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ALTERNATIVE PIPING MATERIAL FOR MALAYSIAN FUEL GAS DISTRIBUTION

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Abstract. Fuel gas distribution system in Malaysia can be divided into the Natural Gas (NG) and the Liquefied Petroleum Gas (LPG) distribution system. The distribution pipeline system for NG and LPG in Malaysia are using either steel pipes or plastic pipes (polyethylene pipe). However it has become common in other parts of the world such as the United States, Australia, Canada, Europe and Japan that copper pipes are being used for their distribution system. They have found that copper is an alternative for safe and superior piping material suitable for interior distribution systems. Therefore copper pipes should also be considered as an alternative piping material for Malaysian gas distribution.

This paper will discuss what the International Code and Malaysian Code of Practice has to say about copper, what are the limitations of using copper and also the testing of Malaysian Gas in order to determines its suitability in using copper as pipe material. The comparisons were made between the utilisation of copper pipe in gas pipeline installation in other countries and the limitations of gas pipeline systems in Malaysia, the assessment of their performance and the duty limit of copper pipes.

Keyword: Copper pipe, fuel gas reticulation, gas pipeline

Abstrak. Sistem pengagihan bahan api gas di Malaysia boleh dibahagikan kepada sistem pengagihan gas asli dan sistem pengagihan gas petroleum cecair. Sistem talian paip pengagihan untuk gas asli dan gas petroleum cecair di Malaysia menggunakan bahan perpaipan sama ada dari jenis keluli ataupun jenis plastik (paip polietilena). Walau bagaimanapun, adalah menjadi kebiasaan bagi negara-negara seperti Amerika Syarikat, Australia, Kanada, Eropah dan Jepun menggunakan paip "copper" dalam sistem talian paip pengagihan mereka. Paip tembaga telah didapati sebagai bahan yang alternatif yang sesuai dan selamat untuk sistem pengagihan dalaman. Oleh itu, paip "copper" sepatutnya turut dipertimbangkan sebagai bahan alternatif bagi perpaipan untuk pengagihan gas di Malaysia.

Kertas kerja ini akan membincangkan tentang apa yang dinyatakan dalam piawai dan kod antarabangsa serta tempatan mengenai paip "copper", had penggunaan dan pengujian ke atas kandungan hidrogen sulfida dalam bahan api gas di Malaysia dalam menentukan kesesuaian penggunaan "copper" sebagai bahan alternatif bagi perpaipan. Perbandingan terhadap penggunaan paip "copper" pada sistem talian paip di negara lain dan had sistem talian paip gas di Malaysia, penilaian terhadap prestasi dan juga had penggunaan paip "copper" dari perspektif kod amalan antarabangsa dan kod amalan di Malaysia juga dibincangkan.

Kata kunci: Paip "Copper", retikulasi bahan api gas, perpaipan gas

1.0 INTRODUCTION

The term fuel gases are referring to Natural Gas (NG) and Liquefied Petroleum Gas

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(LPG). In Malaysia, NG is transported through the transmission and distribution system pipelines to the consumers. While LPG, a mixture of propane and butane gas which is derive from oil and gas through the gas processing plants and oil refineries, is bottled before arriving at consumers' premises. In Peninsular Malaysia, NG is only supplied from the Gas Processing Plant (GPP) in Kertih. However LPG is supplied from various sources. The sources of LPG used in Peninsular Malaysia are derived from GPP in Kerteh, Petronas Refinery in Kerteh, Gas Processing Plant near Sri Ranca in Thailand, Esso Refinery in Port Dickson, Shell Refinery in Port Dickson, Petronas Refinery in Melaka and Refinery in Singapore. Whether NG or LPG, transporting it to the final user requires pipelines. There are various alternatives to the type of material used for these pipes which are installed within the consumers' premises. However, it is important to note that, only materials that conform to Malaysian Standards and appropriate International Standards are recommended to be used as a piping material. The used of copper tubes has been established in a wide variety of environments as well as for the installations of all types, including hot and cold water system, drainage and venting, heating, air conditioning and refrigeration. Nowadays, copper can compete with other materials for installation of gas system due to its advantages hence adding the choices available to the customers.

1.1 Properties and Composition of Copper

Copper and its alloy cover a wide range of useful engineering applications. The reason why copper is required in many applications are because of its properties. Some of the unique properties of copper are as follows:

(i) electrical and thermal conductivity;
(ii) corrosion resistance;
(iii) high ductility;
(iv) pleasing colour;
(v) ease of forming and working;
(vi) retention of tensile properties at extremely low temperature.

