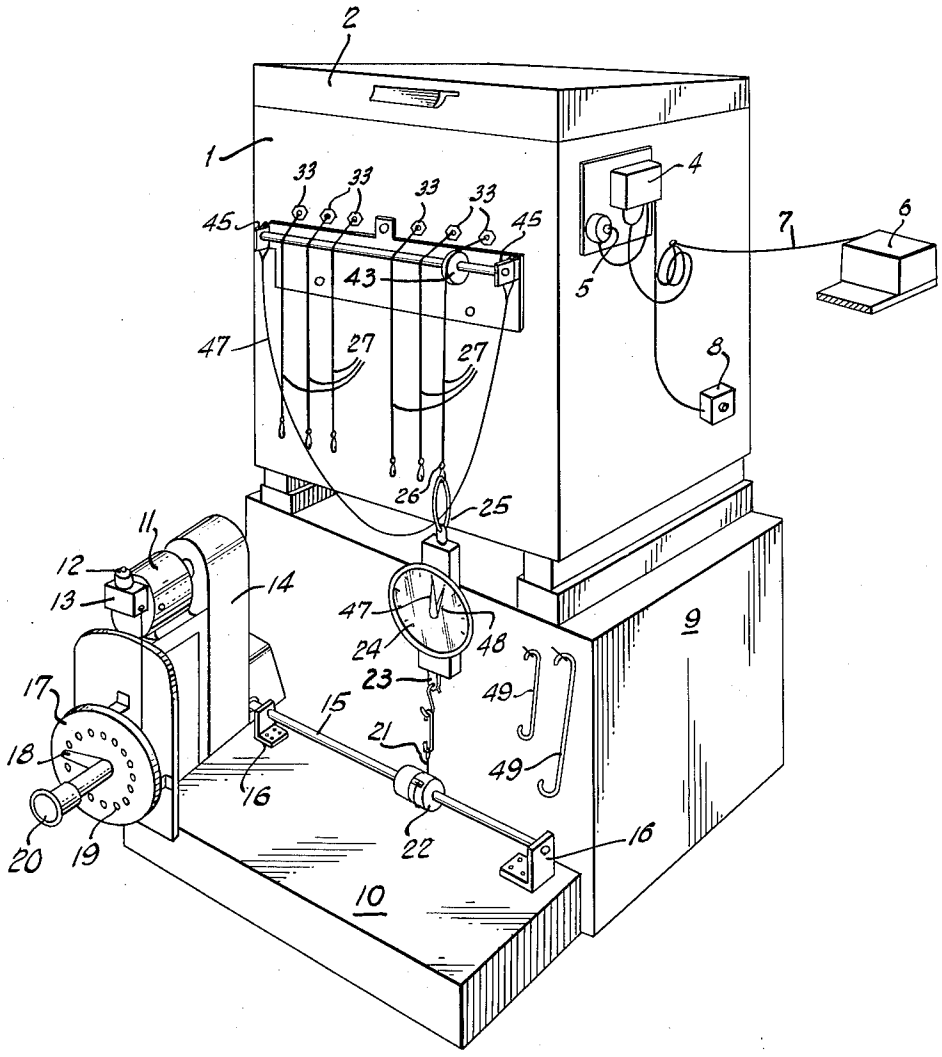
April 24, 1962 H. LACKS ETAL 3,030,797

METHOD AND APPARATUS FOR SELECTION AND COMPARISON OF THE ADHESION OF ICE TO SURFACES AND COATINGS

Filed April 30, 1958 3 Sheets-Sheet 1

Fig. 1.



