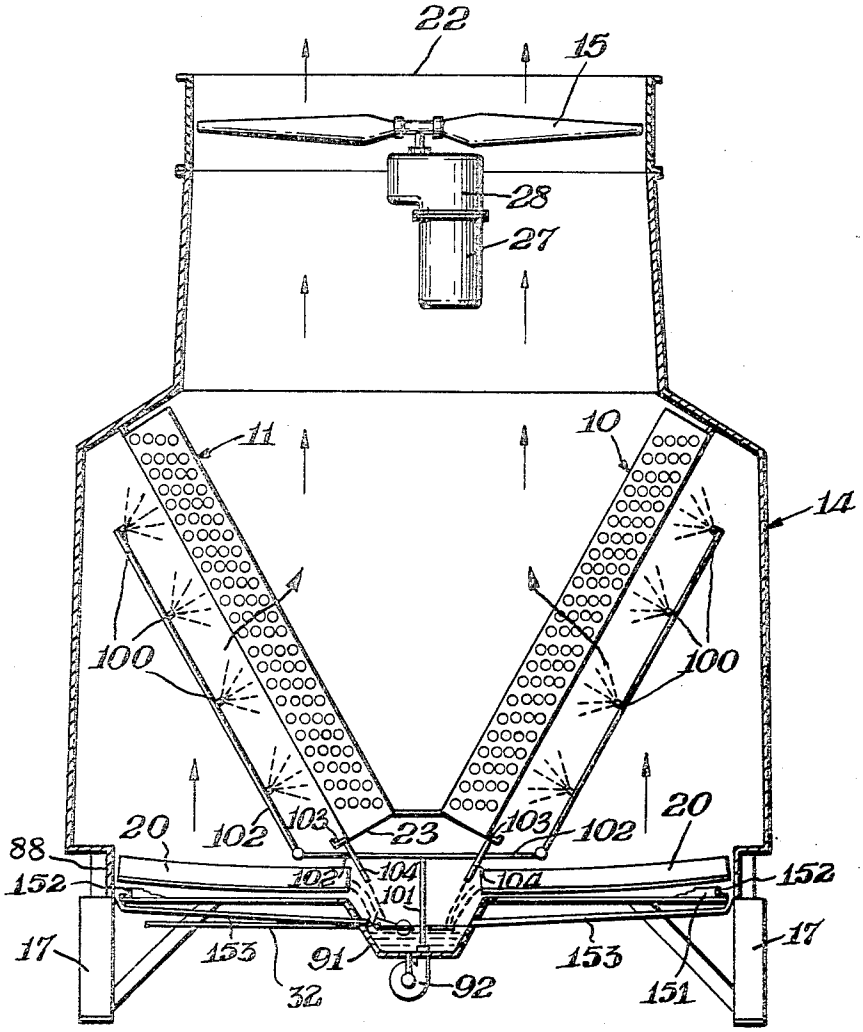
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LOUVER

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Fig. 1.



INVENTOR

Ralph T. Mathews

BY Harry J. McCauley

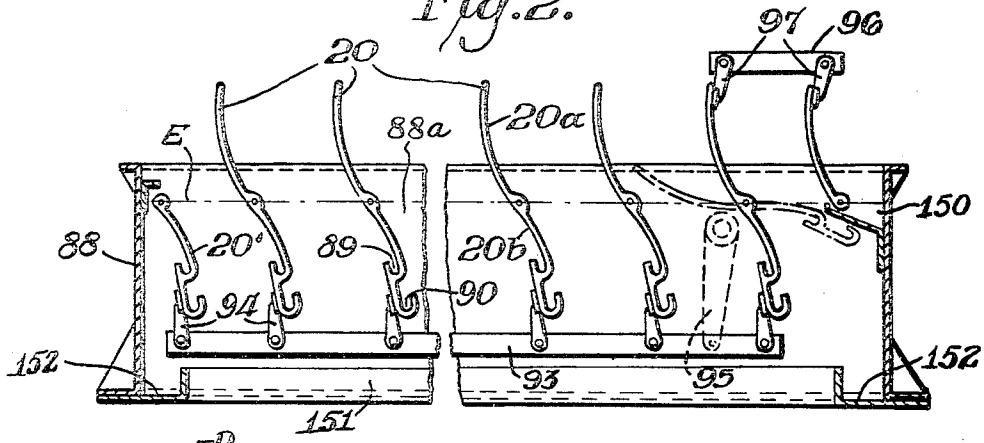
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LOUVER

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Fig. 2.



