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METHOD CURING A FOAM INSITU USING A CHANGING MODE MICROWAVE GENERATOR

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This invention pertains to a method of manufacture and more particularly to a method of and apparatus for filling a space with foam material.

The excellent insulating efficiency, the light weight and structural reinforcing ability of substantially rigid foam materials has been recognized. However, when these materials are used in high volume production, many molds are required. Further, the cell structure of the foam is not uniform on account of the heat dissipating effect of the walls of the mold and other temperature differences. This lack of uniformity causes the foam material to be more dense and less efficient in insulating effect in some areas. Temperature differences and differences in thermal expansion cause tearing and rupturing of the cells.

It is an object of this invention to provide a method of and apparatus for rapidly filling a space by inserting the foam-forming materials and a microwave antenna into the space and discharging microwave electromagnetic energy from the antenna into the foam-forming materials in the space to produce rapidly a foam having a more uniform cell structure with a lower uniform density and more impervious cell walls.

It is another object of this invention to provide a method of and apparatus for rapidly filling a space by inserting the foam-forming materials and a microwave antenna into the space and discharging microwave electromagnetic energy from the antenna into the foam-forming materials in the space at the optimum frequency and power for a sufficient time to control and make more uniform the reaction of the foam-forming materials for providing a foam of superior insulating properties.

These and other objects are attained in the forms shown in the drawings in which the insulating space of the refrigerator cabinet is substantially entirely enclosed by thin sheet metal walls. Through an opening in the back wall, there is inserted a microwave antenna which extends into the insulation space. Through this same or other opening, there is introduced heat responsive, foam-forming materials into the insulation space. A microwave generator operatively connected with the microwave antenna causes microwaves to be discharged from the antenna into the foam-forming materials during a part or all of the foaming operation. The microwave antenna may be provided with a rotary stirrer to make more uniform the penetration of the microwaves throughout the insulation space of the refrigerator cabinet. The discharge of the microwave energy into the foam-forming materials speeds the reaction and also makes the reaction more uniform, thereby producing a more uniform cell structure with a lower density and more impervious cell walls.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein preferred embodiments of the present invention are clearly shown.

In the drawings:

FIGURE 1 is a vertical, longitudinal sectional view through a partially foamed refrigerator cabinet and microwave generating apparatus illustrating one form of my improved method and apparatus;

FIGURE 2 is an enlarged vertical sectional view of the microwave antenna and mode changing means such as a wave stirrer shown in FIGURE 1; and

FIGURE 3 is a view in elevation of a modified form

of microwave carrying connection between the microwave generator and the microwave antenna.

Referring now more particularly to FIGURE 1, there is shown a refrigerator cabinet 20 provided with an outer metal shell 22 preferably of sheet steel, an inner metal liner 24 likewise of sheet steel and a plastic breaker strip 26 extending completely around the door opening connecting the inner liner 24 and the outer shell 22. To provide a space for refrigerant conduits and electric wiring beneath the breaker strip 26, there is provided a strip 28 of glass fiber or mineral wool extending completely around the door opening of the cabinet beneath the breaker strip 26. The cabinet 20 is placed with its open side face down upon a supporting platform 30 preferably of sheet steel. The back wall 40 of the cabinet 20 is provided with a filler opening 42 through which the foam-forming material 44 is discharged into the insulation space 45 between the inner liner 24 and the outer shell 22. The foam-forming material issues from a mixer 46. The foam-forming material is ordinarily composed of two components: an A component which is circulated through the conduit and the valve chamber 50 and, when not discharged into the cabinet, is returned through a return conduit 52 to the circulating system; the B component is circulated through the conduit 54 to the valve chamber 50 and, when not required, is returned through a separate conduit 56 to the recirculating system. When desired, both A and B components are delivered concurrently in proper proportions from the valve chamber 50 into a mixing chamber 51 from which the mixed components are delivered from an outlet 53 through the aperture 42 into the insulation space 45. When a sufficient amount of the components have been discharged into the insulation space to eventually fill the space 45, the mixing apparatus 46 is withdrawn and the opening 42 is covered by a metal plate 58.

