and 10 are based on a round-robin test conducted by the polyolefin subcommittee in 1988, involving three materials tested in eight laboratories. For each material, all samples were molded at one source, but the individual specimens were prepared at the laboratories that tested them. Each test result was the average of five individual determinations. Each laboratory obtained three test results for each material.

**TABLE 5 Tensile Yield Stress, for Ten Laboratories, Eight Materials**

| Material | Test Speed, in./min | Values Expressed in psi Units | | | | |
|---|---|---|---|---|---|---|
| | | Average | $S_r$ | $S_R$ | $r$ | $R$ |
| LDPE | 20 | 1544 | 52.4 | 64.0 | 146.6 | 179.3 |
| LDPE | 20 | 1894 | 53.1 | 61.2 | 148.7 | 171.3 |
| LLDPE | 20 | 1879 | 74.2 | 99.9 | 207.8 | 279.7 |
| LLDPE | 20 | 1791 | 49.2 | 75.8 | 137.9 | 212.3 |
| LLDPE | 20 | 2900 | 55.5 | 87.9 | 155.4 | 246.1 |
| LLDPE | 20 | 1730 | 63.9 | 96.0 | 178.9 | 268.7 |
| HDPE | 2 | 4101 | 196.1 | 371.9 | 549.1 | 1041.3 |
| HDPE | 2 | 3523 | 175.9 | 478.0 | 492.4 | 1338.5 |

**TABLE 6 Tensile Yield Elongation, for Eight Laboratories, Eight Materials**

| Material | Test Speed, in./min | Values Expressed in Percent Units | | | | |
|---|---|---|---|---|---|---|
| | | Average | $S_r$ | $S_R$ | $r$ | $R$ |
| LDPE | 20 | 17.0 | 1.26 | 3.16 | 3.52 | 8.84 |
| LDPE | 20 | 14.6 | 1.02 | 2.38 | 2.86 | 6.67 |
| LLDPE | 20 | 15.7 | 1.37 | 2.85 | 3.85 | 7.97 |
| LLDPE | 20 | 16.6 | 1.59 | 3.30 | 4.46 | 9.24 |
| LLDPE | 20 | 11.7 | 1.27 | 2.88 | 3.56 | 8.08 |
| LLDPE | 20 | 15.2 | 1.27 | 2.59 | 3.55 | 7.25 |
| HDPE | 2 | 9.27 | 1.40 | 2.84 | 3.91 | 7.94 |
| HDPE | 2 | 9.63 | 1.23 | 2.75 | 3.45 | 7.71 |

**TABLE 7 Tensile Break Stress, for Nine Laboratories, Six Materials**

| Material | Test Speed, in./min | Values Expressed in psi Units | | | | |
|---|---|---|---|---|---|---|
| | | Average | $S_r$ | $S_R$ | $r$ | $R$ |
| LDPE | 20 | 1592 | 52.3 | 74.9 | 146.4 | 209.7 |
| LDPE | 20 | 1750 | 66.6 | 102.9 | 186.4 | 288.1 |
| LLDPE | 20 | 4379 | 127.1 | 219.0 | 355.8 | 613.3 |
| LLDPE | 20 | 2840 | 78.6 | 143.5 | 220.2 | 401.8 |
| LLDPE | 20 | 1679 | 34.3 | 47.0 | 95.96 | 131.6 |
| LLDPE | 20 | 2660 | 119.1 | 166.3 | 333.6 | 465.6 |

**TABLE 8 Tensile Break Elongation, for Nine Laboratories, Six Materials**

| Material | Test Speed, in./min | Values Expressed in Percent Units | | | | |
|---|---|---|---|---|---|---|
| | | Average | $S_r$ | $S_R$ | $r$ | $R$ |
| LDPE | 20 | 567 | 31.5 | 59.5 | 88.2 | 166.6 |
| LDPE | 20 | 569 | 61.5 | 89.2 | 172.3 | 249.7 |
| LLDPE | 20 | 890 | 25.7 | 113.8 | 71.9 | 318.7 |
| LLDPE | 20 | 64.4 | 6.68 | 11.7 | 18.7 | 32.6 |
| LLDPE | 20 | 803 | 25.7 | 104.4 | 71.9 | 292.5 |
| LLDPE | 20 | 782 | 41.6 | 96.7 | 116.6 | 270.8 |

**TABLE 9 Tensile Stress at Yield, $10^3$ psi, for Eight Laboratories, Three Materials**

| | Mean | $S_r$ | $S_R$ | $I_r$ | $I_R$ |
|---|---|---|---|---|---|
| Polypropylene | 3.63 | 0.022 | 0.161 | 0.062 | 0.456 |
| Cellulose acetate butyrate | 5.01 | 0.058 | 0.227 | 0.164 | 0.642 |
| Acrylic | 10.4 | 0.067 | 0.317 | 0.190 | 0.897 |

13.1.3 Table 11 is based on a repeatability study involving a single laboratory. The two materials used were unfilled polypropylene types. Measurements were performed by a single technician on a single day. Each test result is an individual determination. Testing was run using two Type B-1 extensometers for transverse and axial measurements at a test speed of 5 mm/min.

13.1.4 In Tables 2-11, for the materials indicated, and for test results that derived from testing five specimens:

**TABLE 10 Elongation at Yield, %, for Eight Laboratories, Three Materials**

| | Mean | $S_r$ | $S_R$ | $I_r$ | $I_R$ |
|---|---|---|---|---|---|
| Cellulose acetate butyrate | 3.65 | 0.27 | 0.62 | 0.76 | 1.75 |
| Acrylic | 4.89 | 0.21 | 0.55 | 0.59 | 1.56 |
| Polypropylene | 8.79 | 0.45 | 5.86 | 1.27 | 16.5 |

**TABLE 11 Poisson's Ratio Repeatability Data for One Laboratory and Two Polypropylene Materials**

| Materials | Values Expressed as a Dimensionless Ratio | | |
|---|---|---|---|
| | Average | $S_r$ | $r$ |
| PP #1 Chord | 0.412 | 0.009 | 0.026 |
| PP #1 Least Squares | 0.413 | 0.011 | 0.032 |
| PP #2 Chord | 0.391 | 0.009 | 0.026 |
| PP #2 Least Squares | 0.392 | 0.010 | 0.028 |

13.1.4.1 $S_r$ is the within-laboratory standard deviation of the average; $I_r = 2.83\ S_r$. (See 13.1.4.3 for application of $I_r$.)

13.1.4.2 $S_R$ is the between-laboratory standard deviation of the average; $I_R = 2.83\ S_R$. (See 13.1.4.4 for application of $I_R$.)

13.1.4.3 *Repeatability*—In comparing two test results for the same material, obtained by the same operator using the same equipment on the same day, those test results should be judged not equivalent if they differ by more than the $I_r$ value for that material and condition.

13.1.4.4 *Reproducibility*—In comparing two test results for the same material, obtained by different operators using different equipment on different days, those test results should be judged not equivalent if they differ by more than the $I_R$ value for that material and condition. (This applies between different laboratories or between different equipment within the same laboratory.)

13.1.4.5 Any judgment in accordance with 13.1.4.3 and 13.1.4.4 will have an approximate 95 % (0.95) probability of being correct.

13.1.4.6 Other formulations may give somewhat different results.

13.1.4.7 For further information on the methodology used in this section, see Practice E691.

13.1.4.8 The precision of this test method is very dependent upon the uniformity of specimen preparation, standard practices for which are covered in other documents.

13.2 *Bias*—There are no recognized standards on which to base an estimate of bias for this test method.

## 14. Keywords

14.1 modulus of elasticity; percent elongation; plastics; Poisson's Ratio; tensile properties; tensile strength

# ANNEXES

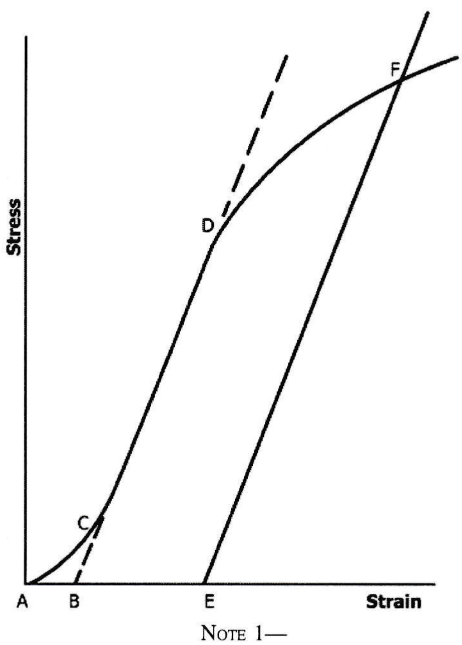
## (Mandatory Information)

## A1. TOE COMPENSATION

A1.1 In a typical stress-strain curve (Fig. A1.1) there is a toe region, *AC*, that does not represent a property of the material. It is an artifact caused by a takeup of slack and alignment or seating of the specimen. In order to obtain correct values of such parameters as modulus, strain, and offset yield point, this artifact must be compensated for to give the corrected zero point on the strain or extension axis.

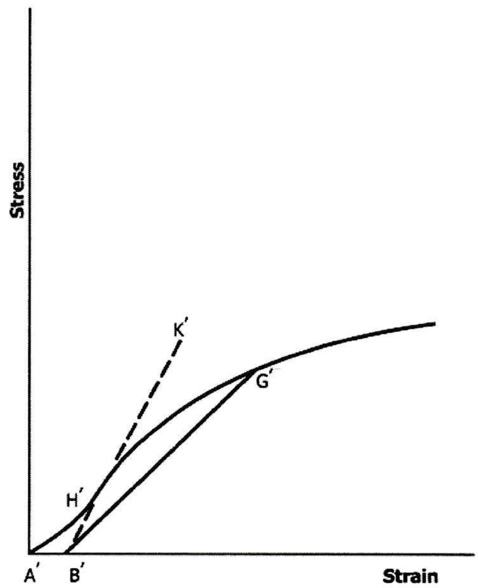
A1.2 In the case of a material exhibiting a region of Hookean (linear) behavior (Fig. A1.1), a continuation of the linear (*CD*) region of the curve is constructed through the zero-stress axis. This intersection (*B*) is the corrected zero-strain point from which all extensions or strains must be measured, including the yield offset (*BE*), if applicable. The elastic modulus can be determined by dividing the stress at any point along the line *CD* (or its extension) by the strain at the same point (measured from Point *B*, defined as zero-strain).

A1.3 In the case of a material that does not exhibit any linear region (Fig. A1.2), the same kind of toe correction of the zero-strain point can be made by constructing a tangent to the maximum slope at the inflection point (*H*'). This is extended to intersect the strain axis at Point *B*', the corrected zero-strain point. Using Point *B*' as zero strain, the stress at any point (*G*') on the curve can be divided by the strain at that point to obtain a secant modulus (slope of Line *B*' *G*'). For those materials with no linear region, any attempt to use the tangent through the inflection point as a basis for determination of an offset yield point may result in unacceptable error.




NOTE 1—
Some chart recorders plot the mirror image of this graph.

**FIG. A1.1 Material with Hookean Region**




NOTE 1—Some chart recorders plot the mirror image of this graph.

**FIG. A1.2 Material with No Hookean Region**

## A2. DEFINITIONS OF TERMS AND SYMBOLS RELATING TO TENSION TESTING OF PLASTICS

A2.1 *elastic limit*—the greatest stress which a material is capable of sustaining without any permanent strain remaining upon complete release of the stress. It is expressed in force per unit area, usually megapascals (pounds-force per square inch).

NOTE A2.1—Measured values of proportional limit and elastic limit vary greatly with the sensitivity and accuracy of the testing equipment, eccentricity of loading, the scale to which the stress-strain diagram is plotted, and other factors. Consequently, these values are usually replaced by yield strength.

A2.2 *elongation*—the increase in length produced in the gage length of the test specimen by a tensile load. It is expressed in units of length, usually millimetres (inches). (Also known as *extension.*)

NOTE A2.2—Elongation and strain values are valid only in cases where uniformity of specimen behavior within the gage length is present. In the case of materials exhibiting necking phenomena, such values are only of qualitative utility after attainment of yield point. This is due to inability to ensure that necking will encompass the entire length between the gage marks prior to specimen failure.

A2.3 *gage length*—the original length of that portion of the specimen over which strain or change in length is determined.

A2.4 *modulus of elasticity*—the ratio of stress (nominal) to corresponding strain below the proportional limit of a material. It is expressed in force per unit area, usually megapascals (pounds-force per square inch). (Also known as *elastic modulus* or *Young's modulus*).

NOTE A2.3—The stress-strain relations of many plastics do not conform to Hooke's law throughout the elastic range but deviate therefrom even at stresses well below the elastic limit. For such materials the slope of the tangent to the stress-strain curve at a low stress is usually taken as the modulus of elasticity. Since the existence of a true proportional limit in plastics is debatable, the propriety of applying the term "modulus of elasticity" to describe the stiffness or rigidity of a plastic has been seriously questioned. The exact stress-strain characteristics of plastic materials are very dependent on such factors as rate of stressing, temperature, previous specimen history, etc. However, such a value is useful if its arbitrary nature and dependence on time, temperature, and other factors are realized.

A2.5 *necking*—the localized reduction in cross section which may occur in a material under tensile stress.

A2.6 *offset yield strength*—the stress at which the strain exceeds by a specified amount (the offset) an extension of the initial proportional portion of the stress-strain curve. It is expressed in force per unit area, usually megapascals (pounds-force per square inch).

NOTE A2.4—This measurement is useful for materials whose stress-strain curve in the yield range is of gradual curvature. The offset yield strength can be derived from a stress-strain curve as follows (Fig. A2.1):

On the strain axis lay off *OM* equal to the specified offset.

Draw *OA* tangent to the initial straight-line portion of the stress-strain curve.

Through *M* draw a line *MN* parallel to *OA* and locate the intersection of *MN* with the stress-strain curve.

The stress at the point of intersection *r* is the "offset yield strength." The specified value of the offset must be stated as a percent of the original gage length in conjunction with the strength value. *Example:* 0.1 % offset yield strength = ... MPa (psi), or yield strength at 0.1 % offset ... MPa (psi).

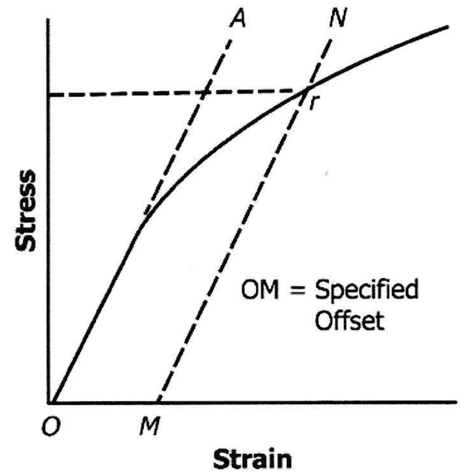



**FIG. A2.1 Offset Yield Strength**

A2.7 *percent elongation*—the elongation of a test specimen expressed as a percent of the gage length.

A2.8 *percent elongation at break and yield:*

A2.8.1 *percent elongation at break*—the percent elongation at the moment of rupture of the test specimen.

A2.8.2 *percent elongation at yield*—the percent elongation at the moment the yield point (A2.22) is attained in the test specimen.

A2.9 *percent reduction of area (nominal)*—the difference between the original cross-sectional area measured at the point of rupture after breaking and after all retraction has ceased, expressed as a percent of the original area.

A2.10 *percent reduction of area (true)*—the difference between the original cross-sectional area of the test specimen and the minimum cross-sectional area within the gage boundaries prevailing at the moment of rupture, expressed as a percentage of the original area.

A2.11 *Poisson's Ratio*—The absolute value of the ratio of transverse strain to the corresponding axial strain resulting from uniformly distributed axial stress below the proportional limit of the material.

A2.12 *proportional limit*—the greatest stress which a material is capable of sustaining without any deviation from proportionality of stress to strain (Hooke's law). It is expressed in force per unit area, usually megapascals (pounds-force per square inch).

A2.13 *rate of loading*—the change in tensile load carried by the specimen per unit time. It is expressed in force per unit time, usually newtons (pounds-force) per minute. The initial rate of loading can be calculated from the initial slope of the load versus time diagram.

A2.14 *rate of straining*—the change in tensile strain per unit time. It is expressed either as strain per unit time, usually metres per metre (inches per inch) per minute, or percent elongation per unit time, usually percent elongation per minute. The initial rate of straining can be calculated from the initial slope of the tensile strain versus time diagram.

NOTE A2.5—The initial rate of straining is synonymous with the rate of crosshead movement divided by the initial distance between crossheads only in a machine with constant rate of crosshead movement and when the specimen has a uniform original cross section, does not "neck down," and does not slip in the jaws.

A2.15 *rate of stressing (nominal)*—the change in tensile stress (nominal) per unit time. It is expressed in force per unit area per unit time, usually megapascals (pounds-force per square inch) per minute. The initial rate of stressing can be calculated from the initial slope of the tensile stress (nominal) versus time diagram.

NOTE A2.6—The initial rate of stressing as determined in this manner has only limited physical significance. It does, however, roughly describe the average rate at which the initial stress (nominal) carried by the test specimen is applied. It is affected by the elasticity and flow characteristics of the materials being tested. At the yield point, the rate of stressing (true) may continue to have a positive value if the cross-sectional area is decreasing.

A2.16 *secant modulus*—the ratio of stress (nominal) to corresponding strain at any specified point on the stress-strain curve. It is expressed in force per unit area, usually megapascals (pounds-force per square inch), and reported together with the specified stress or strain.

NOTE A2.7—This measurement is usually employed in place of modulus of elasticity in the case of materials whose stress-strain diagram does not demonstrate proportionality of stress to strain.

A2.17 *strain*—the ratio of the elongation to the gage length of the test specimen, that is, the change in length per unit of original length. It is expressed as a dimensionless ratio.

A2.17.1 *nominal strain at break*—the strain at the moment of rupture relative to the original grip separation.

A2.18 *tensile strength (nominal)*—the maximum tensile stress (nominal) sustained by the specimen during a tension test. When the maximum stress occurs at the yield point (A2.22), it shall be designated tensile strength at yield. When the maximum stress occurs at break, it shall be designated tensile strength at break.

A2.19 *tensile stress (nominal)*—the tensile load per unit area of minimum original cross section, within the gage boundaries, carried by the test specimen at any given moment. It is expressed in force per unit area, usually megapascals (pounds-force per square inch).

NOTE A2.8—The expression of tensile properties in terms of the minimum original cross section is almost universally used in practice. In the case of materials exhibiting high extensibility or necking, or both (A2.16), nominal stress calculations may not be meaningful beyond the yield point (A2.22) due to the extensive reduction in cross-sectional area that ensues. Under some circumstances it may be desirable to express the tensile properties per unit of minimum prevailing cross section. These properties are called true tensile properties (that is, true tensile stress, etc.).

A2.20 *tensile stress-strain curve*—a diagram in which values of tensile stress are plotted as ordinates against corresponding values of tensile strain as abscissas.

A2.21 *true strain* (see Fig. A2.2) is defined by the following equation for $\varepsilon_T$:

$$\varepsilon_T = \int_{L_o}^{L} dL/L = \ln L/L_o \quad (A2.1)$$

where:

$dL$ = increment of elongation when the distance between the gage marks is $L$,
$L_o$ = original distance between gauge marks, and
$L$ = distance between gauge marks at any time.

A2.22 *yield point*—the first point on the stress-strain curve at which an increase in strain occurs without an increase in stress (Fig. A2.2).

NOTE A2.9—Only materials whose stress-strain curves exhibit a point of zero slope may be considered as having a yield point.

NOTE A2.10—Some materials exhibit a distinct "break" or discontinuity in the stress-strain curve in the elastic region. This break is not a yield point by definition. However, this point may prove useful for material characterization in some cases.

