RECENT DEVELOPMENTS IN THE AX MULTI-COMPONENT MIXING HEAD

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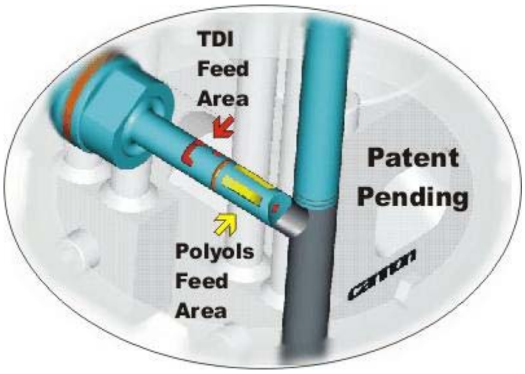
ABSTRACT

This paper describes the innovative modifications which have been introduced to the mixing head design in order to meet the needs of car seat producers who wish to mould TDI and MDI-based foams, thus allowing them to work with maximum formulation flexibility.

The AX mixing head is able to process six components in different combinations and with full high-pressure re-circulation of each component. The new version offers the capability to increase the throughputs and viscosity of the components fed via the two axial streams.

In particular, it is important to consider how TDI-based, MDI-based or blends of both Isocyanates (TM or MT) can be injected through the axial stream at pressures as low as 20 bar, with highly satisfactory mixing results and great simplification of the ISO-feeding circuit.

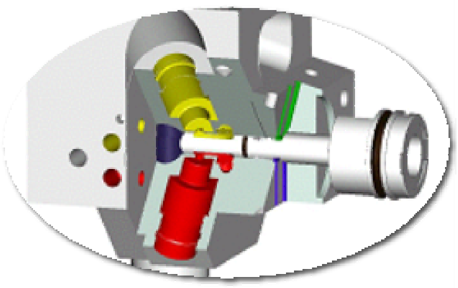
The compact design of this new mixing device and the absolute simplicity of its pressure settings, make it the most desirable alternative to the currently large, heavy and complex heads, which are used for automotive industry applications.



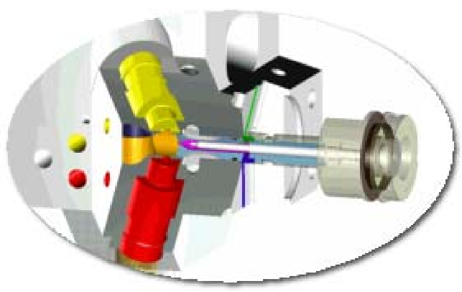
AX TECHNICAL FEATURES

Some alternative solutions already available on the market, include mix-heads with up to six separate component streams but they come with external re-circulation nozzle based systems. This means reduced efficiency and poorer dosing accuracy. It also means increasing the size and weight of the mixing head, thus requiring heavy-duty pouring robots. It necessitates speed and pouring pattern limitations in operation as well as complex pressure set-up and control procedures.

In the AX mixing head, four components can be injected radially into the mixing chamber and re-circulated at high pressure along the four grooves carved into the mixing chamber cleaning piston prior to foaming. Either Isocyanates or low-output compatible components (water, silicon, catalysts, etc.) can also be injected axially through the hole bored into the length of the mixing chamber closing piston. It is worth noting how the axially injected compatible components also re-circulate directly into the head, ensuring excellent output and pressure stability on injection phase (see pictures 1 and 2).



Picture 1: Re-circulation for each stream



Picture 2: Pouring with radial and axial injection

Seating is one of the most important and critical components in a vehicle, requiring a combination of high performance and styling. In fact, its finish and comfort define the car quality; its long-term performance and durability determine customer satisfaction. With the main targets being to reduce manufacturing costs and improve quality and properties of the foamed products under a range of climatic conditions, carmakers are defining highly sophisticated seating specifications to increase production flexibility and enhance environmental compatibility.

Today the traditional methods used to produce cushions with metal frames and a single Polyurethanes core supported by lightweight pan is quickly replacing springs. For these reasons the properties of the foam, such as its hardness, become an important factor in defining overall performance; also foam dynamic creep performance is the key to controlling long-term driving comfort, durability and to reduce foam core thickness. This change in approach requires a strong development effort, by certainly defining chemical systems as well as reliable and efficient dosing/mixing equipment, also able to exploit more automated production techniques.

