INSULATED METAL WALL STRUCTURE
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ABSTRACT OF THE DISCLOSURE
An insulated metal wall structure of the double metal sheath type, comprising a fluted inner metal sheath, a relatively thin substantially impervious membrane ap-
plicated over the fluted inner metal sheath, insulating ma-
terial applied over the membrane, an outer metal sheath positioned over the insulating material, connecting means for fastening the outer metal sheath to the inner metal sheath, and sealing means for sealing at least one and preferably both ends of the passageways defined by the insulating material and the fluted inner metal sheath. The sealing means prevents ingress of air into the wall struc-
ture. Convected circulation of air within the wall struc-
ture is minimized. Low over-all heat-transfer coefficient values are realized.

CROSS-REFERENCES TO RELATED APPLICATIONS
This application is a continuation of pending applic-
ation S.N. 577,079 filed Sept. 2, 1966 now abandoned and assigned to the assignee of this invention.

BACKGROUND OF THE INVENTION
Field of the Invention
This invention relates to building wall structures, and more particularly to insulated metal wall structures of the double metal sheath type, having a surprising and com-
pletely unexpected low over-all heat-transfer coefficient.

Description of the prior art
In the past, insulated metal wall structures included an inner metal sheath, an outer metal sheath, means for con-
necting the outer metal sheath to the inner metal sheath in spaced parallel relation therewith, and insulating material interposed between the inner and outer metal sheaths. Vapor barriers in the form of thin substantially impervious membranes have also been applied over the inner metal sheath of these wall structures.

Heretofore, the inner metal sheath comprised generally U-shaped pan sections erected in side-by-side abutting relation to the structural framework of a building. The pan sections include flat, generally rectangular webs which cooperate to provide a pleasing flat interior wall.

Wall structures of this type which employ one and one-half inches of insulation, have relatively good over-
all heat-transfer coefficients, also known as "U" values, ranging from 0.12 to 0.14 b.t.u./hr./°F. of wall area. Similar wall structures employing four inches of insulation, have lower "U" values ranging from 0.07 to
0.08 b.t.u./hr./°F. of wall area. Similar wall structures employing four inches of insulation, have lower "U" values ranging from 0.07 to 0.08 b.t.u./hr./°F. of wall area. The decrease in the "U" value is, of course, attributed to the increased resistance to heat flow provided by the greater thickness of insulation.

Despite the conventional wall structures described above serve extremely well for most environments, one situa-
tion arises wherein these wall structures are not par-
ticularly suited. This situation involves an environ-
nment wherein the inside face of the wall structures is sub-
jected to average or higher temperatures with a rela-
tively high humidity and wherein the other or outside face

of the wall structure is subjected to temperatures which dip well below freezing. In essence, there exists a large temperature drop between the outside temperature and the inside temperature which, of course, tends to in-
crease the heat flow from the inside of the building to the outside of the building. Under these extreme condi-
tions, it should be immediately apparent that condensa-
tion will form on the inside face of the wall structure if the wall structure has any of the "U" values recited above. Consequently, a wall structure having a lower "U" value must be employed.

There are several well-known methods of decreasing the "U" value of a wall structure. For example, an in-
crease in the thickness of the insulation increases the re-
sistance to heat flow through the wall structure. There
is, however, a practical limit to the insulation thickness which may be conveniently employed. Further, an in-
insulating material having a lower thermal conductivity may be employed to obtain a specific "U" value, al-
though, the cost of this insulation may become prohibi-
tive. Still further, through-conduction in the wall struc-
ture may be minimized to effect a reduction in the heat trans-
fer through the wall and, hence, a reduction in the "U" value. Other methods of decreasing the "U" value of a wall structure are also well known and will not be mentioned here.

SUMMARY OF THE INVENTION
As an overall object, the present invention seeks to pro-
provide an insulated metal wall structure having a low over-all heat-transfer coefficient.