A2.23 *yield strength*—the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. Unless otherwise specified, this stress will be the stress at the yield point and when expressed in relation to the tensile strength shall be designated either tensile strength at yield or tensile stress at yield as required in A2.18 (Fig. A2.3). (See *offset yield strength.*)

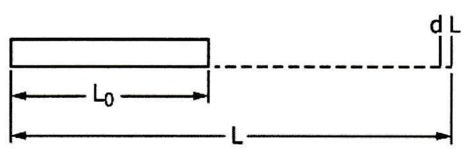



**FIG. A2.2 Illustration of True Strain Equation**

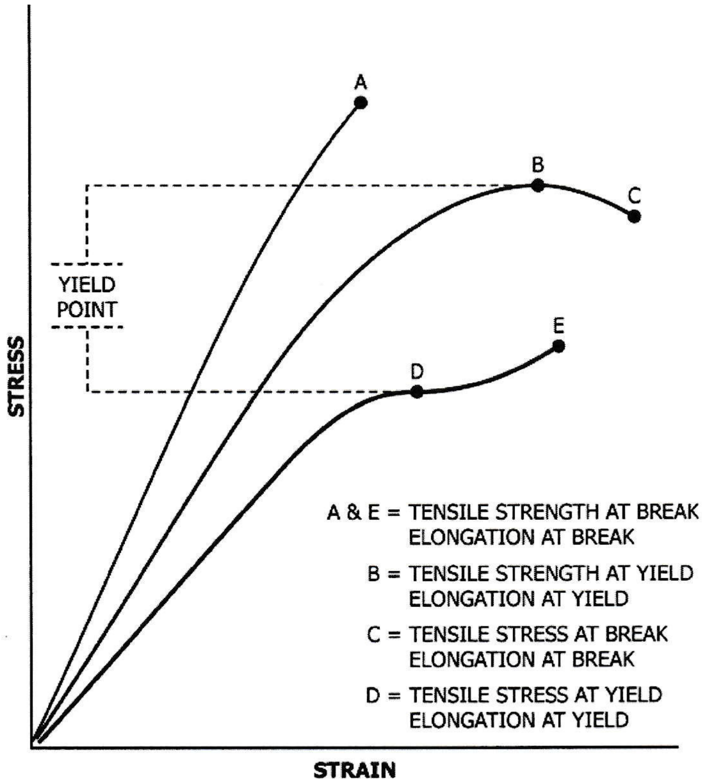



**FIG. A2.3 Tensile Designations**

A2.24 *Symbols*—The following symbols may be used for the above terms:

| Symbol | Term |
|---|---|
| $W$ | Load |
| $\Delta W$ | Increment of load |
| $L$ | Distance between gage marks at any time |
| $L_o$ | Original distance between gage marks |
| $L_u$ | Distance between gage marks at moment of rupture |
| $\Delta L$ | Increment of distance between gage marks = elongation |
| $A$ | Minimum cross-sectional area at any time |
| $A_o$ | Original cross-sectional area |
| $\Delta A$ | Increment of cross-sectional area |
| $A_u$ | Cross-sectional area at point of rupture measured after breaking specimen |
| $A_T$ | Cross-sectional area at point of rupture, measured at the moment of rupture |
| $t$ | Time |
| $\Delta t$ | Increment of time |
| $\sigma$ | Tensile stress |
| $\Delta\sigma$ | Increment of stress |
| $\sigma_T$ | True tensile stress |
| $\sigma_U$ | Tensile strength at break (nominal) |
| $\sigma_{UT}$ | Tensile strength at break (true) |
| $\varepsilon$ | Strain |
| $\Delta\varepsilon$ | Increment of strain |
| $\varepsilon_U$ | Total strain, at break |
| $\varepsilon_T$ | True strain |
| $\%El$ | Percentage elongation |
| Y.P. | Yield point |
| $E$ | Modulus of elasticity |

A2.25 Relations between these various terms may be defined as follows:

| | | |
|---|---|---|
| $\sigma$ | = | $W/A_o$ |
| $\sigma_T$ | = | $W/A$ |
| $\sigma_U$ | = | $W/A_o$ (where $W$ is breaking load) |
| $\sigma_{UT}$ | = | $W/A_T$ (where $W$ is breaking load) |
| $\varepsilon$ | = | $\Delta L/L_o = (L - L_o)/L_o$ |
| $\varepsilon_U$ | = | $(L_u - L_o)/L_o$ |
| $\varepsilon_T$ | = | $\int_{L_o}^{L} dL/L = \ln L/L_o$ |
| $\%El$ | = | $[(L - L_o)/L_o] \times 100 = \varepsilon \times 100$ |

Percent reduction of area (nominal) = $[(A_o - A_u)/A_o] \times 100$
Percent reduction of area (true) = $[(A_o - A_T)/A_o] \times 100$
Rate of loading = $\Delta W/\Delta t$
Rate of stressing (nominal) = $\Delta\sigma/\Delta = (\Delta W]/A_o)/\Delta t$
Rate of straining = $\Delta\varepsilon/\Delta t = (\Delta L/L_o)\Delta t$

For the case where the volume of the test specimen does not change during the test, the following three relations hold:

$$\sigma_T = \sigma(1+\varepsilon) = \sigma L/L_o \quad \text{(A2.2)}$$

$$\sigma_{UT} = \sigma_U(1+\varepsilon_U) = \sigma_U L_u/L_o$$

$$A = A_o/(1+\varepsilon)$$

## A3. MEASUREMENT OF POISSON'S RATIO

### A3.1. Scope

A3.1.1 This test method covers the determination of Poisson's ratio obtained from strains resulting from uniaxial stress only.

A3.1.2 Test data obtained by this test method are relevant and appropriate for use in engineering design.

A3.1.3 The values stated in SI units are regarded as the standard. The values given in parentheses are for information only.

NOTE A3.1—This standard is not equivalent to ISO 527-1.

### A3.2. Referenced Documents

A3.2.1 *ASTM Standards:*[2]
D618 Practice for Conditioning Plastics for Testing
D883 Terminology Relating to Plastics
D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens
E83 Practice for Verification and Classification of Extensometer Systems
E132 Test Method for Poisson's Ratio at Room Temperature
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E1012 Practice for Verification of Testing Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application

A3.2.2 *ISO Standard:*[4]

ISO 527–1 Determination of Tensile Properties

**A3.3. Terminology**

A3.3.1 *Definitions*—Definitions of terms applying to this test method appear in Terminology D883 and Annex A2 of this standard.

**A3.4. Significance and Use**

A3.4.1 When uniaxial tensile force is applied to a solid, the solid stretches in the direction of the applied force (axially), but it also contracts in both dimensions perpendicular to the applied force. If the solid is homogeneous and isotropic, and the material remains elastic under the action of the applied force, the transverse strain bears a constant relationship to the axial strain. This constant, called Poisson's ratio, is defined as the negative ratio of the transverse (negative) to axial strain under uniaxial stress.

A3.4.2 Poisson's ratio is used for the design of structures in which all dimensional changes resulting from the application of force need to be taken into account and in the application of the generalized theory of elasticity to structural analysis.

NOTE A3.2—The accuracy of the determination of Poisson's ratio is usually limited by the accuracy of the transverse strain measurements because the percentage errors in these measurements are usually greater than in the axial strain measurements. Since a ratio rather than an absolute quantity is measured, it is only necessary to know accurately the relative value of the calibration factors of the extensometers. Also, in general, the value of the applied loads need not be known accurately.

**A3.5. Apparatus**

A3.5.1 Refer to 5.1 and 5.3 of this standard for the requirements of the testing machine and micrometers.

A3.5.2 For measurement of Poisson's Ratio use either a bi-axial extensometer or an axial extensometer in combination with a transverse extensometer. They must be capable of recording axial strain and transverse strain simultaneously. The extensometers shall be capable of measuring the change in strains with an accuracy of 1 % of the relevant value or better.

NOTE A3.3—Strain gages are used as an alternative method to measure axial and transverse strain; however, proper techniques for mounting strain gauges are crucial to obtaining accurate data. Consult strain gauge suppliers for instruction and training in these special techniques.

**A3.6. Test Specimen**

A3.6.1 *Specimen*—The test specimen shall conform to the dimensions shown in Fig. 1. The Type I specimen is the preferred specimen and shall be used where sufficient material having a thickness of 7 mm (0.28 in.) or less is available.

A3.6.2 *Preparation*—Test specimens shall be prepared by machining operations, or die cutting, from materials in sheet, plate, slab, or similar form or be prepared by molding the material into the specimen shape to be tested.

NOTE A3.4—When preparing specimens from certain composite laminates such as woven roving, or glass cloth, care must be exercised in cutting the specimens parallel to the reinforcement, unless testing of specimens in a direction other than parallel with the reinforcement constitutes a variable being studied.

NOTE A3.5—Specimens prepared by injection molding have different tensile properties than specimens prepared by machining or die-cutting because of the orientation induced. This effect is more pronounced in specimens with narrow sections.

A3.6.3 All surfaces of the specimen shall be free of visible flaws, scratches, or imperfections. Marks left by coarse machining operations shall be carefully removed with a fine file or abrasive, and the filed surfaces shall then be smoothed with abrasive paper (No. 00 or finer). The finishing sanding strokes shall be made in a direction parallel to the long axis of the test specimen. All flash shall be removed from a molded specimen, taking great care not to disturb the molded surfaces. In machining a specimen, undercuts that would exceed the dimensional tolerances shown in Fig. 1 shall be scrupulously avoided. Care shall also be taken to avoid other common machining errors.

A3.6.4 If it is necessary to place gage marks on the specimen, this shall be done with a wax crayon or India ink that will not affect the material being tested. Gauge marks shall not be scratched, punched, or impressed on the specimen.

A3.6.5 When testing materials that are suspected of anisotropy, duplicate sets of test specimens shall be prepared, having their long axes respectively parallel with, and normal to, the suspected direction of anisotropy.

**A3.7 Number of Test Specimens**

A3.7.1 Test at least five specimens for each sample in the case of isotropic materials.

A3.7.2 Test ten specimens, five normal to, and five parallel with, the principle axis of anisotropy, for each sample in the case of anisotropic materials.

**A3.8. Conditioning**

A3.8.1 Specimens shall be conditioned and tested in accordance with the requirement shown in Section 9 of this standard.

**A3.9. Procedure**

A3.9.1 Measure the width and thickness of each specimen to the nearest 0.025 mm (0.001 in.) using the applicable test methods in D5947. Follow the guidelines specified in 10.1.1 and 10.1.2 of this standard.

A3.9.2 Poisson's Ratio shall be determined at a speed of 5 mm/min.

A3.9.3 Place the specimen in the grips of the testing machine, taking care to align the long axis of the specimen and the grips with an imaginary line joining the points of attachment of the grips to the machine. The distance between the ends of the gripping surfaces, when using flat specimens, shall be as indicated in Fig. 1. Tighten the grips evenly and firmly to the degree necessary to prevent slippage of the specimen during the test, but not to the point where the specimen would be crushed.

A3.9.4 Attach the biaxial extensometer or the axial and transverse extensometer combination to the specimen. The transverse extensometer should be attached to the width of the specimen.

A3.9.5 Apply a small preload (less than 5 N) to the specimen at a crosshead speed of 0.1 mm/min. This preload will eliminate any bending in the specimens.

A3.9.6 Rebalance the extensometers to zero.

A3.9.7 Run the test at 5 mm/min out to a minimum of 0.5 % strain before removing the extensometers, simultaneously recording the strain readings from the extensometers at the same applied force. The precision of the value of Poisson's Ratio will depend on the number of data points of axial and transverse strain taken. It is recommended that the data collection rate for the test be a minimum of 20 points per second (but preferably higher). This is particularly important for materials having a non linear stress to strain curve.

A3.9.8 Make the toe compensation in accordance with Annex A1. Determine the maximum strain (proportional limit) at which the curve is linear. If this strain is greater than 0.25 % the Poisson's Ratio is to be determined anywhere in this linear portion of the curve below the proportional limit. If the material does not exhibit a linear stress to strain relationship the Poisson's Ratio shall be determined within the axial strain range of 0.0005 to 0.0025 mm/mm (0.05 to 0.25 %). If the ratio is determined in this manner it shall be noted in the report that a region of proportionality of stress to strain was not evident.

NOTE A3.6—A suitable method for determination of linearity of the stress to strain curve is by making a series of tangent modulus measurements at different axial strain levels. Values equivalent at each strain level indicate linearity. Values showing a downward trend with increasing strain level indicate non linearity.

## A3.10. Calculation

A3.10.1 *Poisson's Ratio*—The axial strain, $\varepsilon_\alpha$, indicated by the axial extensometer, and the transverse strain, $\varepsilon_t$, indicated by the transverse extensometers, are plotted against the applied load, *P*, as shown in Fig. A3.1.

A3.10.1.1 For those materials where there is proportionality of stress to strain and it is possible to determine a modulus of elasticity, a straight line is drawn through each set of points within the load range used for determination of modulus, and the slopes $d\varepsilon_a / dP$ and $d\varepsilon_t / dP$, of those lines are determined. The use of a least squares method of calculation will reduce errors resulting from drawing lines. Poisson's Ratio, |µ|, is then calculated as follows:

$$|\mu| = (d\varepsilon_t/dP)/(d\varepsilon_a/dP) \quad (A3.1)$$

where:

$d\varepsilon_t$ = change in transverse strain,
$d\varepsilon_a$ = change in axial strain, and
$dP$ = change in applied load;

$$|\mu| = (d\varepsilon_t)/(d\varepsilon_a) \quad (A3.2)$$

A3.10.1.2 The errors that are introduced by drawing a straight line through the points are reduced by applying the least squares method.

A3.10.1.3 For those materials where there is no proportionality of stress to strain evident determine the ratio of $d\varepsilon_t / d\varepsilon_a$ when $d\varepsilon_a = 0.002$ (based on axial strain range of 0.0005 to 0.0025 mm/mm) and after toe compensation has been made.

$$|\mu| = d\varepsilon_t)/0.002 \quad (A3.3)$$

## A3.11. Report

A3.11.1 Report the following information:

A3.11.1.1 Complete identification of the material tested, including type, source, manufacturer's code numbers, form, principal dimensions, previous history, etc.,

A3.11.1.2 Method of preparing test specimens,

A3.11.1.3 Type of test specimen and dimensions,

A3.11.1.4 Conditioning procedure used,

A3.11.1.5 Atmospheric conditions in test room,

A3.11.1.6 Number of specimens tested,

A3.11.1.7 Speed of testing,

A3.11.1.8 Classification of extensometers used. A description of measuring technique and calculations employed,

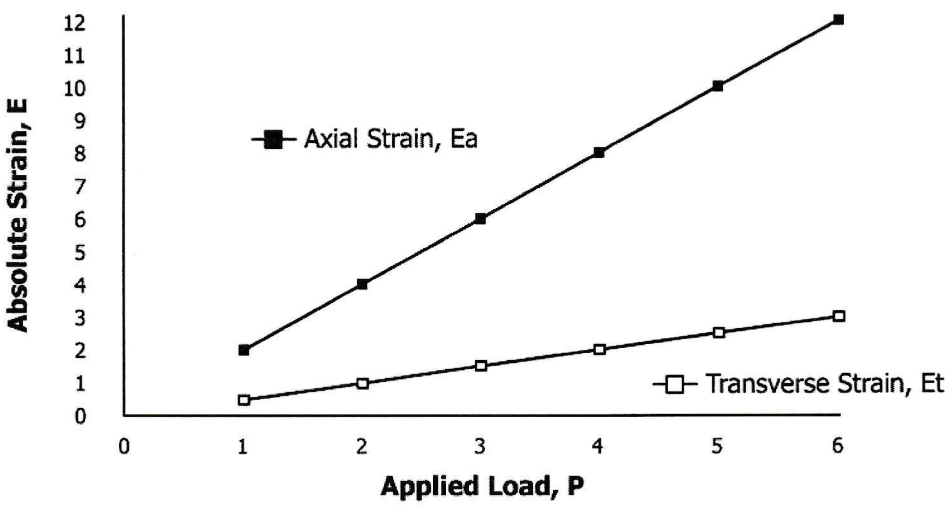



FIG. A3.1 Plot of Strains Versus Load for Determination of Poisson's Ratio

A3.11.1.9 Poisson's ratio, average value, standard deviation, and statement of whether there was proportionality within the strain range,

A3.11.1.10 Date of test, and

A3.11.1.11 Revision date of Test Method D618.

## A3.12. Precision and Bias

A3.12.1 *Precision*—The repeatability standard deviation has been determined to be the following (see Table A3.1.) An attempt to develop a full precision and bias statement for this test method will be made at a later date. For this reason, data on precision and bias cannot be given. Because this test method does not contain a round-robin based numerical precision and bias statement, it shall not be used as a referee test method in case of dispute. Anyone wishing to participate in the development of precision and bias data should contact the Chairman, Subcommittee D20.10 Mechanical Properties, ASTM International, 100 Barr Harbor, West Conshohocken, PA 19428.

## A3.13 Keywords

axial strain; Poisson's ratio; transverse strain

**TABLE A3.1 Poisson's Ratio Based on One Laboratory**

| Material | Extensometer Type | Average | $V_r$[A] | $V_R$[B] | r[C] | R[D] |
|---|---|---|---|---|---|---|
| PP Copolymer | 2–point | 0.408 | 0.011 | | 0.031 | |
| PP Copolymer | 4–point | 0.392 | 0.010 | | 0.028 | |
| PP Homopolymer with 20 % Glass | 2–point | 0.428 | 0.013 | | 0.036 | |
| PP Homopolymer with 20 % Glass | 4–point | 0.410 | 0.015 | | 0.042 | |

[A] $S_r$ = within laboratory standard deviation for the indicated material. It is obtained by first pooling the with-laboratory standard deviations of the test results from all the participating laboratories:

$$S_r = \{[(S_1)^2 + (S_2)^2 + \ldots\ldots + (S_n)^2]/n\}^{1/2}$$

[B] $S_R$ = between-laboratories reproducibility, expressed as standard deviation: $S_R = [S_r^2 + S_L^2)^{1/2}$
[C] r = within-laboratory critical interval between two test results = 2.8 × $S_r$
[D] R = between-laboratories critical interval between two test results = 2.8 × $S_R$

## SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D638 - 10) that may impact the use of this standard. (December 15, 2014)

*(1)* Revised Note 1 since changes were made to ISO 527-1, and it is no longer equivalent to this standard.
*(2)* Removed permissive language.
*(3)* Made some editorial changes.
*(4)* Moved Tables 2-5 to Section 13 on Precision and Bias.
*(5)* Revised Summary of Changes section.

# Standard Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)[1]

This standard is issued under the fixed designation D2444; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This test method covers the determination of the impact resistance of thermoplastic pipe and fittings under specified conditions of impact by means of a tup (falling weight). Three interchangeable striking noses are used on the tup, differing in geometrical configuration. Two specimen holders are described.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

## 3. Significance and Use

3.1 The impact resistance of thermoplastic pipe and fittings relates to suitability for service and to quality of processing. Impact resistance may also provide a relative measure of a material's resistance to breakage during handling and installation and, for non-buried applications, to in-service breakage. See Appendix X4 for guidelines for selecting testing combinations.

3.2 Results obtained by use of this test method can be used in three ways:

3.2.1 As the basis for establishing impact test requirements in product standards,

3.2.2 To measure the effect of changes in materials or processing, and

3.2.3 To measure the effect of the environment.

## 4. Apparatus

4.1 *General*—One type of impact tester is illustrated in Fig. 1.

4.2 *Tup:*

4.2.1 The tup nose shall be as shown in Fig. 2. When used with the 0.50-in. (12.7-mm) radius nose, it is designated as Tup A. When used with the 2.00-in. (51-mm) radius nose, it is designated as Tup B. When used with the 0.25-in. (6.3-mm) radius nose, it is designated as Tup C.

