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The History and Influence of PEX Pipe on Indoor Environmental Quality

+ + + Editors note to readers: the following text is a work in progress as the author recognizes that **historical interpretations are generalizations, approximations and nominalizations;** readers are encouraged to contribute to its thoroughness, integrity, and accuracy by sharing your details at the online forum at www.healthyheating.com.

1933

As told by Professor Thomas Engel, the **big bang of PEX goes back to March of 1933** after a high pressure experiment with ethylene gas caused a potentially fatal explosion at the **Imperial Chemical Industries (ICI)** laboratories in England leaving behind little else except a white wax like precipitate in the remains of an autoclave. This is where the future of polyethylene began but it took two more years, countless failed experiments, and ultimately a controlled duplication of the original blast under 3400 bars (50,000 psi) of pressure to reproduce the same substance. It was the heat, pressure and the oxygen acting as a catalyst on the gas that left behind a material, which had properties that would soon change the world of plastics.

1939

The original 8 grams in 1933 led to a small scale 50 kg pilot plant to a U.S. facility built in 1939 capable of producing a few hundred tons and the **DNA for today's polyethylene pipe**. The first real application came as an insulator for power cables in submarines. According to Professor Engel (b.1927) it was the **adoption of polyethylene**, "that Sir Robert Wattson was able to discover radar and develop it to perfection." It was during the war, the Germans discovered Allied use of polyethylene upon examining wreckage from a British bomber.

Circa 1944 -1959

Following WWII, Frank Lloyd Wright's projects and America's Levittown were introducing **radiant copper tube systems** to thousands of homeowners while Germanys' B.A.S.F. (Badische Anilin- & Soda-Fabrik) was experimenting with the production of polyethylene having obtained a license from England's **I.C.I.** In 1954, Hoechst (**Today's Basell**, one of today's largest producers of PE and catalysts) began its testing on pipes made from Hostalen high-density polyethylene. In 1959, Hoechst laboratory technicians extrapolated that the pipes made from Polyethylene would last over 50 years. As we now know, this is a very conservative estimate with modern made PE based pipes expected to last at least double earlier expectations. What the pioneer manufacturers found, was a need to increase the polyethylene's resistance to higher temperatures and so began an almost 20 year quest to safely and economically produce a network of connected molecules then known as **VPE (Vernetztes Polyethylene)** or today as **PE-X (crosslinked polyethylene).** It should also be noted that it was also during this era ca. 1953 and 1954 that two other plastics were first synthesized, polypropylene, and polybutylene respectively.

Circa 1960 – 1969

B.A.S.F. had discovered that the use of highly active radiation could cause the cross linking but the method was extremely expensive and dangerous. (According to Tomas Lenman some of these earlier extrusions are still under test in the B.A.S.F. laboratories.) From his discussions with **Phillips Petroleum** in Oklahoma, Professor Engel pursued more safe and less costly methods, focusing on numerous attempts using high compression and heat in the presence of a peroxide catalyst. It was with his first employee **Friedrich Imgram** (worked later on **Wirsbo's Quick and Easy connection**) that Dr. Engel found a suitable method which according to **Phillips Petroleum** analysis had obtained 97% crosslinking well beyond the 65% to 70% required by today's ASTM Standards. Like many great inventions, Engel struggled to find anyone who could image using the plastic product until a neighborhood chicken farmer asked him if pipes could be made from the material. It was out of desperation that he modified his Heusenstamm autoclave into an extruder and herein was his first application of plastic pipes warming the floors of the chicken coop. In 1965 Engel patented his method and in 1967 sold license options to a number of companies including among others, **Rehau** (December 1967), then the **Swedish Bonnier Group** (who sold its license to **Wirsbo**(now Uponor) in 1968), **Pirelli, Dunlop, Mitsubishi, Goodrich and Continental.** Between 1968 and 69 most with the exception of Wirsbo and Rehau, did not believe Engel's method could actually produce a commercially viable pipe.