Cannon applied its knowledge and vast experience as worldwide leading machinery and mixing head manufacturer, to develop the innovative range of AX multi-components heads, which is now successfully expanded to include the new AX 24.

On the whole, this model has the same technical features and pouring piston as its little sister - AX 18, but a different diameter self-cleaning piston (now 24 mm) and new axial stream feeding duct geometry. This extends the free-pouring operation to a total output up to 670 g/sec. The viscosity of the axially fed components can be higher as well: these improvements allow for the reduction of the the shot time as well as providing very good pouring quality with no splash effects. The result: car seat makers can now increase their production capacity and efficiency and maintain their quality standard.

The table below shows a comparison of the main technical parameters of the AX 18 and AX 24heads.

	Cannon AX 18 Mixing Head					Cannon AX 24 Mixing Head *				
	Viscosity (cps)	Single Component Output (cc/sec)		Working Pressure (bar)		Viscosity (cps)	Single Component Output (cc/sec)		Working Pressure (bar)	
		Min	Max	Min	Max		Min	Max	Min	Max
Radial Stream 1 to 4 ①	1.000	6	380	100	200	1.000	6	450	100	200
	2.000	6	300	100	200	2.000	6	350	100	200
	3.000	6	200	100	200	3.000	6	230	100	200
Axial Stream 5 to 6 ②	<10 ③	6	130	10	30	<10 ③	6	200	10	30
	<1000 ③	1	30	10	30	<1000 ③	1	40	10	30
	Total Max Laminar Output (cc/sec)		Oil Requirement (cc/shot)		Weight (Kg)	Total Max Laminar Output (cc/sec)		Oil Requirement (cc/shot)		Weight (Kg)
	400		850		22,1	700		2.800		39

* Preliminary
① If the radial streams are less than 4, the minimum total output is 105 cc/sec.
② The 6^{th} component must be chemically compatible with the 5^{th}.
③ The main TDI stream, if injected axially, is alone or split with MDI/TDI blend with the same output.

POURING PRESSURE CONTROL

The four radially injected components enter the mixing chamber through special needle valve injectors, which transform the injection pressure into kinetic energy. For those applications that require a rapid sequence of shots with different outputs using the same mixing head, the mixing pressure becomes the critical parameter to control.

Picture 3
Cannon AX 24 Mixing Head equipped with Re.Co. System

Pressure control in the component injectors, which is very important to ensure proper mixing of the different liquid streams, has been achieved through two different approaches:

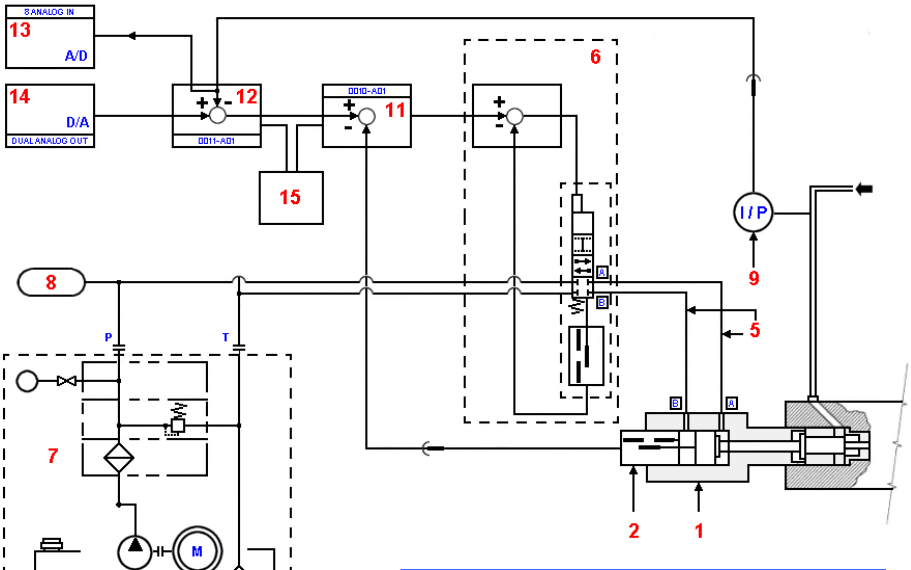
1) Re.Co. System – Cannon Remote Pressure Control. This is essentially a closed-loop system to control injection pressure through proportional hydraulic servo valves and feedback from the pressure transducers in order to maintain a constant mixing pressure, even when output variations occur (picture 3).

