United States Patent

[11] 3,612,175

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[21] Appl. No. 838,172
[22] Filed July 1, 1969
[45] Patented Oct. 12, 1971
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[54] **CORRUGATED METAL TUBING**
6 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **165/179,** 138/38
[51] **Int. Cl.** **F28f 1/42**
[50] **Field of Search** 138/38; 165/177, 179, 156

[56] **References Cited**

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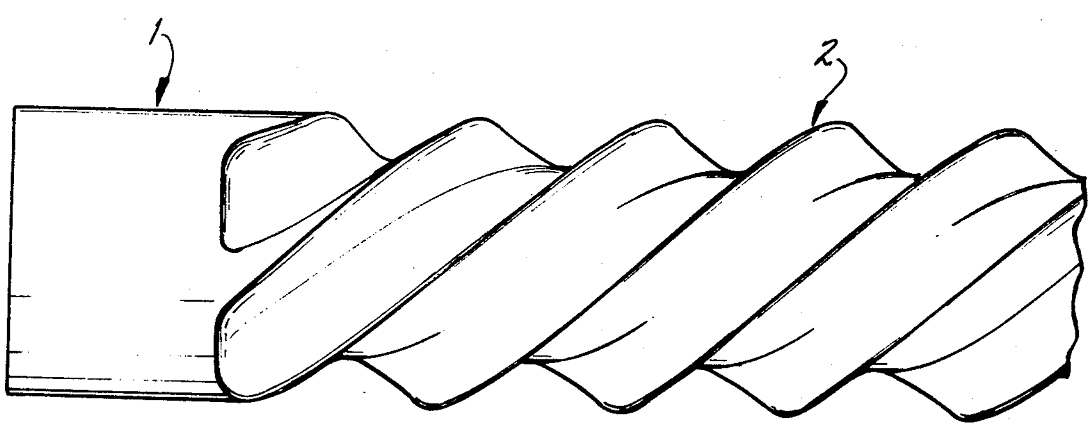
ABSTRACT: The instant disclosure teaches an improved corrugated metal tubing having an improved heat-transfer coefficient and having a plurality of lands and grooves extending along the circumference thereof. The grooves comprise at least two independent, continuous grooves extending helically along the circumference of the tube, with each groove being in spaced relationship to each other. Improved heat transfer is obtained by providing that the land width, the groove width and the angle of advance of the helically extending grooves are related in a particular defined manner.



