NOVEL MIXING HEADS FOR PIPE-IN-PIPE INSULATION PROCESS

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ABSTRACT

Cannon has been successfully testing an innovative high pressure mixing head, specifically designed for piping insulation in continuous/discontinuous foaming production processes. The special requirements of this application meant the need for the development of a completely new mixing head in order to meet specific and severe technical requirements. Its compactness and its slim curved shape characterize the new Cannon ZX high pressure mixing head.

It is important to note that the head's thickness is only comprised in less then 25 mm! This is necessary to enable it to be inserted through the cavity generated from the coaxial feeding of the steel service pipe with the extruded high-density polyethylene external pipe. Both tubes run in the same direction at the same speed.

In the case of two specific applications in China for two important insulated pipe-in-pipe manufacturers, the production capacity was controlled mainly by the line speed and the length of both pipes was practically "endless". The speed had to be set relative to the diameters of the pipes and the PU thickness. Due to the size of the mixing heads, nothing less than 25 mm of PU foam thickness could be obtained. The minimum diameter of the internal steel pipe was 50 mm, the maximum of external plastic pipe was 450 mm and the PU thickness range of PU foamed could be between 25 up to 50 mm. The speed of the line could be set from 3.5 up to 6 metres/min for a 90 mm diameter steel pipe.

INTRODUCTION

Whether we are talking about water, gas and oil supply lines (both on and off shore) or a local community district heating/cooling system, rigid polyurethane foam plays a vital part in protecting and enhancing the effectiveness of the relevant distribution systems. While it has been used for the insulation and protection of pipes for more than 30 years, today thanks to better mechanical and physical properties, it is more widely used than ever and increasingly displacing alternative materials such as mineral wool, foamed glass and other inorganic materials (see table 1).

Table 1 - Insulating Properties Comparison for Piping Insulation

Insulating materials	Density (kg/m^3)	Thermal Conductivity 50°C (mW/m.K)	Relative insulation thickness at equal heat loss
Rigid polyurethane foam	70	27-30	1
Mineral wool	200	45	1.7
Foamed glass	125	52	1.9
Bitumen/cork mixture	880	105	3.9
Foamed concrete	400	160	5.9

Polyurethane foam is a proven insulant recognized for its reliability, durability and efficiency. Its outstanding insulation properties prevent heat loss, or alternatively maintain temperatures, over an extremely wide range of conditions, from extreme cold environments to ones of intense heat without freezing or cracking. In addition PU is clearly the most effective material, being suitable for applications ranging from small plumbing pipes up to the largest heating pipes (from 10 mm to 2000 mm in diameter and 250 mm of maximum insulation thickness), and also giving significant further advantages in terms of perfect adhesion to both metal and casing pipes. Beyond this, the closed cell structure of the foam inhibits penetration of water into the foam along the whole length of the pipe even if the casing pipe is damaged.

Local community district heating networks are becoming part of the common infrastructure of most cities all around the world. In this case, the hot water has to be transported in a closed loop from the power plants, often located outside large cities, to the heat exchanger stations, which in turn serve extensive distribution grids. Polyurethane-insulated pipes are used in both networks.

The fundamental idea of district heating is a piping network that allows energy sources to be connected to multiple energy sinks. The existence of the network enables complex and environmentally optimum energy solutions to be developed. The ability to assemble heat distribution system enables renewable fuels such as biomass and sources such as geothermal to be used in a cost-effective way. In the EU, some countries, in particular Scandinavian countries, show a significant penetration of district heating of up to 80% of the heating market. However, district heating represents only a small fraction of the total heat market of the EU. Therefore the potential is large and varies in each country depending on past national policies. The market share of district heating in the UE countries could be much higher. In the United States and in other countries where cooling is important, district cooling networks are increasing in significance. The technical possibility of using waste heat and thermal storage to produce economic cooling services is attracting a lot of attention.