2) Fixed position control via various hydraulic valves pre-set at different values. Special spring nozzles must be used to keep the pressure stable even when the output varies between 10 and 15%.

In this second configuration, the mixing head is supplied with a package for fixed position pressure control that includes hydraulically driven nozzles to be installed on the mixing head for the radial components. Each nozzle has a dual function: it selects the component to be used in a specific formulation and controls the re-circulation/injection pressure during the pouring stage.

CANNON RE.CO. SYSTEM

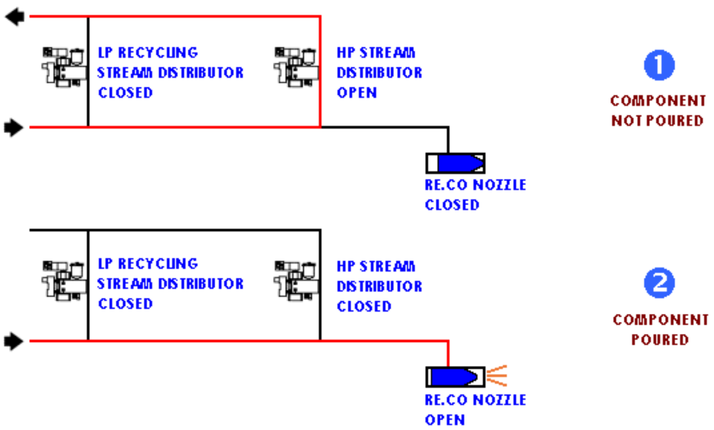
The AX mixing heads are equipped with Cannon's Re.Co. System, based on nozzles mounted on the four radial components, for the injection pressure closed-loop control and for component selection (picture 4). The nozzles are hydraulically driven: the position of each one is controlled in closed loop and adjusted in real time by a proportional valve, in order to keep the injection pressure constant at the set value, even after variations in output.



1	Re.Co nozzle
2	LDVT (Linear Voltage Differential Transducer): position transducer
5	Hydraulic oil lines for position setting
6	Proportional valves for nozzle position control
7	Hydraulic unit for Re.Co. nozzles operation
8	Hydraulic accumulator
9	Pressure transducer
11	Position control card (by Cannon Automata)
12	Pressure control card (by Cannon Automata)
13÷14	PLC interfacing cards
15	Power supply

Picture 4 – Re.Co. Component Circuit

The Cannon Re.Co. System also allows automatic modification of the chemical formulation, offering the facility to choose the specific component to be poured. On the whole, if the nozzle is in the closed position, the relevant component is not poured but recycled close to the mixing head through special high performance by-pass stream distributors, hydraulically driven and equipped with a pressure regulator valve (Picture 5). Because of the pressure regulator valve, when the component is recycled, the pressure of the line up to the nozzle is just about 10 bar less than the working pressure (i.e., the injection pressure when the Re.Co. nozzle is open).

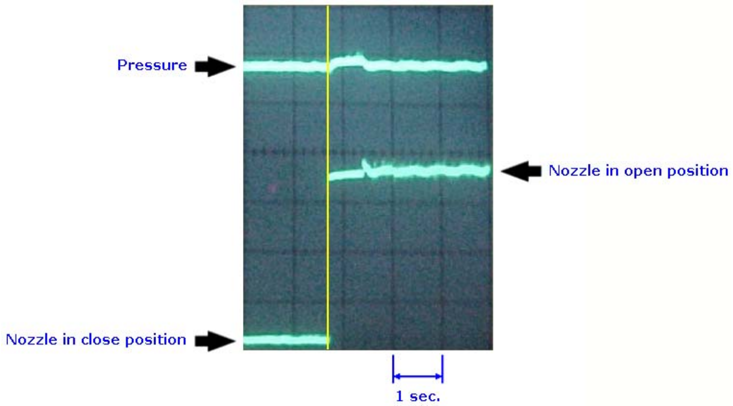


Picture 5 – Detailed view of the Re.Co. System: recycling/pouring phases through LP/HP by-pass stream distributors