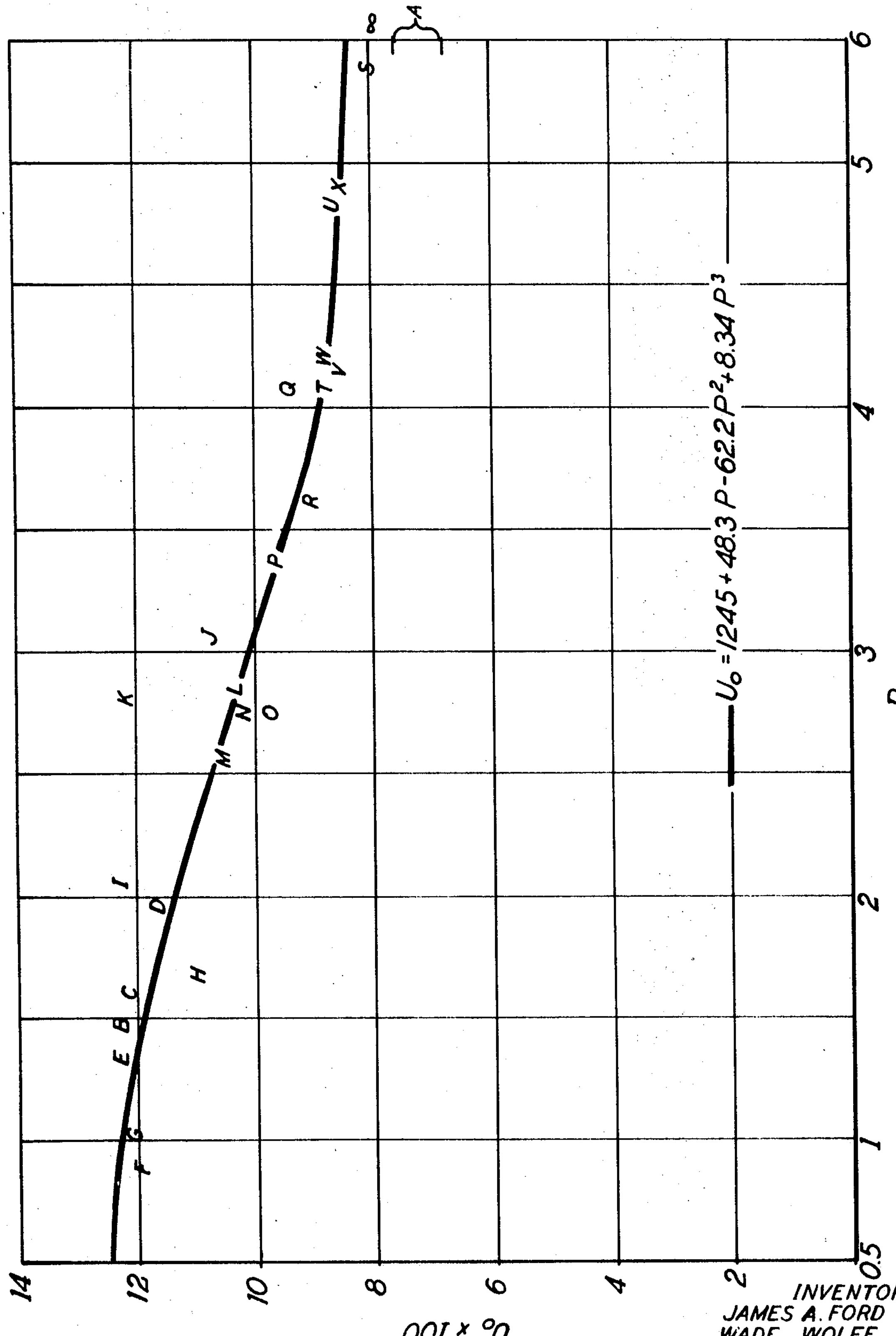


FIG. 1

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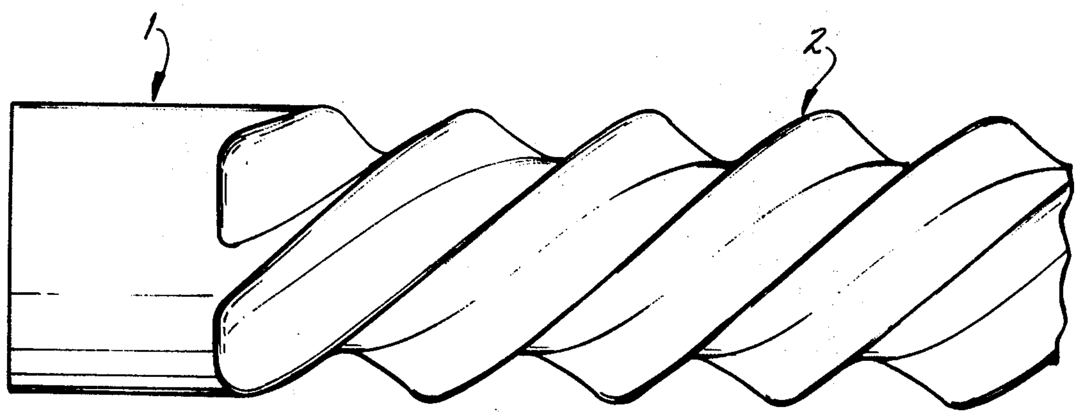

FIG- 2

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CORRUGATED METAL TUBING

The production of potable water from saline water requires extensive quantities of heat-transfer surface in the form of condenser tubing. Estimates have variously placed the capital investment involved with the heat exchange surface in desalting plants at as much as 50 percent of the total.

Accordingly, it becomes extremely pertinent in the continuing efforts to reduce the cost of potable water that the cost of the heat-transfer surface be reduced. It is known in the art that corrugated tubing or surface enhancement provides an improved heat-transfer coefficient as compared to a plain cylindrical tube.