Another object of the present invention is to provide an insulated metal wall structure which may be used in environments wherein internal high humidity and external low temperatures exist on the opposite sides of the wall structure, without the formation of condensation on the inside surface thereof.

Still another object of the invention is to provide an insulated metal wall structure which is relatively inex-
pensive to manufacture and which may be erected in a rapid and efficient manner.

A further object of the invention is to provide a novel spacer member for maintaining an outer metal sheath con-
ected to and spaced apart from an inner metal sheath.

Another object of the invention is to provide a novel spacer member which provides a thermal break, that is, minimizes through-conduction, thereby contributing to the decrease in the over-all heat-transfer coefficient.

In accordance with the present invention, an insulated metal wall structure is provided comprising an inner metal sheath normally secured to the structural framework of a building. The inner metal sheath has a fluted profile, including crests and valleys. A relatively thin, substantially impervious membrane, such as polyethylene film, is applied over the inner metal sheath in substantially con-
tensive engagement therewith. Insulating material is applied over the membrane and in substantially coextensive covering relation with the inner metal sheath. The insulating material cooperates with the valleys of the inner metal sheath to form passageways through which air tends to circulate by convection. An outer metal sheath is posi-
tioned over the insulating material. Connecting means are provided for fastening the outer metal sheath to the inner metal sheath in spaced-apart, substantially parallel rel-

Finally, sealing means are provided for sealing at least one and preferably both ends of the passageways to prevent ingress of air into the wall structure. The overall arrangement is such that convective circulation of air within the wall structure is minimized. Minimization of convective circulation of internal air is believed to be one of the major factors contributing to the significant reduc-
tion in the over-all heat-transfer coefficient of the wall structure.

Further in accordance with the present invention, a novel spacer member is provided for connecting the outer metal sheath in spaced, substantially parallel relation with and to the inner metal sheath. The spacer member comprises a block or core of thermal insulating rigid foam, having at least one and preferably two metal facing plates, each one secured to opposed faces of the block. Additionally, the block is provided with spaced leg portions on one face thereof, which define a central groove adapted to receive a crest of the inner metal sheath. The overall arrangement is such that the block of rigid foam provides an efficient thermal break while, at the same time, the composite structure of rigid foam block and at least one metal facing plate, is strong enough to support the outer metal sheath.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a fragmentary isometric view illustrating the several component parts of the present insulated wall structure, in assembled form;

FIG. 2 is a fragmentary front view of an inner metal sheath secured to the structural framework of a building and provided with several spacer members of the present invention;

FIG. 3 is a cross-sectional view taken along the line III—III of FIG. 1;

FIG. 4 is a cross-sectional view taken along the line IV—IV of FIG. 3;

FIG. 5 is an isometric view illustrating a spacer member of the present invention;

FIG. 6 is an isometric view illustrating a fragment of a sealing member employed with the inner metal sheath;

FIG. 7 is an isometric view of a fragment of a sealing member employed with the outer metal sheath of the present wall structure;

FIG. 8 is an isometric view of an alternative spacer member;

FIG. 9 is a cross-sectional view, taken along the line IX—IX of FIG. 8; and

FIG. 10 is a cross-sectional view, similar to FIG. 3, illustrating a wall structure incorporating the spacer member of FIG. 8.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

General description

Referring now in particular to FIGS. 1, 2 and 4, there is illustrated a wall structure 10 comprising, in general, an inner metal sheath 12 secured to a skeletal framework 14 which, as is conventional, comprises columns 16 and girt members 18 (only one of each shown); a substantially impervious membrane 20 applied over the inner metal sheath 12; a plurality of spacer members 2 secured at spaced locations to the inner metal sheath 12, as best shown in FIG. 2; batts of insulating material 24 applied over the membrane 20; subgirt members 26, one secured to each row of the spacer members 22; first sealing means 30 (FIG. 4) positioned at least at the lower end of the inner metal sheath 12 and preferably at both ends thereof; and, finally, second sealing means 32 (FIG. 4) applied at least at the lower end of the outer metal sheath 28 and preferably at both ends thereof.