NOTE 1—It is suggested that tups be made of scratch-resistant steel to reduce damage to the nose. Badly scarred noses may affect test results.

4.2.2 The mass of the tup shall be 6, 12, 20, or 30 lb (2.7, 5.4, 9.1, or 13.6 kg).

4.3 *Drop Tube:*

4.3.1 The drop tube shall be of sufficient length (approximately 12 ft (3.7 m)) to provide for a fall of at least 10 ft (3.0 m) and shall be mounted so that the lengthwise direction is vertical as measured with a plumb bob or a spirit level at least 2 ft (610 mm) in length.

4.3.2 Care must be taken to ensure that the tup falls freely; it must not "chatter" down the tube.

NOTE 2—No material for the drop tube is specified. However, a colddrawn seamless steel tubing with an inside diameter of 2.563 ± 0.003 in. (65.10 ± 0.08 mm), or acrylonitrile-butadiene-styrene (ABS) or poly(vinyl chloride) (PVC) plastic pipe, 2½ in. nominal pipe size, with a standard dimension ratio (SDR) of 21, have been found to be satisfactory.

NOTE 3—Provided equivalent results are obtained, the tup may be dropped without a drop tube or guided by other means. The drop tube is used to reduce the hazard to operators and property that may occur when the tup rebounds. It also helps guide and center the tup so that it will be more likely to strike the top of the test specimen. It may also be necessary to provide a protective barrier around the specimen, particularly for larger sizes of pipe and fittings, to protect the operator from flying broken pieces.

[1] This test method is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.40 on Test Methods.

Current edition approved Aug. 1, 2010. Published November 2010. Originally approved in 1965. Last previous edition approved in 2005 as D2444 – 99(2005). DOI: 10.1520/D2444-99R10.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

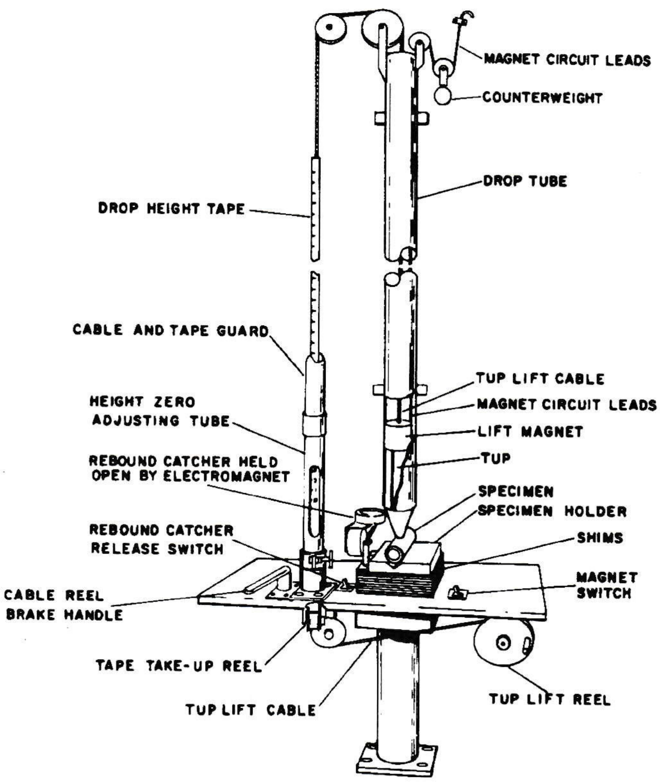
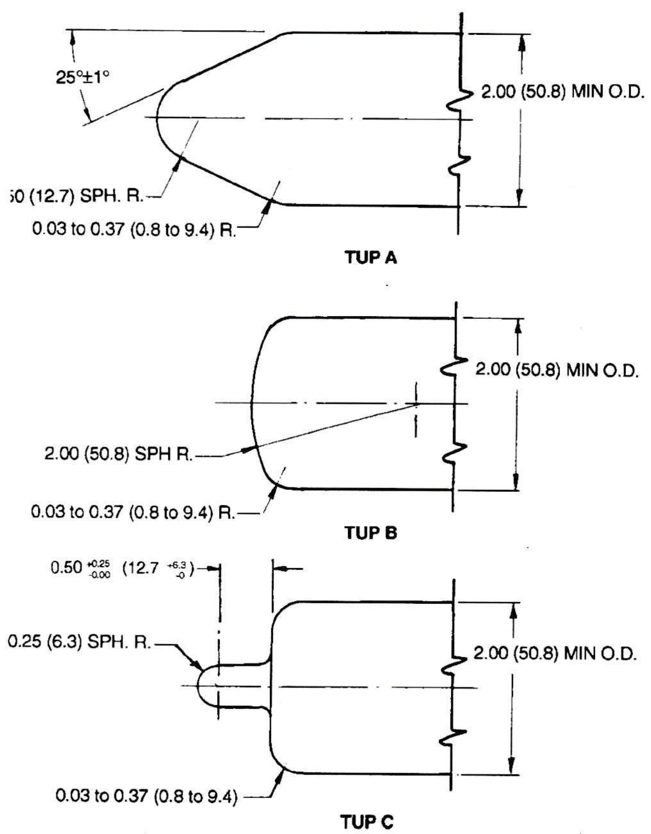



FIG. 1 One Type of Tup Impact Tester




NOTE 1—Dimensions are in inches (millimetres).

FIG. 2 Tup Nose Detail

NOTE 4—The tup may not fall freely if the clearance between the tup and tube is too large or too small, or if it is restrained by a partial vacuum above the tup, such as can be caused by the hold and release device.

4.3.3 Means shall be provided (*1*) to hold the tup at steps of 2 in. (50.8 mm) for a distance of 2 to 10 ft (610 mm to 3.0 m) above the specimen holder, (*2*) to release the tup in a reproducible manner, (*3*) to allow the tup to fall freely, and (*4*) to catch the tup on the first rebound. Refer to Fig. 1.

4.4 *Specimen Holder*—Two specimen holders are described. The V-block (Holder A) is usually used with Tups A and C; the flat plate (Holder B) is often used with Tup B or for testing fittings.

4.4.1 The V-block holder shall be at least as long as the specimen being tested and shall have a 90-deg included angle. It may be fabricated or of solid construction. The side supports shall be of sufficient depth to support the specimen in the V and not on the top edges of the V-block.

NOTE 5—Both aluminum and steel have been found suitable for the holders.

4.4.2 The flat-plate holder shall consist of a plate approximately 8 by 12 by 1 in. (203 by 305 by 25.4 mm) in which a groove to position the pipe specimen shall be cut. This groove shall be about 0.12 in. (3 mm) in depth with the edges rounded to a radius of about 0.06 in. (1.5 mm). Fittings that do not contact the plate directly under the point of impact shall be supported at this point by a flat steel plate or shim. The specimen holder shall be mounted on a rigid base fastened to a concrete slab. Means shall be provided to center the specimens under the drop tube. A bar or rod placed inside the specimen and retained by a light spring may be employed if difficulty is encountered in holding the specimen in position.

## 5. Test Specimens

5.1 The pipe specimens shall be equal in length to the nominal outside diameter but not less than 6 in. (152 mm) in length. Burrs shall be removed.

5.2 Fittings shall be tested either unassembled or assembled to pieces of pipe each 6 in. in length.

## 6. Number of Test Specimens

6.1 A minimum of 20 specimens are required for preliminary tests.

6.2 A minimum of 100 specimens are required for final tests, and 50 additional specimens may be required.

## 7. Conditioning

7.1 Condition the test specimens at 40 h, 23°C, 50 % RH and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618, for those tests where conditioning is required.

7.2 *Test Conditions*—Conduct the test in a room maintained at the test temperature or, if the test is made in an atmosphere or at a temperature other than that at which the specimens are conditioned, conduct the test as soon as possible after removal from the conditioning atmosphere, but in any case within 15 s. In case of disagreement, conduct the tests in a room maintained at the test temperature.

## 8. Procedure—General

8.1 Measure the dimensions of the test specimens in accordance with Test Method D2122.

8.2 The point of impact for all specimens shall be at the top of the vertical diameter.

8.3 Test unsymmetrical fittings with the specimen lying on its side.

8.4 Position the pipe specimens at random angular orientations.

8.5 Impact each specimen only once.

## 9. Procedure—Details

9.1 Impact one of the sets using an energy estimated to cause 15 % of the specimens to fail; impact the second set at an energy estimated to cause 85 % to fail. Record the actual percentage that fail and plot on normal probability graph paper.

9.2 *Preliminary Tests:*

9.2.1 The purpose of the preliminary tests is to identify the optimum tup mass and to determine the drop heights to be used for the final tests.

NOTE 6—The use of this preliminary procedure is optional. Trial and error, previous experience with the material, or guesswork may serve as well. Also, see Appendix X3.

NOTE 7—The chief source of problems in conducting impact tests is the ratio of the standard deviation to the mean strength. Use of Tup C with pipe specimens will reduce the size of the problem.

9.2.2 Select a tup estimated to cause failure of some specimens when dropped from a height of 5 ft (1.5 m) and use it to test four specimens.

9.2.2.1 If at least one but not all four specimens fail with the first tup selected, continue the test as described in 9.2.3.

9.2.2.2 If all four specimens fail, test four more specimens with a lighter tup.

9.2.2.3 If all four specimens pass, test the same specimens with a heavier tup, at a drop height of 5 ft (1.5 m).

9.2.2.4 Once a weight has been used that results in the failure of some, but not all, specimens at a height of 5 ft (1.5 m), continue the test as described in 9.2.3. If no failures occur with the heaviest tup at a drop height of 5 ft (1.5 m), test at the maximum drop height. If no failures occur with the maximum weight at the maximum drop height, test a total of 50 specimens at this drop height, record the results, and discontinue testing. If one or more of the preliminary test specimens passes with the maximum weight at the maximum drop height, proceed to 9.2.3.

9.2.3 After the optimum tup weight has been determined, divide the remaining group of preliminary test specimens into two equal lots. Each group shall contain at least eight specimens. Test one lot at a lesser drop height so that substantially less than 50 % failures result. Test the second lot at a greater drop height so that substantially more than 50 % failures result. Plot these results on probability graph paper to serve as the basis for estimating the proper drop heights for the final test.

9.2.4 If the 6-lb (2.7-kg) tup produces 100 % failures at 5 ft (1.5 m), use lesser drop heights for the procedures outlined in 9.2.3.

NOTE 8—Because there must be both failures and nonfailures in this test, conditions that result in 100 % failures or 100 % passes are of limited value in the development of information. When all specimens pass, the problem can be helped by (*1*) changing from the flat-plate holder to the V-block holder (in the case of pipe specimens), (*2*) changing from Tup B to Tup A, and finally to Tup C, and (*3*) lowering the test temperature. When all specimens fail, the sequence is reversed.

9.3 *Final Test:*

9.3.1 Divide 100 test specimens into two equal sets.

9.3.2 On the basis of the preliminary test, trial and error, or judgment, estimate the drop height at which 85 % of the specimens will pass and test the first set of 50 specimens at this height. Record the value of the mass, the drop height, and the number of passes.

9.3.3 Estimate the drop height at which 85 % of the specimens will fail and, if it is 10 ft (3.0 m) or more, use this height. Test 50 specimens and record the number of passes and the drop height.

9.3.4 *Acceptable Data:*

9.3.4.1 To be acceptable, there must be at least one pass and at least one fail in each set of data; one set of data should list less than 50 % failures; the number of passes in the two sets should differ by at least 20.

9.3.4.2 If the requirements of 9.3.4.1 have not been met, test 50 additional specimens at a drop height chosen to rectify the deficiency.

9.3.5 Construct a straight-line plot of the test results on normal probability paper. Preliminary tests which were conducted at the same drop height as the final tests shall be used to compute the percent passing at that height. All other preliminary test results are ignored for purposes of obtaining the final plot.

9.3.6 The intercept of the plot with the 50 % pass/fail line is the average impact resistance of the set as measured by the test.

9.3.7 The intercept of the plot at the 16 % or the 84 % pass/fail line differs from the average strength by (for practical purposes) one standard deviation.

## 10. Definition of Failure

10.1 Failure in the test specimens shall be shattering or any crack or split created by the impact and that can be seen by the naked eye. Lighting devices may be used to assist in examining the specimens. A crease visible on the surface shall not be construed as failure. If criteria of failure other than those cited here are used, they shall be listed in the report.

## 11. Report

11.1 The report shall include the following:

11.1.1 Complete identification of pipe or fittings tested, including type of plastic, source, manufacturer's code, size, average dimensions and minimum wall thickness, and history,

11.1.2 In the case of fittings, the dimensions of pipe used to prepare the specimens, how joints were made, and the position of the weld mark in relation to the point of impact,

11.1.3 Test temperature and conditioning procedure,

11.1.4 Tup used,

11.1.5 Holder used,

11.1.6 The mass of the tup, lb (kg),

11.1.7 Point of impact for fittings,

11.1.8 Types of failure and any deformation observed,

11.1.9 Date of test, and

11.1.10 Copy of probability plot, including number of specimens tested at each drop height.

## 12. Precision and Bias

12.1 This test method is neither precise nor accurate within the limits usually associated with those terms unless larger numbers of test specimens are employed. Therefore, no statement of bias can be made.

NOTE 9—A brief treatment of the subject of precision and accuracy for binomial tests is provided in Appendix X1.

## 13. Keywords

13.1 fittings; impact resistance; pipe; thermoplastic; tup (falling weight)

# APPENDIXES

**(Nonmandatory Information)**

## X1. GUIDELINES FOR DETERMINING PRECISION AND ACCURACY BY APPLYING BINOMIAL PROBABILITY TECHNIQUES

X1.1 Tests that have only two possible results (pass or fail, heads or tails, black or white) are governed by the rules of probability.

X1.2 The most elementary application of the rules occurs when the true probability of success is known. When a fair coin is tossed, for example, the probability for "heads" is known to be exactly 0.5 chance out of 1.

X1.3 The probability,$_rP_n$, for exactly $r$ successes in $n$ tries when the probability for success, $p$, is known for each try, is given by the equation

$$_rP_n = \frac{n!}{r!\,(n-r)!}(p^r)\,(1-p)^{n-r} \qquad \text{(X1.1)}$$

*Example*— The chance that one will obtain exactly 25 heads when a fair coin is tossed 50 times is equal to

$$\frac{50!}{25!\,(50-25)!}\,(0.5^{25})\ or\ 0.112 \qquad \text{(X1.2)}$$

The factorial of zero (0) is one (1).

X1.4 The total of the probabilities for all possible results is equal to 1. The equation is mathematically exact.

X1.5 A complication exists when the true probability of success is not known, but must be deduced on the basis of binomial test data. This is the case when thermoplastic pipe and fittings are subjected to impact testing as outlined in this test method.

X1.6 The binomial probability equation can be employed to define the likely limits of error for binomial test data. It will be simpler to refer to a statistics text or to use the approximate equation as follows:

$$s = \sqrt{\frac{p(1-p)}{N}} \qquad \text{(X1.3)}$$

where:

$s$ = standard error,
$N$ = number of specimens tested, and
$p$ = measured rate of success.

*Example*—50 specimens are tested and 32 pass. Then the best estimate for $p$ (true probability of success) is 0.64, and the standard error equals:

$$\sqrt{\frac{0.64\,(1-0.64)}{50}} = 0.07 \qquad \text{(X1.4)}$$

The confidence level is 68.27 % (note the similarity to plus and minus one standard deviation); the true probability of success is in the range 0.64 ± 0.07, or from 0.57 to 0.71.

X1.7 The 90 % confidence interval is equal to the experimental value $p$ plus and minus 1.65 standard errors, and the 95 % confidence interval is equal to the experimental value plus and minus 1.96 standard errors. Note that the foregoing deals with error due to probability only and does not take account of error caused by equipment or experimental technique.

X1.8 Charts defining the confidence limits for binomial test data are listed in many reference works. Dixon and Massey[3] provide charts for 80, 90, 95, and 99 % confidence coefficients.

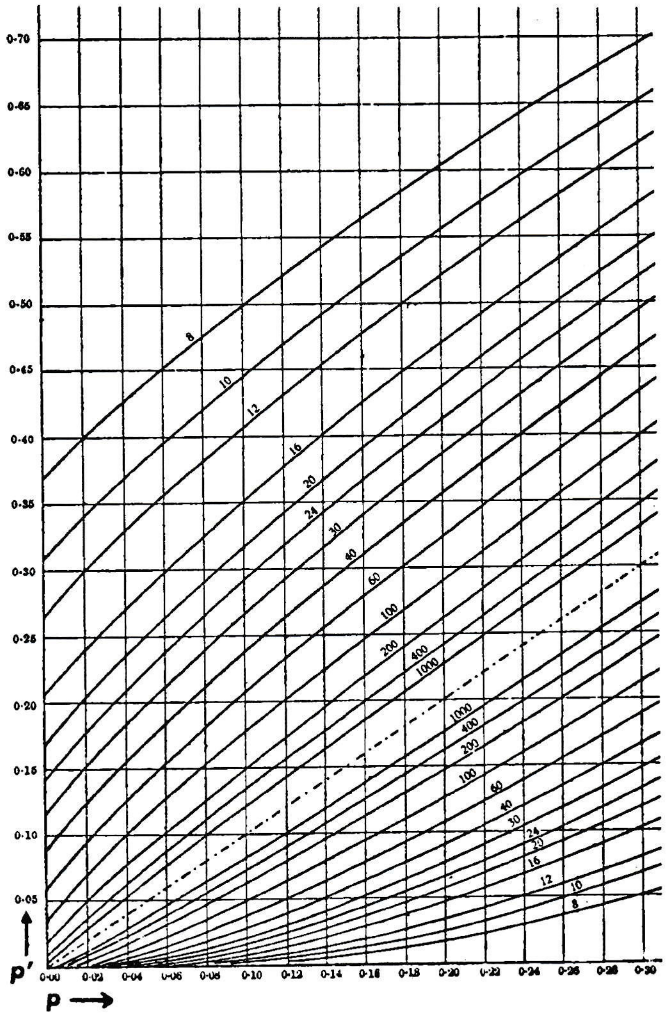
X1.8.1 *Use of* Fig. X1.1—If 100 specimens are tested, and 24 pass, calculate $p = 0.24$. Find the ordinate labeled 0.24 at the bottom of the chart and read up. At the intersection with the first curved line labeled "100", move to the left-hand side of the chart and read $p' = 0.16$. Return to the ordinate labeled 0.24 and find the intersection with the upper curved line labeled "100" and read "0.33" at the left-hand side of the chart. The probability of success ($p'$) is identified as 0.16 to 0.33, to a 95 % confidence level.

X1.9 *Improving Accuracy:*

X1.9.1 This test method provides less accuracy than may be required for some purposes.

X1.9.2 Analysis of the material represented by Fig. X1.1 reveals that accuracy is related to the square root of the number of specimens subjected to test. To reduce the size of error by a factor of 2 requires that four times as many specimens be

[3] Dixon, D. W., and Massey, Jr., F. J., "Introduction to Statistical Analysis," 3rd ed., McGraw Hill Book Co., Inc. New York, NY, 1969, pp. 501–504.




NOTE 1—Reproduced by permission of the Biometrika Trust.

NOTE 2—This figure provides confidence limits for $p'$ in binomial sampling, given a sample fraction. Confidence coefficient = 0.95. The numbers printed along the curves indicate the sample size $n$. If for a given value of the abscissa, $P_A$ and $P_B$ are the ordinates read from (or interpolated between) the appropriate lower and upper curves, then $Pr\ \{p_A \leq p' \leq p_B\} \geq 0.95$.