Most of these service lines are laid underground and are typically made of a steel pipe surrounded by polyurethane insulation and protected by a tubular casing of high-density polyethylene (HDPE). The long-distance transmission of district heating relies on the thermal and mechanical performance of polyurethane rigid foam. Market penetration in this area is bound to increase over-proportionately in the next decade because of the many advantages offered by pipe work in terms of flexibility and energy savings.

Another interesting growth sector is the inner service pipe made of cross linked polyethylene (PEX), which is corrosion proof, chemically resistant and approved for food contact, making the pipe-in-pipe suitable for diverse uses such as food and beverages, drinking water, supply, sewage and cooling systems, industrial and agricultural applications and swimming pools, marine systems, air conditioning systems.

THE SOLUTIONS AVAILABLE: CONTINUOUS & DISCONTINUOUS PRODUCTION PROCESSES BASED ON LOW PRESSURE TECHNOLOGY

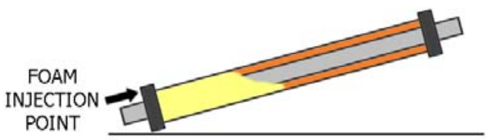
Pipe manufacturing could be achieved by applying continuous and discontinuous production techniques but only with a foaming system based on low-pressure technology. Generally, the continuous process requires that the steel service pipes be fed one by one into the extruder’s head. The junction point has a temporary internal metal double male manifold, which is use to connect the pipes, while externally an adhesive tape is manually applied, just to avoid any possible internal leaks during the polyurethane foaming phase which follows.

Table 2 - Comparison of Discontinuous and Continuous Pipe Filling Technique

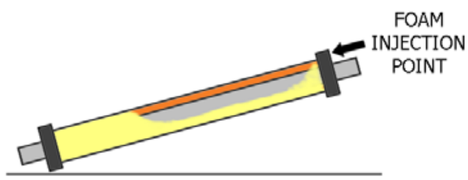
Discontinuous	Continuous
Advantages	
▪ easy set-up ▪ convential hardware ▪ large range of pipe dimensions ▪ technically less demanding	▪ lower foam density ▪ thinner HPDE casing ▪ even distribution of foam properties ▪ more automation in process
Disadvantages	
▪ high foam overpack required ▪ even property distribution difficult ▪ labour intensive	▪ according to the automation level, specially skilled operators required ▪ limited flexibility ▪ complex hardware

In contrast pipes produced by the discontinuous process are foamed one by one with a single shot using one of four main different filling techniques. Once assembled ready for insulation, the pipe-in-pipe can be set on an inclined table (generally with an inclination between 1° and 20°) and is foamed by pouring the reacting polyurethane mixture into the cavity between the internal steel pipe and the external extruded one in HDPE.

Both pipes are held coaxially in position by spacers. The foaming process can be carried out by either filling with PU from the top or from the bottom end of the pipe (see picture 1-2). Both ends of the pipe are sealed with special tightly fitting caps complete with dedicated injection and air venting holes.



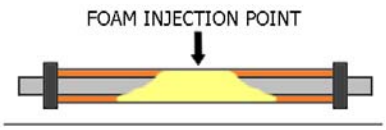
Picture 1 - Bottom-Up Filling Configuration



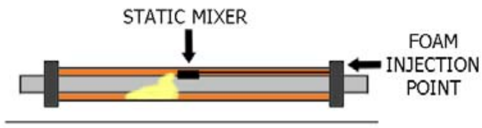
Picture 2 - Top Filling

Where inclined table are not available, the assembled pipe is set on a flat base with both ends sealed. In this case the typical filling methods are as follows:

- PU can be poured through an injection point drilled into the middle of the pipe length (picture 3).
- A special distribution lance can be introduced along the length of the pipe and simultaneously retracted during the pouring phase (picture 4).



Picture 3 – Central PU Injection



Picture 4 – Static Mixer Mounted on Retractable Lance System

For a good PU adhesion, we should remind that the foam requires clean surfaces: in particular steel pipes have to be grease, oil and rust free while the HDPE pipe should be pre-treated using the Corona treatment to guarantee a strong bond.