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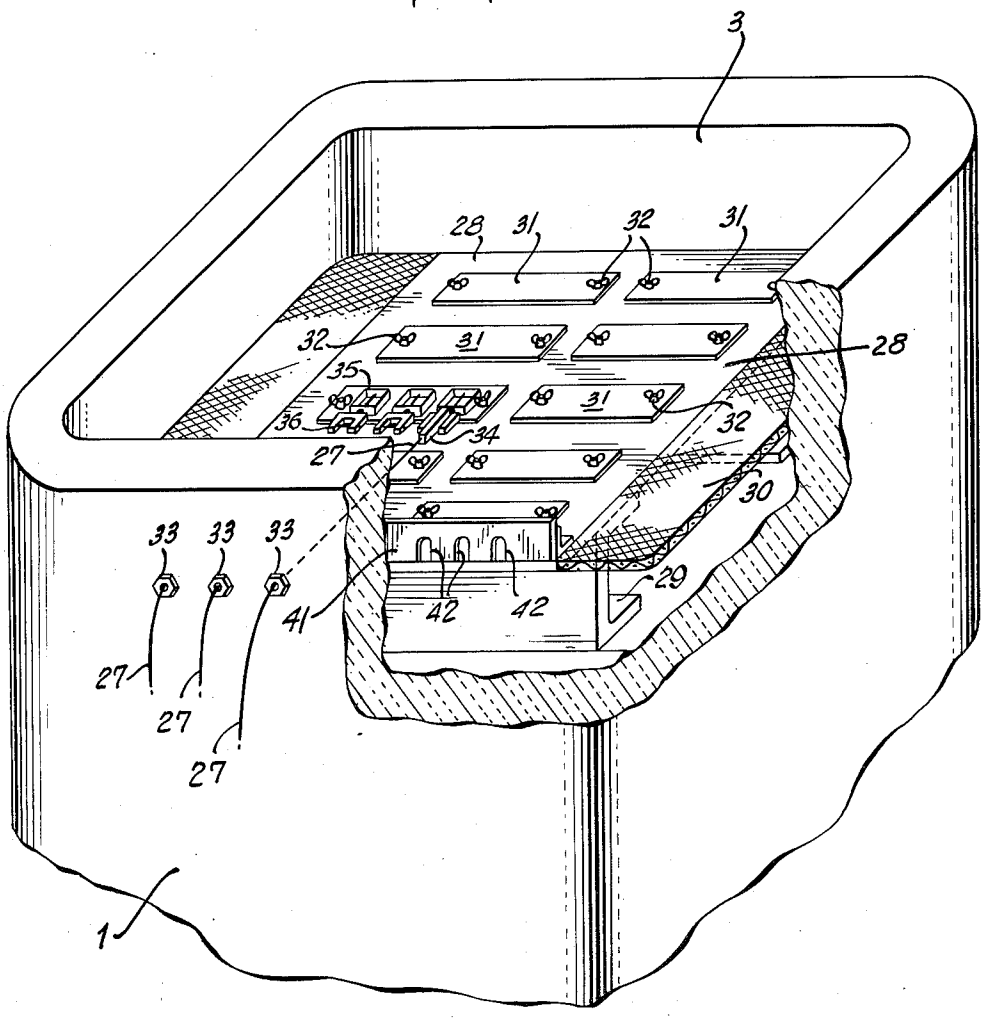
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METHOD AND APPARATUS FOR SELECTION AND COMPARISON OF THE ADHESION OF ICE TO SURFACES AND COATINGS

Filed April 30, 1958 3 Sheets-Sheet 2

Fig. 2.



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METHOD AND APPARATUS FOR SELECTION AND COMPARISON OF THE ADHESION OF ICE TO SURFACES AND COATINGS

Filed April 30, 1958 3 Sheets-Sheet 3

Fig. 3.

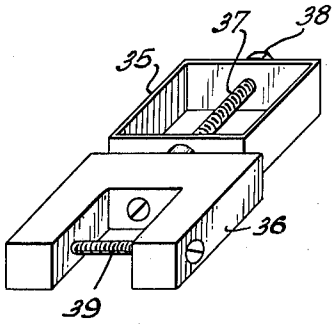


Fig. 4.

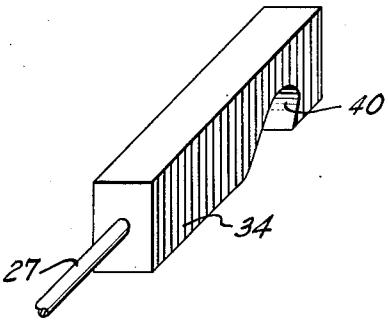
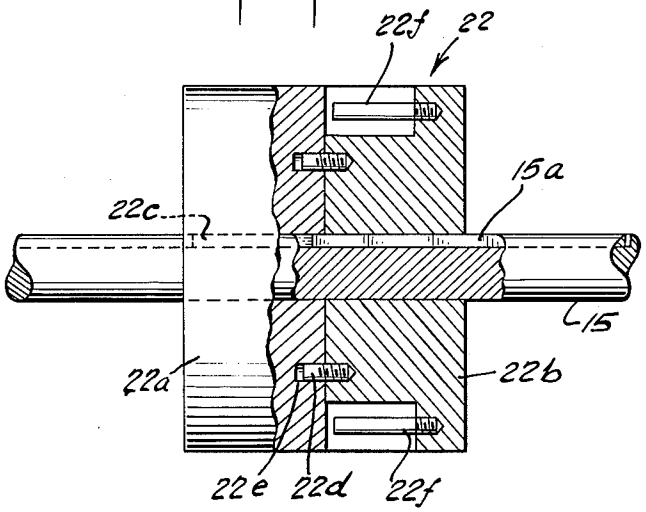


Fig. 5.