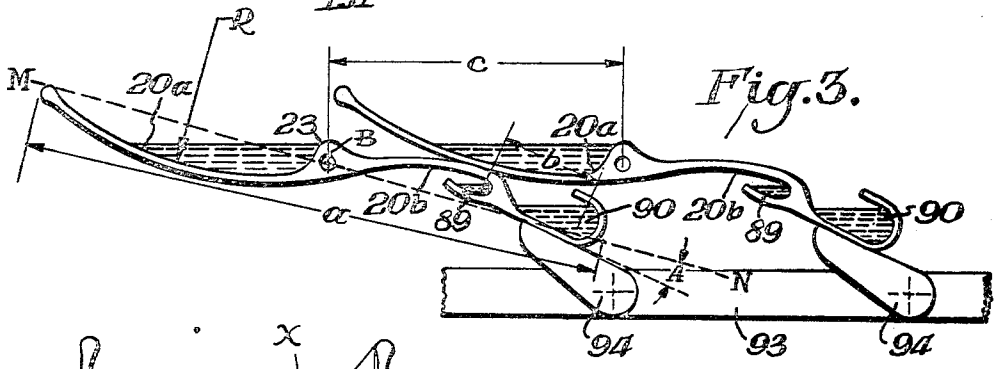
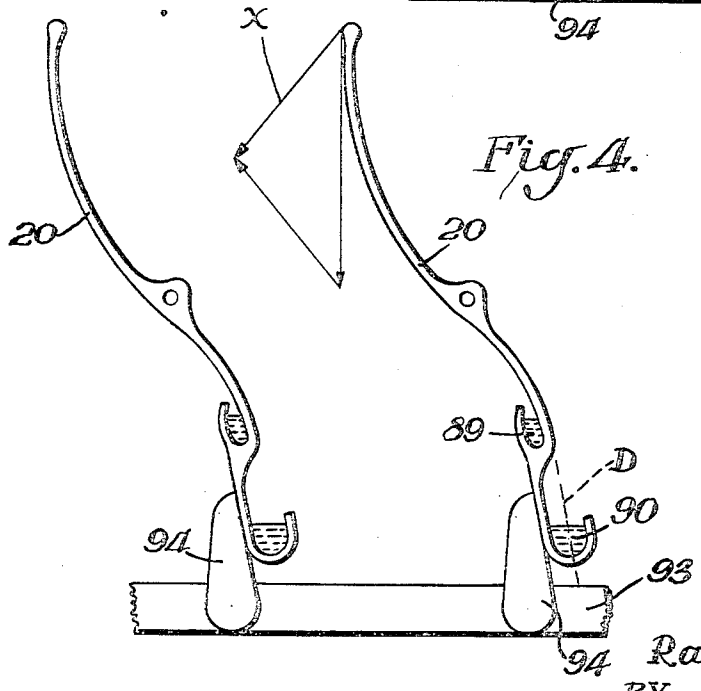


Fig. 3.

Fig. 4.



INVENTOR
Ralph T. Mathews
BY Harry J. McCauley
ATTORNEY

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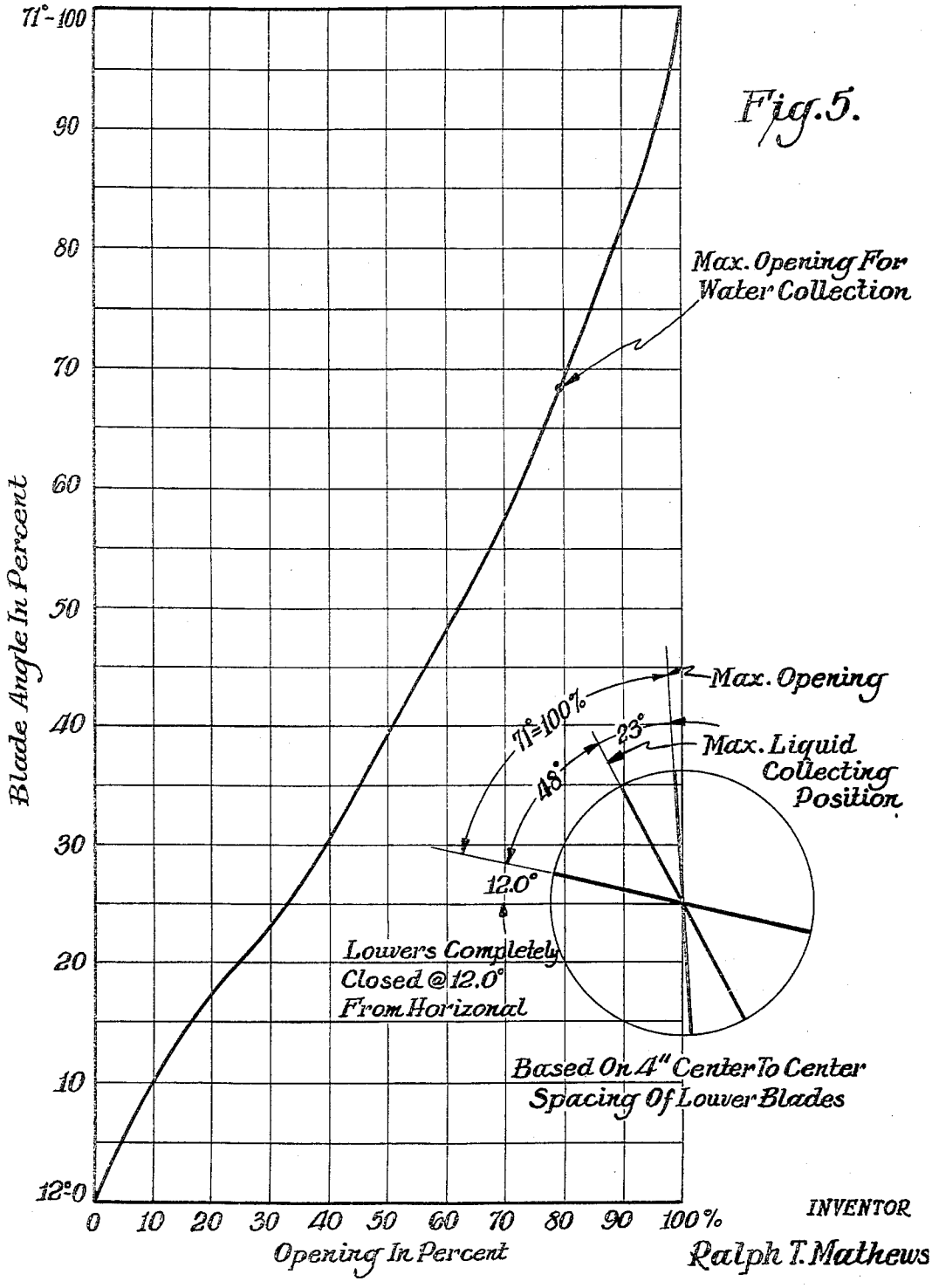