The switch over between formulations (changing the components in the formulation to be poured and achievement of the set pressure and output) is executed in 0.7". In order to avoid peaks of pressure during switch over, the operator can set, for each component, the delay between the opening/closing of the high pressure stream distributor and the closing/opening of the Re.Co. nozzle.

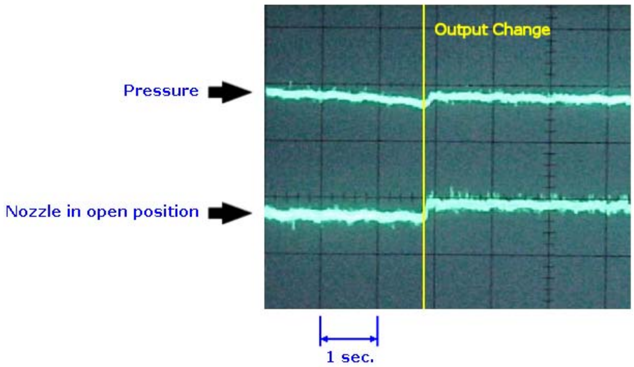
Recycling Phase – Pouring Phase

Starting the pouring phase the nozzle comes across the closed position to the open one. The relevant graphic shows how the pressure (set to 150 bar value) also remains almost constant during the switch over from the component recycling to the component pouring.



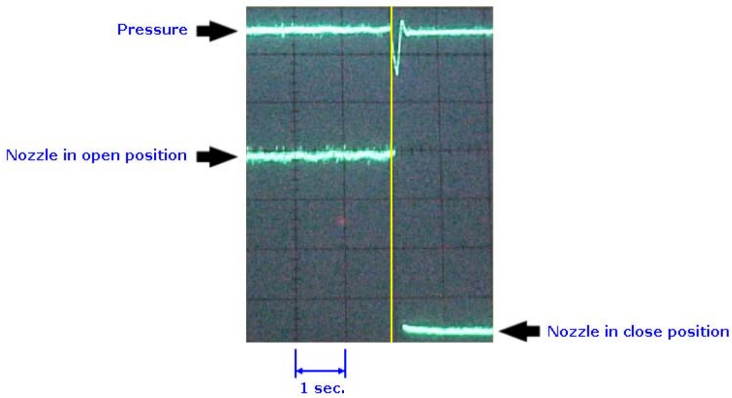
Pouring Phase

The diagram shows a typical output change from 300 to 200 g/s during the pouring phase: the pressure is at 150 bar and it remains constant during the switch over.



Pouring Phase – Recycling Phase

At the end of the pouring phase the nozzle comes across the open position to the closed one. The relevant graphic shows how the pressure (set to 150 bar value) also remains almost constant during the switch over from the component pouring to the component-recycling phase.



THE INNOVATIONS INTRODUCED BY THE CANNON AX MULTI-COMPONENT MIXING HEAD RANGE

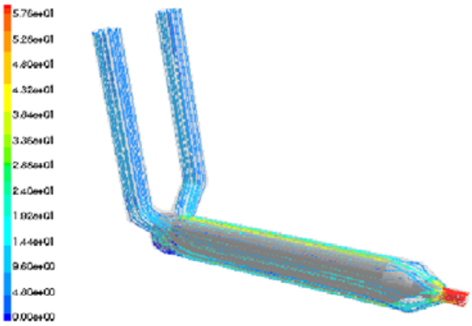
AX has been designed, developed and tested according to specific quality standards set out by Cannon technical specialists. The innovative design and geometry of this range of models comes from a new development concept, in which has been, obviously transferred the Cannon manufacturing ability and experience, following a completely different technological approach.