Circa 1970-1979

The 70's proved to be both the most exciting and controversial times for PEX pipe. It was in 1971 when a young **Tomas Lenman**, a Wirsbo Bruks development engineer, met Professor **Thomas Engel** and worked along with **Lubonyl's Lennart Agren** (now of LK Pex AB) to refine the processes of today's PEX-a methods. Agren, at Lubonyl (later acquired by Uponor), invented the **PEX-d** (Azo Compounds) process. It was also during the mid 70's that the oxygen permeation through plastic pipes arose which required Tomas Lenman and others to lead a corrosion research program lasting into the 80's. This event was the precursor leading up to the 1980's creation of DIN 4726 allowing a maximum oxygen gas transmission rate of $0.1 g/m^3$ per day at 40°C or less. At some point Wirsbo purchased most of the Engel licenses for the rest of the world with **Rehau retaining its German license.** It was during the

mid to late 70’s then Wirsbo owner Mr. **Bengt Lagercrantz sold one of it’s Engel license to Golan Plastics in Israel** who produced the PEX-a pipe and later PEX-c for domestic sales but subsequently in the late 80’s/early 90’s exported under private label to American (**Crawford Group**) and Canadian interest (Polytech (now Heat Link Group)). During the 70’s Velta’s Heino Stüfen along with founder Dietrich Liedelt agreed to purchase PEX pipe made from an Engel extruder acquired by **Mr. Wagner, owner of Rehau.** Later, Velta transferred its entire production requirement to Wirsbo as told by **Ake Forsell**, when Wirsbo purchased Velta for its stable of ever growing radiant piping businesses. It was also during the mid to late 70’s that Heino Stüfen, Dietrich Liedelt and several others created the workings of a standard for PEX heating pipes in Germany; a process which took over ten years to develop having much opposition from steel and copper pipe producers. The standards main author was **Dr. Peter Stagge** of Materialprufungsanstalt Darmstadt working with **Achim Seydel**, Technical Director of Wirsbo Germany (now: Becker-Plastics, Germany), **Tomas Lenman**, MSc., **Dr. Bassewitz** of Rehau and Stüfen with Liedelt of Velta. It was again during the late 70’s that Velta’s Stüfen became interested in the physiological side of heating and subsequently contacted indoor environmental specialist, **Professor Ole Fanger** from the Danish Technological University in Copenhagen, who later introduced him to **Dr. Bjarne Olesen**. Sadly, Professor Ole Fanger passed away in 2006 leaving behind a legacy of research which building scientist all over the world use in creating spaces for human occupancy. Dr. Olesen eventually became the technical director at Wirsbo Velta for many years until returning in 2005 to the Denmark Technical University where he had replaced retiring Professor Fanger. One of Dr.Olesen last projects as a direct employee of Wirsbo Velta was working with Dr. Peter Simmonds on the Bangkok Airport, as of today, the world’s largest radiant cooling project. It was also in 1977 that **JRG Gunzenhauser (Sanipex)** and another soon to be well known control company, **TA, Tour Andersson** (a merger of then Tour Agenturer and A.H. Andersson) became a Wirsbo customer and known for their radiant systems businesses. History shows the predecessors of TA selling valves to Danish distributor Dahl**,** which just happened to employ a young Norwegian by the name of Mr. Trygve Husebye. The original company, **Broderene Dahl,** founded in Denmark in 1867, established an importing and distributin branch in Toronto, Ontario, in 1952. One year later Mr. Husebye found himself moving from his Norwegian roots to Canada and, in 1954, he joined Dahl’s Toronto office. In 1960, he bought the company and began transforming it from a distributor into a manufacturer. In 1984, **Dahl Brothers (Canada) Limited** introduced its new and innovative line of mini-ball™ valves for residential plumbing applications and, by the end of the 1980’s, was supplying them to almost all of the PEX producers in North America for both plumbing and hydronic heating applications .
1980’s. The **oxygen permeation debate** which got started in the mid 70’s got off to a grand start when German trade magazine: “Sanitær und Heizungstechnik” published its November 1979 interview with Mr. Hans Viessmann, CEO of Viessmann GmbH, who essentially stated, “The situation is basically clear: In accordance with existing technical practices, there must not be any air - and thereby oxygen - let in into closed loop heating systems. Anyone that supplies heating products, which load the water with oxygen, acts in contradiction with technical codes, and must be liable for consequential claims. It is not only the boiler that is at risk, but all other ferrous parts like radiators, heating elements, and pipes.” As we know from the 70’s, the efforts to create a European standard was initiated earlier but it took seven years for the drafts, revisions and appeals before DIN 4726 was finalized in 1987 but it wasn’t until 1992 that it was finally accepted by industry institutes and association in North America. Surprisingly 20 years after its European acceptance and 15 years in America a tempered debate continues today. In 1982’s “Water and Pipes” was authored by **Lenman and Skarelius** one of the modern day texts on applications and science of plastic PEX pipes. At the same time the