Fig. 5.

INVENTOR
Ralph T. Mathews
BY Harry J. McCauley
ATTORNEY

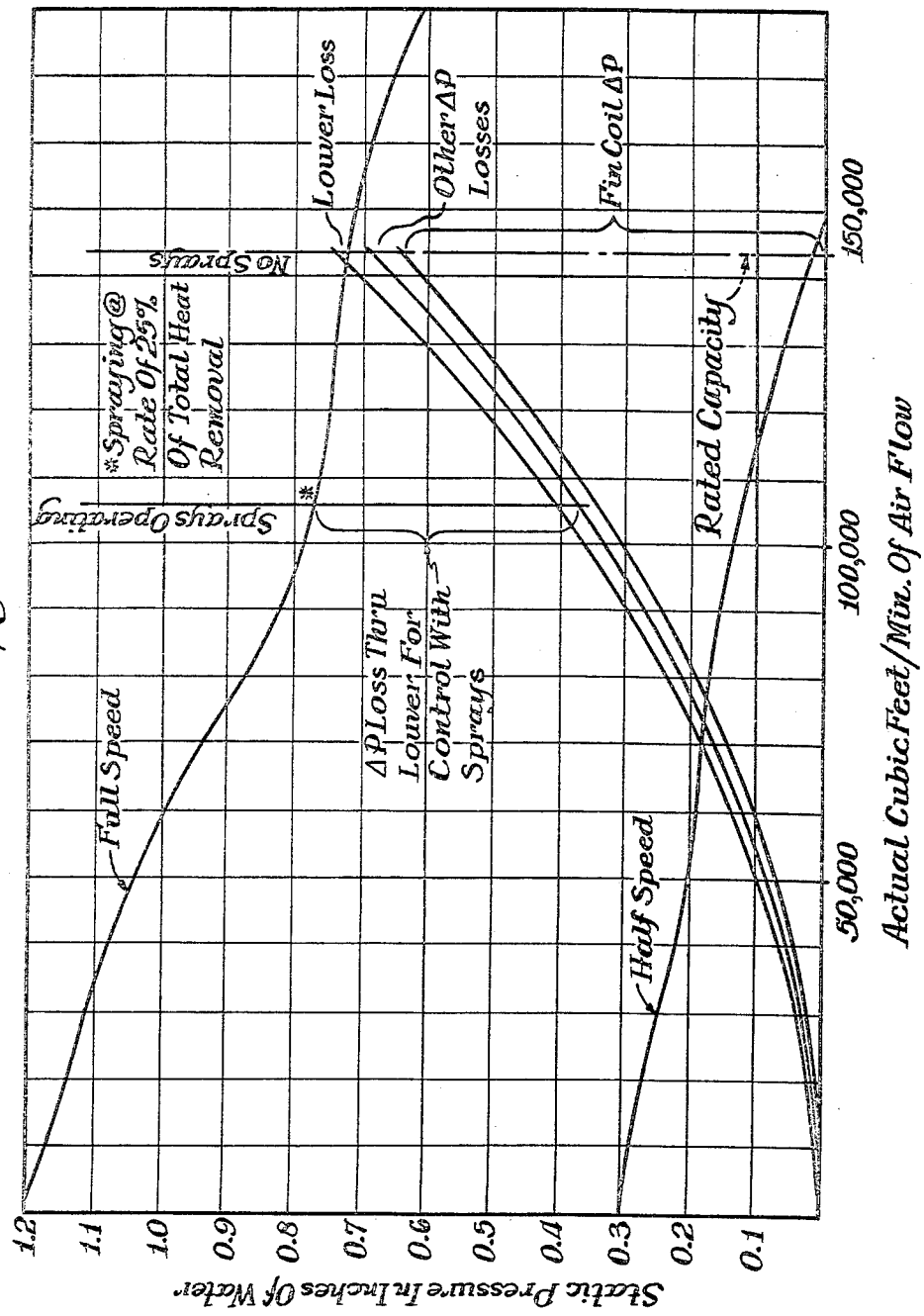


Fig. 6.