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United States Patent Office

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METHOD AND APPARATUS FOR SELECTION AND COMPARISON OF THE ADHESION OF ICE TO SURFACES AND COATINGS

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to the selection and comparison of surfaces and coatings to determine which has the least adhesion to ice frozen thereto. Ice formations on the decks and superstructures of vessels often make the vessels unseaworthy, and may also interfere with the normal manipulations of operating mechanism that is exposed on the decks and superstructures of vessels. This ice formation becomes particularly troublesome on vessels that operate in those latitudes where ice formations are likely to occur. Forced mechanical removal of ice from exposed surfaces of vessels are often imperative, and the use of those coatings for such exposed surfaces to which ice has a minimum of adhesion will greatly facilitate such ice removal. It is desirable that one be able to preliminarily test and compare the effectiveness of different coatings in facilitating ice removal therefrom without the necessity of applying such coatings to actual vessels that are exposed to ice formations.

An object of this invention is to provide improved methods and apparatus for quickly and easily comparing different surfaces and coatings in the laboratory, as to the ease of which ice that has been frozen to the surface or coating may be removed therefrom; which will indicate as accurately as possible the resistance of ice against removel from a surface or coating to which it has been frozen in a manner comparable to the mechanical procedure that would normally be necessary or employed in removing ice from an exposed surface of a vessel; with which one may determine the amount of adhesion of ice to a surface or coating by a procedure that may be duplicated with fairly uniform results; with which the tests and comparisons may be performed by relatively unskilled operators; and which employs apparatus that is relatively simple, compact, practical and inexpensive.

Other objects and advantages will be apparent from the following description of one embodiment of the invention, and the novel features will be particularly pointed out hereinafter in connection with the appended claims.

In the accompanying drawings:

FIG. 1 is a perspective of an apparatus constructed in accordance with this invention;

FIG. 2 is a perspective of the top of this cabinet, with the cover removed to show interior details of construction, and with a portion of the cabinet wall broken away;

FIG. 3 is a perspective of one of the frame elements by which ice may be frozen to a test specimen surface;

FIG. 4 is a perspective of a hook on one end of a cable to permit attachment and detachment of the cable with a frame as shown in FIG. 2; and

FIG. 5 is an elevation of part of the power operated pulling shaft, with a collar thereon and shaft shown in longitudinal section.

In the illustrated embodiment of the invention, a closed cabinet 1 is provided with a movable cover 2 on the top thereof for providing access to a closed chamber 3, FIG. 2, in the upper part of the cabinet. The sidewalls of the

cabinet are refrigerated in any suitable manner, so that the chamber 3 in the cabinet may be refrigerated to a desired temperature well below the freezing temperature of water. The refrigerating mechanism which is provided in the lower part of the cabinet 1, has a temperature control device 4, FIG. 1, which is mounted on the exterior of the cabinet but which controls the temperature to which the interior of the cabinet will be cooled and automatically held at that temperature, and which, as usual, permits adjustment of the temperature which the refrigerating mechanism will automatically maintain in the chamber 3 of the cabinet. A manually operable switch 5 also controls the activity of the refrigerating mechanism, by controlling the circuit to operating motor of such mechanism.

Also provided on the exterior of the cabinet is a thermocouple potentiometer indicator 6 which has a connection 7 to the temperature controller and refrigerating mechanism, enabling one to read the temperature existing within the chamber 3 at any time without the necessity of raising or removing the cover 2. An outlet box or connection 8 is provided on the cabinet to provide means for connecting the motor of the refrigerating mechanism to a source of electric power. Inasmuch as refrigerating mechanisms and their controls are old, and any suitable refrigerating mechanism and controls can be used, the details of such mechanisms have not been illustrated because the invention is not in any particular refrigerating mechanism or controls, but only in the use of refrigerating mechanism with their usual controls in the manner herein disclosed.

The cabinet 1 is supported upon a suitable base 9, and a platform 10 is disposed in front of the base 9 but at a lower level than the top of the base 9. Mounted on the platform 10 is an electric motor 11 that is controlled by a manually operable switch 12. The switch 12 is mounted on an outlet box 13 through which connections may be made to a source of electric current for operation of the motor 11. The rotor of the motor 11 has a driving connection through speed reduction means enclosed in a casing 14 to a shaft 15 which extends across and in front of the base 9 and is rotatably mounted in spaced apart bearings 16 provided on the upper face of the platform 10. A rheostat 17 is mounted on platform 10 in front of and below the motor 11, and has a contact arm 18 movable over a circular row of contacts 19. This rheostat is connected with the motor 11 so as to control the speed of operation of the motor. An operating handle 20 enables one to turn the contact arm 18 over and along the row of contacts 19 to vary the speed of motor 11. This rheostatic control of the speed of a motor and the speed reduction mechanism in casing 14 are common expedients and, therefore, have been shown only conventionally.