Copper has long been produced on a commercial scale in a highly refined form. Commercial copper should contain less than 0.5% impurities or alloying elements. Typical analyses of the compositions commercial copper are shown in Table 1. It has been commercially available in five basic types [1] as follows:

(i) phosphorus deoxidezed copper of phosphorized copper;
(ii) tough pitch copper;
(iii) oxygen-free copper;
(iv) arsenical copper;
(v) silver bearing copper.

Table 1 Typical chemical analyses of copper

Type of copper	% Cu*	% O_2	% P	% Arsenic	Ag (oz/ton)
Tough pitch	99.90	0.04	–		–
Oxygen free	99.92		–		–
Phosphorized	99.90	–	0.015–0.04		–
Silver bearing	99.90	–	–		8–25
Arsenical	99.57–99.7		0.02–0.03	0.25–0.4	–
Tellurium, beryllium, cadmium and other special copper.	The chemical composition of these varies widely to meet specific end uses.				

All copper pipe is manufactured from phophorus deoxidized copper which has 99.99% copper and 0.015% to 0.040% phosphorus. It has designated as CU-DHP by Australia specification and UNS C12200 by ASME specification. Physical properties of copper are as in Table 2.

Table 2 Physical properties of copper

Properties	Value Measured
Melting point	1083°C
Density	8.94 X 10^3 kg/m^3 at 20°C
Thermal expansion coefficient	17.7 X 10^{-6} per °K
Thermal conductivity	305 – 355 W/(m.K)
Specific heat capacity	0.385 kJ/(kg.K)
Electrical conductivity (annealed)	75 – 90% IACS
Electrical resistivity (annealed)	0.0192 – 0.0230 microhm at 20°C
Modulus of elasticity	117 Gpa
Modulus of rigidity	44 Gpa

1.2 Application of Copper Pipe

Copper pipe or tubes have been used successfully within many types of fluid processing system. Installations of hot and cold water plumbing, sanitation, fire services and sprinklers, heating, refrigeration, air conditioning and medical gases are some well known application. Copper is by far the world's preferred choice of another piping materials. No other material comes close to matching copper's wide range of applications such as above. Copper tube or pipe offers the designer and installer versatility

and performance like no other piping material. Copper piping systems can be fabricated on or off site taking advantage of its flexibility. It can adapt to the most complex designs and confined locations that could be encountered during construction of piping systems commercially and industrially.

The following describe features and benefits of copper applications in piping systems:

(i) Less clipping required – the inherent strength and light weight of copper pipe and fittings, combined with self-supporting joining methods. This means fewer clips and hangers are required to maintain secure support and alignment.

(ii) Space saving – due to copper flexibility, copper pipe installations can solve the problems of limitation of space for piping installation.

(iii) Impermeability – copper tube is impervious to leached petrochemicals or solvent that may be either present in ground soil or used as cleaning agents.

(iv) Cost effective – only copper pipe or tube permits economical on site fabrication of bends, tees and junction in pipe work without affecting system performance or quality.

(v) Environmental friendly – copper is stable, natural material that is 100% recyclable.

These features and benefits together with the unique properties of copper has given enormous advantages to copper and has been reflected by the selection of copper as a preferred piping material in various applications.

1.3 Bending, Jointing, Concealment, Testing and Sizing of Copper Pipe

The making of good bends in copper tube requires care and skill. One essential requirement is that the material must have sufficient ductility for it to deform into the wanted shape or bend without seriously weakening the pipe structure. Worn bending tools or lack of proper bending techniques usually causes distortion and fractures. Several bending methods [2,3] of copper pipes are as follow;

(i) annealing (softening) for bending;
(ii) cold bending;
(iii) hot bending;
(iv) stress relief after bending.

Copper pipes and fittings for fuel gas application can be connected easily by using a range of mechanical joints [4,5]. These includes:

(i) compression;
(ii) silver brazed joints;
(iii) soft soldering capillary fittings;
(iv) expanded joints;
(v) branch pulling method;
(vi) victaulic copper connection system (roll grooved).

