Dedicated Solutions for the Industrial Manufacture of Curved Insulated Roofing Panels

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ABSTRACT

Curved insulated roofing panels are increasingly being requested by the building market in various lengths from three to six meters. Curved panels have been insulated with polyurethane foam, mineral wool and expanded polystyrene. For the manufacturer, these panels require a lot of storage space and represent a significant inventory investment while waiting for a customer. These are two good reasons for demanding “just-in-time” production solutions that deliver a flexible product mix in terms of dimensions, materials used for cladding, and insulation.

Cannon has developed different assembly and foaming solutions, based on rotating carriers able to hold multiple molds served by carts traveling on rails or with automated guided vehicles systems (AGV) allowing for a very high degree of flexibility (in panel’s radius, thickness and type of foam) with output as high as 800-900,000 square meters per year.

This paper describes these innovative solutions, in operation at two major European producers of curved roof panels.

THE MARKET

Curved insulated panels for industrial and recreational buildings have gained a significant share of the roofing market in Italy and other European countries because of architectural design requirements and increased energy costs. Old curved roofs made decades ago with non-insulated, asbestos-based curved and grooved roofing sheets are being banned for the serious health hazard they represent today.

For these reasons, the demand has increased for both new construction and renovation of buildings requiring safe, highly efficient panels. The local building codes and project budget will dictate the type of insulation within the panels. The production methods to be described can utilize polyurethane foam, expanded polystyrene or rock wool.

Producers of building materials have quickly provided the market with valid alternatives to the simple old elements: Asbestos has already been replaced in these panels with synthetic reinforcements – usually combinations of poly vinyl alcohol and polyethylene fibers. These, blended with a fine grade of cement and sand, provide excellent mechanical properties, weather resistance and aging. Metal panels made with pre-painted steel or anodized aluminium sheets, are also available.

THE PRODUCTS

These curved panels, available with a wide range of profiles, come in lengths from 1.2 to 6 m, with a standard width around 1 m and a radius from 3.3 to 6 m. Thickness varies from 40 to 60 mm for the foamed version, up to 120 mm for those made with rock wool.

The internal faces of the panels can be made from curved steel or aluminum, fiber-reinforced concrete, glass-reinforced resin, aluminum foil, or polyethylene film. The exterior is always made from corrugated steel sheet or fiber-reinforced concrete.

Their production requires large manufacturing space and automating the process is the key to a consistent quality low cost panel. Applying a layer of polyurethane foam or another type of insulation requires precise repetition of a number of tasks that are better suited to automation.

When a producer supplies the entire range of insulating media, he also requires an optimized production solution, adapting most of the handling and manufacturing tools to the technological requirements of each material. Since polyurethane requires a clamping device to contain the foam's rise, it is quite natural to adapt the application of the other media to its production tooling. In all cases because of the shape of the finished product, it is necessary to produce with a discontinuous process.

Cannon has identified a good potential in this area of the building industry, and has engineered two innovative assembly and foaming solutions. The first is a Drum System based either on rotating multiple molds and served by carts traveling on rails. The second solution is with (AGV's) allowing for a very high degree of flexibility (in panel's radius, thickness and type of foam).

THE DRUM SOLUTION

The labor and space required for foaming these large and quite heavy panels has been evaluated by engineering specialists. The result is an extremely reliable, highly automated solution (Figure 1).

The drum offers mixed model or size production as well as optimal foam properties due to the best possible distribution of foam.

The Supply

1. Automatic handling system of stacks of upper and lower facings
2. Preheating station for the fibrous-concrete curved, grooved facing
3. Assembly station for the panel
4. Foam molds
5. Foam machine
6. Foaming station
7. Automatic handling and palletizing of finished panels
8. Computerized Control Unit