A flexible cord 21 is connected at one end to a drum 22 on the shaft 15, and its other end is connected to a hook depending from the movable element 23 of a spring scale 24. The frame of the scale, at its top, has a loop 25 to which a snap clip 26 may be detachably secured. A snap 26 is provided upon the free end of each of plurality of flexible cables 27, the use of which will be described presently.

Referring next to FIGS. 2 to 4, the interior of the cabinet 1, somewhat below the top of the cabinet, is provided with a partition support or plate 28. This plate 28 is of good heat conducting material, such as of metal, and is supported by and bridges two channel beams 29 provided adjacent the front and rear walls of the chamber 3. This plate 28 at its sides does not extend entirely to the sidewalls of the cabinet, and the gap along each side edge of the plate 28 is closed by a perforate screen 30 which permits free movement of air between op-

posite faces of the plate 28, and at the same time it prevents the falling of any articles from above the plate 28 down into the lower part of the chamber 3. A plurality of specimen plates 31 are arranged in two rows from front to rear on the top of the plate 28, in spaced apart relation to one another, and each plate 31 is detachably clamped or secured to the plate 28 by bolts upstanding from the upper face of the plate 28 and carrying wing nuts 32. These plates 31 are rectangular in shape and the wing nuts engage the top faces of the end margins of the plates to detachably confine them to the plate 28. Each row of these plates extends from adjacent the front of the cabinet to adjacent the rear, that is, from end to end of the plate 28.

The front wall of the cabinet is provided with a plurality of passages from face to face therethrough and each is lined by a plastic bushing 33. These plastic bushings are of poor heat conducting material and, therefore, they can extend entirely through the front wall of the cabinet without materially causing any substantial cold loss and thus they do not materially affect the temperature maintained within the cabinet. These passages through the front wall of the cabinet are arranged in a horizontal row across the front of the cabinet, and the cables 27 extend through these plastic bushings into the interior of chamber 3 of the cabinet above plate 28. The inner end of each flexible cable 27 is connected to a hook 34 (FIG. 4). For each specimen plate 31 there are a plurality of separate, rigid, rectangular frames or members 35 which are open at both end faces. A bifurcated coupling member 36 is connected at its base or crosspart to each frame 35 by a bolt 37 that extends through opposite side walls of the frame and carries a nut 38 at its rear end, so that each frame 35 is detachably coupled to a member 36. The bolt 37 is swiveled to the member 36, so that the member 36 may rock about the axis of bolt 37 somewhat without similarly rocking the frame 35. A bolt or pin 39 extends between the arms of the member 36, near their free ends, and the hook 34 has an undercut slot or notch 40 which may be engaged over the pin or bolt 39 in order to couple a cable 37 detachably to each member 36.

A plurality, such as three, of these frames 35 with attached coupling members 36 are provided for each specimen plate 31, and they are disposed side by side in a row along the length of each specimen plate, as shown in FIG. 2. A bar 41 is mounted on the end of the plate 28, adjacent the front wall of the cabinet, and is provided with a plurality of notches or arches 42 in its lower edge through which the cables 27 may pass without flexing or turns, one cable in each notch or arch 42, so as to be guided thereby. The notches 42 are sufficiently narrow to prevent passage therethrough of any hook 34 when its cable 27 is pulled too far in an outward direction. To reduce friction on the cables 27 and make possible a right angle turn in each cable 27, an idler pulley 43, FIG. 1, is rotatably and slidably mounted on a cylindrical rod or shaft 44 mounted in brackets 45 on a plate 46 on the front of the cabinet immediately below the plastic bushings 33. The pulley 43 may be slid along the rod or bar 44 so as to be aligned with whichever cable 27 is at any time connected to the scale. The idler pulley 43 enables the cable 27 to make a sharp downward turn in the direction of its movement without undue friction arising. The progressively increasing pull on that cable 27 which is connected at its outer end to the scale 24 and at its inner end to a frame 35, exerts a shearing pull on the frame 35 to which it is connected, in a direction parallel to the upper face of the test specimen 31 that is beneath that frame 35. When the force exerted on the frame 35 through the cable 27 becomes great enough, it will shear the ice block within the frame 35 from the surface or coating of the test plate 31 below it, and by noting the pressure indicated on the scale 24 at the time the ice is broken loose from or sheared from the test plate below it, one has a value representing or corresponding to the adhesive force between the ice block and the test specimen. By making the area within the frame 35 one square inch and having the scale 24 read pressures in pounds, one can obtain a direct reading of the force in pounds per square inch which caused the shearing of the ice block from the specimen plate.