Project guidelines were: compactness (only 40 cm), lightness (22.1 Kg for AX 18 and 39 kg for AX 24), high mixing efficiency, low maintenance and reliability.

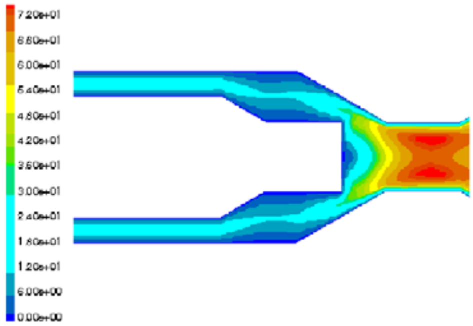
The developing phases of a new mixing head can be summarized mainly in 4 significant steps.

1. **Definition of targets and manufacturing constraints**
   In the particular case of the AX development process, the targets set were to improve the mixing efficiency, give a higher flexibility to the foaming process, allow the option to change the formulations in as short a time as possible, reduce the feeding pressure of TDI to achieve a significant simplification of the TDI circuit and in the meantime to avoid possible leakages. The manufacturing constraints were to contain mixing head dimension and size with a compact design in order to handle the mixing head with standard industrial manipulators.

2. **Design and dimensioning**
   The design has been carried out with the aid of modern and sophisticated 3D CAD to define the head's mechanical features, such as internal geometry of the cavities. The resulting 3D model was tested with dedicated software: stress-analysis tools to verify if the mechanical dimensioning is correct and a fluid-dynamics simulator to check the mixing efficiency and the mixture flow in order to adjust and optimise internal geometry of the head. The example given here shows the fluid dynamics simulation on the axial stream feeding ducts, used as a guideline in the development of AX injectors.



Component Path Lines colored by Velocity Magnitude (m/e)



Contours of Velocity Magnitude (m/e)

3. **Laboratory trials**
   The mixing head prototype was tested by Cannon specialists in tough foaming trials, simulating the most critical working conditions. In particular Cannon tested the cleaning piston gluing resistance and the mixing head performances in typical working conditions, in order to ensure its maximum reliability. When the Laboratory trials produced the desired results and met the expectations of Cannon's Internal Quality Standards, the project was closed and industrial production of the mixing head was implemented.

4. **Close to the customer**
   Following the launch of a new product, Cannon's efforts continue with dedicated after sales services which include production performance monitoring and technical updating of the customer.

THE METERING EQUIPMENT

A high pressure multi-component metering unit - the Cannon "A-System" Servo – has been specially designed for car seat makers with a pump dosing system that can accurately dose TDI and other low-viscosity components. On-the-fly output adjustment and closed-loop control, which can be easily obtained by means of piston-driven metering units, were engineered for pump-driven machines as well.

The number of main components (Polyols and Isocyanates) can be set according to the need, since the design is modular. Cannon is able to supply machines tailored to the specific requirements of each customer using a flexible system based on a wide range of available options (including tanks, dosing pumps, temperature controls, high and low pressure filters, re-circulation valves, control panel, etc.) which offer the opportunity to "tailor" machines with dedicated equipment (pictures 6-7-8).

Picture 6

Detail of the frame installed on the robot, supporting the valves for controlling the mixing head, the Re.Co. System and the high performance stream distributors