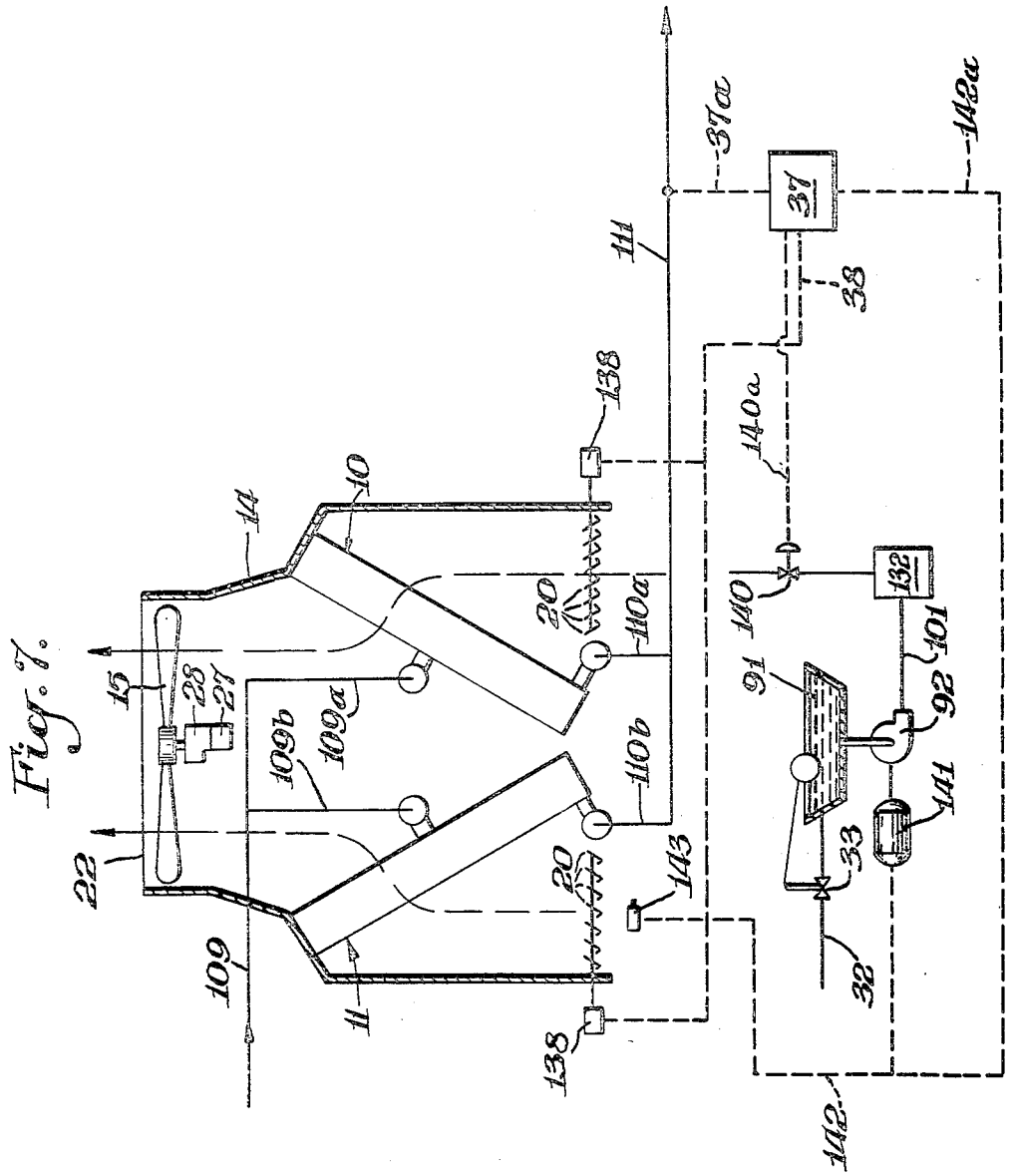
INVENTOR
Ralph T. Mathews
BY Harry J. McCauley
ATTORNEY

Nov. 25, 1969 R. T. MATHEWS 3,479,948

LOUVER

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Fig. 7.



INVENTOR
Ralph T. Mathews
BY
Harry J. McCauley
ATTORNEY

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3,479,948

LOUVER

Ralph T. Mathews, Wallingford, Pa., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

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Int. Cl. F24f *13/08;* F25d *21/14*
U.S. Cl. 98—121 3 Claims

ABSTRACT OF THE DISCLOSURE

An air flow-regulating louver shaped to an inwardly directed concave moisture-collecting transverse profile and provided with moisture-collecting gutter means on the leading edge.

CROSS REFERENCE TO RELATED APPLICATIONS

The louver of this invention is a particularly useful auxiliary for air-cooled heat exchangers of the design taught in U.S. application S.N. 524,712, now Patent No. 3,384,165, filed in the name of the same applicant.

BRIEF SUMMARY OF THE INVENTION

Generally, this invention comprises an elongated air-impervious member provided at the ends with journal means for rotation of the member about a line substantially co-parallel with the longitudinal axis of the member, the member being sigmoid-like, formed to an arcuate transverse cross-section presenting a concave liquid reception space on the inwardly directed trailing portion of the member and to a reverse arcuate transverse cross-section of relatively small convexity on the inwardly directed leading portion of the member, and gutter means on the leading edge entrapping liquid draining by gravity transverse the member.