The frames 35 which encircle the blocks of ice and which abut against the top of the specimen plate 31, limit the shearing action on the ice block to that portion of the ice block in close proximity to the test surface. Since the frames 35 are open at the top face as well as at the bottom face, the water in each frame, in freezing, may expand upwardly. The height of each wall of each frame 35 should be substantial in order that the frame wall does not cut through the ice block during the shearing pull, and a height of about one-half inch has been found entirely satisfactory.

The scale 24 has an indicator hand 47 which moves back and forth over the graduations on the scale with variations in the pull on the scale so as to indicate the pressure or pull on the scale at any time. One reads the scale beneath this hand 47 at the instant when the ice is sheared from the test specimen. This requires constant attention in order that the scale may be read at exactly the time when the rupture between the ice and test specimen occurs. The scale 24 may also have another hand 48 which is normally reset at zero to be in alignment with the hand 47 at the start of the operation, and which is pushed along by the hand 47 as the pull increases. This hand 48 will remain in any position into which it has been pushed by the hand 47, until it is reset, even after the hand 47 has started its return to zero position following the breaking loose of an ice block from a test specimen. The hand 48 thus gives a maximum pressure reading each time, and it is not necessary to watch the scale closely in order to make the pressure reading at exactly the time when the ice in a frame 35 breaks loose from the test specimen.

The drum 22 (FIG. 5) is formed of two separate cylindrical sections 22*a* and 22*b* abutting face to face and both slidable along the shaft 15, so that they can be placed in vertical alignment with the scale 24 and any cable 27 in use at any time. The shaft 15 has a keyway 15*a* extending along it and one section, such as 22*a* of the drum, carries a key 22*c* fixed thereto and engaging in and slidable along the shaft, so that drum section 22*a* will always rotate with the shaft yet can be slid along it. The other drum section such as section 22*b* is freely rotatable on as well as slidable along the shaft 15. The abutting faces of the drum sections have coupling clutch portions that may be engaged or disengaged by sliding one of the sections along the shaft relatively to the other. For example either section may have pins 22*d* projecting from its face that abuts the other section and is received in aligned recesses 22*e* in the abutting face of the other section. The section that is free on the shaft, such as section 22*b*, has a pin or element 22*f* accessible from its periphery to which the cord 21 is attached. When the sections 22*a* and 22*b* are coupled face to face they will both be driven by the shaft 15 to pull on a frame 35 by winding cord 21 on the coupled drum sections. At the conclusion of a shearing operation the motor 11 is stopped by operation of switch 12, the sections 22*a* and 22*b* separated apart on the shaft, the section 22*b* rotated on the shaft to place pin or element 22*f* at the top and unwind cord 21, and then the sections recoupled by moving them back into face to face coupling. The sections may then be moved together along shaft 15 into alignment with another cable 27.

A flexible cord 47 (FIG. 1) is connected at its ends to, and extends between, brackets 45 and depends downwardly at the front of the cabinet. The intermediate part of the cord 47 passes loosely through the loop or ring 25 on the frame of the scale, with sufficient slack,

so that it does not interfere with the normal vertical movements or displacements of the scale, yet it will catch the scale after a pulling operation releases the scale. This prevents the scale from falling upon the platform 10 if the notches 42 in the bar 41 do not stop the outward movement of the cable 27 to which the scale is connected. The cord 47 also serves to hold the scale in approximate operative position while the scale is being uncoupled from one cable 27 and coupled to another cable 27.

In use, the refrigerating mechanism is started and after it has brought the temperature of the interior of the chamber 3 down to the desired temperature below the freezing temperature of water, the frames 35 are arranged in a row along each of the test specimen plates 31. There are a plurality such as three of these frames 35 for each test specimen plate. The test specimen plates are either made of different materials or the upper faces of the plates are thoroughly cleaned and then coated with suitable coating materials or paints to be tested, and the coatings allowed to harden. With the frames 35 arranged in rows upon the upper surface of each of the plates 31, and while frames 35 are refrigerated to the temperature within the cabinet, the space encircled by each frame 35 while the frame is resting on a specimen test plate 31 is filled with water, usually distilled water, that has a temperature approximately at the freezing point of water. The cover is closed so that the refrigerating mechanism then freezes the water in each frame 35 into a solid block of ice that adheres by freezing to the upper finished or coated surface of the plate 31 below it. The refrigeration continues for a period of time long enough for the ice to freeze firmly to the plate 31 below it, and for the frame and the ice to assume the normal temperature of the chamber 3.