**FIG. X1.1 95 % Confidence Limits for Binomial Test Data**

tested. Note, also, that when the failure rate is close to zero (0 %) or one (100 %), then it requires more testing than when the failure rate is somewhat removed from these points.

X1.9.3 The use of only two data points presumes that the distribution of attributes is normal. When good information is required at some specific point (for example, the place where 90 % of all specimens should pass), then the two-point plot can be used to define the new test level most likely to be correct, and a third series of tests run at that level to check the accuracy of the preliminary plot at that point.

X1.9.4 Finally, a series of tests can be conducted at different energy levels when it is desired to define the true distribution of attributes over the range $p = 0$ to $p = 1$.

## X2. PROBABILITY GRAPH PAPER

X2.1 Probability graph paper is available in a variety of forms. One of the most common is illustrated in Fig. X2.1.

X2.2 The vertical grid is evenly spaced, whereas the horizontal grid spacing expands in both directions from the line labeled "50". The spacing is such that when statistical data are plotted, and when the distribution of attributes is normal, the plot will be a straight line. Numbers printed on the sides of the graph will typically read "0.01, 0.1, 0.2, 0.5, 1, 2, ... 40, 50, 60, ... 99, 99.9, 99.99." These numbers refer to the percent passing or failing at a given test level. The user labels the vertical lines. Ordinarily, equal increments will be used to label these lines. If it is known, for example, that all data of interest will fall in the region encompassed by 60 ft·lbf and 160 ft·lbf, the lines would be labeled "60, 70, 80, 90, ... 150, and 160." Two data points suffice to define the plot if the distribution is normal. Note that if the two data points are close to each other (for example, 40 and 52 % passing), then errors in either will affect the slope of the plot seriously. This is the reason for the requirements listed in 9.3.4.1. The mean impact resistance of the lot is defined by the intersection of the plot with the line labeled "50 %." To find the standard deviation, locate the intersection of the plot with the line for 16 % or for 84 %. The difference between either of these points and the 50 % point is equal to one standard deviation. Since there is no assurance that the properties will be distributed completely normally (particularly true for yardaged pipe exposed to differing amounts of ultraviolet light), the reliability will fall off in the regions where few pass or few fail. The plot suffices, nevertheless, to give a good general description of the properties of the pipe.

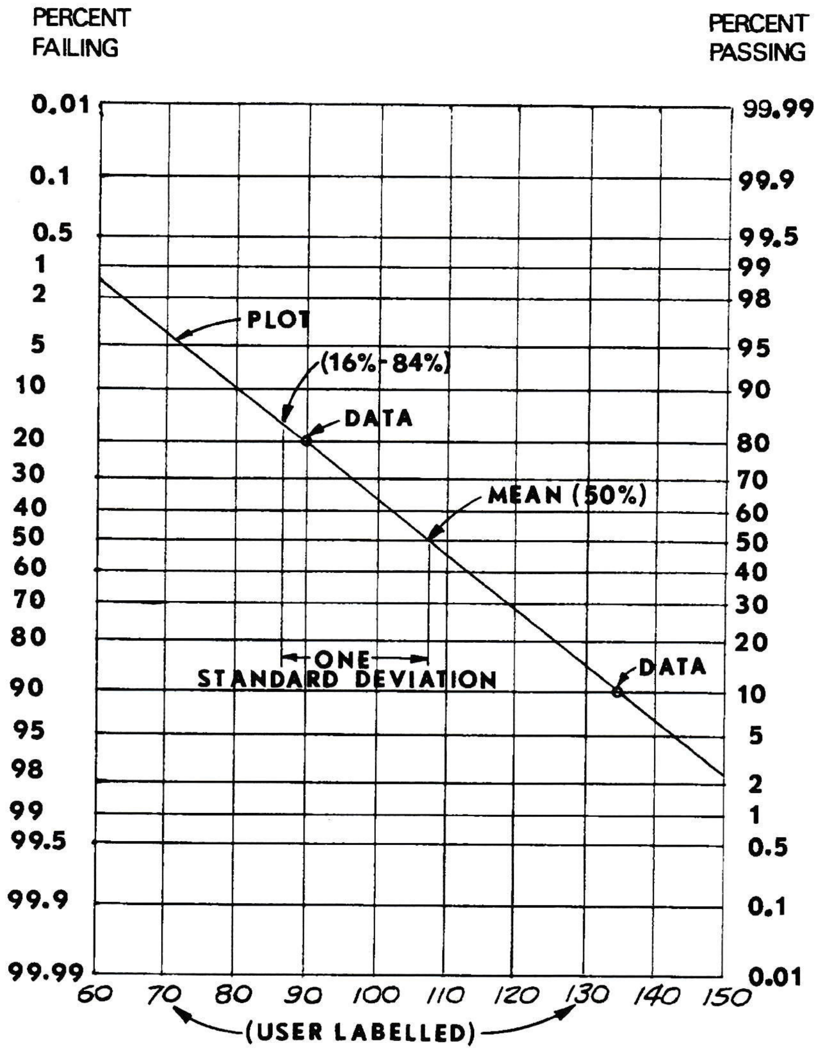



FIG. X2.1 Probability Graph

## X3. "UP/DOWN" TEST PROCEDURE TO DEFINE THE MEAN IMPACT RESISTANCE

### X3.1 Number of Test Specimens

X3.1.1 *Determination of Median Value:*

X3.1.1.1 Six or more specimens shall be used to determine the approximate starting point of the test. Once this is done for a specific size and type of pipe, it may not be necessary to repeat this preliminary step.

X3.1.1.2 The median impact resistance shall be determined with 20 test specimens of each sample. The specimens shall be labeled from 1 to 20 and the order of testing determined by a set of random numbers.

X3.1.2 For specification purposes, the number of specimens tested shall be in accordance with Section X3.5.

### X3.2 Conditioning

X3.2.1 *Conditioning*—Condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618, for those tests where conditioning is required.

X3.2.2 *Test Conditions*—Tests at lower or elevated temperatures shall be made in a room maintained at the test temperature, or if the test is made in an atmosphere at a temperature other than that at which the specimens are conditioned, the test shall be made as soon as possible on removal from the conditioning atmosphere, but in any case within 15 s after removal from the conditioning atmosphere. In case of disagreement, the tests shall be conducted in a room maintained at the test temperature.

### X3.3 Procedure—General

X3.3.1 Measure the dimensions of the test specimens in accordance with Test Method D2122. Note the position of the thinnest wall of each specimen.

X3.3.2 Mount the first test specimen with the thinnest wall section on top so that the tup strikes this area. Mount the second specimen so that the point of impact is 18° from the thinnest wall, the third 36°, etc.

X3.3.3 Test unsymmetrical fittings by laying the specimen on its side and impacting the other side. Strike six specimens on one side and six on the other.

X3.3.4 The point of impact for all specimens shall be at the top of the vertical diameter.

X3.3.5 Determine the impact resistance (energy) by the" Up and Down" (hereafter called UD) method.[4] In this method the energy required to break the specimens is bracketed by making the tests at different heights of drop in a systematic manner. No specimen is tested more than once in this method.

### X3.4 Procedure—Details

X3.4.1 The weight (mass) of the tup shall be 6, 12, 20, or 30 lb (2.7, 5.4, 9.1, or 13.6 kg).

X3.4.2 Make preliminary tests to determine the approximate height of fall of the tup required to produce failure in the pipe or fittings made of the particular material and in the particular dimensions to be tested.

NOTE X3.1—It has been found desirable to use increments of at least 6 in. (152 mm) for this initial testing.

X3.4.3 Test the first specimen, chosen by a set of random numbers as indicated in X3.1.2, by dropping the tup onto it from the 2-in. (50.8-mm) or 6-in. (152-mm) increment immediately below the approximate height determined in X3.4.2. If this specimen ruptures or cracks, test the second specimen at the next lower increment. If the first specimen does not fail, test the second one at the next higher increment. In a similar manner, determine the height of fall of the tup to test each specimen from the results observed with the specimen tested immediately prior.

### X3.5 Procedure—Specification Requirement

X3.5.1 For use in determining whether or not a sample meets the impact requirement in pipe or fitting specifications, it is recommended that specimens be tested on a "go, no-go" basis. The tup, the weight, and the height from which the tup is dropped shall be specified in the product specification.

X3.5.2 For pipe or symmetrical fittings, ten specimens shall be tested. When two or more specimens fail, the product does not meet the impact requirement. Nine nonfailures out of ten specimens tested shall be acceptable.

X3.5.3 For unsymmetrical fittings, six specimens shall be struck on one side and six on the other. When two or more of the specimens fail, the product does not meet the specified impact requirement. Eleven nonfailures out of twelve specimens tested shall be acceptable.

### X3.6 Definition of Failure

X3.6.1 Failure in the test specimens shall be shattering or any crack or split on the inside or outside created by the impact and that can be seen by the naked eye. Lighting devices shall be used to assist in examining for cracks and splits in the walls of the pipe or fittings specimens. Any permanent deformation of the specimens shall be reported with a short description of the deformation. If other criteria of failure than those cited here are used they shall be given in the report.

### X3.7 Calculations

X3.7.1 Calculate the median height of fall ($h$) and standard deviation ($s$) from the test data obtained as follows:

$$h = h_o + d\,[\,(A/N) \pm (1/2)] \qquad \text{(X3.1)}$$

$$s = 1.620d\left(\frac{NB - A^2}{N^2} + 0.029\right) \qquad \text{(X3.2)}$$

where:

$h$ = median height of fall, ft (m),
$d$ = increment in height of drop, ft or m, (⅙ for 2-in. or ½ for 6-in. (50.8 or 152 mm) increment),
$s$ = standard deviation for $h$,
$N$ = lesser number, either failures or nonfailure,
$h_0$ = lowest height at which any one of $N$ occurs, ft (m),
$A$ = $\sum_{i=0}^{k} i\, n_i$

where $h_0$, $h_1$, $h_2$, $h_3$, etc. are the heights in progressive order of magnitude in the range of heights where $N$ occurs: $i$ is the subscript of $h$, and $n_i$ is the number of failures or nonfailures, whichever is pertinent, at the level of $i$, and

$B$ = $\sum_{i=0}^{k} i^2 n_i$.

X3.7.2 The negative sign is used in the parentheses to calculate $h$ when $N$ refers to failures, and the positive sign when $N$ is the number of nonfailures. Calculate the median impact resistance by multiplying $h$ by the weight used in pounds. Calculate the standard deviation by multiplying $s$ by the weight used in pounds.

[4] This system of testing, nomenclature, and calculations is described by Dixon, W. J., and Massey, F. J., Jr., *Introduction to Statistical Analysis*, Chapter 19, Third Edition 1969, McGraw Hill Book Co. Inc., New York, NY.

## X4. GUIDELINES FOR SELECTION OF TESTING COMBINATIONS

X4.1 It is recognized that the impact resistance of thermoplastic pipe and fittings is a function of the material in the product, of the quality of the extrusion or molding, of the geometry and dimensions of the test specimen and of the testing variables used (temperature, tup nose geometry, tup weight, specimen support, and height of drop). Because all these factors and their interrelations affect the test results, impact tests are useful mainly for quality control and comparative purposes, not as simulated service tests. The combinations of test variables should be selected so that the test can be easily run with little or no hazard to personnel and the results obtained are reasonably reproducible. To achieve this end, the following guidelines for selection of the testing variables are suggested:

X4.1.1 Use the tup which will give the best reproducibility.

X4.1.2 Use the tup which is most representative of the service concerned.

X4.1.3 Use the tup and weight combination which will produce failure within a drop height between 2 and 10 ft (0.6 and 3.0 m).

X4.1.4 If no combination of tup-weight-height-support is available that will give satisfactory results because of high-impact resistance, lower the test temperature of the test specimen by use of an ice-water mixture or by an air-conditioned environment to an even lower temperature.

X4.1.5 The impact resistance of a specimen increases when (*a*) the temperature is increased; (*b*) the tup nose geometry changes in order to C, A, B; (*c*) the specimen support is changed from the V-block to a flat plate; (*d*) the tup weight is decreased; and (*e*) the height drop is decreased.

FR

Tubi multistrato metallo-plastici e relativi raccordi in ottone per distribuzione sanitaria e riscaldamento.
*Metal-plastic ,ulti-layer pipes and relative brass fittings for domestic water and heating.*

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# CERTIFICAT

## Systèmes de canalisations de distribution d'eau

Décision n° 1541-110-1559 du 1 septembre 2010
attachée à l'Avis Technique n° 14/10-1559

le produit :

**VALSIR MIXAL**

De la société VALSIR Spa
Localita Merlaro 2
IT - 25078 VESTONE (BRESCIA)
Usine de IT - 25079 VOBARNO

bénéficie de la marque CSTBat en application des exigences générales de la certification CSTBat et du règlement technique n°15.1. Cette décision atteste que le produit ci-dessus est certifié conformément à ces référentiels.

**CHAUFFAGE ET DISTRIBUTION SANITAIRE**

CSTBat -110-1559

La Direction Technique
Yannick LEMOIGNE

## CARACTÉRISTIQUES CERTIFIÉES

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NATURE DU SYSTEME : multicouche

**Tube multicouche à âme aluminium**
- Caractéristiques dimensionnelles
- Retrait à chaud
- Taux de gel sur couche intérieure PEX
- Résistance à l'oxydation sur couche intérieure PEX
- Résistance à la pression
- Résistance à la décohésion

Ce certificat comporte 1 page.

Correspondant :

Guy CALIN

Tél. : 01 64 68 82 52

Fax : 01 64 68 84 44

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DE

Tubi multistrato metallo-plastici per sistemi di tubazioni per acqua potabile calda e fredda (DVGW W542 e BGA KTW).
*Metal-plastic multi-layer pipes for piping systems for hot and cold drinking water (DVGW W542 and BGA KTW).*

DVGW CERT

DVGW

CERT

# DVGW type examination certificate
## *DVGW-Baumusterprüfzertifikat*

**DW-8231BN0466**
Registration Number
*Registriernummer*

| | |
|---|---|
| **Field of Application** *Anwendungsbereich* | products of water supply *Produkte der Wasserversorgung* |
| **Owner of Certificate** *Zertifikatinhaber* | Valsir S.p.A. Loc. Merlaro, 2, I-25078 Vestone (BS) |
| **Distributor** *Vertreiber* | Valsir S.p.A. Loc. Merlaro, 2, I-25078 Vestone (BS) |
| **Product Category** *Produktart* | composite tubes for drinking water installations: PE-Xb/Al/PE-Xb tube, manufacturing group 1 (8231) |
| **Product Description** *Produktbezeichnung* | multilayer pipe PE-Xb/Al/PE-Xb for the drinking water installation |
| **Model** *Modell* | Pexal, FG 1 |
| **Test Reports** *Prüfberichte* | type testing: 549/12 from 21.03.2014 (IMA)<br>laboratory control test: 321313/1.1/107657 from 30.10.2013 (SKZ)<br>supplement test: B016/12 from 06.07.2012 (IMA)<br>supplement test: B077/10 from 01.06.2011 (IMA)<br>supplement test: 44381/01-V from 23.02.2005 (SKZ)<br>type testing: 44381/01-V from 05.11.2003 (SKZ)<br>KTW testing: KR 193/13 from 17.10.2013 (TZW)<br>hygienic testing: MO 267/10 from 26.08.2011 (TZW) |
| **Test Basis** *Prüfgrundlagen* | DVGW W 542 (01.08.2009)<br>UBA KTW (07.10.2008)<br>DVGW W 270 (01.11.2007) |
| **Date of Expiry / File No.** *Ablaufdatum / Aktenzeichen* | 05.11.2018 / 14-0152-WNA |

70029-04-A-DE

16.04.2014 Wg A-1/2
Date, Issued by, Sheet, Head of Certification Body
Datum, Bearbeiter, Blatt, Leiter der Zertifizierungsstelle

DVGW CERT GmbH is an accredited body by DAkkS according to EN 45011:1998 for certification of products for energy and water supply industry.

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DE

Tubi multistrato metallo-plastici per sistemi di tubazioni per acqua potabile calda e fredda (DVGW W542 e BGA KTW).

*Metal-plastic multi-layer pipes for piping systems for hot and cold drinking water (DVGW W542 and BGA KTW).*

A-2/2 **DW-8231BN0466**

| **Type** *Typ* | **Technical Data** *Technische Daten* | **Remarks** *Bemerkungen* |
| --- | --- | --- |
| Pexal | manufacturing group: 1 | diameters: up to 63 mm |

**Hints of Utilization / Remarks**
***Verwendungshinweise / Bemerkungen***

tested diameters: 16,0 x 2,00 mm (Al: 0,30 mm), 20,0 x 2,00 mm (Al: 0,40 mm), 26,0 x 3,00 mm (Al: 0,58 mm), 32,0 x 3,00 mm (Al: 0,70 mm), 40,0 x 3,50 mm (Al: 0,85 mm) and 50,0 x 4,00 mm (Al: 1,01 mm)

IT

Idoneità del tubo multistrato metallo-plastico Pexal a trasportare acqua destinata al consumo umano (DM 174/2004)
*Suitability of the multi-layer metal-plastic pipe Pexal for trasporting water destined for human consumption (DM 174/2004).*

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ACCREDIA
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LAB n°0097

## RAPPORTO DI PROVA N° 0589LP/2014

Monza, 13/10/2014

Richiedente: IIP S.r.l. - Ufficio Certificazione Prodotti - via Velleia, 2 - 20900 Monza (MB)

Campionamento: a cura del richiedente (nel corso della verifica ispettiva n° 3370)

Produttore: VALSIR SPA - VIA DELLA FERRIERA 1 - 25079 VOBARNO (BS)

Data ricevimento campione: 26/09/2014

Campione dichiarato: Sistemi di tubazioni di PE-X / Al / PE-X e PPSU norma UNI EN ISO 21003 - 5 : 2009

Descrizione del campione: DN 40

Identificazione campione: 675/14

Marcatura del campione: VALSIR PEXAL 40 x 3,5 Made in Italy PE-Xb/Al/PE-Xb 140607 Sanitario Riscaldamento Temp. max 95 °C IIP 205 UNI EN ISO 21003 classe 1,2,4,5 / 10 bar AS4176 W 00083 ATEC 14/13-1923 CSTbat 110-1923 Classe 2 (70 C - 10 bar) Classe 4 (60 C - 10 bar) Classe 5 (80 C - 6 bar) Prodotto Conforme DM 174/2004 Linea 101 V0073 KIWA classe 2/10 bar KOMO classe 5/6 bar ONORM EN ISO 21003 gepruft Klassen 1,2,4,5 / 10 bar TW OVGW W1 404 ON-N 2010 026

### MIGRAZIONE GLOBALE IN ACQUA
### (TUBAZIONI ED ACCESSORI A CONTATTO CON ACQUE DESTINATE AL CONSUMO UMANO)

Riferimenti normativi/metodi di prova: DM n° 174 06/04/2004 GU n° 166 17/07/2004

Data di inizio prova: 08/10/2014 Data di fine prova: 13/10/2014

Caratteristiche di prova:
- Simulante: acqua distillata
- Condizioni di contatto: 40 °C per 24 h
- Rapporto superficie/volume: 1.0

Risultato della prova: < 1 [mg]/[dm]^2 (equivalente a: < 6 [mg]/[kg])

Limite di migrazione globale indicato dal D.M. n° 174 del 6/4/2004: 60 [mg]/[kg] (materie plastiche)

L'incertezza di misura, ove indicata nei risultati, è espressa come incertezza estesa ottenuta moltiplicando l'incertezza tipo per il fattore di copertura K che corrisponde ad un livello di fiducia di circa il 95% Normalmente tale fattore di copertura K vale 2.