DRAWINGS

The following drawings detail the construction and operation of a louver according to this invention, as to which:

FIG. 1 is a side elevation cross-sectional view of a typical air-cooled heat exchanger provided with the louvers,

FIG. 2 is a transverse cross-sectional view of the multiple louver installation alone shown in FIG. 1,

FIG. 3 is a transverse end view showing a pair of louvers according to this invention in fully closed position,

FIG. 4 is a transverse end view showing the pair of louvers of FIG. 3 in near fully open position,

FIG. 5 is a plot of opening in percent v. blade angle in percent for a preferred design of louver of this invention,

FIG. 6 is a plot of actual cubic feet/min. of air flow v. static pressure in inches of water for an air-cooled heat exchanger provided with a multiple louver air supply of this invention, and

FIG. 7 is a schematic automatic louver control diagram for an air-cooled heat exchanger shown in side elevation cross-section, as in FIG. 1.

DETAILED DESCRIPTION

There is a great need for moisture-collecting or otherwise protective louvers in cooling and ventilating practice, and especially in the cooling of chemical process fluids and the like by the use of air-cooled heat exchangers of the general design shown in FIG. 1, described in complete detail in said U.S. application Ser. No. 524,712.

Such heat exchangers comprise a pair of tube bundles indicated generally at **10** and **11**, respectively, mounted in upright V arrangement, preferably at a 60° included angle, the individual finned tubes of which can be advantageously relatively long (e.g., 36') and supported at intervals by horizontally disposed support straps (not here detailed) which space the tubes uniformly and stably, thereby insuring uniform cooling air throughput along the course indicated by the arrows. Process fluid to be cooled is circulated interiorly of the tubes, a wide variety of flow patterns being obtainable by the use of baffles or other flow regulators not detailed.

Cooling air is drawn through the exchanger by induction fan **15** driven by motor **27** through gear box **28**, which fan is supported on mountings (not shown) disposed across the mouth of stack opening **22** exhausting the air upwardly into the atmosphere. The entire apparatus is mounted within an open-bottomed housing indicated generally at **14**, to shield operation from the disturbing effects of drafts and unfavorable weather conditions, which housing is supported on elevating legs, indicated at **17**, which usually are mounted high overhead in order to allow open cool air access and discharge of the heated exhaust air remote from plant personnel and equipment.

It is highly desirable during periods of high ambient outside temperatures or humidities, which may occur approximately 5–10% of the time, or when an overload in terms of cooling demand exists, to supplement the ordinary cooling achieved by air transit past the finned tubes of tube bundles **10** and **11** with cooling water projected against the tubes by spray nozzles **100** supplied with water under pressure by pump **92** via supply lines **101** and **102**, with gravitational drainage return effected via gutters **103** and drain pipes **104** discharging into sump **91**.

It is usually necessary to employ spray water considerably in excess of the amount required for evaporative heat removal because: (1) excess water washes any solids or foreign material from the fin surfaces, thereby improving heat transfer, (2) water in excess of the evaporation rate prevents build-up of solids, thereby greatly reducing pitting type corrosion from galvanic cells and (3) circulation of excess water insures evaporative cooling closely approaching ambient air wet bulb temperatures, thereby obtaining lower outlet process fluid temperatures from the exchanger while using higher temperature inlet make-up water.

It is also occasionally necessary to cleanse the surfaces of the finned tubes of bundles **10** and **11** by spraying independently supplied water thereon, detergents or other adjuvants being added, to scrub away dust or incrustations deposited from evaporated cooling water, so that clean metal-to-cooling air contact is assured so far as practicable. Wetting agents are also advantageously added to the spray water, thereby obtaining thin wetted surfaces on the finned tubes contributing greater effectiveness in evaporative cooling and also better wetting of louver blade surfaces, thus improving drop collection, as the drop spatter is reduced and the water made to adhere as a liquid film.

The intermittent use of cooling water requires the employment of air flow-controlling louvers for the reasons hereinafter explained. Also, even though the bulk of the cooling water is retrieved by gutters **103**, there is always a residual water spray problem resulting from objectionable spray dissemination over personnel and neighboring plant equipment, which can have serious consequences, especially as regards electrical equipment in the area. Louvers according to this invention, seen in longitudinal side elevation at **20**, FIG. 1, are conjointly employed to entrap such spray, as well as even larger water accumulations, such as those arising from tube washing operations, heavy rainstorms or the like. To automatically drain collected water to a safe collection point, trough-like louvers **20** can be inclined inwardly, as indicated in FIG. 1, so as to discharge water by gravity run-off into sump **91**, which can be especially desirable from

the standpoint of water conservation, particularly in arid regions.

Referring to FIGS. 2, 3 and 4, the louvers are mounted within a squat, square cross-section breeching **88** located beneath the upright V tube bundle assembly and athwart the lowermost air passage of the apparatus, which is provided with a pair of end walls **88***a* upon which are pivotally mounted on common horizontal level E the co-parallel individual louvers **20**. These louvers have a length *a* (FIG. 3) of typically 8 7/16", measured tip-to-tip, and are spaced at uniform distances *c* apart of about 4", so that they overlap when closed, as will be apparent from the right-hand broken-line representation of a single louver shown in closed position in FIG. 2, but even more clearly in FIG. 3, which details the closed louver positional arrangement.

In FIG. 2 it will be noted that the left-hand louver **20'** is of shortened construction, so that it presents no interference troubles in the course of closure.