While any minimum temperature well below freezing may be employed, we have found that a temperature of about 10° F. is very satisfactory for this purpose. After the ice has been firmly frozen in this manner and is at the below freezing temperature within the chamber 3, the cover is opened momentarily, and three of the cables 27 are connected to the bifurcated members 36 on the frames 35 that rest upon a specimen plate 31, of either row, that is nearest to the bushings 33. This coupling of a cable 27 to a frame 35 is accomplished by merely dropping a cable hook 34 over the pin or bolt 39 of the bifurcated member 36 that is connected to that frame 35. The other three cables 27 are similarly connected to frames 35 that have been frozen to that specimen plate 31 which is nearest to the front wall of the cabinet in the other row of specimen plates.

The cover is then closed and the outer ends of the cables 27 connected in succession, but one at a time, by their swiveling clips 26 to the ring 25 on the frame of the spring scale 24. With the parts in such positions the motor 11 is started. As it operates the shaft 15 is rotated which rotates the drum 22 to which one end of the cord 21 is attached. The cord 21 is wound slowly upon the drum 22 and this applies a progressively increasing pull on the movable element of the scale 24, and through the scale this progressively increasing force applies a similarly increasing pull on that cable 27 which is attached at that time to the frame of the scale through ring 25.

After each frame on a test specimen has been broken loose in this manner, the next cable 27 is connected to another frame 35 and the shearing operation repeated. After a plurality of frames 35 which have been frozen by ice to the same test specimen have been pulled loose in this manner, one can average the scale readings and thus determine the average force that is necessary to break the ice blocks from each test specimen plate. This provides a value which fairly represents the degree of adhesive force between the ice block and the surface or coating on a particular test plate. After the frames have been broken loose in this manner from the front test specimens, the cables 27 are similarly connected to the frames 35 on the next specimen plate in each row, and the operation repeated. This procedure is continued until all the ice blocks have been broken free from the test specimen plates. It will be understood that after each ice block has been broken free from a test specimen plate, the motor 11 is stopped and the drum 22 returned to staring condition on shaft 15. Coupling links 49 which are bars with the ends turned back, may be interposed between the free end of the cord 21 and the movable element 23 of the scale 24 when the cables 27 are connected to the frames 35 on the specimen plates 31 near the rear of the chamber 3.

The method and apparatus employed by applicants make is possible to obtain repeatable adhesion values closely representing the forces necessary to chip ice from a surface, and it is possible to make the tests rapidly and easily for large numbers of test panels.

The apparatus illustrated and described makes it possible to measure, under specified temperature and humidity conditions, the adhesion of ice to a surface in terms of the force in pounds per square inch that is required to shear the ice horizontally from the test surface. The speed reduction means in casing 14 between the motor 11 and shaft 15 in the example illustrated, causes a reduction in the speed of the shaft 15 to about one-half revolution per minute. The speed of rotation of the shaft can also be varied by operation of the rheostat 17. The pulling force which is noted on the scale increases at the rate of about three pounds per second.

In preparing the specimen plates, the surfaces are first carefully cleaned by sandblasting, emery polishing, solvent rinsing and airblast drying. When the test plates are of steel, they are also demagnetized and electrically grounded before ice is formed thereon, which gives more uniform ice adhesion values. The coatings may be applied by brush or spray to that side of the plate 31 which is to be uppermost in the cabinets. The coatings are allowed to dry thoroughly and harden before any ice is formed on them. After the test plates 31 with their cleaned test surfaces or applied test coatings have been prepared in this manner, they are bolted to the partition plate or support 28 with the test surface or applied coating uppermost, and the cabinet then closed. The temperature maintained in the cabinet may be any uniform temperature well below the freezing point of water. A temperature of 10° F. is very suitable for this purpose.

