The present invention relates to a heat transfer element comprising two opposed essentially rectangular plates (2, 4), joined together along essentially all sides (8, 10), but with channels between them for a flow of heat transfer medium. An essential feature of the invention is that the channels (14) of the element are tube-like and that the plates (2, 4) are attached to each other by seams (6), essentially parallel with the sides (8) of the plates.
## FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

<table>
<thead>
<tr>
<th>Code</th>
<th>Country</th>
<th>Code</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT</td>
<td>Austria</td>
<td>GB</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>AU</td>
<td>Australia</td>
<td>GE</td>
<td>Georgia</td>
</tr>
<tr>
<td>BB</td>
<td>Barbados</td>
<td>GN</td>
<td>Guinea</td>
</tr>
<tr>
<td>BE</td>
<td>Belgium</td>
<td>GR</td>
<td>Greece</td>
</tr>
<tr>
<td>BF</td>
<td>Burkina Faso</td>
<td>HU</td>
<td>Hungary</td>
</tr>
<tr>
<td>BG</td>
<td>Bulgaria</td>
<td>IE</td>
<td>Ireland</td>
</tr>
<tr>
<td>BJ</td>
<td>Benin</td>
<td>IT</td>
<td>Italy</td>
</tr>
<tr>
<td>BR</td>
<td>Brazil</td>
<td>JP</td>
<td>Japan</td>
</tr>
<tr>
<td>BY</td>
<td>Belarus</td>
<td>KE</td>
<td>Kenya</td>
</tr>
<tr>
<td>CA</td>
<td>Canada</td>
<td>KG</td>
<td>Kyrgyzstan</td>
</tr>
<tr>
<td>CF</td>
<td>Central African Republic</td>
<td>KP</td>
<td>Democratic People's Republic of Korea</td>
</tr>
<tr>
<td>CG</td>
<td>Congo</td>
<td>KR</td>
<td>Republic of Korea</td>
</tr>
<tr>
<td>CH</td>
<td>Switzerland</td>
<td>KZ</td>
<td>Kazakhstan</td>
</tr>
<tr>
<td>CI</td>
<td>Côte d'Ivoire</td>
<td>LI</td>
<td>Liechtenstein</td>
</tr>
<tr>
<td>CM</td>
<td>Cameroon</td>
<td>LK</td>
<td>Sri Lanka</td>
</tr>
<tr>
<td>CN</td>
<td>China</td>
<td>LV</td>
<td>Luxembourg</td>
</tr>
<tr>
<td>CS</td>
<td>Czechoslovakia</td>
<td>MC</td>
<td>Monaco</td>
</tr>
<tr>
<td>CZ</td>
<td>Czech Republic</td>
<td>MD</td>
<td>Republic of Moldova</td>
</tr>
<tr>
<td>DE</td>
<td>Germany</td>
<td>MG</td>
<td>Madagascar</td>
</tr>
<tr>
<td>DK</td>
<td>Denmark</td>
<td>ML</td>
<td>Mali</td>
</tr>
<tr>
<td>ES</td>
<td>Spain</td>
<td>MN</td>
<td>Mongolia</td>
</tr>
<tr>
<td>FI</td>
<td>Finland</td>
<td>MR</td>
<td>Mauritania</td>
</tr>
<tr>
<td>FR</td>
<td>France</td>
<td>MW</td>
<td>Malawi</td>
</tr>
<tr>
<td>GA</td>
<td>Gabon</td>
<td>NE</td>
<td>Niger</td>
</tr>
<tr>
<td>NL</td>
<td>Netherlands</td>
<td>NO</td>
<td>Norway</td>
</tr>
<tr>
<td>NZ</td>
<td>New Zealand</td>
<td>PL</td>
<td>Poland</td>
</tr>
<tr>
<td>PT</td>
<td>Portugal</td>
<td>RO</td>
<td>Romania</td>
</tr>
<tr>
<td>RU</td>
<td>Russian Federation</td>
<td>SD</td>
<td>Sudan</td>
</tr>
<tr>
<td>SE</td>
<td>Sweden</td>
<td>SI</td>
<td>Slovenia</td>
</tr>
<tr>
<td>SK</td>
<td>Slovakia</td>
<td>SN</td>
<td>Senegal</td>
</tr>
<tr>
<td>TG</td>
<td>Togo</td>
<td>TJ</td>
<td>Tajikistan</td>
</tr>
<tr>
<td>TT</td>
<td>Trinidad and Tobago</td>
<td>UA</td>
<td>Ukraine</td>
</tr>
<tr>
<td>US</td>
<td>United States of America</td>
<td>UZ</td>
<td>Uzbekistan</td>
</tr>
<tr>
<td>VN</td>
<td>Viet Nam</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
FALLING FILM EVAPORATOR

