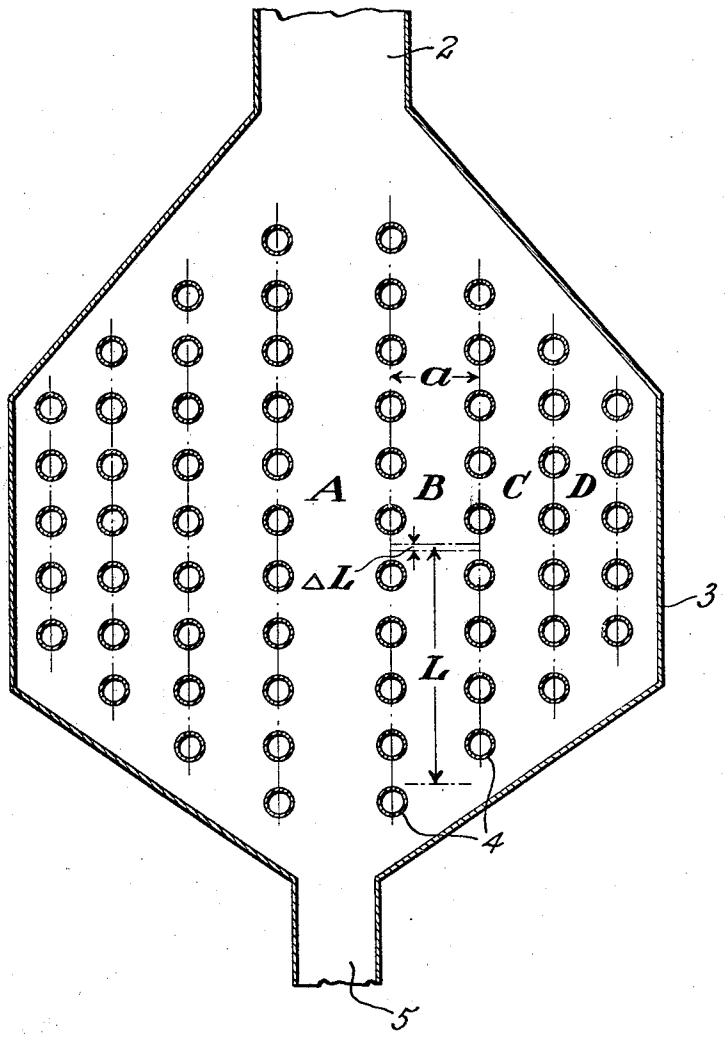
March 15, 1932. D. K. DEAN 1,849,057

CONDENSER

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Fig. 1.