One of the difficulties encountered with the casting of foam material in the insulation space was that the exothermic reaction took a considerable period of time and curing was required. Because of the excessive pressures generated, molds to prevent bulging and distortion of the walls also were required until the curing was completed. In high volume production, therefore, many of these molds were required. Some of these molds were relatively expensive thereby incurring a relatively high initial cost to achieve volume production. Even though this investment was made, there was a lack of uniformity in the insulation. Some portions of the insulation foam would have a relatively low density and other portions would be provided with a relatively high density. Also, the size of the cells were not uniform throughout the mass of insulation. Different temperatures were attained in different zones causing different speeds of reaction within the insulation space which not only caused a lack of uniformity in density and size but also produced undesirable skin effects as well as tearing of the insulation and rupturing of the cells and also left voids in certain locations. This all reduced the quality and effectiveness of the insulation material and made some portions structurally weak.

According to my invention, throughout the casting of the foam material in the insulation space and especially prior to the exothermic reaction and resulting higher pressures, microwave energy is simultaneously introduced through the introduction of a microwave antenna into the space. A stirrer in conjunction with the microwave antenna assures substantially uniform distribution of the microwaves throughout the insulation space. This speeds and makes more uniform the reaction and also insures the attainment of substantially uniform temperatures, thereby producing a more impervious foam with more uniform density and cell size and more uniform filling of the insulation cavity. As shown in FIGURE 1, there is provided

a microwave generator 60 having a magnetron tube 62 projecting into the wave guide 64. The wave guide 64 extends from the magnetron tube to a receiver radiator dipole antenna 66 which projects from the upper wall of the wave guide 64 down through an opening 68 into the insulation space 45. The microwave energy generated by the generator 60 is transmitted from magnetron tube 62 to the dipole antenna 66. The portion of the dipole antenna 66 within the cabinet wall insulation space 45 reradiates the microwaves within the insulation space to be absorbed by the foam-forming materials.

If the distribution of microwaves by the antenna 66 within the insulation space 45 is not sufficiently uniform, there may be added a mode changing means such as a mechanically operated, electromagnetic wave stirrer device 70, which constantly changes the microwave field energy mode within the cavity. The stirrer 70 may consist of two metal blades 72 and 74 positioned at oblique angles to the antenna 66. For example, angles of 45° or 30° may be used, if desired. These plates 72 and 74 are fixed to a sleeve 76 of thermoplastic material. The plate 74 is mounted at one end of the sleeve while the plate 72 is mounted at an intermediate point on the sleeve, all within the insulation space 45. The aperture 68 in the rear wall 40 is made large enough that the plates 72 and 74 may readily pass through it. The sleeve 76 is provided with spaced nylon bearings 78 and 80 for its rotatable mounting upon the stub antenna 66. The sleeve 76 is also rotatably mounted in a flanged plate 82 which covers the aperture 68 in the rear wall 40. A portion of the sleeve 76 extends into the wave guide 64 and is provided with an integral pulley 84 thereon. This pulley 84 is connected by a belt 86 driven by a pulley 88 upon the drive shaft of an electric motor 90. The motor 90 is operated concurrently with the operation of the microwave generator so that a substantially uniform distribution of the microwave energy throughout the insulation space 45 is assured while the generator 60 is in operation.

In FIGURE 3, a modified form of the invention is shown in which the microwave generator 121 is directly connected through a coaxial cable 123 with the stub antenna 125 extending into the insulation space 45 as in FIGURE 1. The mode changing means or stirrer 127 is substantially identical to the stirrer 70 and includes the metal plate 129 similar to the metal plate 72. It is also rotatably mounted by suitable bearings upon the antenna 125 and is also rotatably mounted within the flanged plate 131 which covers the opening 68 in the rear wall 40 of the outer shell 22. Instead of providing a pulley upon the stirrer 127, there is provided gear teeth 133 above the cover 131 upon the upper extension of the stirrer 127. These gear teeth 133 are engaged by a driver gear 135 mounted on the drive shaft of the electric motor 137. Preferably, the microwave generator 121 and the electric motor 137 are operated simultaneously to discharge microwaves within the insulation space 45 and to distribute these waves substantially uniformly throughout the insulation space 45.

As one specific example of the foam-forming material suitable for introduction into the insulation space 45 for subsequent or simultaneous processing utilizing the facility and beneficial effects afforded by microwave energy, for the A component, there is employed 100 parts by weight of a prepolymer made from 79 parts by weight of a polydiisocyanate mixture comprising 80 parts by weight of 2,4 toluene diisocyanate and 20 parts by weight of 2,6 toluene diisocyanate together with 21 parts by weight of a polyether A as defined hereafter. This component is continuously circulated through the conduit 48, the valve chamber 50 and the return conduit 52.