It is further well known that large amounts of cooling water, sea water in the case of desalting apparatus, must be pumped through condenser tubing. Surface enhancement always leads to increased pumping requirements because the pressure drop, ΔP, on the inside of the condenser tubes is increased by the surface enhancement. Thus it becomes highly desirable to provide for improved condenser tubing in which the heat transfer is maximized but the increase in the pressure drop kept as low as practical.

It is highly desirable, however, to provide still further improvement in this art.

Accordingly, it is a principal object of the present invention to provide an improved metal tubing.

A further object of the present invention is to provide a large increase in heat transfer with a minimum increase in pressure drop.

It is a still further object of the present invention to provide an improved tubing as aforesaid which achieves a surprisingly high heat-transfer coefficient at a reasonable cost.

Still further objects and advantages of the present invention will appear from the ensuing specification, especially when taken into consideration with the accompanying drawings, wherein:

FIG. 1 graphically represents heat-transfer data from the examples which form a part of the present specification; and

FIG. 2 shows a side view of a portion of representative tubing of the present invention.

In accordance with the present invention it has now been found that the foregoing objects and advantages may be readily achieved and a metal tubing with improved heat transfer provided. The tubing of the present invention comprises a hollow corrugated tube having a plurality of lands and grooves extending along the circumference thereof, said grooves comprising at least two independent, continuous grooves extending helically along the circumference of the tube, with each groove being in spaced relationship to each other, with said tubing satisfying the following formula:

$$(L.W./G.W.)+(\theta\times0.03)=\text{From } 0.5 \text{ to } 2.25$$

wherein L.W. = land width, G.W. = groove width, and θ = angle of advance of the helically extending grooves. In the preferred embodiment of the present invention the grooves comprise three independent, continuous grooves extending helically along the circumference of the tube, with each groove being in spaced relationship to each other.

In accordance with the present invention it has been found that the foregoing corrugated metal tubing achieves a surprising high heat-transfer coefficient. This surprising heat-transfer coefficient could not be anticipated even in view of the improved heat-transfer coefficient obtained by corrugated tubing in general.

A further advantage of the improved heat-transfer coefficient is the resultant equipment savings and many other cost savings in heat exchange machinery. This is especially important in cases where large capital investment is required.

In accordance with the present invention the metal tubing may be corrugated by any method known in the art. A particularly preferred method and apparatus is shown in copending application Ser. No. 679,459, now abandoned, by Joseph Winter for "Apparatus For Forming Corrugated Tubing." In accordance with the teaching of the foregoing patent application, corrugated tubing is produced by an apparatus characterized by having an inner frame movably mounted on an outer frame, with a die rotatably mounted on the inner frame. The die has an annular opening through which passes the tube to be corrugated and shaped die members projecting into the annular opening. The pitch and depth of the spirals or corrugations can be adjusted and controlled over a wide range of configurations. The resultant corrugated tubing is characterized by having a plurality of lands and grooves extending helically along the circumference thereof. In cross section, the tube has a plurality of uniform, symmetrical, wavelike indentations, with the wall thickness of the tube being approximately uniform throughout. The grooves comprise a plurality of independent, continuous grooves extending helically along the circumference of the tube, with each groove being in spaced relationship to each other.

The tubing of the present invention may be made of a wide variety of metals and their alloys. For example, copper and its alloys, aluminum and its alloys, titanium and its alloys, iron and its alloys and so forth. Corrugated tubing made from welded seam tube may be readily used.

The corrugated tubing of the present invention should preferably have a wall thickness from 0.010 inch to 0.50 inch and an outside diameter of from 0.25 inch to 10.5 inch.

In use, when tubing is corrugated normally a section of the tubing is left uncorrugated to provide a plain undistorted tube wall at each end of the corrugated tubing for a locus for sealing into a tube sheet. A multitude of tubes are conventionally attached to tube sheets which separate the heat-transfer media on the outside from the heat-transfer media on the inside of the tubes. The tubes are normally sealed at the point between the heat exchange tubes and the tube sheet by rolling in the tubes or by welding or by brazing.