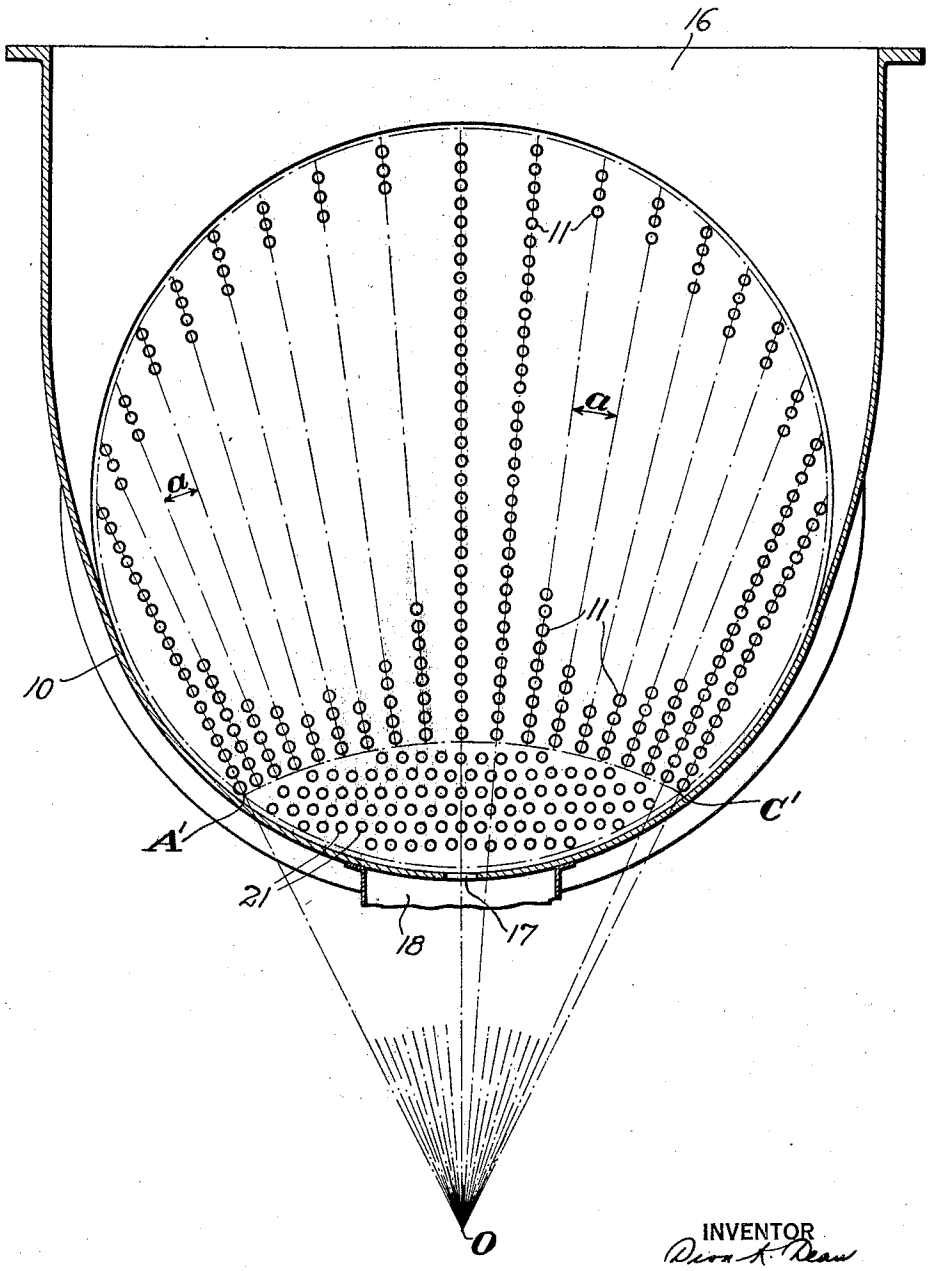
INVENTOR
Dean K. Dean
BY
William G. McKnight
his ATTORNEY

March 15, 1932. D. K. DEAN 1,849,057

CONDENSER

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Fig. 2.