In known aggressive environments, copper and copper alloy piping should be protected along its entire length with polyethylene coating [2]. In such cases, fittings and joints should be protected continuously by a tough waterproof covering such as petrolatum tape. Therefore, unprotected pipes should not be laid in or allowed to cross rubble drains or similar waste disposal systems. It is strongly recommended that installed copper pipeline be tested prior to burial or concealment. Adherence to this procedure will facilitate the location and repair of any leak exposed by the pressure test. Radiographic testing of joints is not required. Copper piping system installed should be tested to the following procedure [2, 3];

(i) Using compressed air, carbon dioxide or nitrogen as per installation standard.
(ii) Bubble leak detection and leak detection fluid.

Copper pipe sizing is equivalent to steel pipe at the same line pressure and demand capacities. However, copper will deliver better flow due to less internal obstructions and smooth bore pipe or tube. Australia is the only country that has specified certain specification for copper pipeline sizing. The standard [6] (AG 601) of copper sizing systems depends on pipeline allowable pressure drop.

2.0 INTERNATIONAL CODES OF PRACTICE FOR COPPER PIPING

The utilisation of copper pipe in fuel gas pipeline depends largely on the limitation specified by the gas installation code and the availability of copper pipe. Several standard specifications are referred in order to make a comparison on the utilisation of copper pipe at pressure below 200 kPa for fuel gas pipe line in several countries such as the America, Australia, Britain, Europe, New Zealand and Japan.

2.1 Composition of Copper Pipe

Phosphorized copper is selected as suitable type of copper to use in fuel gas piping. However, there was a little different in the composition of copper pipe use in certain

Table 3 Phosphorized copper composition for gas pipeline system

Element	(%)	
Cu* P As Ni Others	99.90 0.015 – 0.04	99.85 0.13 – 0.05 0.05 0.1 0.06
Country	Australia, Europe, USA, Japan	New Zealand, Britain

* including silver

country. The following table (Table 3) shows the composition of copper pipe for gas pipeline system between several countries [7–13].

2.2 Temper of Copper Pipe

There were four categories to describe the copper pipe temper used in 200 kPa and below gas pressure piping system. The four categories are known as hard drawn, half-hard, bendable and annealed [7–13]. The following table (Table 4) shows the temper and form of copper pipe or tube for gas pipeline systems.

Table 4 Temper and form of copper pipe

Temper	Form	Country
Hard drawn	Straight lengths	Australia, Britain, Europe, USA, Japan
Half hard	Straight lengths	New Zealand, Britain, Europe, Japan
Bendable	Straight lengths	Australia
Annealed	Coils	Australia, Britain, Europe, USA, New Zealand and Japan

2.3 Classification of Pipe Size, Operating Temperature and Pressure

There were slight differences in copper pipe size classification, maximum operation temperature and pressure for fuel gas pipeline in countries referred to in this study. The difference may cause by the copper availability and the limitations of standards used in those countries [7–13]. The above differences are shown in Table 5.

Table 5 Classification of copper pipe size, operating temperature and pressure

Country and Standard referred	Size Classification	Maximum operating pressure range (kpa)	Operation temperature
Australia (AS 1432)	A	910 – 11990	50°C
	B	720 – 8710	
	C	2700 – 5610	
	D	800 – 2150	
New Zealand (NZS 3501)	Copper tube	2.75 – 10.50	65°C
	Light gauge copper	5.35 – 6.00	
Britain (BS 2871)	X	1500 – 13300	65°C
	Y	2900 –18800	
		2200 – 14400	
	Z	1500 – 11300	
Europe (EN 1057)	X	1200 – 16100	65°C
	Y	2200 – 22300	
USA (ASTM B88)	K	2385 – 7520	50°C
	L	1720 – 6360	
Japan (JISH 3300)	K	3040 – 7625	50°C
	L	18100 – 6510	

2.4 Limitations of the Utilisation of Copper Pipe in Gas Pipeline

Limitation specified in gas installation code is one of the major factors that influence the utilisation of copper pipe in 200 kPa and below gas pressure system. According to code for pressure piping, gas transmission and distribution piping systems (ANSI/ ASME B31.8), when used for gas pipeline, copper pipe or tube shall conform to the following requirements [14]:

(i) Copper pipe or tube shall not be used for gas pipeline where the gas carried contains more than an average of 0.3 grains of hydrogen sulphide per 30.48 m^3 of gas.
(ii) Copper pipe or tube use for NG and LPG pipeline shall have a minimum wall thickness of 1.651mm and shall be hard drawn.
(iii) Copper pipe or tube shall not be used for gas pipeline systems where strain or external loading may damage the piping.