As pointed out hereinabove, it is a finding of the present invention that improved overall heat-transfer coefficient, U_o, is obtained when the tubing satisfies the following formula:

$$(L.W./G.W.)+(\theta\times0.03)=\text{From } 0.5 \text{ to } 2.25$$

The term L.W. refers to the land width in inches, with the land being measured at right angles instead of along the tube axis. The term G.W. refers to the groove width measured in the same manner. The term θ refers to the angle of advance of the helically extending grooves from a right angle to the tube axis. In general, it can be stated that the lower the value of (L.W./G.W.), the better the heat-transfer coefficient. It may be hypothesized that the lower values of L.W./G.W. are caused by larger groove widths in relation to smaller land widths which enhance liquid film thinning at the peaks of the lands and decreases film thickening at the valleys of the grooves. The relatively larger groove width in relation to relatively smaller land width is clearly shown in FIG. 2, wherein reference numeral 1 shows the plain uncorrugated end and reference numeral 2 shows the corrugated portion. This is particularly apparent with respect to the heat-transfer coefficient on the steam side.

The value for $(L.W./G.W.)+(\theta\times0.03)$ may for convenience be termed the heat transfer efficiency number, P.

Furthermore, the overall heat-transfer coefficient for corrugated tubes may be expressed in terms of the above geometric parameters by the following formula:

$$U_o=1245+48.3P-62.2P^2+8.34P^3$$

wherein P is the heat-transfer efficiency number defined above and U_o is the overall heat-transfer coefficient. In accordance with this equation for the enhancement of the present invention, the value of P may vary from 0.5 to 2.25.

In addition to the foregoing, the pressure drop, ΔP, should be kept at a reasonable value, preferably between 0.6 and 4.5 at 6 feet per second of water.

The present invention will be more readily apparent from a consideration of the following illustrative examples.

EXAMPLE I

This example utilizes a copper base alloy having the following composition: iron, 2.3 percent; phosphorus, 0.025 percent; copper essentially balance. Several pieces of seam-welded tubing were prepared from the foregoing alloy having a tube length of 42 inches. The tubing had a 1-inch O.D. and a wall thickness of 0.049 inch. Some of the tubing was formed into corrugated tubing having a plurality of lands and grooves extending along the circumference thereof with the grooves comprising at least two independent, helically extending continuous grooves. The characteristics of the corrugated tubings are shown in table I below. The corrugated tubing of the present invention generally exhibited no change in weight per unit length, i.e., the corrugated tubing had no greater surface area in one part. The convoluted section of the tube was about 33 inches long. The corrugated tubing had about a 4 to 5 inch plain section on either end.

In the following table: Tube A represents plain, uncorrugated tubings; tubes B–I represent the tubing of the present invention; and tubes J–X represent comparative tubing.

TABLE I

Tube	Number of leads	Pitch, inch	Groove depth, inches	Width, inches		Bore diameter, inches	Weight per foot, lb.	Angle of advance, degrees
				Land	Groove			
A						.900	.589	
B	3	.406	.108	.168	.207	.644	.575	22
C	3	.411	.100	.185	.200	.676	.606	23
D	3	.408	.060	.215	.168	.763	.591	23
E	2	.440	.084	.205	.228	.711	.591	15
F	3	.292	.070	.068	.245	.712	.578	20
G	3	.292	.050	.100	.208	.773	.591	18
H	4	.281	.167	.140	.138	.507	.775	23
I	2	.625	.127	.310	.227	.620	.589	22.5
J	4	.281	.182	.185	.082	.405	.765	26
K	3	.406	.223	.250	.118	.379	.706	23
L	4	.438	.184	.190	.105	.407	.703	34
M	3	.588	.110	.318	.195	.671	.595	31.5
N	3	.588	.075	.330	.182	.744	.591	31
O	6	.445	.066	.200	.137	.711	.585	43
P	2	.885	.091	.555	.222	.711	.595	29
Q	4	.625	.174	.335	.131	.504	.613	50
R	3	.875	.136	.470	.197	.623	.595	40
S	2	1.688	.097	.855	.195	.697	.592	48
T	4	.813	.164	.350	.140	.553	.585	53
U	2	1.302	.100	.780	.215	.696	.595	40.5
V	3	1.153	.122	.528	.195	.660	.589	49
W	3	.875	.218	.380	.137	.428	.619	48
X	3	1.153	.078	.580	.170	.750	.591	49