Picture 7

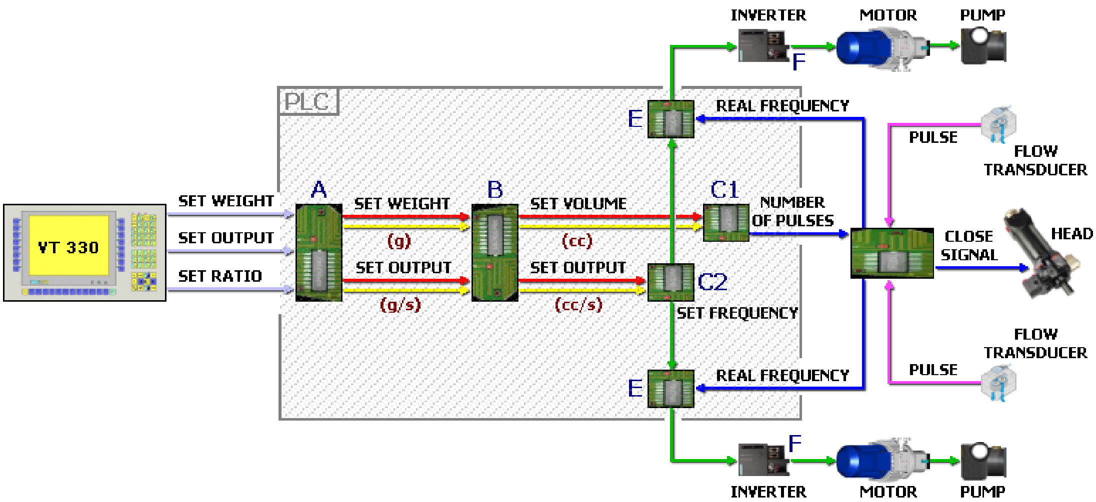
Mass flow transducer

Picture 8

Bosch pumps

The control system of a Standard Servo machine allows monitoring and constant control of the output of each component, the poured weight and also, through dedicated software, to manage special tasks such as setting of the alarm levels, reporting the status of malfunctioning devices, setting up of the week-end cycle, forcing the digital outputs, scheduling the maintenance tasks.

The diagram below shows how control of the output and of the shot weight is performed. It relates to a two component machine: on the multi-component machine the same configuration is extended to all the other components.



Main working steps of Servo closed-loop control circuit:

A) PLC calculates the pouring weight and the output of each component

B) the pouring weight and the output of each component are divided by the specific gravity (g/cc) of each component (set by the operator through the VT330 panel). The set pouring volume and output are calculated for each component.

C1) control of the poured weight: the PLC calculates the number of pulses corresponding to the set pouring volume, given the constant of the flow transducer (i.e., cc of component for each pulse; this parameter is set when the machine is tested in Cannon). The number of pulses calculated by the PLC is sent to a card dedicated to the control of the poured weight. The use of an independent card from the PLC for controlling the poured weight makes for very precise control.

The control card counts the number of pulses coming from the flow transducers of both components. When the set number of pulses is reached, the control card closes the mixing head and keeps counting until the signal "mixing head closed" doesn't reach the control card. In this way the actual poured weight is displayed on the operator panel.

C2) control of the output: the PLC calculates the frequency (number of pulses per second, in Hz) corresponding to the set output. The independent control card sends to the PLC the actual frequency of each component, given by the flow transducers. In real time, the PLC compares the actual output and ratio with the set ones **(E).**

Where the actual values don't match the set ones, the difference in frequency is sent to the inverters in order to adjust the rotation speed of the motors, increasing or decreasing the output of each component.

The nominal precision of the foaming machine is: 1% of the output on poured weight. For instance if total working output is 500 g/s, and the poured weight is 1000 g, the relevant precision will be in a range of 1000 g (± 5 g). "Nominal" means the precision achieved when the machine is working in optimal conditions and it is properly maintained. The nominal precision of the output on poured weight depends on two factors: the pump and the control system accuracy.

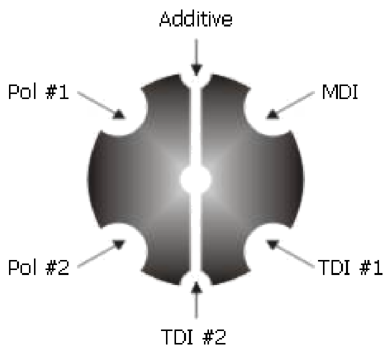
Herein there is a brief description of some typical multi-component circuit configurations based on AX mixing head realized by the Cannon Group.