Inner metal sheath 12

Referring now to FIGS. 1—4 and in particular to FIG. 1, the inner metal sheath 12 comprises a plurality of liner sheets 34 each having a fluted profile and presenting crests 36 and valleys 38 connected by inclined side walls 40. The liner sheets are secured to the framework 14 by conventional means 42 and such that a lateral edge 34a of one liner sheet 34 is overlapped by a lateral edge 34b of an adjacent liner sheet 34, as best shown in FIG. 1.

The liner sheets 34 preferably comprise suitably protected metal sheeting, such as, painted galvanized steel, painted aluminum alloys, asphalt-asbestos coated galvanized steel.

Impervious membrane 20

Referring now to FIGS. 1, 3 and 4, the impervious membrane 20 is applied substantially coextensive with the inner metal sheath 12 and preferably comprises a film of polyethylene having a thickness of about 0.002 inch. It should be understood, however, that other suitable plastic sheets may be used instead of the preferred polyethylene film.

As shown in FIG 4, the lower end 20a of the membrane 20 is passed beneath the lower edges of the insulating material 24 and around the outer face thereof. Similarly, the upper end 20b of the membrane 20 is passed over the upper ends of the insulating material 24 and down the front face thereof. With this arrangement, air is prevented from entering, for example, through the lower end of the wall structure 10, through the insulating material 24 into the interior of the wall structure 10.

Insulating material 24

Referring now to FIGS. 1, 3 and 4, two batts of the insulating material 24 are applied over the membrane 20 in substantially coextensive covering relation with the inner metal sheath 12. The insulating material 24 and the coke-cores 36 and cooperates with the inclined side walls 40 and the valleys 38 to define a plurality of first passageways 44 through which air tends to circulate by convection. As will be described, the sealing means 30 minimizes the convective circulation of the air within the panel.

Spacer members 22

Referring now in particular to FIG. 5, the spacer member 22 comprises a block or core 46 of foamed thermal insulating material, such as foamed polyurethane, for example, and, at least one and preferably two metal facing plates, hereinafter termed first metal facing plate 48 and second metal facing plate 50. The block 46 comprises a generally rectangular base 52 having a stem portion 54 projecting from one face of the base 52 and preferably positioned centrally thereof. The first metal facing plate 48 has a generally hat-shaped configuration including a U-shaped central portion 56 and oppositely extending flanges 58, the arrangement being such that the shape of the first metal facing plate 48 corresponds to the shape defined by the exposed surfaces of the base 52 and the stem portion 54.

Additionally, leg portions 50, formed integrally with the opposite or remote face of the block 46, extend along each side of the block 46. The second metal facing plate 50 has a generally hat-shaped configuration including a U-shaped central portion 62 and oppositely extending flanges 64. It should be noted that the U-shaped central portion 62 of the second metal facing plate 50 provides a relatively wide central groove 66 which is adapted to receive a crest of the inner metal sheath 12, as will be described in conjunction with FIG. 3.

The spacer members 22 may be manufactured by foam- ing a quantity of the thermal insulating material between relatively long lengths of the plates 48, 50 which are rigidly supported in spaced parallel relation. During the foaming operation, the foaming material expands into contact with and bonds to the inner surfaces of the first and second metal facing plates 48, 50. Thereafter, the elongated composite structure is cut into a plurality of segments each of which comprises one of the spacer members 22. Openings 68 may be drilled through the oppositely extending flanges 58, the block 46 and the oppositely extending flanges 64 to receive fasteners for securing the spacer member 22 to the inner metal sheath 12. If desired, a pair of openings 70 may be drilled through the upper face of the U-shaped central portion 56, for receiving fasteners employed in securing the subgirt members 26 to the spacer member 22, as will be described.
Referring now to FIG. 3, one of the spacer members 22 is shown installed in the present wall structure 10. As can be seen, the oppositely extending flanges 64 of the second metal facing plate 50 engage adjacent valleys 38 while the crests 36 along with the side walls 40 disposed between the adjacent crests 38 are received within the central groove 66. Sufficient clearance is provided between the crests 36 and the U-shaped central portion 62 for the membrane 20.