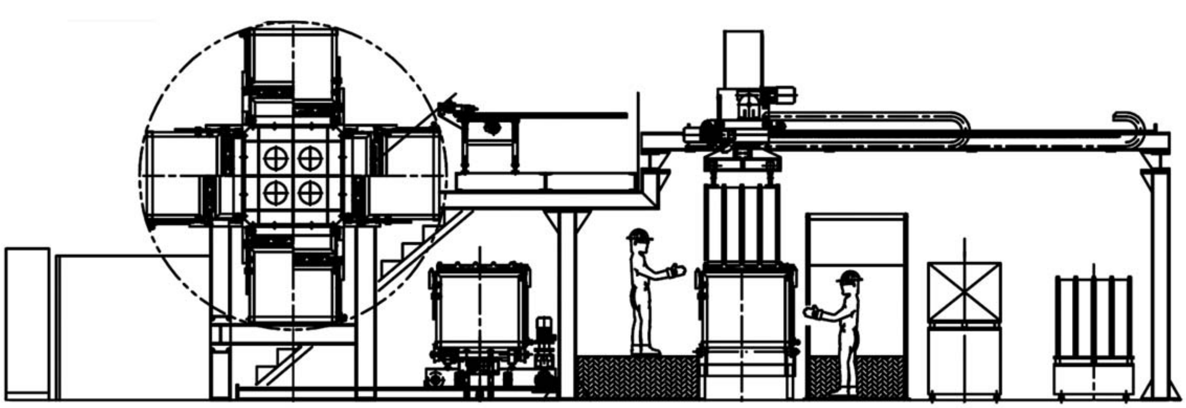


FIGURE 1: Drum Solution Layout

FIGURE 2: Mold Half

Two workers prepare the panels while one forklift operator supplies pallets of facings and removes pallets of finished panels. The production sequence works as follows:

- Stacks of 80-100 curved, grooved, 5-mm-thick fibrous-concrete sheets are moved by forklift into an unloading/centering station, mounted on a rotating platform with two side-by-side docks. Leaving the stack on the unloading station, all the sheets are automatically centered. Once the other dock is empty, the platform rotates and the full dock is positioned near the pre-heating station.

- When required, a roof-mounted 3-axis robot with vacuum cups picks-up one curved element and moves it laterally over the pre-heating station. Here a series of low-inertia, high-efficiency MVL IR elements heat the fibrous-concrete sheet to remove all humidity and ensure that its surface temperature will be of 40°C. To achieve this result, the temperature of the sheet must reach 80°C at the end of the heating phase. When the panel has reached this pre-set temperature the MVR heaters automatically stop.

- In the meantime, at the assembly station one empty mold-half has been transported and loaded with the lower facing of the panel that can be either fibrous-concrete or pre-painted steel (Figure 2). These facings – that come from an unloading/centering bay equal to the one described above for the curved facing are automatically positioned on the bottom of the mold. The operators apply strips of thin flexible polyurethane foam over the perimeter of the panel, to prevent the contact between rigid foam and the mold inner sides. When the lower facing and the sides are ready, one heated curved element is transferred from the pre-heating station using the same robot described above – and deposited over the just-prepared lower mold-half.

- When required, this package is conveyed on the loading/unloading cart that services the foaming jig. To save service time and energy this cart has been designed with two places: one is used to return an empty mold-half to the assembly station, the other to bring a ready mold-half to the foaming jig.

- The core of the plant is the special foaming jig, designed to hold four large molds, mounted on each side of a square-sectioned steel structure (Figure 3). This system utilizes the patented Zero Time Change concept to produce two or four different models of domestic refrigerators in the same foaming station. For these panels a larger version has been designed with four mold carriers. When one finished panel is ready for demolding, the operation is performed on the lower of the four molds. This is opened with a parallel movement of the lower mold half, which goes over an unloading table with flanged wheels. While the mold carrier opens, the lower mold-half remains on the wheels of the unloading table and is shuttled out to the jig. It is deposited on the empty place of the loading/unloading cart that makes one side step at the end of this operation, to present the mold-half containing the panel to be injected with foam in front of the drum unit. The same unloading table with flanged wheels lifts the panel and brings it into the lower mold. The mold then closes with an upward parallel movement and locks it in position.

FIGURE 3:

- The drum unit with four mold carriers rotates clockwise by 180°, so that the newly-introduced panel is brought to the uppermost position and is now presented with its concave side upwards. The LN mixing head, mounted on a head carrier, is inserted in the injection hole positioned midway on the long side of the mold. This is the ideal foaming position, because the liquid polyurethane is injected in the mechanically-most critical part of the curved panel, where we do not want to have air traps and junction lines of rising foams. The reacting liquid completely wets this part of the panel then the foam starts rising and distributes sidewise; pushing all the air out of the two short edges of the panel. Optimum distribution of densities is obtained, and the well-controlled temperature of the facings helps the foam's flow and adhesion.

- Polyurethane is metered and dispensed using a high-pressure foam machine. The machine dispenses the 8 kg of foam in approximately 7 seconds, and the foam has a final molded density of 45 kg/m^3 .

- The LN head – specially designed for applications where a long "nose" is requested. The mixhead enables high-pressure recirculation of components up to the injection nozzles, to ensure the temperature conditioned urethane and viscosity prior to the injection.