The present invention relates to a falling film evaporator comprising
- a shell with a plurality of evaporator elements arranged therein, each element being
formed by two vertical, essentially rectangular heat transfer plates;
- means for feeding the liquid to be evaporated so as to flow downwards as a thin film
along the outer surfaces of the evaporator elements; and
- means for directing steam to the inside of the evaporator elements and for discharging
formed condensate from the inside.

A well-known falling film evaporator apparatus comprises evaporator elements made of
two metal plates so that the plates are attached to each other not only by their edges but
also by certain dot-like places. In a complete heat transfer element the flow channel for
the heat transfer medium is thereby formed in areas between these dot-like places, i.e.
in areas where the plates are separated from each other. This kind of elements have been
formed by placing a pair of plates between studded support plates, the studs of which
define the position of the dot-like fastening spots, dimples, of the heat transfer elements.
The plates are then separated from each other by means of internal hydrostatic pressure.

US patent 3,736,783 discloses an apparatus for manufacturing heat transfer elements, the
apparatus comprising a fixed bottom part and an upper part, movable along tracks onto
the lower part once a pair of heat transfer plates has been located in the lower part. The
fixed bottom part comprises an upwards opening box-like space containing an inflatable
bag. A piston plate supported by this bag can be moved vertically. The piston plate in
turn supports a studded plate, the studs of which are directed upwards. When the pair of
plates has been positioned between the studded plates, it is pressed against the upper part
of the apparatus by filling the bag with, e.g. water, causing the piston plate to move
upwards. In order to form flow channels, the plates are separated from each other by
means of hydraulic pressure, i.e. by directing pressurized water between plates, whereby
the plates are separated from each other in other places except at the edges and the dot-
like places where the studs prevent expansion and maintain the plates in contact. The
plates can be spot-welded to increase strength at the dimples, between which flow channels were formed.

The heat transfer elements described above are often used in evaporators, in which – in case it is a falling film apparatus – the liquid to be evaporated is directed to flow along the outer side of the element and steam is directed to flow inside the element in the channels between the dimples. Evaporators often operate in high steam pressures, e.g. about 4 bar, which places a great stress on the dot-like fastening points, and can even break the fastening. Even though the elements are always pressure tested at pressures exceeding the projected operating pressures, it is still reasonable to develop more pressure resistant heat transfer elements. This is especially necessary because of the tendency towards higher operating pressures, because of the advantages brought about by increased steam pressure.

The object of the present invention is to provide a falling film evaporator, with an essentially more pressure resistant evaporator element structure than that of the present designs.

A characterizing feature of an evaporator according to the invention is that the heat transfer plates of each of the evaporator element are joined together along the upright edges and seam joints, parallel with the upright edges and located within a distance from each other, thus forming tube-like flow channels for steam inside the element.

According to an advantageous embodiment of the invention the seam joints do not extend quite from one to the other end of the plate, but feed and discharge chambers, perpendicular to the seams and thus also to the flow channels, are formed for feeding and discharging steam at the ends of the element. These chambers communicate with the flow channels.

According to another advantageous embodiment of the invention, the seam extends the whole length of the plates. In this case, the chambers for directing steam are formed by
joining, preferably by welding, a separate tubular chamber at both the upper and lower edges of the pair of plates.

The feed chambers of each heat transfer element communicate with a header for directing steam from the steam ducts to the elements. Correspondingly, discharge chambers communicate at the lower end of the elements with steam and condensate discharge conduits.