EXAMPLE II

The plain tubing and the corrugated tubing were both tested in the same manner. A single-tube, horizontal calorimeter was used operating on filmwise condensation of steam at approximately 240° F. using water as cooling water on the interior of the tube. The inlet temperature of the tap water was about 40° F. The heat transfer and pressure drop characteristics of the tubes were determined over a range of water velocity. The values in table II set out below are for a velocity of 6 feet per second. The heat-transfer coefficient was determined by measuring cooling waterflow in mass rate and measuring inlet and outlet temperature of cooling water to determine heat flux. This was related to overall heat-transfer coefficient, U_o, using the equation

$Q=U_oA\Delta T$ wherein

Q = heat flux in B.t.u. per hour;

A = heat transfer area of the outside surface of the tube; and

ΔT = log mean temperature difference for condensing steam—cooling water system.

The results are shown in table II below. The heat transfer coefficients are expressed in the following units: B.t.u./hour square foot °F.

The pressure drop was measured directly in feet of water using appropriate indicating gauges at the calorimeter inlet and outlet. The results are shown in table II.

In addition, table II below shows the value for (L.W./G.W.)+ck×0.03), expressed as the heat transfer efficiency number, P.

The heat-transfer data are shown more graphically in the drawing which forms a part of the present specification

From the foregoing data it can be clearly seen that the tubing of the present invention achieves a surprisingly high heat-transfer coefficient while the accompanying increased pressure drop may be kept at a reasonable level.

This invention may be embodied in other forms or carried out in other ways without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered as in all respects illustrative and not restrictive, the scope of the invention being indicated by the appended claims, and all changes which come within the meaning and range of equivalency are intended to be embraced therein.

TABLE II

Tube	Overall heat transfer coefficient, U_0	Pressure drop, ΔP, at 6 f.p.s. ft. H_2O	Heat transfer efficiency No., P
A	760	0.6	∞
B	1,235	3.6	1.48
C	1,210	3.8	1.60
D	1,170	2.1	1.98
E	1,230	4.4	1.35
F	1,200	2.4	.88
G	1,215	2.1	1.02
H	1,100	3.4	1.705
I	1,220	4.4	2.045
J	1,090	5.5	3.04
K	1,215	6.7	2.81
L	1,035	3.8	2.84
M	1,055	2.7	2.58
N	1,025	1.85	2.75
O	985	1.60	2.75
P	975	2.70	3.38
Q	950	1.80	4.06
R	915	1.80	3.58
S	800	1.00	5.82
T	890	1.30	4.09
U	875	1.70	4.85
V	875	1.30	4.17
W	890	2.20	4.21
X	865	1.00	4.88

We claim:

1. Improved metal tubing having improved heat-transfer characteristics comprising: a hollow corrugated metal tube having a plurality of lands and grooves extending along the circumference thereof, wherein there is relatively larger groove widths in relation to relatively smaller land widths, said grooves comprising at least two independent, continuous grooves extending helically along the circumference of the tube with each groove being in spaced relationship to each other, said tubing exhibiting substantially no change in weight per unit length, with said tubing satisfying the following formula:

$(L.W./G.W.)+(\theta \times 0.03)$ = From 0.5 to 2.25

wherein L.W. = land width,

G.W. = groove width, and

θ = angle of advance of the helically extending grooves.

2. Tubing according to claim 1 made of a copper base alloy.

3. Improved tubing according to claim 1 having a wall thickness of from 0.010 to 0.50 inch.

4. Improved tubing according to claim 1 having an outside diameter of from 0.25 to 10.5 inches.

5. Improved tubing according to claim 1 wherein the pressure drop is from 0.6 to 4.5 feet of water at 6 feet per second of water.

6. Improved tubing according to claim 1 having three independent, continuous grooves.