Case 1 - Laboratory Machine for Trials

Recently, Cannon has supplied a complete plant based on an A-System Servo machine for one of the largest worldwide chemical Suppliers for Laboratory Trials. The foaming system has been customized to meet specific requirements for testing formulations for flexible moulded foam, exploiting the operational flexibility and the performances of the Cannon AX mixing head. The machine is equipped with the Cannon AX 18 mixing head: up to 6 components (4 radial, 2 axial) can be injected simultaneously in the mixing chamber. The mixing head is installed on a Kuka robot, serving two presses on which the foaming jigs are mounted. The six components are distributed in the AX 18 mixing head as follows:

The required outputs were:

Component	Max Output	Viscosity
POL #1	300 g/s	2000 cps
POL #2	300 g/s	2000 cps
MDI	300 g/s	300 cps
TDI #1	200 g/s	5 cps
TDI #2	150 g/s	5 cps
Additive	5-25 g/s	---



The configuration of the machine is as follows:

- **POL #1** and **POL #2** are radially injected. The relevant lines are both complete with a tank group comprising one 70 litre jacketed tank in carbon steel, pressurized and tested according to TÜV specifications (8 bar); level gauges, mechanical agitator, pressurization circuit, a couple of 2 m^2 heat exchangers and temperature control system. The metering group comprises one single shaft AC motor with frequency controlled by inverter. The group is equipped with one Rexroth Hydromatic pump (28 cc/rev) with magnetic coupling, high and low pressure transducers and mass flow transducer.

- **MDI** and **TDI #1** are also radially injected. The component lines have the same previous configuration while the relevant metering groups are equipped, one with one Rexroth Hydromatic pump (12 cc/rev) and the other with one high pressure Bosch PE6ZWM piston pump.

- **TDI #2** is axially injected into the mixing chamber. The relevant circuit is comprises a tank group complete with a 24 litre jacketed stainless steel tank pressurized at 4 bar, floating level, pressurization circuit and temperature control system. The dosing line is based on one Bosch ZWM pump.

- **ADDITIVE** is also axially injected through the pouring piston. The line is basically the same as the previous one except for the 18 liters tank in stainless steel mounted on the storage group and the Speck pump that is installed on the metering group.

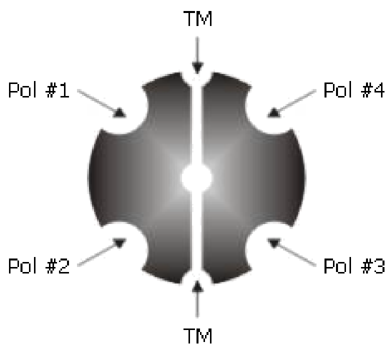
Case 2 - Automotive Industry Application. TDI + MDI Isocyanate blend axially injected.

Cannon has supplied an AX mixing head to one of the major Italian seat producers. The head isable to axially inject a blend of TDI and MDI. In this case, to meet specific customer technical requirements, a particular component feeding configuration has been applied, which allows injection of the Polyols through the four radial streams and the same blend of Isocyanates requested by the formulation (TDI-MDI 80/20) injected on both axial streams.

Using only one type of Isocyanate, it is possible to increase the total output (140 g/s), avoiding turbulence in the mixing head feeding ducts (total ΔP = 7-10 bar). Depending on the total output required (generally between 300 - 400 g/s), either a single Polyol or a blend of several could be injected, while the ISO output is maintained constant.

The required outputs were:

Component	Max Output	Viscosity
POL #1	220 –25 g/s	1500 - 2500 cps
POL #2	220 –25 g/s	1500 - 2500 cps
POL #3	220 –25 g/s	1500 - 2500 cps
POL #4	220 –25 g/s	1500 - 2500 cps
TDI + MDI 80/20	70 g/s	12 – 15 cps
TDI + MDI 80/20	70 g/s	12 – 15 cps



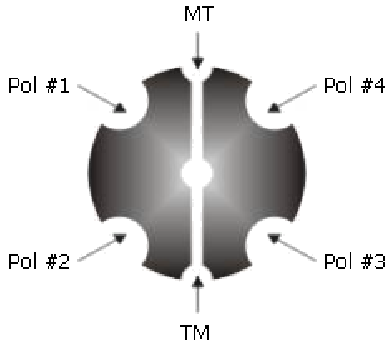
The customer is now working, with good results, with a TDI (viscosity of 3-5 cps) blended with graphite.