The spacer member 22 is secured to the inner metal sheath 12 and to the girt member 18 by means of a fastener 72 which preferably comprises a tubular member 74 having prongs 76 at one end thereof and a self-tapping screw 78 extending through the tubular member 74. The prongs 76 are spaced when the self-tapping screw 78 is threaded into the inner metal sheath 12 and the girt member 18. As the prongs 76 are spread apart, they collapse or compress the rigid foam material disposed therearound and their ends engage the lower surface of the oppositely extending flange 58. The opposite end of the tubular member 74 is engaged with the inner metal sheath 12, the overall arrangement being such that the tubular member 74 prevents crushing of the rigid foam when the self-tapping screw is tightened.

It should be evident that, although the fasteners 72 and 78 are shown, the installation of conventional self-tapping screws with the aid of controlled torque applying wrenches may be used with equal utility.

Referring now to FIGS. 1 and 3, it will be seen that the batts of insulation 24 surround each of the spacer members 22 and fill the space between the crests 36 and the outermost face of the first metal facing plate 48. In this manner, little if any interior space of the wall structure 10 is left uninsulated.

Subgirt members 26

Referring now to FIGS. 1, 3 and 4, each of the subgirt members 26 has a channel-shaped profile including oppositely extending longitudinal flanges 80 which engage a row of the spacer members 22. Fasteners 82 passing through the longitudinal flanges 80 and threadedly engaging the openings 70 in the spacer members 22, secure the subgirt members 26 to the spacer members 22.

Outer metal sheath 28

Referring now in particular to FIGS. 1, 3 and 4, the outer metal sheath 28 comprises a plurality of facing sheets 84 each having a fluted profile including crests 86 and valleys 88 which are connected by means of inclined side walls 90. The liner sheets 84 are erected in side-by-side overlapping relation such that, as best shown in FIG. 3, a lateral valley 88a of one liner sheet 84 overlaps a lateral valley 88b of an adjacent one of the liner sheets 84. A plurality of fasteners 92 secure the overlapped lateral valleys 88a, 88b to the subgirt member 26. Additional fasteners 94 extend through intermediate valleys 88 and further secure the facing sheets 84 to the subgirt members 26.

The facing sheets 84 cooperate with the insulation material 24 to define second passageways 96 through which air tends to circulate by convection. As shown in FIG. 4, the sealing means 30 is applied at least to the lower end and preferably at both upper and lower ends of the passageways 96 so as to prevent ingress of outside air into the interior of the wall structure 10. Accordingly, convective circulation of air within the second passageways 96 is minimized.

The facing sheets 84 preferably comprise suitably protected metal sheeting, such as, painted galvanized steel, painted aluminum alloys, asphalt-asbestos coated galvanized steel.

Sealing means 30 and 32

Referring now to FIGS. 4 and 6, the sealing means 30 may comprise, for example, an insert, shown in FIG. 6, having a fluted configuration corresponding to the fluted profile of the inner metal sheath 12. That is to say, the sealing means 30 has surfaces 98, 100 and 102 corresponding, respectively, to the crests 36, the valleys 38 and the inclined side walls 40. The sealing means 30 may be formed from a substantially vapor-impervious rubber or other closed cell, resilient, foamed plastic material, and may, if desired, have an adhesive applied to the surfaces 98, 100 and 102 to facilitate installation.

Referring now to FIGS. 4 and 7, the sealing means 32 may comprise, for example, an insert having a fluted profile corresponding to the fluted profile of the facing sheets 84. That is to say, the sealing means 32 has surfaces 104, 106 and 108 corresponding, respectively, to the crests 86, valleys 88 and intermediate side walls 90 of the facing sheets 84. The sealing means 30 may be formed from a substantially vapor impervious rubber or other closed cell, resilient, foamed plastic material and may, if desired, have an adhesive applied to the surfaces 104, 106 and 108 to facilitate installation.