development for **ASTM for PEX** began headed by Tomas Lenman, initially with **PEX-a being the only process**, which could meet the standard at that time. PEX-d was later listed at the end of 1983 and then in 1984, almost 50 year after the explosion in England, the first publication of ASTM F 876/877 came out. In 1989 Lenman also began the work on the **Canadian Standard CSA 137.5 for PEX** and it was during this time that PEX-c received its listing and later still came PEX-b. The year before this work, **Uponor acquired Hewing** in April of 1988, and the **Wirsbo Group** in August of 1988. Between 1983 and 84, Water and Pipes was translated into English and its author, **Tomas Lenman** moved to the United States to open Wirsbo North American operations with two people in Rockford, Ill., and introduced Engel-method PEX for radiant heating to the U.S. market. Shortly thereafter, domestic and foreign manufactures of boilers, expansion tanks, and circulators begin to issue warnings about oxygen related corrosion from non-barriered pipe used in heating systems. (Note: Wirsbo being informed about risks associated with oxygen diffusion provided barriered tubing from the start in the USA). It was also during the mid to late 80's that importer Hubert Eckhart (Vancouver, BC) and later **Calgary's Polytech** (Schmidt's) developed the Polytherm brand in North America. This arrangement continued until Polytherm joined the Wirsbo group, which in 1991 led to Polytech, and the Crawford Group of Grand Rapids, MI to work together as importers of **Golan's PEX**, distributed in North America under the Heat-Link brand. Each of these businesses has since refocused to their own interests following Polytechs extruder purchases from **Arne Heino**, a previous employee of a defunct Uponor Group called **Pexep Oy**. The balance of the 80's was an interesting match between American and European pipe and components producers as they saw the growing potential for radiant based systems in Canada and the United States. Regional and national debates (much around oxygen permeation) led to the creation and dissolving of several associations each believing strongly in their ability to lead the evolving tumultuous growth. Despite the friction, history will show it was necessary to go through this robust period to create a solid foundation for substantial growth, which came from demands created by shifting demographics during the later part of the 80's and into the 90's.

Circa 1990 – 2007

During the past years, industry has seen most of the early pioneers of different American made radiant piping systems (Bow, BioEnergy, CPI now Nibco, Plasco, Heatway now Watts, Vanguard now Viega, Zurn) close down or morph into producers of various methods of crosslinked polyethylene (PEX-a,b or c) and multi layer pipes such as PEX-Al-PEX and recent derivatives such as PE-RT piping. Long gone are the original Engel patents and licenses.

KWD, RPA and other industry reports provide details as to the strengths of each domestic and foreign producer but its suffice to say that the early inventors, producers and certainly the market leader did a tremendous amount of costly legwork to create the **demand for today's PEX pipe**. This includes the study and **influence radiant cooling and heating systems** have on thermal comfort and indoorenvironmental quality and the **DIN/ASTM/CSA Standards** used by all producers. This should be duly acknowledged and respected. The various **extrusion and cross-linking methods** provide an edge for serving customer preferences and for differentiating product.