- At the end of the injection, when the foam has filled the panel, the Drum rotates backwards by 90°, to allow for the unloading of a foamed panel from another mold. The foaming sequence continues with this alternated movement of 180° clockwise and 90° counter-clockwise, that guarantees the best positioning of the panel while the foam is expanding.

- The double-station unloading cart that received the finished panel still positioned on its mold half moves sideways again to allow for the automatic pick-up of the part with another dedicated 3-axes suspended robot. This stacks the finished panel on a special pallet, and when this is full of product, it is removed by the forklift and sent to the warehouse.

The system produces 20 panels per hour with three people on 275 m^2 of factory floor. Three combinations of upper and lower facings can be used with this plant.

The capacity of this system can be doubled with the addition of another Drum unit utilizing the same foam machine with a second mixhead. The same loading/unloading cart could be used for the second drum. Doubling the capacity can be achieved without doubling the investment.

The main advantages of this solution are economies, flexibility and quality, derived from:

- Limited floor space with the compact layout of the Drum unit foaming jig with the use of robots and loading systems. Similar systems based on conventional rows of fixed presses occupy more than double the space.
- Low cost of labor due to automation and to the reduced maintenance to be carried on a single rotating drum unit instead of multiple conventional drums.
- High manufacturing flexibility due to its ability to produce different models.
- High quality of the finished products due to optimum mixing and distribution of foam.

THE AGV SOLUTION

The plant based on Automated Guided Vehicles (AGV) (Figure 4) allows for a very high degree of flexibility in panel's radius, thickness and type of foam. It provides an output as high as 800-900,000 square meters per year with four AGVs working on a three-shift basis.

The experience already gained in the production of large, irregularly shaped insulating panels enabled the ability to offer a made-to-measure plant capable of producing thousands of square meters of paneling per shift while reducing labor. It makes use of a highly innovative solution for moving the large molds needed for this foaming process.

A fleet of AGV's transports a combination of different molds from one station where foam is injected, to another where curing continues (Figure 5). After several minutes, the molds are taken to an unloading station where the curved panels are removed, stacked and then sent for final packing.

The plant, complete with an automatic profiling and cutting line for the inner panel facings can produce a mix of panels insulated with either polyurethane or rock wool.

The Supply

The plant has been designed to facilitate any possible future expansion. The working stations have all been put in position while some other components required to increase the output of the plant can be added later.

The panels are made using molds with two curved metal surfaces. The molds adapt to all the types of facings and can produce panels thicknesses up to 200 mm with a layer of insulation of 40 to 60 mm of polyurethane foam and of up to 120 mm using rock wool.

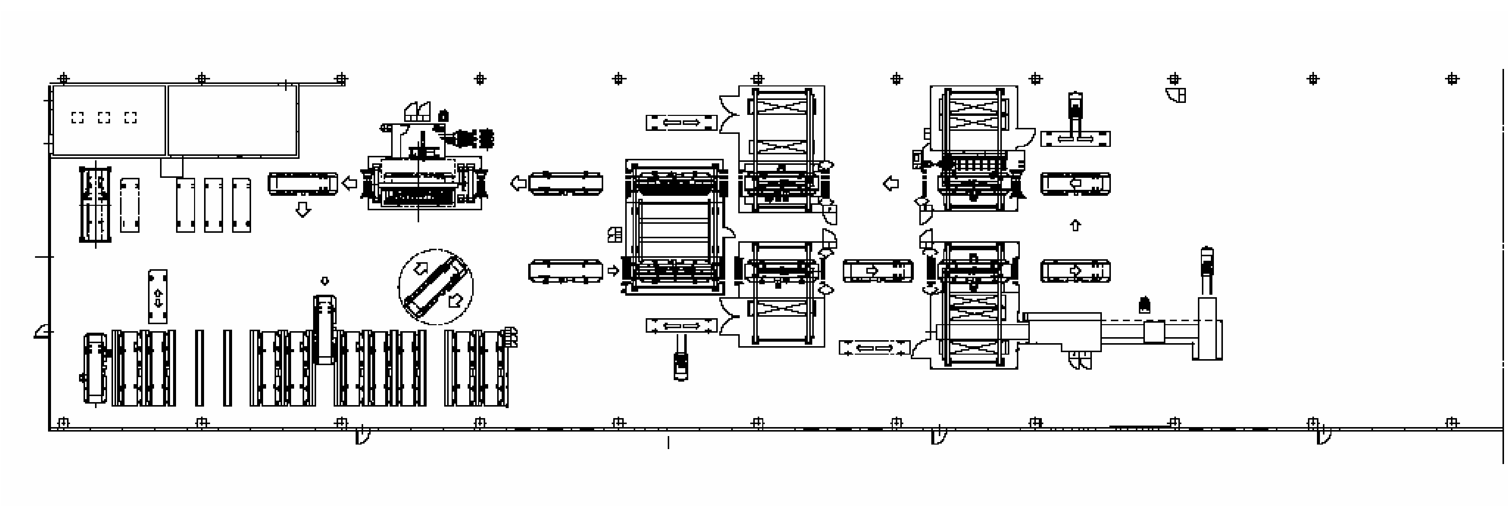


FIGURE 4: AGV Solution Layout

FIGURE 5: Automated Guided Vehicle (AGV)