(iv) The specification of copper pipe stated in ASTM B88 and ASTM B280 [12–13] (type K and L) are suitable piping material use in 200 kPa fuel gas pipeline.

(v) Use either a compression type coupling or a brazed or soldered lap joint to join copper pipe or tube. Copper pipe for gas pipeline shall not be threaded. Copper pipe or tube with wall thickness equivalent to the size of Schedule 40 steel pipe may be threaded.

2.5 Duty Limits of Copper Pipe

A summarized recommended duty limits of copper piping for fuel gases extracted from International Standards [9–10] are shown in Table 6.

Table 6 Recommended duty limits of copper piping for fuel gases

Operating limit (kPa)	**Acceptable pipe**	
	Pipe	***Limiting conditions***
200	Copper tube to EN 1057/BS 2871 (Equivalent wall thickness to BS 2871, table X) With or without an acceptable protective coating applied by the manufacturer	Not permitted in the ground beneath a building or concealed in concrete at pressures exceeding 7 kPa unless protective coating or covered with a proprietary wrapping acceptable to the Authority. Propriety coated copper tube is available in sizes up to 159 mm. Where plastic coated copper tube is used underground or where adverse environmental conditions exists, all joints and fittings are to be protected and made water tight using an acceptable method and material.
	Acceptable fittings	
	Fitting	***Limiting conditions***
	Copper or copper alloy compression ring fitting to BS 864 or EN 1254	Not permitted in the ground beneath a building or in concealed masonry/ concrete material. Maximum size 35mm.
	Copper alloy brazing capillary fitting to BS 864 or EN 1254	Joints laid in the ground or concealed in concrete mush have protective coating acceptable to the Authority.

(*cont.*)

Table 6 (*cont.*)

	Brazing or composite flange, copper alloy to BS 864/ EN 1254	Not permitted in the ground beneath a building. Not to be used for joining pipe lengths unless other jointing methods are impracticable. Flanges forming a joint are to be of the same size and face type.
	Screwed copper alloy flange, or threaded adapters to BS 864/EN 1254	Not permitted underground or concealed masonry material. Not to be used for joining pipe lengths unless other jointing methods are impracticable. Flanges forming a joint are to be of the same size and face type.
Operating limit (kpa)	**Acceptable jointing**	
	Method	***Limiting conditions***
200	Copper or copper alloy compression ring fitting	Not permitted in the ground beneath a building.
	Open flame brazing equivalent to BS 1723	Brazing alloy of copper phosphorus base (optional inclusion of silver). Acceptable fittings to be copper phosphorus brazed to the pipe not screwed. Maximum pressure for sizes above 108 mm of 100 kPa.

3.0 MALAYSIAN STANDARD FOR COPPER PIPING

Malaysian Standards that is applicable for fuel gas piping system including copper pipe is MS930. MS930 is a Code of Practice for the installation of fuel gas piping systems and appliances. This code is applied for transporting fuel gases that include NG and LPG (vapour phase). Under section 2.6.2 [15] of this code, options for materials used for metallic pipes include: steel and wrought iron, copper and brass, and aluminium alloy. Copper has been one of the options stated in the code and it has certain requirement if one wished to select it. That is, the gas that is being transported should not contain more than an average of 0.1 grain of hydrogen sulphide per standard cubic metre of gas.

Under section 2.6.3 [15] of the same code, options for materials used for metallic tubings include: steel, copper, and aluminium alloy. Again in selecting copper, the gas that is being transported should not contain more than an average of 0.1 grain of hydrogen sulphide per standard cubic metre of gas. Apart from this, the code requires that the copper tubing shall comply with Standard type K or L of ANSI/ASTM B88 or ANSI/ASTM B280.

Under section 2.6.8.5 [15] of similar code, materials used for metallic fittings should be steel, brass, and cast iron or ductile iron when used with steel or wrought-iron pipe: should be copper or brass when used with copper or brass pipe; and should be aluminium alloy when used with aluminium alloy pipe.

Apart from MS930 another appropriate Malaysian Standards which is applicable under the scope of discussion is MS830. MS830 is a Code of Practice for storage, handling and transportation of LPG. Under section 3.2.4 of MS830 code, options for materials used for pipes include: steel and wrought iron, copper, brass, or polyethylene. Copper should fulfils ASTM B42 seamless copper pipe, standard sizes.

Under section 3.2.5 [16] of the same code, options for materials used for tubings include: steel, brass, copper, or polyethylene. Copper tubing should comply with Standard type K or L of ANSI/ASTM B88 or ANSI/ASTM B280.