INVENTOR
Dean K. Dean

BY

his ATTORNEY
William G. McKnight

March 15, 1932. D. K. DEAN 1,849,057

CONDENSER

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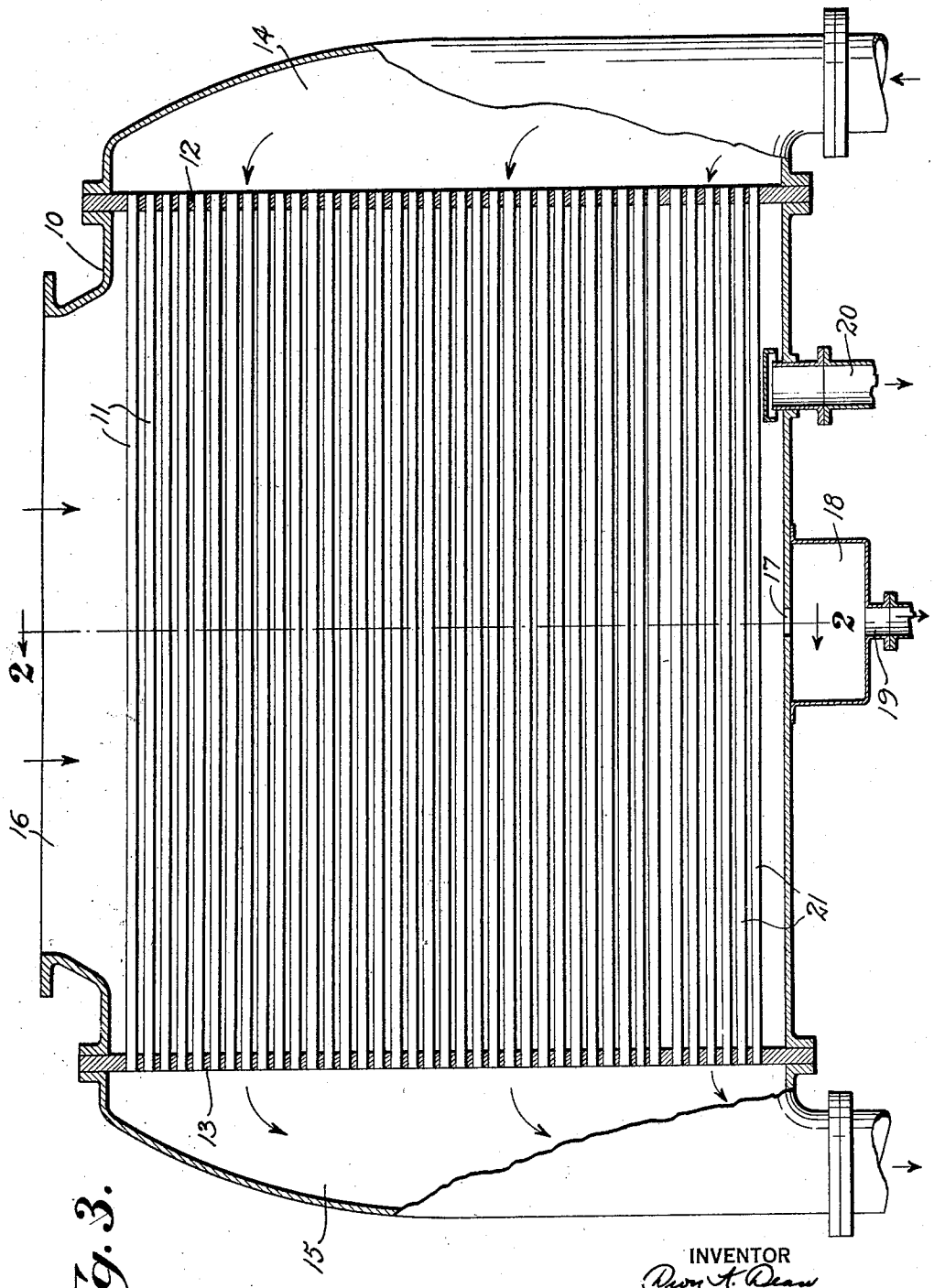


Fig. 3.

INVENTOR
Dean K. Dean
BY
William G. H. Knight
HIS ATTORNEY

Patented Mar. 15, 1932 1,849,057

UNITED STATES PATENT OFFICE

DION K. DEAN, OF RAHWAY, NEW JERSEY, ASSIGNOR TO FOSTER WHEELER CORPORATION, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

CONDENSER

Application filed October 16, 1930. Serial No. 489,052.

My invention relates to surface condensers and more particularly to flow of steam in condensers and still more particularly to distribution of steam transversely to the tube bank of a surface condenser.

The transverse cross-section of a surface condenser is usually of a shape other than rectangular. The condenser tubes are usually arranged in rows extending more or less vertically providing downwardly extending lanes between rows for flow of steam. Consequently the lanes are of different lengths. For example, in a circular shell condenser in which the rows, if continued, would meet at a common low point on the vertical center line of the condenser, the lanes near the vertical center line are considerably longer, and even several times longer, than the lanes at the lateral parts of the condenser. It will be seen that if these lanes have the same mean width, the resistances of the lanes will differ widely since, with a conduit of given cross-sectional area, resistance to flow is directly proportional to the length. Furthermore, the tubes are usually spaced the same distance apart in the rows and therefore, in any one transverse section or in the condenser as a whole, the condensing capacity of a lane may be said to be proportional to the length of the lane.