The molds are quite sturdy with 12 locking points. They also include a double heating circuit, double extractors, automatic plugging of the injection holes and vacuum for holding the facings in the mold. These tools are easy to prepare and load. They are serviced with the concave part down, minimizing the problems of stability for the various types of facings positioned inside.

All the molds are mounted on flat, 7 m long, battery operated AGVs. The AGV's are guided by signals from a network of underground cables. They pick the molds from one station, leave them in another station to perform a task and go somewhere else to transport again. Today the system works using four AGVs and it has been designed for a fleet of eight.

The AGVs have been built by a major manufacturer of these vehicles following specifications. Designed to hold a load of 5 tons, they can move in eight directions plus the complete rotation, providing high performances both in terms of speed and precision.

The plant is made of several machines and devices, described in the order of the production (figure 6):

- The tooling area: the single molds are prepared to produce a given model, according to its size, radius, thickness and type of insulating material

- The profiling and cutting line: used to prepare the inner metal liners.

- The pre-heating stations for the inner metal liners: a bank of MVL lamps bring the temperature of the inner liners up to 45-50 °C

- The inner metal liners loading station: all the types of rigid and flat lower liners are loaded on the molds. The manipulators are designed to load any type of rigid facing: either steel or aluminum, fiber-reinforced concrete and glass-reinforced resin. Should thin aluminum foil or polyethylene film be used, it would be dispensed from rolls and cut to length before loading into the mold.

- The outer metal liners loading station: corrugated steel sheets are sorted with a dedicated machine then transported and stacked on pallets (Figure 6). The sheets are picked up with pneumatic hands and loaded on the molds. The next station is the only manual operation of the entire manufacturing process. The application of open cell foam tape on the edges of the panel assures that the rising foam stays in the panel while the air is evacuated to avoid air pockets in the foam.

FIGURE 6: Outer Metal Liners Loading Station

- The station where the molds are opened and closed the upper mold halves remain here during demolding are again joined with a lower mold and closed.

- The high-pressure foam injection unit: one standard two-component high pressure metering unit, with one mixing head/manipulator guides the head into the injection holes positioned according to the panel model being produced (Figure 7). Each injection puts 10 kg of liquid in the panel that when fully expanded will fill the panel with foam of 40 kg/m^3 density.

- The mold rotation and foaming station: in this massive station a 180° rotation of the mold occurs prior to the injection of foam. This is made in the center of each panel, with the concave part of it up for optimum venting of air from the cavity. Two smaller panels can also be produced side-by-side in a single mold with proper positioning of the metal sheets. When this option occurs, the injection points are positioned laterally, and the injections are made in sequence. Once the foam has filled the cavity and there is no more risk of air entrapments, the mold is again rotated by 180°; bringing it back to its original position with the concave face looking down. The curing time starts here. At this point of the process the metal sheets have a temperature of approx. 40 °C, to provide the best conditions for proper adhesion and flowability of the foam.

FIGURE 7: High Pressure Metering Unit

FIGURE 8: Curing Area

- The curing area: the molds are transported and left for the entire curing time (Figure 8). For these type of foams is in the range of 2 minutes per centimeter of thickness, so the curing time for the thicker panels is about 25-30 minutes. Sitting on four centering devices mounted on columns, the molds are connected to a pack of electric contacts which feed the mold's heating system to maintain the desired temperature during the curing process.

- The unloading station: the panels arriving from the curing station are removed from the mold. The largest weighing 300 kg each. Once the molds are unloaded, they start a new cycle. If a mold is not called to duty by the central computer, it is brought back to the cure area to stay warm using the electric heating system described above.

- The panel stacking manipulator: panels are stacked according to their model and size.

- The packaging station: a rotating device wraps up the stacks of panels with a plastic film, prior to sending them to the storage area.