After the test specimens have been maintained at this cabinet temperature for a substantial period of time, such as about one hour, 6 ml. of distilled water, in equilibrium with ice, are poured into each frame 35. During the pouring, the motors in the equipment are preferably stopped in order to minimize vibration. The cabinet is closed and the temperature of 10° F. maintained for a minimum of about two hours which enables the ice to form and reach the 10° F. temperature of the apparatus before any attempt is made to shear the ice from the test panels. In preparing the water in equilibrium with ice, the water is poured from a mixture of approximately equal proportions of ice and water in equilibrium at 32° F., but no ice is allowed to fall into the holders or frame during the pouring. This mixture is preferably used because we have found that the adhesion values were higher when ice was present in the water at the pouring. The ice water is poured gently and in one continuous operation into the holder to avoid splashing. It was found that the use of less than 6 ml. of water did not usually permit the holder to grip the ice block adequately.

Tests indicated that ice adhesion values were affected somewhat by the rate of freezing of the water, and that the higher rates of freezing, as indicated by the shorter freezing times or by the lower freezing temperatures, resulted in lower ice adhesion values, also that lowering of the temperature of the ice-metal systems or ice-paint-metal systems after freezing raised the ice adhesion values.

The ice adhesions directly on steel panels were usually greater than on paint coatings over the steel panels. When the pulls on the ice blocks are made in succession first in panels at the front of the cabinet, then progressively toward the rear, the ice blocks in the rear positions would be subjected to the shocks of the early releases of ice from the test specimens.

The test panels are sufficiently rigid to avoid any material flexing or buckling under the forces tending to pull the ice blocks loose therefrom. Test specimen metal plates of about one-quarter (¼) inch in thickness were found sufficient to prevent this flexing or buckling while the ice blocks are being pulled therefrom. These test panels or plates should also be straight and not warped, so that clamping will not flex them. The ice holders are aligned so that the pull wires extend from the holders in directions parallel to the faces of the test specimens, and swivels are provided in the pull wires so that no twisting forces would be applied to the ice blocks while they are being sheared from the test panel.

In testing the adhesion of ice to various surfaces and coatings when the surface is merely of polished steel, the pull in pounds per square inch necessary to shear the ice from the test surface varied usually between about 120 and 160, whereas when the panels were coated with Navy grey deck paint, such as described by Joint Army-Navy Specification JAN–P–669, the average ice adhesion of this paint measured about 85 lbs. per square inch, and the calculated error was about 13 percent. This indicates that the ice adhesion to the painted surface was very much less than that on the polished steel surface. The ice adhesion varies with different coatings on the specimen plates.

It was also found that the exposure of coated surfaces to different humidities caused variations in the ice adhesion results. For example, generally the longer the exposure and the higher the humidity, the higher were the adhesion values obtained. Hence, in this cabinet chamber, the temperature and humidity conditions in the test area were controlled and standardized, so that all the work on all samples was conducted under uniform, fixed conditions.

It will be understood that various changes in the details, materials and arrangements of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

We claim:

1. Apparatus for determining the amount of adhesion between a body of ice and a particular surface to which it is frozen, which comprises a closed chamber, means for refrigerating said chamber to a temperature well below the freezing temperature of water, means mounting a rigid body with a specimen of said surface within said chamber with said surface upwardly exposed, a rigid frame open at both ends disposed in said chamber with one of its said open end faces closely fitting and abutting said body surface, pulling means connected to said frame and extending therefrom in a direction substantially parallel to said body surface, and means connected to said pulling means and selectively operable for applying thereto and through it to said frame a progressively increasing shearing force in said direction tending to shear loose from said surface a block of ice that may be frozen within said frame to said surface, whereby the force required to shear said ice block from said surface is an indication of the degree of adhesion of ice to said surface.

2. The apparatus as set forth in claim 1 wherein said means connected to said pulling means includes therein in the connection to said pulling means a spring scale which indicates the amount of the force necessary to shear the ice block from said surface.

3. The apparatus as set forth in claim 2, and means also connected to said scale to limit its bodily displacement to that which is not greatly in excess of that required during a shearing operation.

4. The apparatus as set forth in claim 1, and means readable from the exterior of said chamber for indicating the temperature within said chamber at all times.

5. Apparatus for determining the resistance to removal of a body of ice from a particular surface to which it is frozen, which comprises a closed insulated cabinet having a refrigerating chamber and a movable closure enabling access to said chamber, means for refrigerating said chamber to a temperature well below the freezing temperature of water, an approximately horizontal support within said chamber in said cabinet, means for detachably securing face to face on the upper face of said support a rigid plate having on its upper face a specimen of said particular surface, a rigid frame open at both ends and disposed within said chamber above said plate, with one of open end faces closely fitting and abutting downwardly against said specimen surface, and in which water may be placed for freezing to said surface, a flexible cable connected at one end to said frame and extending approximately horizontally therefrom to an upright wall of said cabinet, said cabinet having a bushing of non-heat conducting material extending through said upright cabinet wall, the free end of said cable extending through said bushing to the exterior of said cabinet, means connected to the outer free end of said cable and operable thereon to pull said cable in an outward direction with a progressively increasing force, until a body of ice in said frame and frozen to said specimen surface is sheared from said specimen surface, and means for indicating the amount of such force necessary to shear said ice from said specimen surface to which it had been frozen.