Apart from good insulation and adhesion properties, the typical operating conditions of a district heating distribution system make high demands on the foam's thermal and mechanical performance, including high creep resistance. Generally, a transmission system is expected to have a technical lifetime exceeding 30 years, supplying water at 125 °C but with outside temperatures, which depend on the locality, sometimes dropping in winter to well below freezing point.

THE CANNON CHALLENGE: INTRODUCE HIGH PRESSURE TECHNOLOGY INTO THE PROCESS

Cannon was approached to explore the potential for development of a local supply solution in China and was chosen over other competitors for its long-standing expertise, capability in the manufacture of rigid polyurethane foam systems and for its ability to supply customers with tailor made solutions. On the contrary Cannon took its decision to explore the possibilities because it was fascinated with the challenge of such an interesting project. Traditionally machines based on low-pressure are used for the pipe foaming insulation processes: Cannon changed the meaning, evaluating the possibility to apply the high-pressure technology to those production processes.

Close co-operation and the benefits of backward integration, available through the vast resources of the Cannon Group contributed to a complete solution with total customer satisfaction. Technical engineers responded quickly and the development analysis and strong fundamental research programmes, which helped in the development of a new mixing and foaming system, began immediately.

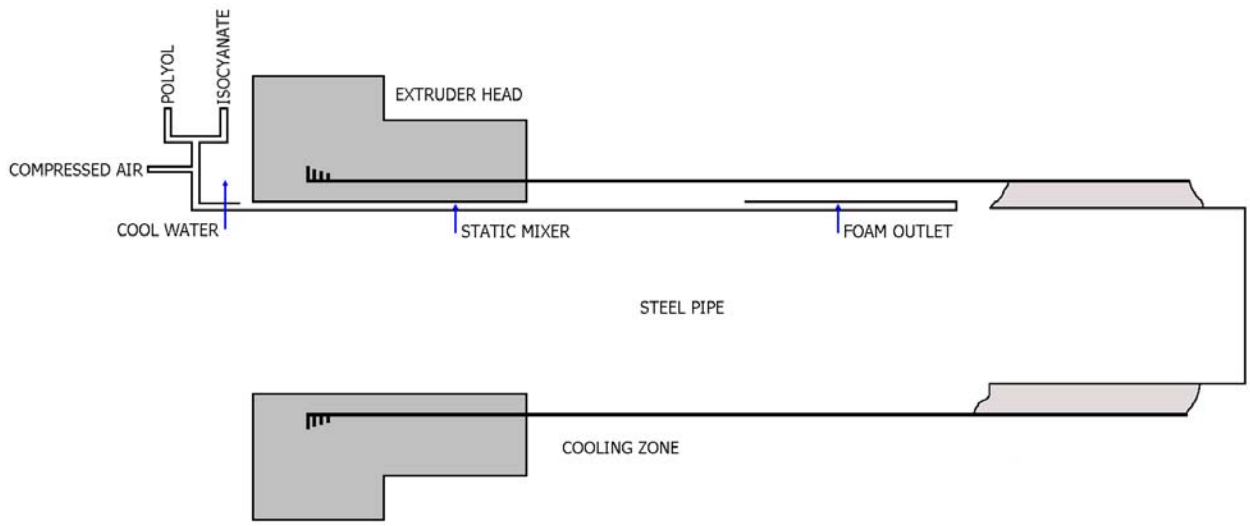
The global project commissioned to Cannon consisted of 9 high pressure Cannon A-System 20 dosing units for the continuous foaming lines and 3 high pressure Cannon A-System 350 metering machines for the discontinuous lines. Those machines provided a complete conversion of the existing production facilities, replacing CFC's with HCFC 141 based foam systems.

The flexible design and the easy and friendly management make those units a valid alternative to low pressure machines on which to begin the development of a technical solution able to meet the main requirements of this project. Initially they provided the high-pressure technology that offers the opportunity to define an environmental friendly mixing process. This means that the mixing chamber cleaning operation is no longer required, eliminating the utilization of toxic solvent, avoiding any ambient pollution caused by it and improving the quality of the working conditions.