- The power station: the AGV's electric batteries are equalized, i.e. they are completely discharged prior to a complete recharging phase. Mechanical maintenance is also performed when needed. Standard refill of power is performed on the AGVs batteries at every stop in the mold opening/closing station where two metal contacts in the floor provide a 48-volt flow of power. This position was chosen for the task because the AGVs spend their longest stop – 1 minute - due to the length of the operation performed here.

- The computerized control for the entire process - a sophisticated three-level Siemens system, controllable remotely via Internet for diagnosis and statistical purposes allows a user-friendly production schedule input and retrieval of all production data. Historic report of every injection and error is available for quality assurance purposes.

The rock wool panels are made using part of the above mentioned stations, plus a few dedicated tools:

- The positioning station where the rock wool is placed over the inner metal liners, using special needle-fitted hands that pick up the heavy material: Up to 350 kg of mineral wool can be safely handled by these special Cannon-designed grips.
- The robot which applies the glue for the rock wool panels, and its relevant dosing unit.

They skip the foaming cycle and go directly to the cure area, where they stay for a few minutes to guarantee the optimum adhesion of the rock wool to the glue-primed metal sheets.

THE ADVANTAGES

- High productivity: with a fleet of four AGVs, the plant – working 240 days on a 3-shifts basis – can produce 900,000 msq of curved panels per year.

- The manufacturing process is very regular and flexible, due to the very specialized task performed by each station. Since every operation is performed in a dedicated station, the entire process can be sped up without suffering from the longer cycle of some of the operations.

- One of the most-appreciated advantages of this concept is the possibility of introducing small special orders “on the fly” fitting them into pre-scheduled production programs. A non-scheduled mold can be prepared off-line, without disturbing a pre-set sequence of operations simply because this rigid schedule does not exist! Each station performs the needs of the mold that is arrives next, which is clearly identified by the computerized sequence of operations.

- High flexibility of production, expandable and modular.

- Panels of different thickness - with different curing time can easily be mixed in the production schedule without forcing the plant to adapt the cycle time to the longest one.

- Very few operators are required for this high-productivity unit: one supervisor, one forklift operator feeding the corrugated upper sheets from the nearby calendaring line and removing the stacks of finished panels, two workers positioning the foam tape in the molds, two more for the preparation of molds (only when necessary) and for helping during the initial debugging phase of a new model.

- Ergonomic to operate and user friendly to be programmed and controlled.

A plant with this capacity and flexibility requires a certain amount of space to operate efficiently as well as to accommodate future expansions.

The level of investment is higher for the AGV solution than that for fixed presses or with rotary Drums.

CONCLUSIONS

New ways to produce various types of insulating panels for all applications are actively being pursued. The use of innovative foaming methods and mold carriers is constantly studied and applied. Use of vacuum-assisted foaming jigs, for instance, could reduce cycle times and molded density of the foams.

CLIENT BACKGROUND

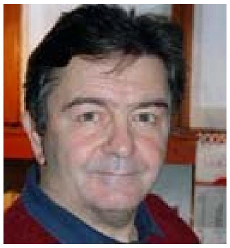
The Landini company was founded in 1954 to produce asbestos-reinforced concrete building products, in Castelnovo Sotto, west of Bologna, Italy. A highly innovative and entrepreneurial instinct soon saw it extending its production program AND its geographic market to cover all of Italy and beyond. In 1989, the company initiated a fundamental technology development project that led to the substitution of obsolete asbestos fibers by fibers made from other minerals and synthetic materials. Today, Landini boasts the only technology in Italy capable of pressing sheets in fiber-reinforced concrete for external cladding.

With a production capability of over nine million square meters per year, it stands as the number one supplier in the country, and continues to grow across Europe. Having reached this important objective, Landini has also invested in metal cladding in order to consolidate its position in the market for industrial structures. Constantly aware of customer requirements, the company was unwilling to stay out of the important sector of thermal insulation cladding. To boost its presence in the market, and to establish its new “Gorland” curved cladding, the company chose Cannon as its technology partner.

Landini set up a new production hall for the new operation which covers an area of 200,000 square meters at its facility near Bologna, Italy. From here it sends out all its building components chimneys in stainless steel, fiber-reinforced concrete, refractory elements, purification plants, coverings in fiber-reinforced concrete or metal to the 5,000 customers that ensure Landini’s widespread coverage of the European market.

BIOGRAPHIES

Max Taverna



Max was born in Buenos Aires, Argentina, in 1949 and has an educational background in Industrial Chemistry. He worked for Upjohn's Polyurethanes Division in Italy and joined Cannon Afros as the European Sales Manager in 1982. Since 1986 he has co-ordinated the Group's communications activities and currently serves as the Corporate Director of Communications.