ALTERNATIVE EMBODIMENT

Referring now to FIGS. 8 and 9 there is illustrated a Z-shaped spacer member 110 including a central web 112 having oppositely extending legs 114, one at each end thereof. The central web 112 has a central opening 116 defined by a peripheral flange 118 projecting substantially perpendicular to a web portion 120 of the central web 112. The opposite edges 122 also project substantially perpendicular to the web portion 120. The flange 118 and edges 122 cooperate with the web portions 120 to define generally U-shaped columns 124 having considerable strength and presenting a minimum cross-sectional area to the through-conduction of heat.

Ribs 126 are provided at the intersection of each leg 114 and the central web 112, to increase the strength of spacer member 110. The ribs 126 are formed by deforming portions of spacer member 110. An opening 128 is provided in each of legs 114.

Reference is now directed to FIG. 10 wherein there is illustrated a wall structure 130 which is similar to the wall structure 10 (FIG. 3) and, hence, corresponding numerals will be employed to identify corresponding parts heretofore described. The wall structure 130 includes the inner metal sheath 12, the membrane 20, the spacer members 110, the insulation 24, the girt members 26, the outer metal sheath 28 and the sealing means 30, 32 (not visible).

In this embodiment, one leg 114 of the spacer member 110 engages the membrane 20 in the region of a valley 38 and secured in place by a fastener 132 passing through the leg 114, the membrane 20, the valley 38 and the girt member 18. The other leg 114 spans across and engages the longitudinal flanges 80 of the subgirt member 26. A fastener 134 secures the subgirt member 26 to the spacer member 110.

Although the spacer member 110 permits some through-conduction of heat, the relatively small cross-sectional area of the columns 124 minimizes the actual heat flow by conduction. The configuration of the columns 124 and the ribs 126 contribute to the great structural strength of the spacer member 110.

TEST RESULTS

In the light of the above-described description, it would appear as though the present wall structures 10 and 130 are conventional wall structures. It would also appear as though the "U" values of the present wall structures 10 and 130 should fall within the range of "U" values reported for prior art wall structures.

Tests were conducted on a 16 sq. ft. wall segment constructed in the manner illustrated in FIGS. 1, 3 and 4 and including a single spacer member 22 at the center of the wall segment. During the tests, the inner metal sheath 12 was exposed to a temperature of 76.6°F, while the outer metal sheath 28 was exposed to a temperature of...
of \(-9.4^\circ\) F. Surface temperatures at preselected locations around the spacer block were measured by thermocouples and recorded. Other thermocouples, arranged in a recommended pattern, measured surface temperatures of the inner and outer sheaths. These temperatures were also recorded. The over-all heat-transfer coefficient of each test was determined by conventional methods.

It was indeed completely surprising and unexpected, as well as completely unobvious to discover that the present wall structure had a "U" value of 0.047 B.t.u./hr. ft. \(\times 760\) sq. ft./F. when both sealing means 30 and 32 are unutilized and a "U" value of 0.049 B.t.u./hr. sq. ft./F. only when the sealing means 30 was used. Comparing these "U" values with the average "U" value of 0.075, of wall structures employing four inches of insulation, we find that when using only the sealing means 30, a significant reduction of 35% in the "U" value is achieved, whereas when both means 30 and 32 are used, a significant reduction of 37% in the "U" value is achieved.

Tests similar to those conducted for the wall structure, were also conducted for the wall structure wherein the inner metal sheath was exposed to a temperature of 76.0\(^\circ\) F. while the outer metal sheath was exposed to a temperature of 2.7\(^\circ\) F.