At the present time, the production comprises insulated heating pipe, manufactured on home-made continuous lines. The steel service pipes have a length of up to 12 metres combined with different internal diameters, while the external polyethylene pipe is generally characterized by a 3 mm thickness and diameters achievable from 110 mm up to 500 mm. The extrusion of the casing and the foaming takes places simultaneously while steel pipe is continuously fed through the head of the extruder. Both pipes are held coaxially in position by a dedicated electronic PLC-based control system that constantly monitors the relative concentricity between each other's.

Since the pipe-in-pipe run over a dedicated conveyor equipped with pipe restriction frame, if the feed backed values exceed the pre-set acceptable tolerances range, the system automatically adjusts those acting with special pushers against the external layer of the HDPE pipe.

The foaming system is composed of very simple dual pump low-pressure machines, basically connected to an "in line" static mixer where Isocyanate, Polyol and air are directly fed by independent streams. When the production starts the mixing device is inserted between the extruder's head and the steel pipe body, right in the proximity of the extrusion area where temperatures can reach more then 160 °C and cause component property degradation (picture 5).



Picture 5 – Polyethylene Extruder and PU Foaming Layout

The production line is working up to 8 hours per day without stopping and the plant has its own batch mixing plant for polyol and CFC. The maximum capacity of the foaming system is 14 kg/min. The output is adjustable according to the speed of the extruder and to the PU insulation thickness, down to 2 kg/min.

Working with this mixing approach the quality of the foam often does not meet the technical specifications in terms of density and homogeneity (the air nucleation was added exactly for improving the mixing quality). For this reason the decision was taken to evaluate the possibility to substitute the existing production facilities with a new solution based on high-pressure technologies in order to obtain a significant improvement of the foam quality and in the meantime reducing the environmental impact.

ZX: THE NEW CANNON HIGH PRESSURE MIXING HEAD FOR PIPING INSULATION

Analysing this attractive project, it became immediately evident to Cannon R&D specialists how the first developing phase required the engineering of a completely new high pressure mixing head. Many difficulties and very severe limits had to be overcome: a dedicated design was necessary for inserting the head between the pipes, considering that in the worst working condition the filling cavity has a maximum width of 25 mm only and the head needs to have a curved shape for introduction between both pipes.

Again, the high temperature (around 160 °C) inside the extruder head means that fitting the mixing head near to this high heat source is not recommended in order to avoid possible chemical damage. In fact, mixing the component in so hot area could cause a fast expiration of the intrinsic properties of the material resulting in poor quality foam.

Considering all those technical constraints an intensive engineering phase was begun and Cannon's development effort culminated in the ZX Head prototype (picture 6).

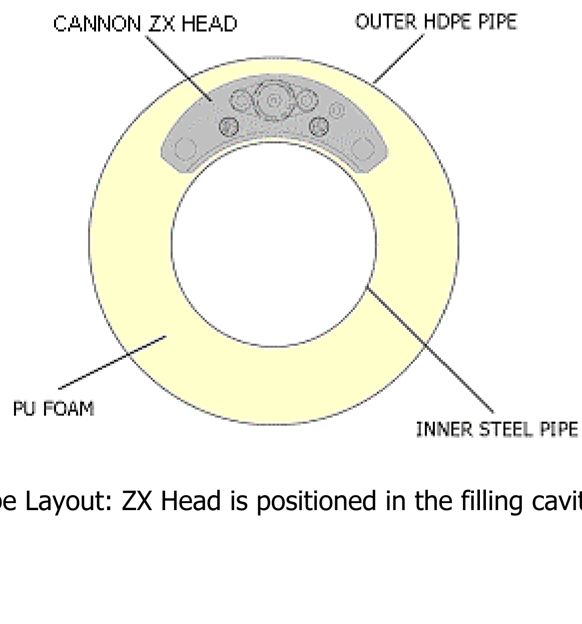
Picture 6 - Details of the new Cannon ZX high pressure mixing heads and relevant spring injector

Basically the head's name was chosen for the innovative mixing chamber geometry, which is based on a Z-shaped layout. It is characterized by a maximum width of 20÷25 mm and can be easily handled for its lightweight (900 g version A; 1.100 g version B). The chemicals are radially injected at high pressure through special spring injector nozzles that are driven by relevant component pressure.