Louvers **20** are formed with reverse curvatures as regards the trailing blade portions **20***a* and the leading blade portions **20***b*, both being formed, typically, on 5" radii (R, FIG. 3). Blade portions **20***b* are provided with oppositely disposed U cross-section water collection gutters **89** and **90**, respectively, each serving an individual side of a louver **20** upon which it is mounted, these gutters also discharging into central sump **91** hereinbefore described.

Louvers **20** are operated in unison through bar connector **93**, which is provided with upstanding finger portions **94**, pinned to bar connector **93** and individually fixedly attached to the ends of the blade portions **20***b*, via actuating crank **95**, pinned to bar connector **93**, through a connecting linkage (not shown) at the right-hand end of the subassembly. In order to coordinate the actuation of the abbreviated right-hand louver with its neighbors, there is provided a short connector bar **96** securely attached through finger portions **97** to the tip ends of the two rightmost louvers shown in FIG. 2.

The ends of louvers **20** provided with the pivot pins permitting predetermined louver rotational positioning clear end walls **88***a* with a small spacing through which some water can leak. Preferably, the lower inside periphery of breeching **88** is fitted with an appropriately sloped, weld-attached angle iron gutter **152** defined by upstanding outboard angle iron legs **151**, which not only receives any water draining down the surfaces of the walls of breeching **88** but also any excess which may drain from the high-level ends of louvers **20**, as best seen in FIG. 1. This water is then drained to sump **91** via drain lines **153**.

In addition, water draining from the abbreviated right-hand louver **20** of FIG. 2 is preferably preliminarily collected within a V cross-section gutter **150** constituting also an air seal against the underside of which the adjacent full-size louver **20** bears. Gutter **150** is located approximately three-fourths of the way up the right-hand wall of breeching **88** and is slit at the ends (not shown) in order to drain moisture therefrom down the wall surface into gutter **152**.

A particularly preferred transverse louver cross-section is the relatively thin sigmoid defined by the angle A, FIG. 3, of approximately 10° extent. This angle is that included within the line tangent to the leading edge of the louver curling into gutter **90** and the line MN drawn tangent to the trailing tip of the louver and passing through the 282° point, referred to conventional polar coordinate axes, of a circle drawn about center B of the central boss **23** carrying the journal pins (not shown) constituting the means for preselected rotational positioning of the louver. Boss **23**, which incidentally provides a reinforcement adding structural strength, is disposed along the central longitudinal axis of the upper face of the louver, so as to constitute a retaining dike for water collected within the concavity of blade portion **20***a*. Also, boss **23** is disposed exclusively on the upper side of the louver, thereby eliminating any depending drip point on the underside, which could otherwise interfere with smooth drainage transverse the louver blade into gutter **89**. The trailing (uppermost) edges of the louver blades are shaped to a teardrop cross-section for increased blade strength with minimum increase in air flow resistance.

As shown in FIG. 3, the water collected within the concavity of blade portion **20***a* is somewhat exaggerated in amount as, usually, runoff to sump **91** safeguards against excessive water accumulation on the louvers. However, in any case, overflow occurring from boss **23** will still be collected within gutter **90** on the louver upper side, leading edge, which thus constitutes a moisture collection backup.

If desired, the lowermost ends of both gutters **89** and **90** can be provided with depending lips (not shown) which lead draining water smoothly into sump **91** without any possibility of reverse flow along the louver undersides. Also, if high service water levels are anticipated for these gutters, it is preferred to close off the high level ends remote from sump **91** with polymeric slip-on caps, which thus constitute dams barring flow of water out of the upstream louver extremities.

In this connection, it is preferred that gutter **90** extend well outboard from the continuation line of blade portion **20***b*, a very effective design being that shown for the right-hand louver of FIG. 4 in which a line D, drawn tangent to the convexity of blade portion **20***b* and parallel to the base line for angle A, FIG. 3, approximately bisects the gutter width. This insures entrapment of water sliding off the louver front side, even when it is draining at relatively high velocity. Gutter **89** can be relatively narrower, because draining conditions are not so severe here.

The water collecting action of louvers **20** is portrayed by the force vector diagram of FIG. 4, showing a pair of associated louvers in near full open position which results in virtually complete entrapment of any droplet water draining from tube bundles **10** or **11** in their upright V mounting, since the resultant of forces (gravitational and air supply velocity) acting on water drops, as shown schematically in FIG. 4, is a component of a force *x* directed against louvers **20** over a 12° to 60° range of blade settings of the louvers. Accordingly, the water droplets impinge on the louvers and drain via gutters **89** and **90** into sump **91**.

Extensive observation coupled with mathematical analysis has confirmed that the force vectors acting upon water droplets of, typically 1/16" dia. (or about 1600 microns) under a cooling air face velocity of 1200'/min. positively deflect the droplets across the space between louver blades of the proportions hereinbefore given to the trailing concave blade portions **20***a*. It will be understood that, as the blades rotate towards the closed position from that shown in FIG. 4, the air velocity increases through the blade-to-blade throat passage, thereby increasing the moisture collection action.

Louvers **20**, of course, have the dual purpose of not only collecting reject water as hereinbefore described but also of regulating air flow for best cooling utilization under conditions where: (1) dry air operation is the desirable mode or (2) during periods when cooling water is sprayed on the tubes as a supplementary measure.