Il Responsabile della Prova
(dott. M. Cecchi)

Il Responsabile del Laboratorio
(ing. L. Galbiati)

I risultati delle determinazioni sovraesposti si riferiscono soltanto al campione ricevuto.
La riproduzione parziale del presente Rapporto di Prova deve essere autorizzata dal Laboratorio Prove I.I.P.
Il campione viene conservato per due mesi dalla data di emissione del presente Rapporto di Prova.
Il campionamento non è oggetto di accreditamento.
MOD RP. 00 - Rev. 0 del 06/13

IT

Qualificazione del processo speciale di saldatura del tubo multistrato metallo-plastico (UNI EN 288–8).
*Qualification of the special welding process of the metal-plastic multi-layer pipe (UNI EN 288–8).*

AIOICI

IIS

# ISTITUTO ITALIANO DELLA SALDATURA

ENTE MORALE

CERTIFICATO N. -LT-606-
CERTIFICATE No

L'ISTITUTO ITALIANO DELLA SALDATURA CERTIFICA CHE / THE ITALIAN INSTITUTE OF WELDING CERTIFIES THAT

the procedure VALSIR S.P.A. WPS No.VALSIR 02/2001 Rev.0

E' QUALIFICATO(A) IN ACCORDO A / IS QUALIFIED ACCORDING TO

the UNI EN 288-8: 1997

NOTE / REMARKS

Annexes No.12

DATA DI EMISSIONE / ISSUE DATE 13 Novembre 2001

*AREA CERTIFICAZIONE CSP*
*CERTIFICATION AREA CSP*
(P.I. Antonio Pandolfo)

*Membro Fondatore / Founder Member:* International Institute of Welding — iiw iis — European Welding Federation



PEXAL PEXALEASY valsir®

Tubi multistrato metallo-plastici e relativi raccordi sia in ottone e sia plastici (PPSU) per impianti sanitari, di riscaldamento e condizionamento nel settore navale (Prescrizioni RINA).

*Metal-plastic multi-layer pipes and relative fittings both in brass and in plastic (PPSU) for domestic, heating and air-conditioning systems in the shipping sector (RINA prescriptions).*

SETTORE NAVALE - *NAVAL INDUSTRY*

## CERTIFICATO DI OMOLOGAZIONE DI TIPO
N. **MAC032514CS/003**

**Si certifica** che il seguente prodotto soddisfa le prescrizioni delle norme qui specificate.

| | |
|---|---|
| *Descrizione* | **Tubi e raccordi in plastica** |
| *Tipo* | **Sistemi PEXAL + PEXAL EASY** |
| *Richiedente* | **VALSIR SPA**<br>**LOCALITA' MERLARO**<br>**25078 VESTONE (BS)**<br>**ITALY** |
| *Fabbricante*<br>*Luogo di produzione* | **VALSIR SPA**<br>**LOCALITA' MERLARO**<br>**25078 VESTONE (BS)**<br>**ITALY** |
| *Norme di riferimento* | **Parte C, Capitolo 1, Appendice 3 delle Norme RINA** |

*Rilasciato a* **Genova il 5 Febbraio 2014**. *Questo Certificato è valido fino al* **4 Febbraio 2019**

RINA Services S.p.A.
*Francesco Sciacca*

Questo Certificato e' composto di 1 pagina e di 1 allegato.
Questo Certificato annulla e sostituisce il precedente N° MAC182308CS/006 rilasciato il 27.01.2009.

RINA Services S.p.A.
Via Corsica, 12 - 16128 Genova
Tel +39 010 53851
Fax +39 010 5351000

IT

Tubi multistrato metallo-plastici e relativi raccordi sia in ottone e sia plastici (PPSU) per impianti sanitari, di riscaldamento e condizionamento nel settore navale (Prescrizioni RINA).

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SETTORE NAVALE - *NAVAL INDUSTRY*

**CERTIFICATO DI OMOLOGAZIONE DI TIPO**

N. **MAC032514CS/003**

**Allegato - Pagina 1/2**

**Sistemi PEXAL + PEXAL EASY**

## Documenti di riferimento

Catalogo Generle VALSIR L02-290/2 - 2007.

## Caratteristiche tecniche

Materiali dei tubi:
- Strato interno ed esterno: Polietilene reticolato PE-Xb in accordo allo Standard EN ISO 21003.
- Strato intermedio: Lega di alluminio saldata testa a testa longitudinalmente.

Materiali dei raccordi:
- Raccordi ad avvitare: Lega di ottone (diametri nominali da 16 a 32 mm).
- Raccordi a pressare: Lega di ottone (diametri nominali da 14 a 63 mm).
- Sistema Pexal EASY: Polifenilsolfone (PPSU) in accordo allo Standard EN ISO 21003.

Pressione interna nominale: 10 bar

Massima temperatura di esercizio: 95° C

Diametri nominali e spessori dei tubi come da tabella:

| Diametro esterno (mm) | Spessore di parete (mm) |
|---|---|
| 14 | 2 |
| 16 | 2 |
| 16 | 2.25 |
| 18 | 2 |
| 20 | 2 |
| 20 | 2.5 |
| 26 | 3 |
| 32 | 3 |
| 40 | 3.5 |
| 50 | 4.0 |
| 63 | 4.5 |

## Campo di applicazione

Impianti sanitari e di riscaldamento.

Servizi non essenziali e posizioni per le quali non sia richiesta alcuna prova di resistenza al fuoco in accordo alla Tabella 1, Appendice 3, Capitolo 1, Parte C dei Regolamenti RINA.

L'impiego di questi tubi e raccordi in plastica è accettabile su sistemazioni per le quali e' richiesta la limitata attitudine a propagare la fiamma come previsto al paragrafo 2.3.2 della sopra citata Appendice 3.

I tubi sono accettabili per impianti soggetti a pressione esterna se dimostrato che la pressione nominale esterna non sia superiore ad 1/3 della pressione di collasso e che la pressione di collasso non sia inferiore a 3 bar.

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IT

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SETTORE NAVALE - *NAVAL INDUSTRY*

**CERTIFICATO DI OMOLOGAZIONE DI TIPO**
**N. MAC032514CS/003**
**Allegato - Pagina 2/2**
**Sistemi PEXAL + PEXAL EASY**

## Condizioni di accettazione

I tubi e gli accessori devono essere marcati in conformità al Paragrafo 2.1.2 della Appendice 3, Capitolo 1, Parte C dei Regolamenti RINA.

La sistemazione e l'installazione a bordo dei tubi in plastica deve essere eseguita in conformità con le istruzioni del Fabbricante e al Paragrafo 3 della sopra citata Appendice 3 del RINA per quanto applicabile.

Qualora siano previsti passaggi di tubi in plastica attraverso divisioni di classe "A" o "B", devono essere realizzate sistemazioni atte a garantire che la resistenza al fuoco delle predette divisioni non venga menomata. Tali sistemazioni devono essere provate secondo le "Raccomandations for fire test procedures for "A", "B" e "F" bulkheads" (Raccomandazioni per le procedure di prova del fuoco per paratie di classe "A","B" e "F") (Risoluzione dell'IMO A.754(18), come emendata).

Qualora tubi in plastica passino attraverso paratie o ponti stagni deve essere assicurata l'integrità della tenuta stagna della paratia o del ponte. Se la paratia o il ponte costituisce anche una divisione tagliafuoco e la distruzione dei tubi da parte di un incendio può causare l'ingresso di liquidi dalle cisterne, deve essere sistemata sulla paratia o sul ponte una valvola d'intercettazione metallica che possa essere comandata dal di sopra del ponte di bordo libero.

Per impianti collegati a scafo, deve essere osservato quanto richiesto al paragrafo 3.7 della summenzionata Appendice 3.

Prima e dopo l'installazione a bordo, i tubi ed i relativi accessori devono essere sottoposti a prove in conformità ai paragrafi 4.2 e 4.3 della stessa Appendice 3.

## Osservazioni

L'installazione a bordo di navi costruite in conformità al "Regolamento per la costruzione e la Classificazione delle unità veloci" del RINA è subordinata alla rispondenza completa di quanto è previsto dalla Risoluzione IMO A.753(18) sulle linee guida per l'applicazione dei tubi in plastica a bordo delle navi.

Questo Certifivato annulla e sostituisce il precedente N° MAC 182308CS/006 rilasciato il 27.01.2009.

**Genova 05/02/ 2014**

RINA Services S.p.A.
Via Corsica, 12 - 16128 Genova
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Tubi multistrato metallo-plastici e relativi raccordi sia in ottone e sia plastici (PPSU) per impianti sanitari, di riscaldamento e condizionamento nel settore navale (Prescrizioni RINA).

*Metal-plastic multi-layer pipes and relative fittings both in brass and in plastic (PPSU) for domestic, heating and air-conditioning systems in the shipping sector (RINA prescriptions).*

SETTORE NAVALE - *NAVAL INDUSTRY*

**TYPE APPROVAL CERTIFICATE**
No. **MAC060014CS/003**

**This is to certify** that the product identified below is in compliance with the regulations herewith specified.

| | |
|---|---|
| *Description* | **Plastic pipes and fittings** |
| *Type* | **PEXAL + PEXAL EASY System** |
| *Applicant* | **VALSIR SPA**<br>**LOCALITA' MERLARO**<br>**25078 VESTONE (BS)**<br>**ITALY** |
| *Manufacturer* | **VALSIR SPA** |
| *Place of manufacture* | **LOCALITA' MERLARO**<br>**25078 VESTONE (BS)**<br>**ITALY** |
| *Reference standards* | **Part. C, Ch. 1, Appendix 3 of RINA Rules** |

*Issued in* **Genoa** on **May 15, 2014**. *This Certificate is valid until* **May 14, 2019**

RINA Services S.p.A.

This Certificate annuls and replaces the preious one No. MAC182308CS/006 issued on the 27 Jennuary 2009.
This certificate consists of this page and 1 enclosure

RINA Services S.p.A.
Via Corsica, 12 - 16128 Genova
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Tubi multistrato metallo-plastici e relativi raccordi sia in ottone e sia plastici (PPSU) per impianti sanitari, di riscaldamento e condizionamento nel settore navale (Prescrizioni RINA).

*Metal-plastic multi-layer pipes and relative fittings both in brass and in plastic (PPSU) for domestic, heating and air-conditioning systems in the shipping sector (RINA prescriptions).*

SETTORE NAVALE - *NAVAL INDUSTRY*

**TYPE APPROVAL CERTIFICATE**
No. **MAC060014CS/003**
**Enclosure - Page 1 of 2**
**PEXAL + PEXAL EASY System**

## Reference documents

General Catalogue VALSIR L02-290/2 - 2007.

## Technical Characteristic

Pipe materials:
- Internal and external layer: cross-linked polyethylene PE-Xb in accordance with Standard EN ISO 21003.
- Intermediate layer: Alluminium alloy and longitudinally electro-butt welded

Fittings materials:
- Screw fittings: Brass alloy (nominal diameter from 16 to 32 mm).
- Press fittings: Brass alloy (nominal diameter from 14 to 63 mm).
- Pexal EASY system: Polyphenylensulphone (PPSU) in accordance with Standard EN ISO 21003.

Nominal internal pressure: 10 bar

Maximum working temperature: 95° C

Nominal diameter and thickness of pipes like indicate in the table:

| External diameter (mm) | wall thickness (mm) |
|---|---|
| 14 | 2 |
| 16 | 2 |
| 16 | 2.25 |
| 18 | 2 |
| 20 | 2 |
| 20 | 2.5 |
| 26 | 3 |
| 32 | 3 |
| 40 | 3.5 |
| 50 | 4.0 |
| 63 | 4.5 |

## Application range

Sanitary system and heating system.

For non essential services and positions where it is not requested the low spread characteristic in accordance with Para. 2.3.2, Appendix 3, Ch. 1, Part C of RINA Rules
The installation of plastic pipes and fittings is acceptable for application where the low spread characteristic is request in accordanece to Para. 2.3.2, Appendix 3, Ch. 1, Part C of RINA Rules.

The pipes are acceptable for use subject to external pressure if demontrated that the external nominal pressure is not higher than 1/3 collapse pressure and the collapse pressure is not less than 3 bar.

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IT

Tubi multistrato metallo-plastici e relativi raccordi sia in ottone e sia plastici (PPSU) per impianti sanitari, di riscaldamento e condizionamento nel settore navale (Prescrizioni RINA).

*Metal-plastic multi-layer pipes and relative fittings both in brass and in plastic (PPSU) for domestic, heating and air-conditioning systems in the shipping sector (RINA prescriptions).*

SETTORE NAVALE - *NAVAL INDUSTRY*

**TYPE APPROVAL CERTIFICATE**
No. **MAC060014CS/003**
**Enclosure - Page 2 of 2**
**PEXAL + PEXAL EASY System**

## Acceptance condition

Pipes and accesories are to be marked in accordance with Para. 2.1.2 of Appendix 3 of RINA Rules.

Installation on board of that piping system is to be carried out in accordance to Para. 3, Appendix 3 of Ch. 1, Part. C of RINA Rules and in accordance to the instruction of the Manufacturer.

Where plastic pipes pass through "A" or "B" class divisions, arrangements are to be made to ensure that fire endurance is not impaired. These arrangements are to be tested in accordance with "Recommendations for Fire Test Procedures for "A", "B" and "F" Bulkheads" (IMO Resolution A754 (18) as amended).

In case of ships flying EC flag, the bulkhead penetrations are to be Certified in accordance with 96/98/EC directive on marine equipment (as amendend) (MED).

When this pipes pass trough watertight bulkhead or watertight deck, the integrity of the watertight bulkhead or watertight deck is to be guaranteed. If the bulkhead or deck are to be considered as structural fire protection and the burning of the pipes could cause the entry of liquid in the tank, a metallic shutoff valve is to be placed on the bulkhead or deck and it is to be actioned over the freeboard deck

For system connected to the hull, the requirement of Para 3.7, Appendix 3 of RINA Rules are to be adopted.

Before or after the installation on board, pipes and relevant accesories are to be tested in accordance to Para 4.2 and 4.3 of Appendix 3.

## Remarks

The installation on board of ships built in accordante with "Rules for the Classification of High-Speed craft" of RINA is subordinated to the compliance to the requirements contained in IMO Resolution A.753(18) about base line of the application on board of plastic pipes.

This Certificate annuls and replaces the preious one No. MAC182308CS/006 issued on the 27 Jennuary 2009.

**Genoa May 15, 2014**

RINA Services S.p.A.
Via Corsica, 12 - 16128 Genova
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# UK

Omologazione dei tubi multistrato metallo-plastici e relativi raccordi sia in ottone (ad avvitamento e a pressare) e sia plastici in PPSU per impianti sanitari e di riscaldamento.

*Approval of metal-plastic multilayer pipes and relative fittings both in brass (compression and crimp) and in PPSU plastic for domestic and heating systems.*

# WRAS®

**Water Regulations Advisory Scheme**

*This certifies that*

**VALSIR SPA**

*has had the undermentioned product examined, tested and found, when correctly installed, to comply with the requirements of the United Kingdom Water Supply (Water Fittings) Regulations/Scottish Water Byelaws.*

**'PEXAL EASY' RANGE PRESS FITTINGS FOR USE WITH PEXEL PIPE: 16MM to 75MM. 'PEXAL BRASS' RANGE PRESS FITTINGS FOR USE WITH PEXEL PIPE: 16MM to 90MM.**

***This certificate by itself is not evidence of a valid WRAS Approval. Confirmation of the current status of an approval must be obtained from the WRAS Directory (www.wras.co.uk/directory)***

*The product so mentioned will be listed in the Water Fittings and Materials Directory for a period until:*

**31 MARCH 2019**

**1403325**

*Certificate No.*

*Chairman, Product Approval Group*

*Secretary*

**WRAS APPROVED PRODUCT**

Omologazione dei tubi multistrato metallo-plastici e relativi raccordi sia in ottone (ad avvitamento e a pressare) e sia plastici in PPSU per impianti sanitari e di riscaldamento.

*Approval of metal-plastic multilayer pipes and relative fittings both in brass (compression and crimp) and in PPSU plastic for domestic and heating systems.*

**WRAS**
Water Regulations Advisory Scheme®

Approval No: 1403325

11th March 2014

Paolo Damioli
Valsir SpA
Localita Merlaro 2
25078 Vestone (BS)
Italy

Dear Paolo Damioli

**MULTI-LAYERED PIPE SYSTEMS**

1. Samples of the fittings or units described below have been subjected to relevant tests and examinations contained in the "Regulators' specifications", and after considering the test reports the Technical Committee's Product Assessment Group (PAG) of the Water Regulations Advisory Scheme (WRAS or "the Scheme") finds that the fittings or units so described comply with, and their use when correctly installed, does not contravene the requirements of The Water Supply (Water Fittings) Regulations 1999, The Water Byelaws 2004 Scotland, and Water Supply (Water Fittings) Regulations (Northern Ireland) 2009.

**1403325**

**This approval is valid for fittings (as listed below in `model`) manufactured AND installed between March 2014 & March 2019.**

**MULTI-LAYERED PIPE SYSTEMS: 1106**
**INCORPORATING AN ALUMINIUM LAYER**
Compatible fittings and pipe systems.

Because there are no accepted tests, WRAS approval of barrier pipe does not include an assessment of its ability to prevent migration of contaminants through the wall of the pipe from the surrounding soil.

IRN R001
Range of PPSU and brass press fittings for use with Pexal pipe. For above ground use only. Maximum working pressure 10.0 bar. Maximum operating temperature 95°C.

| | |
|---|---|
| Size: | 16mm to 75mm – 'Pexal Easy' range fittings.<br>16mm to 90mm – 'Pexal Brass' range fittings. |
| Model: | 'Pexal Easy' range & 'Pexal Brass' range of fittings.<br>Pexel pipe. |

Water Regulations Advisory Scheme Ltd,
30 Fern Close, Pen-Y-Fan Industrial Estate
Oakdale, Gwent, NP11 3EH
Tel: +44 (0) 333 207 9030. Fax: +44 (0) 1495 248 540
Email: info@wras.co.uk. Website: www.wras.co.uk

Omologazione dei tubi multistrato metallo-plastici e relativi raccordi sia in ottone (ad avvitamento e a pressare) e sia plastici in PPSU per impianti sanitari e di riscaldamento.

*Approval of metal-plastic multilayer pipes and relative fittings both in brass (compression and crimp) and in PPSU plastic for domestic and heating systems.*

**Approval No: 1403325** **11th March 2014**

| | |
|---|---|
| Marking: | Pexal Easy fittings: Pexal, Easy and Valsir on body.<br>Pexel Brassfittings: Pexel and Valsir on body.<br>Pexel Pipe: Pexel, size and technical information on pipe. |
| Factor: | Valsir SpA |

2. Installation Requirements & Notes are set out on Page 3.

3. Fittings or units (and any non-metallic components contained within them) are re-assessed and, where necessary, retested every 5 years. You will be advised when your product is due for re-assessment. The extent of any retesting required for a product will be at the discretion of the Technical Manager.

4. **Acceptance for listing entitles you to identify your product with the Scheme's "WRAS" Mark. The use of the Mark will make the identification easier of the approved products by Water Undertakers.** Copies of the 'Mark' are available on request for the purposes of producing artwork.

5. Manufacturers or applicants may only quote in their sales literature, terms used in this letter when indicating the decision of the Group in respect to their fittings or units, namely that the **Product Assessment Group of the Scheme finds that the use of these fittings or units, when correctly installed, will not contravene the requirements of The Water Supply (Water Fittings) Regulations 1999, The Water Byelaws 2004 Scotland or The Water Regulations (Northern Ireland) 2009 and that a reference to the fittings or units will be included in the Scheme's Water Fittings and Materials Directory:** this may be abbreviated to "Water Regulations Advisory Scheme - Approved Product" or "WRAS - Approved Product".