When the pressure in the feeding stream overcomes the nominal strength of the spring the material is poured. The component mixing is achieved by the injection at high-pressure impingement inside the mixing chamber. Also the turbulence generated during the injection is utilized as kinetic energy to improve the mixing phase, the homogeneity and the quality of the polyurethane foamed.

For this particular application the Cannon ZX head with the relevant component feeding pipes is mounted on a special lance, thus it is possible to introduce it along the foaming cavity, crossing the extrusion area and positioning the head close to the casting cooling zone to avoid possible component degradation and obtaining a better foam quality. The lance is supplied complete with a dedicated column support, which has been designed to be driven on three axes for precise alignment with the pipe, according to the processed product.

During the working process the mixing head lies on the external surface of the steel pipe, which is continuously fed, running underneath the head during the complete production run. Utilizing special surface treatments of the manufacturing materials, any creeps between steel pipe and head are avoided and this also ensures a perfect head body wear resistance. Moreover, the temporary piping junction point necessary for a continuous process, is obviously not perfectly plane because of the external sealant winding. For crossing the junction without dangerous snagging the back of the head has been properly shaped with a fully corner-free geometry (picture 7).



Picture 7 – Pipe-in-Pipe Layout: ZX Head is positioned in the filling cavity in working condition

Consideration has been given to the configuration of the mixing head support inside the HDPE pipe in order to make it possible to change the head "on the fly" in case replacement is necessary. At the end of the working day and thanks to its specially-designed base fixing, the lance is retracted and the head can be easily and quickly demounted with a simple manual operation for basic maintenance – if needed – or to let it soak in a DOP-bath – to preserve it in good condition until the next production cycle -.

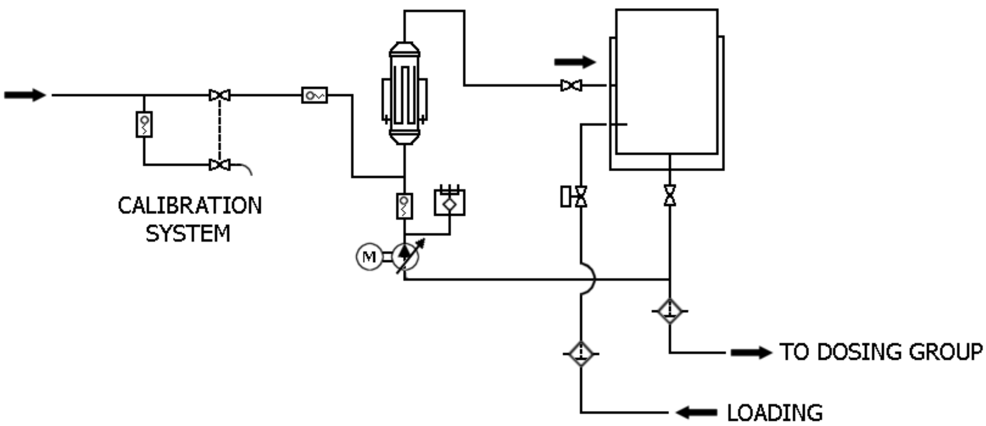
Once the first ZX prototype had been made, Cannon Afros' Laboratory in Caronno Pertusella (Milan – Italy) fully tested it, implementing a complete simulation of the actual foaming process and utilizing the chemicals supplied directly by the customer. Special equipment was built to test in depth all the possible working conditions in order to obtain precious feedback for the definitive system configuration. Lab trials with the new high pressure mixing head gave excellent and impressive results and the construction of the first foaming machine began (picture 8).

Picture 8 – Insulated Pipe-in-Pipe foamed during Lab's Trials

The Cannon ZX heads are characterized by a maximum foaming capacity of up to 14 kg/min, the table below sums products range specifically requested from the project developed in China.