Louvers having the general dimensions detailed are particularly preferred because of the near-linear relationship of opening in percent to blade angle in percent, plotted in FIG. 5. Such a linear relationship is highly advantageous from the standpoint of louver positioning control, because unit control adjustment enables corresponding unit louver positioning. The angular range of adjustment with the specific louvers described is sketched on the FIG. 5 plot, which shows complete closure of the louvers at a 12° clockwise displacement measured to line MN from the horizontal (X axis), with liquid collection achieved during the succeeding 48° of louver placement,

up to the maximum liquid collection position at the 60° point and maximum opening for air throughput at 83°.

As best seen in FIG. 4, the reverse curvature of the louver blades defines a variable cross-sectional venturi for the control of air flow with minimum pressure drop through the louver assembly. This is accomplished by the streamline flow of air into the venturi and the regain of static pressure at the blade discharge end, thereby reducing the net air pressure drop across the louver.

Progressive closing of the louver blades increases the projected horizontal area of the blades in the top half to collect water droplets by gravity while, at the same time, increasing the velocity of the air passage through the blade-defined venturis. This increased air velocity, plus the flat inclination to the vertical at which the air is flowing, deflects water droplets from their vertical trajectories caused by gravity towards the concave blade portions **20***a*, from whence the water drains by gravity to sump **91**.

The reverse curvature of the lower blades always establishes the minimum (venturi throat) opening near the center 50% expanse of blade width, which bars fine water spray downward escape through this throat section while deflecting large water droplets to the collection concavities of blade portions **20***a*.

The operating characteristics ascertained from a model of a typical multiple louver assembly such as hereinbefore described with particular reference to the air-cooled heat exchanger of FIGS. 1 and 2 is plotted in FIG. 6, which details the pressure drop losses due to (1) louvers **20**, (2) other (lumped) losses and (3) the fin coils for the conditions of both full and half blower speed. Thus, with dry air operation, i.e., with spray nozzles **100** shut off, a given cooling load is dissipated by 143,000 actual cubic feet of air flow with the development of a static pressure of 0.73" H_2O measured at the cooling fins. Now, if spray nozzles **100** are turned on to supply supplemental cooling by wetting the tube fins in an amount dissipating 25% of the heat load by water evaporation, the air flow requirement is quickly reduced to about 106,000 actual cubic feet/min. of air flow, or about 75% of the original requirement with air cooling solely. Louver **20** positioning to reduce the air flow from the first level to the second increases the trans-louver loss from about 0.05" H_2O to about 0.39" H_2O, or about eight times the original pressure drop. The blade regulatory position necessary to achieve this must now be altered from near full open position to a position well within the angular range (refer FIG. 5) for water collection. Under these circumstances the increased pressure drop across the louvers coupled with the change in the attack angle of the blades accelerates the air flow to a higher velocity through the louver venturis. This prevents escape of water droplets downward therefrom without their coming into contact with the louver blade surfaces, to thereby form a film of water which is either blown upwardly off the blades as atomized droplets or drains off into gutters **89** and **90**. It is thus seen that the louver air flow regulating action simultaneously establishes ideal conditions producing water droplet throwout.

Moreover, progressive closing of the louver blades to the fully closed state of FIG. 3 presents a larger water collection volume which is particularly advantageous for the recovery of large water amounts which must be accommodated when heavy water washing is periodically resorted to in order to scrub dirt and insects from the fin coils, or to recirculate detergent solutions employed for most efficient cleansing action. A particularly effective cleaning procedure is to locate special cleaning spray nozzles above the finned tubes and oriented in the direction of the tubes inside the V defined by tube bundles **10** and **11**. Then, if the rotation of fan **15** is temporarily halted, wash water can be collected in sump **91** and recycled or run to the sewer, as desired, after which the apparatus can be restored to service when the fin washing is completed.

It is usually the best engineering practice to distribute the air-moving load between a plurality of side-by-side mounted fans **15** disposed lengthwise of the same heat exchanger tube bundles **10** and **11**, which can then be isolated as individual cells one from another by curtain walls extending from top to bottom inside the V defined by tube bundles **10** and **11**, leaving the outside space as an open interconnection between fan cells. Such an arrangement permits convenient exhaust of reversely propelled air out of individual fan cells during occasional cleanings horizontally through the interconnections between neighboring units, and thence upwardly out of these in the normal flow pattern shown by the arrows of FIG. 1, the wash water being then collected as fall out on louvers **20**.

It sometimes happens that cooling tubes leak or break and discharge inflammable or explosive process materials into housing **14**. When this occurs, emergency full closure of louvers **20** to FIG. 3 position isolates the dangerous substances, while simultaneously diluting them with cooling water. This tends to extinguish fires by both cooling and drowning action and is a highly advantageous incidental feature of my invention.

It is sometimes desirable to shield heat exchangers of the general design shown in FIGS. 1 and 2 from the effects of driving rain, intense sunlight or high winds entering via stack opening **22**. A louver assembly such as that detailed in FIG. 2 is well-adapted to this service and can be mounted above opening **22**, either alone or together with a separate louver assembly mounted as hereinbefore described across the bottom air ingress. It will be understood that the operation of the two louver assemblies will then be entirely independent of each other, the upper one being normally full open and partially closed only when adverse weather conditions require. It is desirable to provide a separate water reception sump for the exit end louvers, since rain water often contains adulterants, or at least is not carefully pre-conditioned, as is usually preferred for the cooling spray nozzle **100** water.