Case 3 - Automotive Industry Application. MT and TM Isocyanate blend axially injected

Another interesting application has been for one of the major Japanese seat makers where Cannon has supplied three AX 24 mixing heads, installed within an already existing foaming line. The peculiarity of this application is to alternately inject, through the axial stream, Isocyanate blends: MT (MDI + some TDI) and TM (TDI + some MDI). The six components are distributed in the AX 24 mixing head as follows:

The chemicals:

Component	Viscosity [cps] at 28°C
POL #1	1600
POL #2	1500
POL #3	2000
POL #4	2600
TDI + MDI 80/20	45
MDI + TDI 80/20	5



The required total output was 420 g/s. The possible formulations were:

[Index = 100]		Output [g/s]		
POL	ISO	POL	ISO	Total
POL #1 - 100	MT - 52	276	144	420
POL #2 - 100	MT - 71	246	174	420
POL #3 - 100	MT - 77	237	183	420
POL #4 - 100	MT - 74	241	179	420
POL #1 - 100	TM - 36	309	111	420

Multi –Hardness and Multi-Density foam with Natural Carbon Dioxide

The availability of multi-component mix-heads with variable geometry opens the path to another interesting option: the addition of natural carbon dioxide for expansion of the foam with an environmentally-friendly blowing agent and reduction of the foam density by as much as 20-25%. With this new mix-head, it is possible to use two different approaches to add natural carbon dioxide to the formulations:

- CannOxide™ - a technology developed by Cannon to meter natural carbon dioxide at the point of injection, at the desired percentage, into one of the Polyol streams.
- EasyFroth™ for CO_2 – a technology that allows the premixing of given percentages of blowing agent in one of the two components, usually the Isocyanate.

Both methods are currently in industrial production, each having operating and investment pros and cons that must be evaluated according to the production volumes and flexibility required. For example, a car seat with three different hardnesses can be produced using two different formulations for the hard and soft parts and incorporate some natural carbon dioxide to decrease the seat density below the thighs.

Conclusion

The AX mixing head has been thoroughly tested on the market since 1999 and is currently used all over the world for laboratory trials, flex cold cure prototyping and flex hot/cold cure production applications: Araco, Kurabo and Mitsui Takeda in Japan, Araco in China, Toscana Gomma and Clerprem in Italy, Copo Iberica, Copo Fehrer and Majosa in Spain, Copo Fehrer in Brazil.

Thanks to the proven reliability of these mixing heads, Cannon can offer a guarantee of a million cycles on the mechanical parts. Today, a great number of Cannon AX 18 and AX 24 mixing heads are installed worldwide, meeting the needs of customers (such as car seats makers) who are looking for more flexibility and production capacity.

Now, Cannon R&D department has successfully completed trials in cooperation with an important customer in Asia and soon a new AX model will be available. The new Cannon AX 18/6+3 will be an evolution of the

AX 18, allowing use of additional components in the blend. The concept is to inject an additional compatible component (e.g. Polyol + colour) into one of the radial streams.

The system is controlled and driven by a hydraulic valve, synchronised with the pouring piston to minimise the pre-flow and after-flow caused by the physical position of the nozzle. The additional component re-circulates through this valve. More valves can be added to the head to increase the possible formulations and provide more flexibility.

Future AX evolutions are expected to follow a new approach: Cannon intend to optimise the AX design by implementing projects dedicated to the specific needs of each future potential customer. The target will be to take most of the technological advantages introduced with the AX, providing customized solutions that will be specifically defined for the requirements of the relevant industrial application.

Cannon have always invested significantly in the development of bespoke solutions for the automotive industry and indeed, have a company dedicated to catering for the needs of this specific market. If you need innovative and reliable solutions talk to us!

BIOGRAPHIES

Stefano Andreolli – was born in Milan (Italy) in 1970. He got a degree in Aeronautical Engineering at Politecnico of Milan, with specialization in aerospace systems.
He worked for one year in a company for wireless communication products and joined Cannon Afros in 1999, as sales engineer for Far East markets. Since summer 2002, he is product specialist for automotive seating technology.

Christian Cairati – born in Milan, Italy, in 1970 – has a technical education in Information Technology with specialisation 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.