Under section 3.2.6 [16] of the same code, materials used for fittings should be steel, brass, copper, malleable iron, ductile iron or polyethylene.

Based from the applicable codes discussed, it is important to note that copper has been accepted as one of the material that can be used in gas pipeline transportation. However, certain constrain such as hydrogen sulphide per standard cubic metre of gas must be established prior to its usage. Thus a study on the compatibility of copper with local gas composition should be carried out.

4.0 COMPATIBILITY OF COPPER WITH LOCAL GAS COMPOSITION

Hydrogen sulphide is considered as a hazardous compound found in LPG which strongly act as an oxidizing agent in the formation of sulphides on copper at high temperature to form copper sulphides deposit. Therefore information is necessary in advance to determine the content of this hazardous substance. A specific procedure for the determination of acceptable level of hydrogen sulphide in NG and LPG is proposed by American Society for Testing and Material (ASTM D2420).

The test rig (Appendix A) was set up following the American Society for Testing and Material (ASTM D2420) standard. This method covers detection of hydrogen sulfide in LPG. The vaporized gas is passed over moist lead acetate paper under controlled conditions. Hydrogen sulphide reacts with lead acetate to form lead sulphide and thus produces coloration on the paper, which will vary from yellow to black, depending upon the amount of hydrogen sulphide present. However the sensitivity of the test is about 4 mg/m^3 (0.15 to 0.2 grain of hydrogen sulfide per 100 ft^3) of gas. Lead acetate paper can be prepared by dipping strips of smooth filter paper in 5% (5 mg/100 ml distilled water) lead acetate solution and removing the excess solution with clean blotter. The strips of paper shall be approximately 51 mm long and 9.53 mm wide and has a 3.2 mm hole near one end so they will hang vertical in the test apparatus. Hot water ranging from 50°C to 70°C temperature is proposed to

increase the concentration of hydrogen sulphide hence this will provide much easier detection of the presence of the compound. Moist lead acetate paper is exposed for exactly 2 minutes to the gas flow of 2.3 ± 0.2 liter per minutes.

This method [17] barely indicates the variation that occurs to the coloration of lead acetate test paper. Hydrogen sulphide blackens lead-based paints by forming lead sulphide (PbS) but oxidation to lead sulphate ($PbSO_4$) may occur later with the disappearance of the black. The colours produced by lead acetate test paper signify the concentration of hydrogen sulphide content. Increasing of hydrogen sulphide will vary from yellow to black. Manual observation is very important to ensure the transitory yellow stain on the lead acetate paper when the amount of hydrogen sulphide in LPG is exceeding 4 mg/m^3 and will subsequently fade completely in less than 5 minutes when lead acetate paper is exposed to the ambient air. In the absence of distinct coloration, report is said to be negative in the presence of hydrogen sulphide, whereas lead acetate paper will vary from yellow to black, which is then reported as positive. Experience in conducting all the samples give negative responses in result, which indicates the hydrogen sulphide is less than 0.17 grain. The results (Table 7) suggest that the installation of copper pipes in LPG distribution system did not contravene the Malaysian Standards MS930.

Table 7 Sources of sample collected from various locations in Malaysia

NO	SOURCE	COMPANY	ENTRY POINT	RESULT
1	Singapore	Shell	Pasir Gudang	Negative
2	Singapore	Petronas	Pasir Gudang	Negative
3	Singapore	Summit	Pasir Gudang	Negative
4	Singapore	BP	Pasir Gudang	Negative
5	Singapore	Esso	Pasir Gudang	Negative
6	Thailand	KELOIL	Bachok, Kelantan	Negative
7	Thailand	Bentara Engineering	B. Kayu Hitam, Kedah	Negative
8	Malaysia	Petronas Gas Kerteh	Kerteh, Terengganu	Negative
9	Malaysia	Petronas Refinery	Melaka	Negative
10	Malaysia	Shell Refinery	Port Dickson	Negative
11	Malaysia	Esso Refinery	Port Dickson	Negative
12	Thailand	Summit	Kuala Lumpur	Negative