Continuous process working line with a 25 mm of PU insulation layer	
Steel Pipe External Ø (mm)	*Request output (Kg/min)*
48 ÷ 377	3.80 ÷ 8.18
Continuous process working line with a 40 mm of PU insulation layer	
Steel Pipe External Ø (mm)	*Request output (Kg/min)*
114 ÷ 377	4.99 ÷ 7.87

The foaming line is based on a standard Cannon "A-System" 20 high-pressure dosing unit with a total output from 3 to 16 Kg/min. The chemicals storage group is equipped with 300 litre jacketed tanks. Since the foaming process is continuous (the chemicals do not recirculate through the dosing system), the component temperature control is guaranteed by a low pressure system: a stream distributor is mounted on the circuit at the tank outlet which allows both mixing head feeding and component recycling through the heat exchanger. A transfer-pumping group is equipped with gear pumps with 30 l/min capacity. The very same circuit is also used for automatic refilling of tanks (picture 9).



Picture 9 – Component Recycling Scheme for Temperature Control

The machine is controlled by a Siemens S7 PLC, which has an integrated the Cannon IRD (Instant Ratio Detector). The dosing unit is completed with 2 volumetric flow transducers mounted along the delivery line of each stream. The output and ratio real values are always displayed, even during the low pressure recycle. The machine is equipped with 6 cc/rev high-pressure axial piston pumps driven by an AC electric motor. The output is controlled in close-loop by inverters and automatically maintained at the set value.

The high pressure-metering machine is based on a well-known environmentally friendly mixing technology that does not require mixing chamber cleaning. This means a lower environmental impact within foaming areas ensuring benefits for the health of the workforce and improved working conditions, plus the attractive benefit of reduced disposal costs. On a wider scale, it means a healthy contribution to the global reduction of environmental pollution.

Following a specific request from the customer, Cannon has also implemented a "slave control panel" to be installed close to the foaming area where workers can directly monitor the "on-line" process. This additional control device is a compact and smaller copy of the "master" one, on which the main machine control function has been duplicated: MMI screen, emergency, reset button and alarm signal. The peculiarity of this remote control is the possibility for the worker to manually adjust the current output operating on a special +/- button. This "just in time " output change modifies the preset value and the control automatically accepts the updated value as the new preset one. This technical solution allows a fine-tuning of output, depending on the product and to the changeable working conditions.

CONCLUSIONS

Cannon is a world-class manufacturer of polyurethane foaming systems, with more than 40 years expertise in developing highly efficient and proven metering machines and mixing heads for industrial applications. Today Cannon is a leading international Group with more than 2000 employees locally spread worldwide and serving customers in 70 countries. The Cannon global network provides the market with a fully integrated commercial and technical service. 5% of the total Group turnover is annually invested in R&D activities and a dedicated team of specialists is devoted in the constant development of new solutions and in the technological improvements of those already successfully applied.

New, exciting opportunities are continuously generated in the field of Polyurethanes by the continuing race between end users (asking for new applications) and machinery manufacturer (proposing new technological solutions). Cannon, leading the Polyurethane-processing field for very many years, contributes to the industrial application of these new opportunities by developing the required processing hardware. Also in the specific field of pipes insulation, Cannon has introduced an innovative solution that could revolutionize the traditional production processes in use: the development never stops!

If you require an industrial solution for a manufacturing problem related to your product, do not hesitate to contact the nearest Cannon office.

BIOGRAPHIES

Christian Cairati – born in Milan, Italy, in 1970 – has technical education in Information Technology with few specialisations in Plastics Technologies and a Master in Quality System Management. He worked for ten years in processing companies as production manager and for four years as technical, quality and marketing consultant for the Italian Association of Plastic Processing Machinery Manufacturers - Assocomaplast.
He joined Cannon Afros in 2001, as Company Communication Manager.

Davide Lucca – born in Como, Italy, in 1968 - graduated in Mechanical Engineering in 1994 at "Politecnico" of Milan. He joined Cannon Afros sales department in 1994. Today he is in charge as Area Manager of the Asian market