Applications for PEX Pipe

Others including the manufactures of PEX long ago discovered that **by conditioning interior surfaces using embedded pipes carrying warm of cool fluid**, that building environments and comfort quality is greatly improved. Much of what we know today on human physiology and thermal environmental conditions for human occupancy is described in both **ISO and ASHRAE Comfort Standards** where the influence of radiant is detailed. The human and building sciences show that the body needs to release heat to stay healthy. Conversely if it loses more than its excess capacity it will experience thermal stress both overheating and cooling are called discomfort. So much of this discomforts is contracted with building inefficiencies that in an inefficient building, **at rest well over 50% of the body's sensible heat is lost via radiation**. Conversely if the building is in a hot climate the body will be exposed to radiant gains as the interior surfaces of the building rise above the body's skin temperature. Controlling the interior surfaces temperatures is a proactive way to mechanically contract with the bodies biology allowing one to remain stress free, which means it can focus on the task at hand (relaxation or productivity). As far as efficiency goes, **radiant low temperatures in heating** and high temperatures in cooling are proving to greatly enhance the **efficiency of heat pumps**, condensing boilers and chillers. This may ultimately prove to be the **next raison d'être for PEX as trends** in improving building efficiency reduces the comfort story told in the past.

Summary of PEX types:

Industry distinguishes between four methods of cross linking.
PE-Xa = with peroxide (Engel, PAM, Fränkische, etc.)
PE-Xb = with Silane (Dow Corning/Sioplas)
PE-Xc = by electronic irradiation
PE-Xd = with AZO (Gustavsberg-Lubonyl) now extinct

It is important to note that the degree of cross-linking required by standards is based on the material and methods used and is not a competitive quality within the pipe.

PEX-a, By the exhaustive efforts and perseverance over 40 years ago by Professor Thomas Engel and his first employee Friedrich Imgram, industry has "The Engel" method, or PEX-a (peroxide) method which employs a special extruder with a plunger action where peroxide is added to the base resin and through a combination of pressure and high temperature the cross-linking takes place as the tubing is produced. This method allows for larger extrusions exceeding 500 mm and various joining methods. There are other PEX-a methods such as PAM but it process yields a partly cross-linked pipe only so it has to complete the process in hot air or water afterwards.

PEX-b, Based on a process developed by Dow-Corning, the "Silane" method of PEX production involves grafting a reactive silane molecule to the backbone of the polyethylene. The tubing is produced by blending this grafted compound with a catalyst, which can be done using either the Sioplas method, or by using a special extruder it can be done using the Monosil method. After extrusion the tubing is exposed to either steam or hot water to induce the final cross-linking reaction in the tubing.

PEX-c, Electron Beam cross linking takes place when very high energy radiation is used to initiate molecular cross-linking in high density polyethylene. This product is extruded like normal HDPE then taken to an E-beam facility and routed under a beam or ray in the accelerator where it is dosed with a specific amount of radiation to release the hydrogen atoms and cause polymer chains to bond or link to the open carbon sites.

In European standards these three methods are referred to as PEX-a, PEX-b, and PEX-c, respectively and are not related to any type of rating system. All the resulting PEX tubing products perform similarly, although challenged by some, and are rated for performance by the ASTM, NSF and CSA standards for which they are tested and certified. The listings and certifications met by each product are printed on the print line of the tubing itself to ensure the product is used in the proper applications it was designed for.

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About the author

Robert Bean is a **Registered Engineering Technologist** in the field of building construction. He is an avid student of industrial design (the way things look) and indoor environmental ergonomics (the way things feel) and participates in numerous associations, councils and committees related to these fields of study. In 2006 **Robert was appointed to the National Certification Council for Home and Property Inspectors of Canada** and selected in 2007 as an **ASHRAE Distinguished Lecturer**.

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