It was indeed completely surprising and unexpected, as well as completely unobvious to discover that the wall structure had a "U" value of 0.055 B.t.u./hr. sq. ft./F. This "U" value represents a significant reduction of 27% over the average "U" value of 0.075 reported above for wall structures employing four inches of insulation.

It is not completely understood why the present wall structures and 130 achieve significant reductions in the "U" value. As is known, convective circulation of the air within a wall structure increases the heat transmission through the wall structure. It has been speculated, therefore, that the membrane 20 and the sealing means 30 and 32 operate to minimize the convection circulation of the air within the wall structure and, reduce the heat transmission through the wall. In accordance with this theory, a decrease in the "U" value was expected. However, the significant decrease in the "U" value actually achieved is considerably in excess of the expected decrease.

**SUMMARY**

The present invention provides a wall structure having a significantly low overall heat-transfer coefficient. This result is completely surprising and unexpected. Because of its relatively low overall heat-transfer coefficient, the present wall structure may be used in environments wherein high humidity and low outside temperature exist on the opposite sides of the wall structure, without the formation of condensation on the inside surface. Still further, the present wall structure is relatively inexpensive to manufacture and may be erected in a rapid and efficient manner. Furthermore, the novel spacer members of the present invention provide an efficient thermal break in the through-conduction of the wall structure, thereby contributing to the relatively low overall heat-transfer coefficient.

1. An insulated metal wall structure comprising in combination:
   - an inner metal sheath secured to the structural framework of a building and having a fluted profile presenting crests and valleys;
   - a substantially impervious membrane disposed in substantially coextensive engagement with said inner metal sheath;
   - thermal insulating material substantially coextensive with said inner metal sheath and disposed in covering relation with said membrane, said thermal insulating material cooperating with said valleys to form passageways through which air tends to circulate by convection;
   - an outer metal sheath;
   - means for connecting said outer metal sheath to said inner metal sheath in spaced-apart substantially parallel relationship therewith;
   - said thermal insulating material residing between the said inner metal sheath and the said outer metal sheath; and
   - insert means disposed between said inner metal sheath and said thermal insulating material for sealing said passageways to prevent ingress of air therein.

2. The wall structure as defined in claim 1 wherein said membrane is secured around at least the lower edges of said thermal insulating material thereby preventing ingress of air through said insulating material into the interior of said wall structure.

3. The wall structure as defined in claim 1 wherein said connecting means and inner spacer members secured at space locations on said inner metal sheath, said spacer members comprising a thermal insulating rigid foam block having a facing plate secured thereto and spaced outwardly of said inner metal sheath.

4. The wall structure as defined in claim 1 wherein said insert means is provided at both ends of said passageways.

5. The wall structure as defined in claim 1 wherein said outer metal sheath has a fluted profile presenting crests and valleys which cooperate with said thermal insulating material to form second passageways through which air tends to circulate by convection; and including insert means separate from the first said insert means and disposed between said outer metal sheath and said thermal insulating material for sealing said second passageways to prevent ingress of air therein.

6. The wall structure as defined in claim 5 wherein the first said sealing means is provided at both ends of said passageways, and the second said sealing means is provided at both ends of said second passageways.

7. In a wall structure, the combination of an inner metal sheath, an outer metal sheath, and a spacer member disposed between said inner metal sheath and said outer metal sheath and maintaining the same in spaced-relation, said spacer member comprising:
   - a block of foamed thermal insulating material including a base having a first face opposite said inner metal sheath and a second face remote from said first face, and a stem portion projecting from said second face; and
   - a facing plate secured to said second face and said stem portion in substantially coextensive relationship therewith.

8. A wall structure as defined in claim 7 including a second facing plate secured to said first face of said spacer member in substantially coextensive relationship therewith.

9. The wall structure as defined in claim 7 wherein said spacer member includes leg portions extending along the opposite edges of said first face and projecting away therefrom, said leg portions cooperating with said first face to form a central groove in said base.

10. The wall structure as defined in claim 7, wherein said block of foamed thermal insulating material comprises foamed polyurethane.

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