As hereinbefore mentioned, supplementary water spraying is not resorted to as the usual operating mode; however, where exceedingly high dry bulb air temperatures occur over protracted periods, or where manufacturing requirements temporarily necessitate preselected extraordinary amounts of cooling, it is highly advantageous to resort to spray supplementation. Moreover, since upward air flow in the direction indicated by the arrows in FIGS. 1 and 7 is usually provided on a modular basis by a plurality of independently operated induction fans **15** disposed in parallel one to another with respect to the relatively long-length tubes of bundles **10** and **11**, it is practicable to shut down individual fans for repairs or maintenance while taking over the cooling load by water spray cooling supplementation as regards the remaining modules.

Referring to FIG. 7, from which spray nozzles **100** are omitted for simplicity, there is shown a typical automatic louver control system adapted to accommodate both dry air operation and water spray supplementation.

In this instance, the hot process fluid is introduced to the heat exchanger via line **109**, which is divided into separate branches **109***a* and **109***b* leading to the inboard tubes of tube bundles **10** and **11**, respectively. A box header construction, as taught fully in said application Ser. No. 524,712, routes the flow into the plane of the figure and then on a reverse course. This produces a cooled product fluid withdrawn from lines **110***a* and **110***b*, which latter are manifolded into line **111**.

Supplementary spray water is supplied from sump **91**, which collects spray water recovered via gutters **103** and louvers **20**, any fresh make up water being obtained from line **32** connected through float control valve **33**. Spray water is pumped from the bottom of sump **91** by pump **92** driven by electric motor **141**, the water being circulated

in sequence through line **101**, filter **132**, and water delivery throttling valve **140** to spray nozzles **100** (not shown in FIG. 7). Drive motor **141** for pump **92** is placed in power circuit via signal line **142** provided with an electrical thermal switch **143** disposed in the heat exchanger air intake passage. Thus, when the intake air attains a temperature too high for effective cooling, thermal switch **143** closes the power circuit to drive motor **141** to commence supplementary water spraying. If desired, for increased control flexibility, as the ambient air temperature increases, temperature controller **37** can be made to modulate the supply of cooling water delivered through throttling valve **140** by control imposed via signal line **140***a*.

Direct air flow restriction is effected by conventional pneumatic temperature controller **37**, which operates in the usual 3–15 p.s.i. instrument air pressure range, for control of louver blades **20** throughout their full rotational range for dry air cooling depending upon ambient air temperatures with the upper portion of the 3–15 p.s.i. range being utilized during high ambient air temperatures for essentially full-open blade **20** disposition under the usual condition where dry air cooling is the operating mode, whereas the 3–10 lbs. portion is then reserved to water spray supplementation as hereinafter detailed. Rotational positioning of louvers **20** from full open to closed position is effected by direct-connected air-powered actuators **138** responsive to controller **37** via line **38**. Temperature controller **37** in turn is under the general operating pressure range control of air temperature switch **143** via signal line **142***a*, which constrains controller operation to the 3–10 p.s.i. range reserved for spray supplementation operation. However, the primary control is that achieved by sensing of the temperature of process fluid product delivered via exchanger discharge line **111**, to which controller **37** is connected via temperature sensing line **37***a*.

From the foregoing, it will be understood that this invention can be modified extensively within the skill of the art without departure from its essential spirit and it is accordingly intended to be limited only within the scope of the following claims.

What is claimed is:

1. An inclined air flow-regulating louver comprising an elongated air-impervious member provided at the ends with journal means for rotation of said member about a line substantially co-parallel with the longitudinal axis of said member, said member being formed to an arcuate transverse cross-section presenting a concave liquid reception space on the upper inwardly directed trailing portion of said member and to a reverse arcuate transverse cross-section of relatively small convexity on the lower inwardly directed leading portion of said member, first gutter means on the leading edge entrapping liquid draining by gravity transverse said member and second gutter means on the opposite side of said louver from said first gutter means and adjacent thereto for collecting transverse gravity runoff from the opposite face of said member.

2. An air flow-regulating louver according to claim **1** wherein said journal means are disposed to provide an inclination of said member to the horizontal, maintaining gravity runoff of liquid collecting on said member.

3. An air flow-regulating device comprising, in combination, a plurality of inclined substantially co-parallel louvers each comprising an air-impervious member provided at the ends with journal means for rotation of said member about a line generally co-parallel with the longitudinal axis of said member, said journal means being disposed in a substantially common plane, each said member being formed to an arcuate transverse cross-section presenting a concave liquid reception space on the upper inwardly directed trailing portion of said member and to a reverse arcuate transverse cross-section of relatively small convexity on the lower inwardly directed leading portion of said member, first gutter means on the leading edge entrapping liquid draining by gravity transverse said member and second gutter means on the opposite side of said louver from said first gutter means and adjacent thereto for collecting transverse gravity runoff from the opposite face of said member, said louvers being journaled in said common plane at spacings such that adjacent edges overlie one another in a direction perpendicular to said common plane when said louvers are in air flow close-off position.

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MEYER PERLIN, Primary Examiner

U.S. Cl. X.R.

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