For operating the evaporator, steam is led to a feed chamber located at the upper end of the element, the chamber communicating with each of the upright flow channels formed between the seams. Steam is divided into the flow channels and the formed condensate is discharged from the lower end of the element via a discharge chamber communicating with all the flow channels. Advantageously, steam is fed into the feed chamber via both of its ends, i.e. from two directions, which enables the size of the chamber to be kept small.

When the evaporator elements are installed within the shell of the evaporator, the feed chambers of adjacent elements can form a distribution box for the liquid to be evaporated, because the feed chambers are located so near to each other. Thus, a conventional distribution box is unnecessary. The feed chamber can also act as a mechanical support member of the element within the evaporator, whereby the ends of the chamber are installed at support lugs arranged in the shell of the evaporator.

The seams limiting the tube-like channels are narrow, about 5–15 mm in width. The seams are located within 15–30 mm from each other.

The joining seams between the flow channels of the evaporator elements can be formed either by continuous or spot welding. Should spot welding be used, the weld spots almost contact adjacent ones. In some cases it can be advantageous to break a continuous seam for forming an opening between the flow channels for pressure regulating reasons.
If desired, steam can also be fed from the bottom of the element, in which case condensate is discharged the same way as when feeding steam from the top, but steam is discharged from the top of the element.

In the following, the invention is disclosed in more detail by way of reference to the accompanying figures, of which

Fig. 1 is an illustration of a pair of plates joined together for forming an evaporator element according to the invention;

Fig. 2 shows the cross-section along line A-A in figure 3;

Fig. 3 is a profile view of an evaporator element formed by a pair of plates illustrated in fig. 1; and

Fig. 4 shows an evaporator according to the invention.

Fig. 1 discloses a pair of plates to be used in an evaporator according to the invention. The superimposed plates 2 and 4 are rectangular and symmetrical. Evaporator elements are formed by two metal plates, the thickness of which is usually 1–1.5 mm. The plates are usually welded together continuously parallel with the longer seams of the plates for forming seams 6. The seams do not extend the whole length of the edge 8, but the plates are left unjoined at both ends, so as to enable forming of perpendicular channels between the plates. These channels, one of which is located at the lower end of the element and the other at the upper end, are parallel with the ends 10 of the plate. After this, the plates are joined together by continuous welding along all edges, i.e. sides 8 and ends 10. Thus, a tight and pressure resistant seam 12 is formed around the element along its the edges.

Because the evaporating element is installed during operation so that the channels between seams 6 are upright, the edges 8 form the sides and edges 10 form the upper and lower ends of the element.

The welded pair of plates is then installed in an inflation apparatus (not shown) for opening it and thus defining the final form of the evaporator element. The apparatus
comprises an upper element and a lower element. A piston assembly is connected with
the lower element.

Prior to being inserted in the inflation apparatus, the pair of element plates is placed
between support plates of the same shape and at least the same size as the heat transfer
plates. The support plates comprise longitudinal protrusions, the length and width of
which correspond to the dimensions of the seams 6 of the pair of plates. The pair of
plates is loaded between support plates so that the protrusions face the heat transfer
plates and are located on the seams 6. The pair of plates is transported to the space
between the upper and lower element on an inflation table by means of, e.g. a transport
jig. The piston assembly is hydraulically pressurized as much as necessary, whereby the
piston plate presses the pair of plates against the upper element.

Subsequent to this, the pair of heat transfer plates is actually inflated. Pressurized water
is led between the pair of plates via an opening (not shown) in the seam 12. The
pressure of the water is sufficient to slightly exceed the yield limit of the plate material.
Water is allowed to flow via the space between the end 10 of the plate and seams 6 into
channels between seams 6. The pressure is regulated so as to be sufficient to separate the
plates in all places except seams 6, which are additionally supported by the protrusions
of the support plates. The continuous welds along sides 10 are not supported during
opening, but they will easily withstand a rigorous pressure test.

When the heat transfer plates have been inflated to desired degree, pressure is released
from the element and the piston assembly.