6. The apparatus as set forth in claim 5, wherein said indicating means includes in said cable pulling means, a motor, a drum rotated by said motor, a cord attached at one end to said drum, a spring scale connected between the other end of said cord and the outer free end of said cable, whereby winding of said cord on said drum by operation of said motor will exert said progressingly greater pull on said cable and frame in a direction tending to shear said ice from said specimen surface.

7. The apparatus as set forth in claim 6, and lost motion means connecting said scale to said cable for limiting bodily displacement of said scale materially after movement sufficiently to cause a shearing of said ice from said specimen surface.

8. The apparatus as set forth in claim 6 wherein said indicating means has one indicator which is fully responsive to increases and decreases in the amount of the pulling forces on said scale, and also has another indicator which is responsive to increases in the amount of such pull and indicates maximum pulling forces.

9. The apparatus as set forth in claim 5, wherein said means to pull said cable includes an electric motor, a drum operated by said motor, and a cord connected at one end to said drum to be wound thereon upon operation of said motor, and at its other end connected to said cable to pull the latter.

10. Apparatus for determining the resistance to removal of a body of ice from a particular surface to which it is frozen, which comprises a closed, insulated, cabinet having a refrigerating chamber and a movable closure enabling access to said chamber, means for refrigerating said chamber to a temperature well below the freezing temperature of water, an approximately horizontal support within said chamber in said cabinet, means for detachably securing face to face on the upper face of said support, in horizontally spaced relation to one another, a plurality of rigid plates, each having on its upper face, a specimen of a particular surface the adhesion of which to ice is to be ascertained, a plurality of individual and separate rigid frames open at both ends and disposed within said chamber above said support and dis-

tributed over said plates, each frame having an open end abutting a specimen surface on a plate, whereby when water near the freezing temperature is placed in said frames it will freeze in said frame and adhere to the specimen surface on the plate below it, said cabinet having, in an upright wall thereof, a plurality of passages therethrough from said chamber outwardly, an individual, separate cable extending through each of said passages, and each connected at its inner end to an individual frame and extending approximately horizontally from that frame, means connectable to the outer ends of said cables for applying to those cables progressively increasing pulling forces in an outward direction until the ice in each frame to which a cable is connected is sheared loose from said specimen surface to which it has been frozen, and means for indicating the amount of the pulling force necessary to shear each ice body from a specimen surface to which it was frozen.

11. The apparatus as set forth in claim 10, wherein the outer ends of said cables are detachably connectable one at a time to said means for applying pulling forces, and said indicating means is a spring scale in said means for applying pulling forces.

12. Apparatus for determining the amount of adhesion between a body of ice and a particular surface to which it is frozen, which comprises a closed chamber, means for refrigerating said chamber to a temperature well below the freezing temperature of water, means mounting a rigid body with a specimen of said surface within said chamber with said surface upwardly exposed, a rigid frame open at both ends disposed in said chamber with one of its said open end faces closely fitting and abutting said body surface, said cabinet having a passage through a wall thereof, means slidable in and passing through said passage and connected at its inner end to said frame, means connected to the outer end of said last named means and operable to exert on the latter a progressively

increasing force in a direction to shear loose a block of ice in said frame that may be frozen to said specimen surface, and means for indicating the force necessary to cause such shearing.

13. The apparatus as set forth in claim 12 wherein said indicating means is a spring scale through which the increasing force is applied to said frame.

14. The apparatus as set forth in claim 13 wherein said scale has two force indicating hands, one of which varies its position with variations up and down of said force, and the other of which indicates only maximum force exerted on said frame.

15. The method of indicating, for comparison purposes, the shearing force necessary to separate a body of ice from a selected surface having all of its elemental segments rectilinear and parallel to each other to which said body is frozen, which comprises forming, in an enclosure that is open at its top and bottom, a body of ice frozen to a selected face area of such a surface while said segments of said surface are in a horizontal position and said enclosure has its open bottom resting on said surface, and while said body is firmly frozen to said surface applying to said enclosure a force parallel to said surface segments and in the direction in which said segments extend sufficient to shear said ice body from said surface, and indicating the force necessary for such shearing for comparison with forces necessary to similarly shear bodies of ice from other surfaces.

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