6. Since the incorrect installation of water fittings could result in contravention of the Regulations or Byelaws requirements, **the attention of your customers should be drawn to any Installation Requirements for Regulations or Byelaws compliances set out on Page 3.**

7. Would you please supply the Scheme with a copy of any of your company's literature which may or will make reference to the Scheme's decisions about the products and/or quotes any of the installation requirements.

8. A condition of listing is that **no modification to the fittings or units described above shall be made without first notifying the Scheme** and submitting to the Scheme details of the modification and, if so required, samples of the fittings or units as so modified for consideration by the Scheme's Product Assessment Group. Failure to comply with this condition may result in the removal from the Water Fittings and Materials Directory of the entry relating to the fittings or units in question.

9. Your products are required to be replicas of the samples described above, and the right is reserved to carry out quality surveillance inspections of your production arrangements, reasonable written notice of which will be given.

UK

Omologazione dei tubi multistrato metallo-plastici e relativi raccordi sia in ottone (ad avvitamento e a pressare) e sia plastici in PPSU per impianti sanitari e di riscaldamento.

*Approval of metal-plastic multilayer pipes and relative fittings both in brass (compression and crimp) and in PPSU plastic for domestic and heating systems.*

**Approval No: 1403325** **11th March 2014**

10. Please note that the use of the items described in any particular area of supply is at the discretion of the local Water Undertaking.
11. Manufacturers or factors having appliances or units referred to in the Scheme's Directory which incorporate individually approved components and materials are asked to ensure that such components and materials continue to be approved and/or listed in the Directory, during the current period of approval of their appliance. This may require modifications to approved appliances to ensure their retention in the Scheme's Directory. The Scheme must be informed or any such modifications, (see paragraph 8).
12. You are asked to verify the details of your product as set out in Paragraph 1 and advise us of any discrepancies.

Yours sincerely

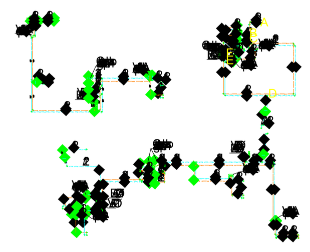
Jason Furnival
Secretary, Product Assessment Group

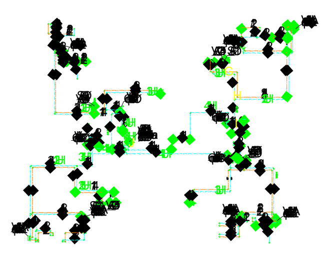
**INSTALLATION REQUIREMENTS & NOTES**

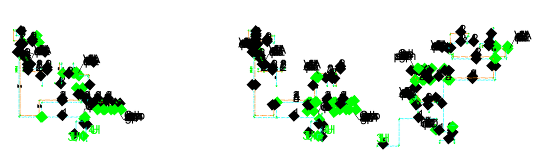
You are advised to draw customers' attention to the installation requirements and notes set out below which must be followed to ensure that the fittings described above are installed in accordance with the requirements of the Regulations and Byelaws:

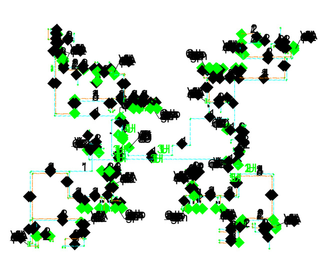
**IRN R001**
See text of entry for Installation Requirements or Notes.

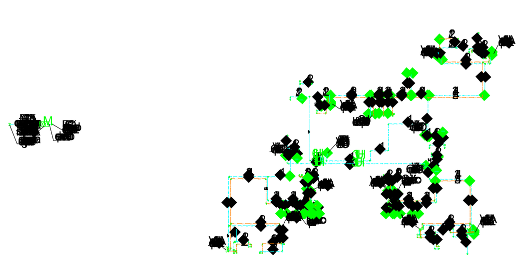
PAG. 1403325

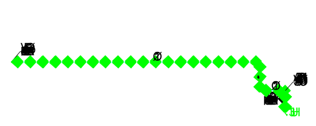


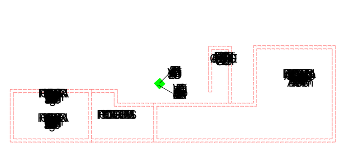


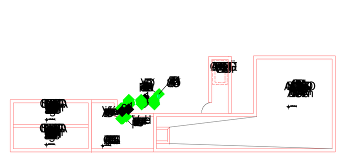


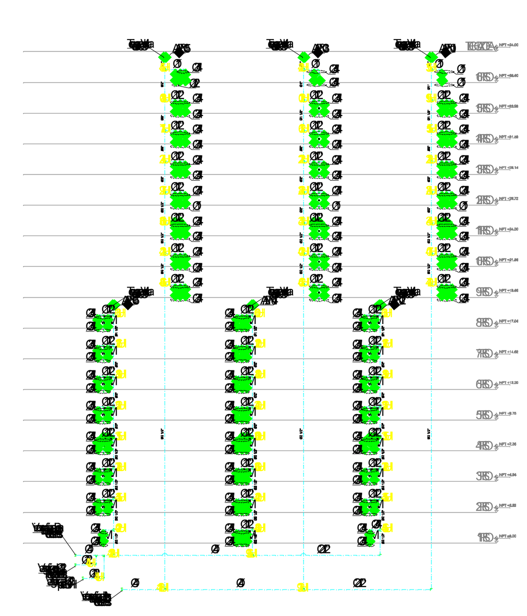


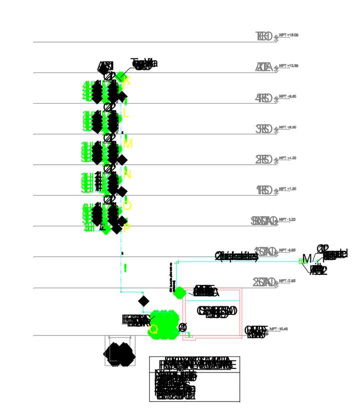


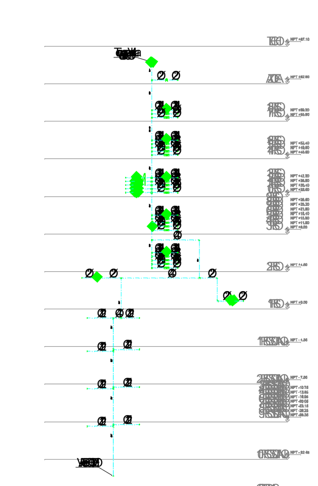


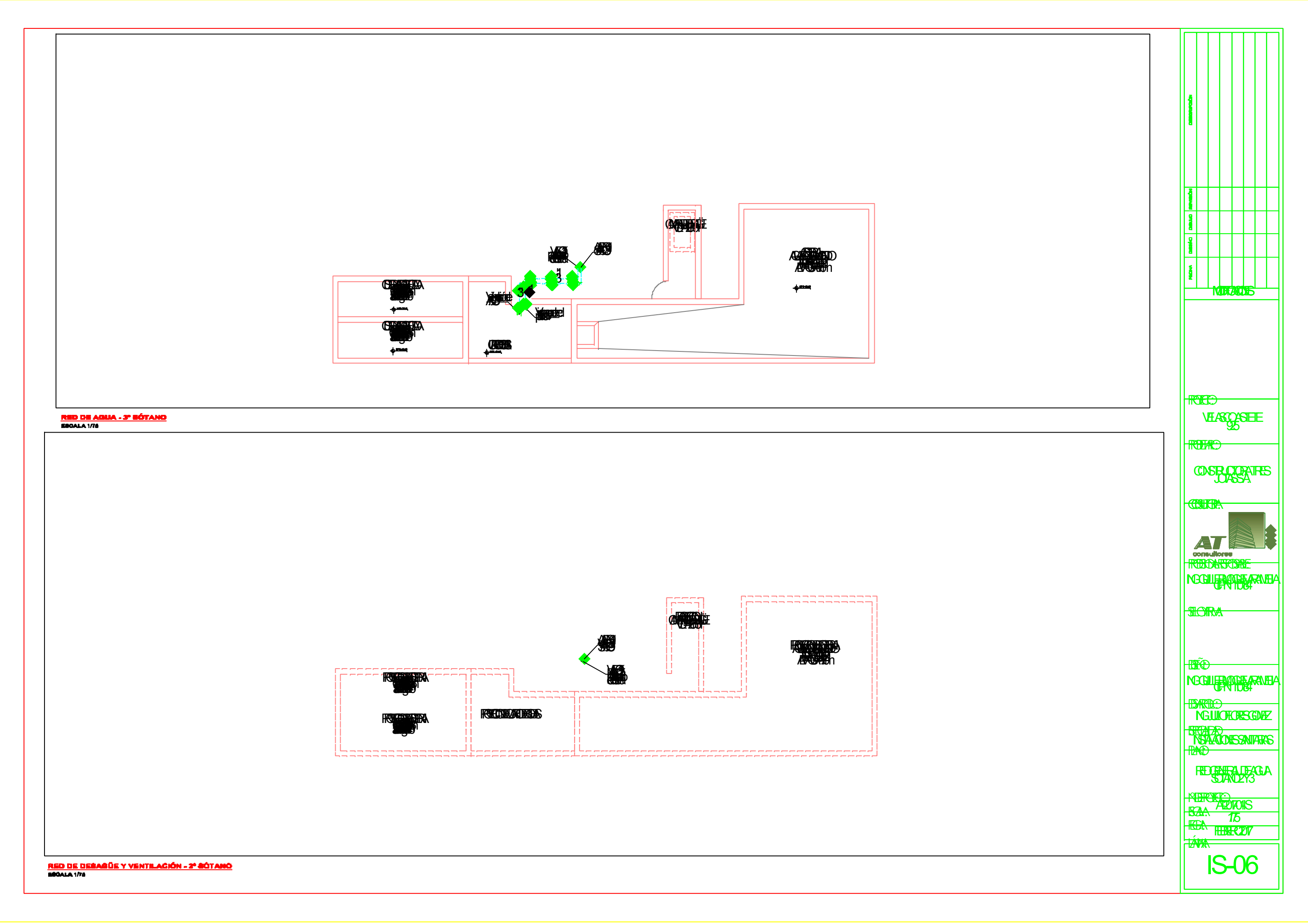


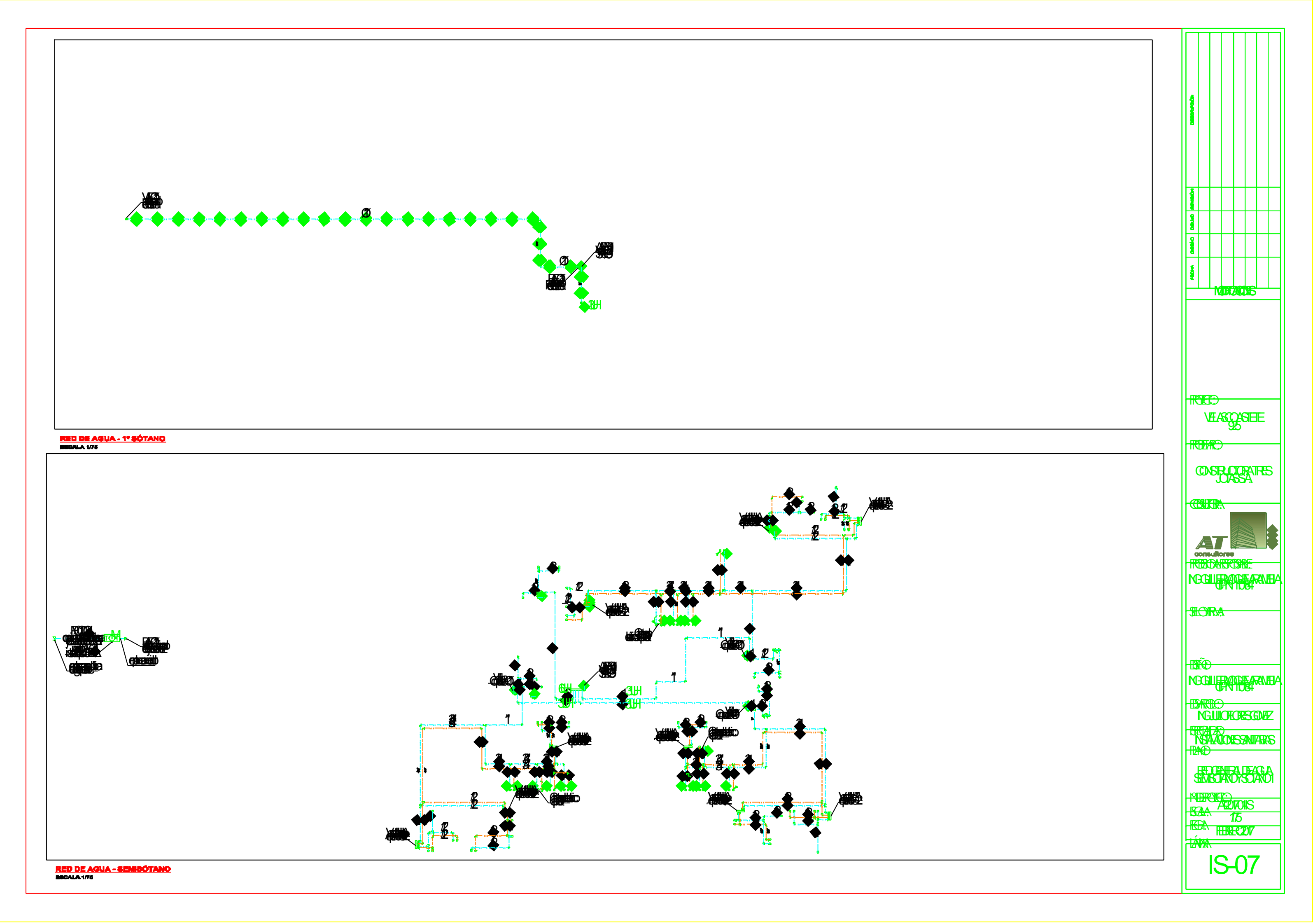









RED DE AGUA - 3° SÓTANO
ESCALA 1/75
RED DE DESAGÜE Y VENTILACIÓN - 2° SÓTANO
ESCALA 1/75
consultores
IS-06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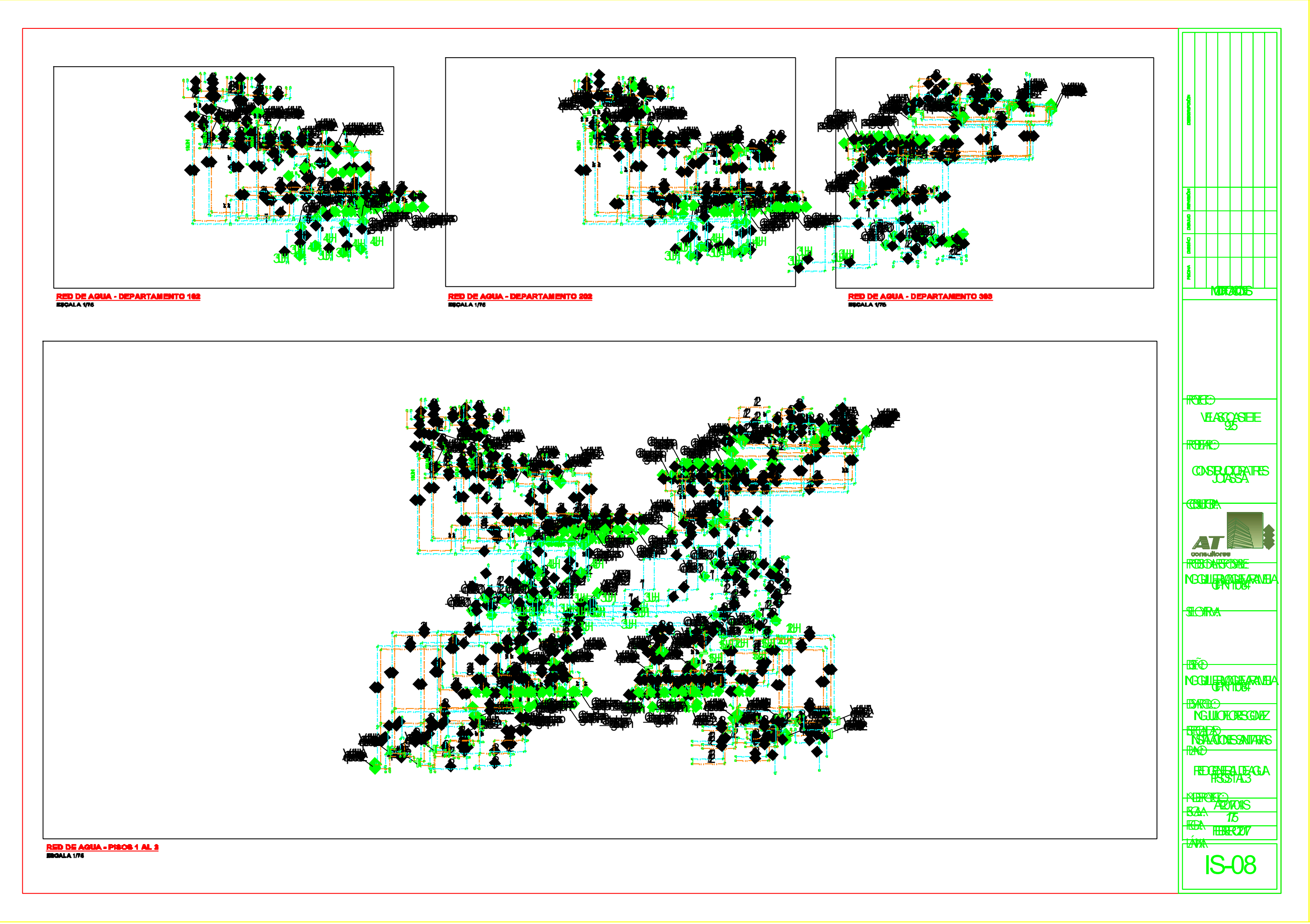
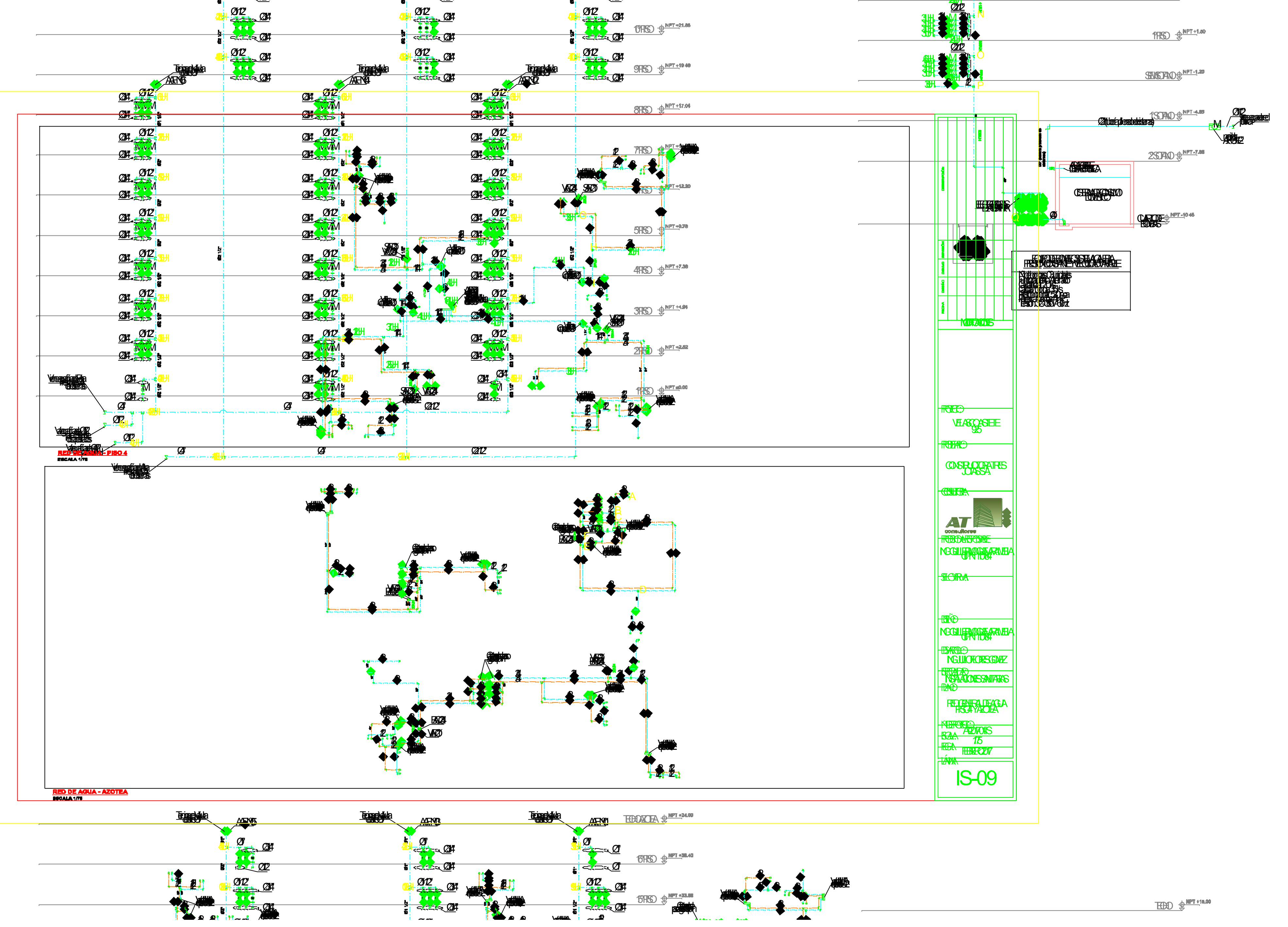
consultores
IS-07