The inflation of the pair of plates produces an element 11, illustrated in figs. 2 and 3. In
the element, the plates 2 and 4 are separated from each other in every other place except
at the welded sides 8 and 10 and seams 6. A plurality of adjacent tube-like channels 14
have been formed between the seams 6, and it is these channels that enable the flow of
heating medium, such as steam, to flow from inlet to outlet. Chambers 16 and 18 are
arranged essentially perpendicularly to the channels 14 for inlet and outlet of steam into
and from the channels 14. The seams between the channels can be welded so that they
extend the whole length of the plate, in which case the chambers 16, 18 are formed by welding tubes, preferably round in profile, to both the upper and lower ends of the pair of plates. The length of the tube is such that the element can be supported by it, hanging on support lugs arranged on the shell of the evaporator.

Fig. 2 illustrates a cross-section, in which the profile of a flow channel is wave-like (two waves positioned opposite each other). The cross-section profile of an open tube-like channel is not limited to this, but the profile can be e.g. round or elliptical. The profile of the channel depends on, among other factors, the plate material and other circumstances during forming, such as pressure.

The complete element is pressure tested and inlet and outlet openings 20, 22 are cut for the medium flowing inside the element.

Fig. 4 shows an evaporator according to the invention, the heat transfer surface of which comprises the above-described elements. Single elements are collected together for one evaporator (e.g. 30 elements) beside each other into assembly jigs, in which they are transported and handled during the manufacture phases of an evaporator unit. In the first phase the steam header 24, condensate header 26 and notched space bars 28 are welded on place in the plate module. Subsequent to this, steam inlet conduit and condensate outlet conduit are welded on the module. A plurality of modules are installed inside a pressure vessel, the shell 34 of the evaporator, to form an "evaporator package".

The steam is fed into the evaporator inlet header 24 via conduit 31. Inside each element, steam flows into the inlet chambers 16, and from there further to flow channels 14. Outlet steam and condensate are discharged from the evaporator via outlet chamber 18 into outlet header 26, from which steam is discharged via conduit 33 and condensate via conduit 35. Evaporated liquid is discharged via conduit 37.

The liquid to be evaporated is fed to the upper part of the elements, from which it flows downwards on the outside of the element, boiling. Fig. 4 shows a conventional distribution box 32 arranged above the elements, the bottom of which is provided with
perforation for allowing the liquid to flow onto the surface of the elements. The
distribution box is not, however, essential, because the liquid can also be distributed
directly into the upper part of the plates, if the inlet chambers 16 of the plates are so
close to each other that they form an effective liquid distributor.

As has been shown in the above, the invention is capable of producing a flow channel
structure far exceeding prior art structures in durability. The invention is not limited to
the embodiment described above, but its details can be varied within the scope of the
invention defined in the appended claims.
WE CLAIM:

1. A falling film evaporator, comprising
   – a shell (34) with a plurality of evaporator elements (11) arranged therein, each of
   which is formed by two upright, essentially rectangular heat transfer plates (2, 4);
   – means (32) for feeding the liquid to be evaporated to flow down on the outer surfaces
     of the evaporator elements as a thin film; and
   – channels (31, 33, 35) communicating with the inside of the evaporator elements for
     feeding steam and discharging steam and formed condensate, characterized in that the
     heat transfer plates (2, 4) of each evaporator element (11) are joined together along both
     their upright edges (8) and seams (6), parallel with the upright edges and located within
     a distance from each other for forming tube-like flow channels (14) inside the element
     for steam.

2. An evaporator according to claim 1, characterized in that the seam joints
   (6) separating the upright channels (14) are shorter than the plates (2, 4) forming the
   element, whereby inlet and outlet chambers (16, 18) are formed perpendicular to the
   upright channels (14) for directing and discharging steam to and from the upright
   channels (14), with the chambers communicating with conduits (31, 33, 35) for directing
   steam to and discharging steam and formed condensate from the channels (14).

3. An evaporator according to claim 1, characterized in that the joint seams
   (6) separating the upright channels (14) are essentially as long as the plates forming the
   element, whereby inlet and outlet chambers have been attached to the upper and,
   correspondingly, lower edges of the element for directing steam in and discharging steam
   and condensate from the elements.

4. An evaporator according to claim 2 or 3, characterized in that the inlet and
   outlet chambers (16, 18) of each element communicate with steam inlet and outlet
   conduits (31, 35) via headers (24, 26).
5. An evaporator according to claim 2 or 3, characterized in that steam is directed into evaporator elements via both ends (20) of the inlet chamber (16).