The B component circulates independently through the valve chamber 50 from the conduit 54 to the conduit 56. The B component is composed of 87 parts by weight of the same polyether A as defined hereinafter to 3 parts by weight of an activator consisting of 2 parts by weight of tetramethylbutane diamine and 1 part by weight of organo

silicon surfactant and 38 parts by weight of trichloromono-fluoromethane. The polyether A is made up of sucrose 1 part; propylene oxide 11 parts; ethylene oxide 4 parts; OH number 445 to 470; water maximum by weight .15%; viscosity cps. at 25° C. 22,000 to 32,000; and pH 3.5 to 5. All these quantities in the formula for the polyether A are expressed in mols unless otherwise noted. These materials, through suitable dual valving arrangements in the valve chamber 50, are separately introduced into the mixing chamber 51 of the mixer 46 in proportion of 100 parts by weight of the A or prepolymer component to 128 parts by weight of the B polyether component. This mixture is discharged into the insulation space 45 through the opening 42 in the rear wall 40.

The microwave energy is introduced into the insulation space 45 preferably during the introduction and the foaming and curing of the foam-forming materials 44. As one specific example, I introduce microwaves at 2450 megacycles frequency. By microwave energy, I mean electromagnetic wave energy having a frequency in the range of about ten to the seventh power (10^7) to ten to the thirteenth power (10^{13}) cycles per second.

The foam-forming materials are introduced into the insulation space 45 and immediately or subsequently subjected to microwave energy. The foaming action is immediately initiated, stimulated and made more uniform and, since it has not substantially reacted chemically yet, the foam material expands under comparatively light pressures, minimizing expansion pressures and the need for supporting the walls of the inner liner 24 and the outer shell 22. It also results in a lighter, more uniform cell structure having more uniform structural strength and insulating value. It minimizes the occurrence of voids in the insulation, skin effects and the shearing and tearing characteristics of materials reacted and expanded to foam by exothermic heat in the conventional methods or process not utilizing microwave energy. The entire foaming operation takes place more quickly so that less space is required on the production line for this particular operation. This makes the use of the foam-forming material more economical and makes it possible to extend their use to many more places wherein it is desired to fill a space with a lightweight material having excellent structural properties.

While I have given one specific example of foam-forming materials which may be used, it is evident that the invention applies to many foam-forming materials such as epoxy foams and especially those whose reaction is exothermic.

The antenna or radiating means and the mode changing means may vary in detail, design, speed or orbit of rotation or it may be integral with or part of the material mixing head. There may be several such radiating mixing means—individually or in combination design concept.

While the embodiments of the present invention, as herein disclosed, constitute preferred forms, it is to be understood that other forms might be adopted.

What is claimed is as follows:

1. The process of filling a space with foam material comprising:

- (a) inserting into said space heat-responsive reactive foam-forming material,
- (b) inserting into said space a microwave antenna in operative relation with a microwave generator located outside said space,
- (c) inserting into said space a rotatable microwave stirrer,
- (d) reacting said foam-forming material within said space to form a foam,
- (e) at the beginning of and during the reaction of said foam-forming material generating microwaves outside said space, transmitting said microwaves to said antenna and discharging said microwaves from said antenna within said space and

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- (f) repeatedly changing the mode of said microwaves discharged from said antenna by rotating said stirrer.
 2. The process of claim 1 in which the foam formed within said space is a polyurethane foam.

References Cited by the Examiner

UNITED STATES PATENTS

2,603,741	7/1952	Seifried et al. --	219—10.55	X
2,738,406	3/1956	Zaleski -----	219—10.55	
2,764,516	9/1956	Pace -----	264—45	10
2,813,185	11/1957	Smith -----	219—10.55	
2,841,205	7/1958	Bird -----	264—47	
2,961,520	11/1960	Long -----	219—10.55	
3,177,333	4/1965	Lamb -----	219—10.55	
3,209,056	9/1965	Jacobs -----	264—54	X 15

6

FOREIGN PATENTS

864,965 4/1961 Great Britain.

OTHER REFERENCES

- 5 Lanigan, W. J.: "Microwave curing of flexible polyurethane foam mouldings." In British Plastics, October 1963, pp. 562-565.

Modern Plastics: "Urethane Foam Brings Back the Gas Refrigerator," vol. 38, No. 8, April 1961, pp. 96-98.

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