RED DE AGUA - DEPARTAMENTO 102
ESCALA 1/75
RED DE AGUA - DEPARTAMENTO 202
ESCALA 1/75
RED DE AGUA - DEPARTAMENTO 303
ESCALA 1/75
RED DE AGUA - PISOS 1 AL 3
ESCALA 1/75
consultores
IS-08


ESCALA 1/75
RED DE AGUA - AZOTEA
ESCALA 1/75
consultores
IS-09

METRADOS DE TUBERÍAS DE PVC

| ITEM | DESCRIPCIÓN | UND | SÓTANO 3 | SÓTANO 2 | SÓTANO 1 | SEMI-SÓTANO | 1ER PISO | 2DO PISO | 3ER PISO | 4TO PISO | AZOTEA | **TOTAL** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| **1** | **INSTALACIONES SANITARIAS** | | | | | | | | | | | |
| **1,1** | **AGUA FRÍA PVC** | | | | | | | | | | | |
| 1.1.1 | PUNTOS DE SALIDA | PTO | 2 | 0 | 1 | 48 | 58 | 58 | 58 | 35 | 44 | **304** |
| 1.1.2 | TUBERÍA PVC 1/2" SAP | ML | 0 | 0 | 2,21 | 144,75 | 162,69 | 162,69 | 162,69 | 114,64 | 111,66 | **861,33** |
| 1.1.3 | TUBERÍA PVC 3/4" SAP | ML | 0 | 0 | 0 | 33,22 | 53,09 | 53,09 | 53,09 | 26,36 | 45,15 | **264** |
| 1.1.4 | TUBERÍA PVC 1" SAP | ML | 4,43 | 0 | 23,99 | 35,01 | 41,21 | 41,21 | 41,21 | 4,1 | 0 | **191,16** |
| 1.1.5 | TUBERÍA PVC 1 1/4" SAP | ML | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 51,34 | 0 | **51,34** |
| 1.1.6 | TUBERÍA PVC 3" SAP | ML | 5,15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **5,15** |
| 1.1.7 | CODOS DE 1/2" SAP | UND | 0 | 0 | 2 | 153 | 189 | 189 | 189 | 162 | 123 | **1007** |
| 1.1.8 | CODOS DE 3/4" SAP | UND | 0 | 0 | 0 | 10 | 11 | 11 | 11 | 4 | 10 | **57** |
| 1.1.9 | CODOS DE 1" SAP | UND | 6 | 0 | 5 | 23 | 32 | 32 | 32 | 0 | 0 | **130** |
| 1.1.10 | CODOS DE 1 1/4" SAP | UND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 0 | **29** |
| 1.1.11 | CODOS DE 3" SAP | UND | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **6** |
| 1.1.12 | TEE DE 1/2" SAP | UND | 0 | 0 | 0 | 29 | 29 | 29 | 29 | 22 | 20 | **158** |
| 1.1.13 | TEE DE 3/4" SAP | UND | 0 | 0 | 0 | 11 | 20 | 20 | 20 | 18 | 16 | **105** |
| 1.1.14 | TEE DE 1 1/4" SAP | UND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | **8** |
| 1.1.15 | REDUCCIÓN 3/4" A 1/2" | UND | 0 | 0 | 0 | 6 | 6 | 6 | 6 | 3 | 13 | **40** |
| 1.1.16 | REDUCCIÓN 1" A 3/4" | UND | 0 | 0 | 0 | 1 | 4 | 4 | 4 | 0 | 0 | **13** |
| 1.1.17 | REDUCCIÓN 1"A 1/2" | UND | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 0 | 0 | **15** |
| | | | | | | | | | | | | |
| **1,2** | **AGUA CALIENTE CPVC** | | | | | | | | | | | |
| 1.2.1 | PUNTOS DE SALIDA | PTO | 0 | 0 | 0 | 27 | 36 | 36 | 36 | 19 | 24 | **178** |
| 1.2.2 | TUBERÍA CPVC 1/2" CPVC | ML | 0 | 0 | 0 | 93,69 | 99,06 | 99,06 | 99,06 | 78,9 | 99,01 | **568,78** |
| 1.2.3 | TUBERÍA CPVC 3/4" CPVC | ML | 0 | 0 | 0 | 64,28 | 57,47 | 57,47 | 57,47 | 35,89 | 26,05 | **298,63** |
| 1.2.4 | CODOS DE 1/2" CPVC | UND | 0 | 0 | 0 | 87 | 106 | 106 | 106 | 96 | 89 | **590** |
| 1.2.5 | CODOS DE 3/4" CPVC | UND | 0 | 0 | 0 | 11 | 21 | 21 | 21 | 18 | 21 | **113** |
| 1.2.6 | TEE DE 1/2" CPVC | UND | 0 | 0 | 0 | 11 | 13 | 13 | 13 | 12 | 11 | **73** |
| 1.2.7 | TEE DE 3/4" AGUA FRIA | UND | 0 | 0 | 0 | 9 | 14 | 14 | 14 | 13 | 13 | **77** |
| 1.2.8 | REDUCCION 1" A 3/4" | UND | 0 | 0 | 0 | 11 | 12 | 12 | 12 | 11 | 11 | **69** |

METRADOS DE TUBERÍAS DE PEXb

| ITEM | DESCRIPCIÓN | UND | SÓTANO 3 | SÓTANO 2 | SÓTANO 1 | SEMI-SÓTANO | 1ER PISO | 2DO PISO | 3ER PISO | 4TO PISO | AZOTEA | **TOTAL** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| **1,3** | **AGUA FRIA FLEX** | | | | | | | | | | | |
| 1.1.1 | PUNTOS DE SALIDA | PTO | 2 | 0 | 1 | 48 | 58 | 58 | 58 | 35 | 44 | **304** |
| 1.1.2 | TUBERÍA PVC 1/2" AGUA FRIA | ML | 0 | 0 | 2,21 | 115,8 | 130,15 | 130,15 | 130,15 | 91,71 | 89,32 | **689,49** |
| 1.1.3 | TUBERÍA PVC 3/4" AGUA FRIA | ML | 0 | 0 | 0 | 26,58 | 42,47 | 42,47 | 42,47 | 21,01 | 36,12 | **211,12** |
| 1.1.4 | TUBERÍA PVC 1" AGUA FRIA | ML | 4,43 | 0 | 15,35 | 28,01 | 32,97 | 32,97 | 32,97 | 4,1 | 0 | **150,8** |
| 1.1.5 | TUBERÍA PVC 1 1/4" AGUA FRIA | ML | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 41,07 | 0 | **41,07** |
| 1.1.6 | TUBERÍA PVC 3" AGUA FRIA | ML | 5,15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **5,15** |
| 1.1.7 | TEE DE 1/2" AGUA FRIA | UND | 0 | 0 | 0 | 29 | 29 | 29 | 29 | 22 | 20 | **158** |
| 1.1.8 | TEE DE 3/4" AGUA FRIA | UND | 0 | 0 | 0 | 11 | 20 | 20 | 20 | 18 | 16 | **105** |
| 1.1.10 | TEE DE 1 1/4"" AGUA FRIA | UND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | **8** |
| | | | | | | | | | | | | |
| **1,4** | **AGUA CALIENTE FLEX** | | | | | | | | | | | |
| 1.4.1 | PUNTOS DE SALIDA | PTO | 0 | 0 | 0 | 27 | 36 | 36 | 36 | 19 | 24 | **178** |
| 1.4.2 | TUBERÍA CPVC 1/2" CPVC | ML | 0 | 0 | 0 | 74,95 | 79,25 | 79,25 | 79,25 | 63,12 | 79,21 | **455,03** |
| 1.4.3 | TUBERÍA CPVC 3/4" CPVC | ML | 0 | 0 | 0 | 51,42 | 45,98 | 45,98 | 45,98 | 28,71 | 20,84 | **238,91** |
| 1.4.4 | TEE DE 1/2" CPVC | UND | 0 | 0 | 0 | 11 | 13 | 13 | 13 | 12 | 11 | **73** |
| 1.4.5 | TEE DE 3/4" CPVC | UND | 0 | 0 | 0 | 9 | 14 | 14 | 14 | 13 | 13 | **77** |

<u>Metrados y Precios Unitarios de PVC Y PEXb</u>

## APU PVC Y CPVC

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.1.1 | SALIDA DE AGUA FRÍA CON TUBERÍA DE PVC- SAP 1/2" | | | | | |
| Rendimiento | m/día | MO. 10.0000 | | EQ 10.0000 | | | 37,31 |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0800 | 18,14 | 1,45 |
| OPERARIO | | | hh | 1,0000 | 0,8000 | 15,12 | 12,10 |
| PEÓN | | | hh | 1,0000 | 0,8000 | 11,84 | 9,47 |
| | | | | | | | **23,02** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | gln | | 0,0030 | 35,00 | 0,11 |
| CINTA TEFLÓN | | | pza | | 0,5000 | 1,50 | 0,75 |
| NIPLE DE F° GALV. DE 1/2"X2" | | | pza | | 1,0000 | 2,30 | 2,30 |
| TUBERÍA PVC SAP 1/2" | | | und | | 0,1500 | 23,00 | 3,45 |
| CODO PVC SAP 1/2"X90° | | | pza | | 2,0000 | 3,50 | 7,00 |
| | | | | | | | **13,61** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 23,02 | 0,69 |
| | | | | | | | **0,69** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.1.2 | TUBERÍA DE PVC- SAP 1/2" C-10 | | | | | |
| Rendimiento | m/día | MO. 25.0000 | | EQ 25.0000 | | | 11,57 |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0320 | 18,14 | 0,58 |
| OPERARIO | | | hh | 1,0000 | 0,3200 | 15,12 | 4,84 |
| PEÓN | | | hh | 1,0000 | 0,3200 | 11,84 | 3,79 |
| | | | | | | | **9,21** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| TUBERÍA DE PVC - SAP 1/2" C-10 | | | und | | 1,0200 | 1,95 | 1,99 |
| | | | | | | | **2,09** |
| | **Equipos** | | | | | | |
| BALDE PRUEBA-TAPÓN-ABRAZ Y | | | HM | | 0,0270 | 10,00 | 0,27 |
| | | | | | | | **0,27** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.1.3 | TUBERÍA DE PVC- SAP 3/4" C-10 | | | | | |
| Rendimiento | m/día | MO. 25.0000 | | EQ 25.0000 | | | 12,87 |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0320 | 18,14 | 0,58 |
| OPERARIO | | | hh | 1,0000 | 0,3200 | 15,12 | 4,84 |
| PEÓN | | | hh | 1,0000 | 0,3200 | 11,84 | 3,79 |
| | | | | | | | **9,21** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| TUBERÍA DE PVC - SAP 3/4" C-10 | | | und | | 1,0200 | 3,22 | 3,28 |
| | | | | | | | **3,39** |
| | **Equipos** | | | | | | |
| BALDE PRUEBA TAPÓN ABRAZ. Y | | | HM | | 0,0270 | 10,00 | 0,27 |
| | | | | | | | **0,27** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.1.4 | **TUBERÍA DE PVC- SAP 1" C-10** | | | | | |
| Rendimiento | m/día | MO. 25.0000 | | EQ 25.0000 | | | **15,43** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0320 | 18,14 | 0,58 |
| OPERARIO | | | hh | 1,0000 | 0,3200 | 15,12 | 4,84 |
| PEÓN | | | hh | 1,0000 | 0,3200 | 11,84 | 3,79 |
| | | | | | | | **9,21** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| TUBERÍA DE PVC - SAP 1" C-10 | | | und | | 1,0200 | 5,73 | 5,84 |
| | | | | | | | **5,95** |
| | **Equipos** | | | | | | |
| BALDE PRUEBA TAPÓN ABRAZ. Y ACCE: | | | HM | | 0,0270 | 10,00 | 0,27 |
| | | | | | | | **0,27** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.1.5 | **TUBERÍA DE PVC- SAP 1 1/4" C-10** | | | | | |
| Rendimiento | m/día | MO. 20.0000 | | EQ 20.0000 | | | **18,92** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0400 | 18,14 | 0,73 |
| OPERARIO | | | hh | 1,0000 | 0,4000 | 15,12 | 6,05 |
| PEÓN | | | hh | 1,0000 | 0,4000 | 11,84 | 4,74 |
| | | | | | | | **11,51** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| TUBERÍA DE PVC - SAP 1 1/4" C-10 | | | und | | 1,0200 | 6,90 | 7,04 |
| | | | | | | | **7,14** |
| | **Equipos** | | | | | | |
| BALDE PRUEBA TAPÓN ABRAZ. Y ACCE: | | | HM | | 0,0270 | 10,00 | 0,27 |
| | | | | | | | **0,27** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.1.6 | **TUBERÍA DE PVC- SAP 3" C-10** | | | | | |
| Rendimiento | m/día | MO. 20.0000 | | EQ 20.0000 | | | **18,36** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0400 | 18,14 | 0,73 |
| OPERARIO | | | hh | 1,0000 | 0,4000 | 15,12 | 6,05 |
| PEÓN | | | hh | 1,0000 | 0,4000 | 11,84 | 4,74 |
| | | | | | | | **11,51** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| | | | und | | 1,0200 | 6,35 | 6,48 |
| TUBERÍA DE PVC - SAP 3" C-10 | | | | | | | **6,58** |
| | **Equipos** | | | | | | |
| | | | | | | | |
| BALDE PRUEBA TAPÓN ABRAZ. Y ACCE: | | | HM | | 0,0270 | 10,00 | 0,27 |
| | | | | | | | **0,27** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.1.7 | **CODO PVC SAP 1/2"x90°** | | | | | |
| Rendimiento | m/día | MO. 12.0000 | | EQ. 12.0000 | | | **12,73** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0667 | 18,14 | 1,21 |
| OPERARIO | | | hh | 1,0000 | 0,6667 | 15,12 | 10,08 |
| | | | | | | | **11,29** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| CODO PVC SAP 1/2"x90° | | | und | | 1,0000 | 1,00 | 1,00 |
| | | | | | | | **1,11** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 11,29 | 0,34 |
| | | | | | | | **0,34** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.1.8 | **CODO PVC SAP 3/4"x90°** | | | | | |
| Rendimiento | m/día | MO. 12.0000 | | EQ. 12.0000 | | | **13,33** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0667 | 18,14 | 1,21 |
| OPERARIO | | | hh | 1,0000 | 0,6667 | 15,12 | 10,08 |
| | | | | | | | **11,29** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| CODO PVC SAP 3/4"x90° | | | und | | 1,0000 | 1,60 | 1,60 |
| | | | | | | | **1,71** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 11,29 | 0,34 |
| | | | | | | | **0,34** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.1.9 | **CODO PVC SAP 1"x90°** | | | | | |
| Rendimiento | m/día | MO. 12.0000 | | EQ. 12.0000 | | | **16,23** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0667 | 18,14 | 1,21 |
| OPERARIO | | | hh | 1,0000 | 0,6667 | 15,12 | 10,08 |
| | | | | | | | **11,29** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| CODO PVC SAP 1"x90° | | | und | | 1,0000 | 4,50 | 4,50 |
| | | | | | | | **4,61** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 11,29 | 0,34 |
| | | | | | | | **0,34** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.1.10 | **CODO PVC SAP 1 1/4"x90°** | | | | | |
| Rendimiento | m/día | MO. 10.0000 | | EQ. 10.0000 | | | **19,76** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0800 | 18,14 | 1,45 |
| OPERARIO | | | hh | 1,0000 | 0,8000 | 15,12 | 12,10 |
| | | | | | | | **13,55** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| CODO PVC SAP 1 1/4"x90° | | | und | | 1,0000 | 5,70 | 5,70 |
| | | | | | | | **5,81** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 13,55 | 0,41 |
| | | | | | | | **0,41** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.1.11 | **CODO PVC SAP 3"x90°** | | | | | |
| Rendimiento | m/día | MO. 10.0000 | | EQ. 10.0000 | | | **60,36** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0800 | 18,14 | 1,45 |
| OPERARIO | | | hh | 1,0000 | 0,8000 | 15,12 | 12,10 |
| | | | | | | | **13,55** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| CODO PVC SAP 1 1/4"x90° | | | und | | 1,0000 | 46,30 | 46,30 |
| | | | | | | | **46,41** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 13,55 | 0,41 |
| | | | | | | | **0,41** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.1.12 | **TEE SANITARIA PVC-SAP DE 1/2"x1/2"** | | | | | |
| Rendimiento | m/día | MO. 12.0000 | | EQ. 12.0000 | | | **13,13** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0667 | 18,14 | 1,21 |
| OPERARIO | | | hh | 1,0000 | 0,6667 | 15,12 | 10,08 |
| | | | | | | | **11,29** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| TEE SANITARIA PVC-SAP DE 1/2"x1/2" | | | und | | 1,0000 | 1,40 | 1,40 |
| | | | | | | | **1,51** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 11,29 | 0,34 |
| | | | | | | | **0,34** |

| Partida | 1.1.13 | TEE SANITARIA PVC-SAP DE 3/4"x3/4" | | | | | |
|---|---|---|---|---|---|---|---|
| Rendimiento | m/día | MO. 12.0000 | | EQ. 12.0000 | | | **13,37** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0667 | 18,14 | 1,21 |
| OPERARIO | | | hh | 1,0000 | 0,6667 | 15,12 | 10,08 |
| | | | | | | | **11,29** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| TEE SANITARIA PVC-SAP DE 3/4"x3/4" | | | und | | 1,0200 | 1,60 | 1,63 |
| | | | | | | | **1,74** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 11,29 | 0,34 |
| | | | | | | | **0,34** |