6. A heat transfer element according to claim 1, characterized in that at least one opening has been arranged into the seams (6) between the channels (14) for regulating pressure in the channels.
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

**IPC6:** B01D 1/22, B01D 1/06, F28F 3/14  
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

**IPC6:** B01D, F28F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>US, A, 4422899 (PENTTI JUHLA ET AL), 27 December 1983 (27.12.83), column 1, line 62 - column 2, line 9; column 2, line 14 - line 16; column 2, line 60 - line 68, column 3, line 28 - line 30, figure 1</td>
<td>1-2</td>
</tr>
<tr>
<td>Y</td>
<td>EP, A1, 0567393 (COMMISSARIAT A L'ENERGIE ATOMIQUE), 27 October 1993 (27.10.93), column 1, line 1 - line 3; column 1, line 17 - line 25; column 1, line 42 - line 53, column 6, line 62 - column 7, line 14, figure 1, 6A, 6B</td>
<td>1-2</td>
</tr>
<tr>
<td>A</td>
<td>EP, A1, 0110311 (FR. KAMMERER GMBH), 13 June 1984 (13.06.84), figure 1, abstract</td>
<td>1</td>
</tr>
</tbody>
</table>

[| Further documents are listed in the continuation of Box C. | See patent family annex. |

* Special categories of cited documents:
  * "A" document defining the general state of the art which is not considered to be of particular relevance.
  * "E" earlier document but published on or after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention.
  * "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified).
  * "O" document referring to an oral disclosure, use, exhibition or other means.
  * "P" document published prior to the international filing date but later than the priority date claimed.
  * "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention.
  * "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone.
  * "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
  * "&" document member of the same patent family.

**Date of the actual completion of the international search:** 29 May 1995

**Date of mailing of the international search report:** 14-06-1995

Name and mailing address of the ISA/Swedish Patent Office
Box 5055, S-102 42 STOCKHOLM
Facsimile No. +46 8 666 02 86

Authorized officer
Bengt Christensson
Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1992)
### INTERNATIONAL SEARCH REPORT

#### DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>US, A, 4076576 (LAURI TAPANI MARTTALA), 28 February 1978 (28.02.78), column 3, line 7 - line 49, figures 1,2</td>
<td>1</td>
</tr>
<tr>
<td>A</td>
<td>US, A, 4683025 (A. ROLAND FLORES), 28 July 1987 (28.07.87), figure 2, claim 4</td>
<td>1</td>
</tr>
<tr>
<td>A</td>
<td>US, A, 3331436 (T.F. PAULS), 18 July 1967 (18.07.67), column 1, line 19 - line 39, figures 2, 5</td>
<td>1</td>
</tr>
</tbody>
</table>

---

Form PCT/ISA/210 (continuation of second sheet) (July 1992)
<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DE-C,C- 3134435</td>
<td>12/10/89</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FR-A,B- 2474647</td>
<td>31/07/81</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SE-B,C- 427240</td>
<td>21/03/83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SE-A- 8105609</td>
<td>23/09/81</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO-A- 8102112</td>
<td>09/08/81</td>
</tr>
<tr>
<td>EP-A1- 0110311</td>
<td>13/06/84</td>
<td>SE-T3- 0110311</td>
<td>14/06/84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE-A,C,C- 3243713</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>US-A- 4687053</td>
<td>18/08/87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO-A- 8402178</td>
<td>07/06/84</td>
</tr>
<tr>
<td>US-A- 4076576</td>
<td>28/02/78</td>
<td>CA-A- 1032465</td>
<td>06/06/78</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FR-A,B- 2297658</td>
<td>13/08/76</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SE-B,C- 410556</td>
<td>22/10/79</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SE-A- 7600478</td>
<td>21/07/76</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SU-A- 1069602</td>
<td>23/01/84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FR-A- 2594043</td>
<td>14/08/87</td>
</tr>
<tr>
<td>US-A- 3331436</td>
<td>18/07/67</td>
<td>FR-A- 1400722</td>
<td>00/00/00</td>
</tr>
</tbody>
</table>