5.0 CONCLUSION

It is established that copper pipes were widely used in fuel gas piping system especially those in United States, Australia, Britain and Canada. This shows that copper can be considered as an alternative safe and superior piping material for gas pipeline system in Malaysia. Furthermore copper is actually recognised as a gas piping material and listed in the Malaysia Standard, MS930 and MS830. Unlike plastics (polyethylene pipe), copper pipe has flexible tail connections to appliances. Therefore it can be installed in long lengths and fabricated to reduce number of joints. The flexibility of copper pipe can make it easier to install and reduce the installation costs without comprising safety. Copper pipe deliver better gas flow rates due to less internal obstructions and smooth bore pipe. It also has resistant to corrosion in both internally and externally. Thus, copper pipe can be installed in area which any leached petrochemical and solvent may be present. However, copper pipeline systems must be designed within the pipeline safe working pressure and temperature limitations specified in either local or international standards where operating pressures do not exceed 200 kPa. When considering all of the features and benefits of copper pipe and fittings as well as longevity, ease of installation and availability of supplies, copper pipe proves itself as the preferred option when specifying gas-piping materials.

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[9] BS 2871, British standard, Copper tube for water, gas and sanitation.
[10] EN 1057, European standard, Copper and copper alloys – seamless, round copper tube for water and gas in sanitary and heating appliances.
[11] JISH 3300, Japanese standard, Copper and copper alloy seamless pipe and tube.
[12] ASTM B88, American National Standard, Seamless Copper Water Tube.
[13] ASTM B280, American National Standard, Seamless Copper Tube for Air Conditioning and Refrigeration Field Service.

[14] ASME B31.8, Code for Pressure Piping, Gas Transmission and Distribution Piping System.
[15] SIRIM, 1986, MS930, Code of Practice for the Installation of Fuel Gas Piping Systems and Appliances.
[16] SIRIM, 1986, MS830, Code of Practice for the Storage, Handling and Transportation of Liquefied Petroleum Gases.
[17] American Society for Testing and Material, 1992. ASTM D2420 – Hydrogen Sulfide in Liquefied Petroleum (LP) Gases (Lead Acetate Method).

APPENDIX A

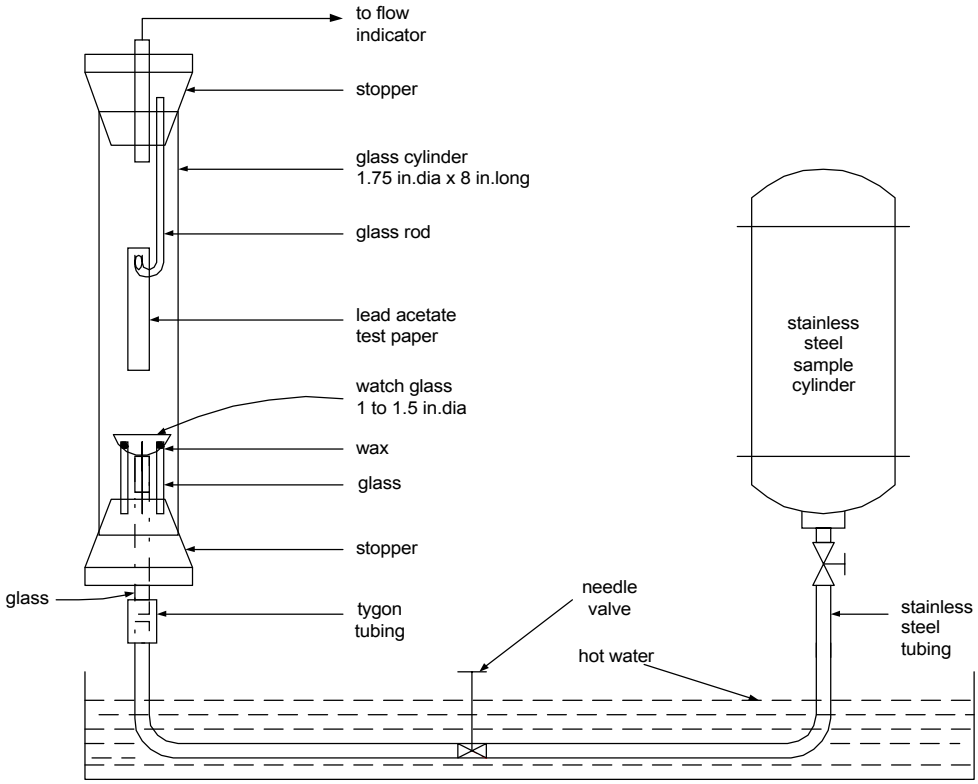

Figure A Standards Testing Rig ASTM D2420