| Partida | 1.1.14 | TEE SANITARIA PVC-SAP DE 1 1/4""X1 1/4"" | | | | | |
|---|---|---|---|---|---|---|---|
| Rendimiento | m/día | MO. 10.0000 | | EQ. 10.0000 | | | **25,18** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0800 | 18,14 | 1,45 |
| OPERARIO | | | hh | 1,0000 | 0,8000 | 15,12 | 12,10 |
| | | | | | | | **13,55** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| TEE SANITARIA PVC-SAP DE 1 1/4"x1 1/4" | | | und | | 1,0200 | 10,90 | 11,12 |
| | | | | | | | **11,22** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 13,55 | 0,41 |
| | | | | | | | **0,41** |

| Partida | 1.1.15 | REDUCCIÓN 3/4" A 1/2" | | | | | |
|---|---|---|---|---|---|---|---|
| Rendimiento | m/día | MO. 12.0000 | | EQ. 12.0000 | | | **13,26** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0667 | 18,14 | 1,21 |
| OPERARIO | | | hh | 1,0000 | 0,6667 | 15,12 | 10,08 |
| | | | | | | | **11,29** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| REDUCCIÓN 3/4" A 1/2" | | | und | | 1,0200 | 1,50 | 1,53 |
| | | | | | | | **1,64** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 11,29 | 0,34 |
| | | | | | | | **0,34** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.1.16 | **REDUCCIÓN 1" A 3/4"** | | | | | |
| Rendimiento | m/día | MO. 12.0000 | | EQ. 12.0000 | | | **14,59** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0667 | 18,14 | 1,21 |
| OPERARIO | | | hh | 1,0000 | 0,6667 | 15,12 | 10,08 |
| | | | | | | | **11,29** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| REDUCCIÓN 1" A 3/4" | | | und | | 1,0200 | 2,80 | 2,86 |
| | | | | | | | **2,96** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 11,29 | 0,34 |
| | | | | | | | **0,34** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.1.17 | **REDUCCIÓN 1" A 1/2"** | | | | | |
| Rendimiento | m/día | MO. 12.0000 | | EQ. 12.0000 | | | **14,59** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0667 | 18,14 | 1,21 |
| OPERARIO | | | hh | 1,0000 | 0,6667 | 15,12 | 10,08 |
| | | | | | | | **11,29** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| REDUCCIÓN 1" A 1/2" | | | und | | 1,0200 | 2,80 | 2,86 |
| | | | | | | | **2,96** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 11,29 | 0,34 |
| | | | | | | | **0,34** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.2.1 | **SALIDA DE AGUA CALIENTE CON TUBERÍA DE CPVC 1/2"** | | | | | |
| Rendimiento | m/día | MO. 10.0000 | | EQ 10.0000 | | | **41,23** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0800 | 18,14 | 1,45 |
| OPERARIO | | | hh | 1,0000 | 0,8000 | 15,12 | 12,10 |
| PEÓN | | | hh | 1,0000 | 0,8000 | 11,84 | 9,47 |
| | | | | | | | **23,02** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| TUBERÍA CPVC D=1/2" | | | und | | 1,0200 | 7,50 | 7,65 |
| CINTA TEFLÓN | | | pza | | 0,5000 | 1,50 | 0,75 |
| NIPLE DE F° GALV. DE 1/2"X2" | | | pza | | 1,0000 | 2,30 | 2,30 |
| CODO PVC SAP 1/2"X90° | | | pza | | 2,0000 | 3,50 | 7,00 |
| | | | | | | | **17,81** |
| | **Equipos** | | | | | | |
| BALDE PRUEBA-TAPÓN-ABRAZ Y ACCES | | | HM | | 0,0270 | 15,00 | 0,41 |
| | | | | | | | **0,41** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.2.2 | **TUBERÍA CPVC SAP 1/2" C-10** | | | | | |
| Rendimiento | m/día | MO. 25.0000 | | EQ 25.0000 | | | **16,35** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0320 | 18,14 | 0,58 |
| OPERARIO | | | hh | 1,0000 | 0,3200 | 15,12 | 4,84 |
| PEÓN | | | hh | 1,0000 | 0,3200 | 11,84 | 3,79 |
| | | | | | | | **9,21** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| TUBERÍA CPVC D=1/2" | | | und | | 1,0200 | 6,50 | 6,63 |
| | | | | | | | **6,74** |
| | **Equipos** | | | | | | |
| BALDE PRUEBA-TAPÓN-ABRAZ Y ACCES | | | HM | | 0,0270 | 15,00 | 0,41 |
| | | | | | | | **0,41** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.2.3 | **TUBERÍA CPVC SAP 3/4" C-10** | | | | | |
| Rendimiento | m/día | MO. 25.0000 | | EQ 25.0000 | | | **16,65** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0320 | 18,14 | 0,58 |
| OPERARIO | | | hh | 1,0000 | 0,3200 | 15,12 | 4,84 |
| PEÓN | | | hh | 1,0000 | 0,3200 | 11,84 | 3,79 |
| | | | | | | | **9,21** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| TUBERÍA CPVC D=1/2" | | | und | | 1,0200 | 6,80 | 6,94 |
| | | | | | | | **7,04** |
| | **Equipos** | | | | | | |
| BALDE PRUEBA-TAPÓN-ABRAZ Y ACCES | | | HM | | 0,0270 | 15,00 | 0,41 |
| | | | | | | | **0,41** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.2.4 | **CODO CPVC DE 1/2"** | | | | | |
| Rendimiento | m/día | MO. 12.0000 | | EQ 12.0000 | | | **13,02** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0667 | 18,14 | 1,21 |
| OPERARIO | | | hh | 1,0000 | 0,6667 | 15,12 | 10,08 |
| | | | | | | | **11,29** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| CODO DE CPVC DE 1/2" | | | und | | 1,0200 | 1,20 | 1,22 |
| | | | | | | | **1,33** |
| | **Equipos** | | | | | | |
| BALDE PRUEBA-TAPÓN-ABRAZ Y ACCES | | | HM | | 0,0270 | 15,00 | 0,41 |
| | | | | | | | **0,41** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.2.5 | **CODO CPVC DE 3/4"** | | | | | |
| Rendimiento | m/día | MO. 12.0000 | | EQ 12.0000 | | | **13,64** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0667 | 18,14 | 1,21 |
| OPERARIO | | | hh | 1,0000 | 0,6667 | 15,12 | 10,08 |
| | | | | | | | **11,29** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| CODO DE CPVC DE 3/4" | | | und | | 1,0200 | 1,80 | 1,84 |
| | | | | | | | **1,94** |
| | **Equipos** | | | | | | |
| BALDE PRUEBA-TAPÓN-ABRAZ Y ACCES | | | HM | | 0,0270 | 15,00 | 0,41 |
| | | | | | | | **0,41** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.2.6 | **TEE SANITARIA CPVC DE 1/2"x1/2"** | | | | | |
| Rendimiento | m/día | MO. 12.0000 | | EQ 12.0000 | | | **14,30** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0667 | 18,14 | 1,21 |
| OPERARIO | | | hh | 1,0000 | 0,6667 | 15,12 | 10,08 |
| | | | | | | | **11,29** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| TEE SANITARIA PVC-SAP DE 1/2"x1/2" | | | und | | 1,0000 | 2,50 | 2,50 |
| | | | | | | | **2,61** |
| | **Equipos** | | | | | | |
| BALDE PRUEBA-TAPÓN-ABRAZ Y ACCES | | | HM | | 0,0270 | 15,00 | 0,41 |
| | | | | | | | **0,41** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.2.7 | **TEE SANITARIA CPVC DE 3/4"x3/4"** | | | | | |
| Rendimiento | m/día | MO. 12.0000 | | EQ 12.0000 | | | **14,04** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0667 | 18,14 | 1,21 |
| OPERARIO | | | hh | 1,0000 | 0,6667 | 15,12 | 10,08 |
| | | | | | | | **11,29** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| TEE SANITARIA PVC-SAP DE 3/4"x3/4" | | | und | | 1,0200 | 2,20 | 2,24 |
| | | | | | | | **2,35** |
| | **Equipos** | | | | | | |
| BALDE PRUEBA-TAPÓN-ABRAZ Y ACCES | | | HM | | 0,0270 | 15,00 | 0,41 |
| | | | | | | | **0,41** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.2.8 | **REDUCCIÓN DE 3/4" A 1/2"** | | | | | |
| Rendimiento | m/día | MO. 12.0000 | | EQ 12.0000 | | | **12,62** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0667 | 18,14 | 1,21 |
| OPERARIO | | | hh | 1,0000 | 0,6667 | 15,12 | 10,08 |
| | | | | | | | **11,29** |
| | **Materiales** | | | | | | |
| PEGAMENTO PARA TUBERÍA PVC | | | und | | 0,0030 | 35,00 | 0,11 |
| REDUCCIÓN DE 3/4" A 1/2" | | | und | | 1,0200 | 0,80 | 0,82 |
| | | | | | | | **0,92** |
| | **Equipos** | | | | | | |
| BALDE PRUEBA-TAPÓN-ABRAZ Y ACCES | | | HM | | 0,0270 | 15,00 | 0,41 |
| | | | | | | | **0,41** |

**APU PEXb**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.2.1 | **SALIDA DE AGUA FRÍA CON TUBERÍA FLEX - SAP 1/2"** | | | | | |
| Rendimiento | m/día | MO. 10.0000 | | EQ 10.0000 | | | **39,26** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0800 | 18,14 | 1,45 |
| OPERARIO | | | hh | 1,0000 | 0,8000 | 15,12 | 12,10 |
| PEÓN | | | hh | 1,0000 | 0,8000 | 11,84 | 9,47 |
| | | | | | | | **23,02** |
| | **Materiales** | | | | | | |
| ADAPTADOR RECTO MACH0 1/2"X | | | pza | | 1,0000 | 4,41 | 4,41 |
| TUBERÍA FLEX 1/2" | | | und | | 0,1200 | 23,49 | 2,82 |
| CODO FLEX 1/2"X90° | | | pza | | 2,0000 | 4,16 | 8,32 |
| | | | | | | | **15,55** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 23,02 | 0,69 |
| | | | | | | | **0,69** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1.2.2 | | **TUBERÍA DE FLEXP 1/2"** | | | | |
| Rendimiento | m/día | MO. 25.0000 | | EQ 25.0000 | | | **11,61** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0320 | 18,14 | 0,58 |
| OPERARIO | | | hh | 1,0000 | 0,3200 | 15,12 | 4,84 |
| PEÓN | | | hh | 1,0000 | 0,3200 | 11,84 | 3,79 |
| | | | | | | | **9,21** |
| | **Materiales** | | | | | | |
| TUBERÍA FLEX 1/2" | | | und | | 0,8160 | 2,61 | 2,13 |
| | | | | | | | **2,13** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 9,21 | 0,28 |
| | | | | | | | **0,28** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1,2,3 | | **TUBERIA DE FLEXP 3/4"** | | | | |
| Rendimiento | m/día | MO. 25.0000 | | EQ 25.0000 | | | **12,90** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0320 | 18,14 | 0,58 |
| OPERARIO | | | hh | 1,0000 | 0,3200 | 15,12 | 4,84 |
| PEÓN | | | hh | 1,0000 | 0,3200 | 11,84 | 3,79 |
| | | | | | | | **9,21** |
| | **Materiales** | | | | | | |
| TUBERÍA FLEX 3/4" | | | und | | 0,8160 | 4,19 | 3,42 |
| | | | | | | | **3,42** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 9,21 | 0,28 |
| | | | | | | | **0,28** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1,2,4 | | | **TUBERÍA DE FLEX 1"** | | | |
| Rendimiento | m/día | MO. 25.0000 | | EQ 25.0000 | | | **15,29** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0320 | 18,14 | 0,58 |
| OPERARIO | | | hh | 1,0000 | 0,3200 | 15,12 | 4,84 |
| PEÓN | | | hh | 1,0000 | 0,3200 | 11,84 | 3,79 |
| | | | | | | | **9,21** |
| | **Materiales** | | | | | | |
| TUBERÍA FLEX 1" | | | und | | 0,8160 | 7,11 | 5,80 |
| | | | | | | | **5,80** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 9,21 | 0,28 |
| | | | | | | | **0,28** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1,2,5 | | | **TUBERÍA DE FLEXP 1 1/4""** | | | |
| Rendimiento | m/día | MO. 25.0000 | | EQ 25.0000 | | | **18,66** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0320 | 18,14 | 0,58 |
| OPERARIO | | | hh | 1,0000 | 0,3200 | 15,12 | 4,84 |
| PEÓN | | | hh | 1,0000 | 0,3200 | 11,84 | 3,79 |
| | | | | | | | **9,21** |
| | **Materiales** | | | | | | |
| TUBERÍA FLEX 1 1/4" | | | und | | 0,8160 | 11,25 | 9,18 |
| | | | | | | | **9,18** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 9,21 | 0,28 |
| | | | | | | | **0,28** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1,2,6 | | | **TUBERÍA DE PEXb 3" HDP** | | | |
| Rendimiento | m/día | MO. 25.0000 | | EQ 25.0000 | | | **24,98** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0320 | 18,14 | 0,58 |
| OPERARIO | | | hh | 1,0000 | 0,3200 | 15,12 | 4,84 |
| PEÓN | | | hh | 1,0000 | 0,3200 | 11,84 | 3,79 |
| | | | | | | | **9,21** |
| | **Materiales** | | | | | | |
| TUBERÍA FLEX 3" | | | und | | 0,8160 | 12,00 | 9,79 |
| ACCESORIOS | | | und | | 0,1900 | 30,00 | 5,70 |
| | | | | | | | **15,49** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 9,21 | 0,28 |
| | | | | | | | **0,28** |

| Partida | 1,2,7 | TEE SANITARIA FLEX DE 1/2"x1/2"x1/2" | | | | | |
|---|---|---|---|---|---|---|---|
| Rendimiento | m/día | MO. 18.0000 | | EQ. 18.0000 | | | **11,80** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0444 | 18,14 | 0,81 |
| OPERARIO | | | hh | 1,0000 | 0,4444 | 15,12 | 6,72 |
| | | | | | | | **7,53** |
| | **Materiales** | | | | | | |
| TEE SANITARIA FLEX 1/2"x1/2"x1/2" | | | und | | 1,0000 | 4,05 | 4,05 |
| | | | | | | | **4,05** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 7,53 | 0,23 |
| | | | | | | | **0,23** |

| Partida | 1,2,8 | TEE SANITARIA FLEX DE 3/4"x3/4"x3/4" | | | | | |
|---|---|---|---|---|---|---|---|
| Rendimiento | m/día | MO. 18.0000 | | EQ. 18.0000 | | | **14,50** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0444 | 18,14 | 0,81 |
| OPERARIO | | | hh | 1,0000 | 0,4444 | 15,12 | 6,72 |
| | | | | | | | **7,53** |
| | **Materiales** | | | | | | |
| TEE SANITARIA FLEX 3/4"x3/4"x3/4" | | | und | | 1,0000 | 6,75 | 6,75 |
| | | | | | | | **6,75** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 7,53 | 0,23 |
| | | | | | | | **0,23** |

| Partida | 1,2,9 | TEE SANITARIA FLEX DE 1 1/4"x1 1/4"x1 1/4" | | | | | |
|---|---|---|---|---|---|---|---|
| Rendimiento | m/día | MO. 15.0000 | | EQ. 15.0000 | | | **20,30** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0533 | 18,14 | 0,97 |
| OPERARIO | | | hh | 1,0000 | 0,5333 | 15,12 | 8,06 |
| | | | | | | | **9,03** |
| | **Materiales** | | | | | | |
| TEE SANITARIA FLEX 1 1/4"x1 1/4"x1 1/4" | | | und | | 1,0000 | 11,00 | 11,00 |
| | | | | | | | **11,00** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 9,03 | 0,27 |
| | | | | | | | **0,27** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1,2,10 | **SALIDA DE AGUA FRIA CON TUBERÍA FLEX - SAP 1/2"** | | | | | |
| Rendimiento | m/día | MO. 10.0000 | | EQ 10.0000 | | | **39,26** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0800 | 18,14 | 1,45 |
| OPERARIO | | | hh | 1,0000 | 0,8000 | 15,12 | 12,10 |
| PEÓN | | | hh | 1,0000 | 0,8000 | 11,84 | 9,47 |
| | | | | | | | **23,02** |
| | **Materiales** | | | | | | |
| ADAPTADOR RECTO MACH0 1/2"X1/2" ( | | | pza | | 1,0000 | 4,41 | 4,41 |
| TUBERÍA FLEX 1/2" | | | und | | 0,1200 | 23,49 | **2,82** |
| CODO FLEX 1/2"X90° | | | pza | | 2,0000 | 4,16 | 8,32 |
| | | | | | | | 15,55 |
| | Equipos | | | | | | |
| HERRAMIENTAS MANUAL | | | | | | 23,0192 | 0,690576 |
| | | | | | | | **0,69** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1,2,11 | **TUBERÍA DE FLEXP 1/2"** | | | | | |
| Rendimiento | m/día | MO. 25.0000 | | EQ 25.0000 | | | **11,61** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0320 | 18,14 | 0,58 |
| OPERARIO | | | hh | 1,0000 | 0,3200 | 15,12 | 4,84 |
| PEÓN | | | hh | 1,0000 | 0,3200 | 11,84 | 3,79 |
| | | | | | | | **9,21** |
| | **Materiales** | | | | | | |
| TUBERÍA FLEX 1/2" | | | und | | 0,8160 | 2,61 | 2,13 |
| | | | | | | | **2,13** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 9,21 | 0,28 |
| | | | | | | | **0,28** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1,2,12 | **TUBERÍA DE FLEX 3/4"** | | | | | |
| Rendimiento | m/día | MO. 25.0000 | | EQ 25.0000 | | | **12,90** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0320 | 18,14 | 0,58 |
| OPERARIO | | | hh | 1,0000 | 0,3200 | 15,12 | 4,84 |
| PEÓN | | | hh | 1,0000 | 0,3200 | 11,84 | 3,79 |
| | | | | | | | **9,21** |
| | **Materiales** | | | | | | |
| TUBERÍA FLEX 3/4" | | | und | | 0,8160 | 4,19 | 3,42 |
| | | | | | | | **3,42** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 9,21 | 0,28 |
| | | | | | | | **0,28** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1,2,13 | **TEE SANITARIA FLEX DE 1/2"x1/2"x1/2"** | | | | | |
| Rendimiento | m/día | MO. 18.0000 | | EQ. 18.0000 | | | **11,80** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0444 | 18,14 | 0,81 |
| OPERARIO | | | hh | 1,0000 | 0,4444 | 15,12 | 6,72 |
| | | | | | | | **7,53** |
| | **Materiales** | | | | | | |
| TEE SANITARIA FLEX 1/2"x1/2"x1/2" | | | und | | 1,0000 | 4,05 | 4,05 |
| | | | | | | | **4,05** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 7,53 | 0,23 |
| | | | | | | | **0,23** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Partida | 1,2,14 | **TEE SANITARIA FLEX DE 3/4"x3/4"x3/4"** | | | | | |
| Rendimiento | m/día | MO. 18.0000 | | EQ. 18.0000 | | | **14,50** |
| | | | | | | | |
| **Descripción Recurso** | | | **Unidad** | **Cuadrilla** | **Cantidad** | **Precio S/.** | **Parcial S/.** |
| | **Mano de Obra** | | | | | | |
| CAPATAZ | | | hh | 0,1000 | 0,0444 | 18,14 | 0,81 |
| OPERARIO | | | hh | 1,0000 | 0,4444 | 15,12 | 6,72 |
| | | | | | | | **7,53** |
| | **Materiales** | | | | | | |
| TEE SANITARIA FLEX 3/4"x3/4"x3/4" | | | und | | 1,0000 | 6,75 | 6,75 |
| | | | | | | | **6,75** |
| | **Equipos** | | | | | | |
| HERRAMIENTAS MANUALES | | | %MO | | 3,0000 | 7,53 | 0,23 |
| | | | | | | | **0,23** |