Thus the condition exists that the lanes of greater cooling capacity have greater resistance to flow. That is, a lane of small condensing capacity will pass a great amount of steam due to its low resistance. Putting it another way, the steam short-circuits through the short lanes and the long lanes do not get enough steam. This is the opposite relation—cooling capacity to lane resistance—which should exist. Considerable steam passes to the vacuum pump by short-circuiting; the long lanes do not get enough steam to utilize their full condensing capacity; and the efficiency of the condenser is lower than what should correspond to the actual condensing capacity.

It is the object of my invention to obviate these disadvantages by so arranging the tubes that the lanes are supplied with quantities of steam proportional to their condensing capacities. To accomplish this, I make the longer lanes wider than the shorter lanes. Furthermore, in the preferred embodiment of the invention, I relate the widths of the lanes to their lengths, as will hereinafter more clearly appear.

The invention will be understood on consideration of the following specification taken in conjunction with the accompanying drawings forming a part thereof and on which:

Fig. 1 is a diagrammatic illustration of the invention;

Fig. 2 is a transverse sectional view of a condenser of the type having rows radiating from a common point and embodying the invention, the section being taken on the line 2—2 of Fig. 3; and

Fig. 3 is a central longitudinal section of the condenser shown in Fig. 2.

The diagrammatic showing of Fig. 1 illustrates a condenser in accordance with the invention. It may be assumed that the condenser is of uniform cross-section throughout its length. The vapor to be condensed is supplied at the top through conduit 2. The shell 3 encloses a condensing chamber through which extend longitudinal cooling tubes 4 carrying the cooling fluid; for example, water. The tubes are arranged in vertical rows and are spaced the same distance apart vertically. Between the rows of tubes are vertical lanes, some of which are lettered A, B, C and D. Due to the configuration of the shell, the lanes are of different lengths. Lane A is the longest and lane D is the shortest. The condensed vapor leaves the condenser through conduit 5.

Assume first that the lanes are of equal width. Assume also that the tubes are of the same temperature at any given cross-section. The condensing capacities of the lanes are then directly proportional to the number of tubes on the sides of the lanes. The tubes being equally spaced in the rows, the condensing capacities are then proportional to the lengths of the lanes. Lane A has, for example, a greater condensing capacity than lane D. Consequently more steam should

pass into lane A than into lane D. However, with lanes of equal width, less steam will pass into lane A than into lane D because lane A is longer than lane D and therefore offers greater total resistance to flow of fluid therethrough than does lane D (other factors being constant), in accordance with the fundamental physical laws of flow of fluids in conduits. As herein used the term "total resistance" means total resistance for a given flow of steam.

But, with lane A wider than lane D, as shown in Fig. 1, the resistance of lane A is less per unit length than lane D. Assume first that lane A is so much wider than lane D that the total resistance to flow in the lanes is equal. Then approximately the same amount of steam would flow into the two lanes. This, however, would not give the result I am to accomplish since I wish to have less steam enter lane D than lane A. Consequently I increase the width of lane A beyond the point where the total resistance is the same and to a point where the total resistance of lane D is so much greater than the total resistance of lane A that a smaller quantity of steam flows into the shorter lane than into the longer lane.

Obviously, the relative widths of rows can be determined by experiment. The objective is attained if, in a condenser where the pressure drop through the lanes is the same, as in Fig. 1, the steam at the ends of the different lanes is of the same temperature. This indicates what might be termed transverse equality of steam penetration, which is the objective of the invention.

However, the widths can, by making certain assumptions, be calculated with a reasonable degree of certainty and without the trouble incident to experimentation by trial and error. Therefore, I will outline the mathematical aspect of the invention.

Assuming that all the steam is condensed in a lane at the exit terminal of the lane, we may say that the volume of steam passing an elementary section in the lane is a function of the distance from such elementary section to the exit terminal of the lane. If, in Fig. 1, we select an elementary section $\triangle L$, the volume of steam passing the elementary section is a function of the distance L from the exit terminal of the lane. Stating it mathematically, $\triangle Q = kL$, where $\triangle Q$ is the quantity passing the elementary section and k is a constant.

The velocity of steam at the elementary section is then

$$\frac{kL}{a},$$

where a is the width of the lane.

The friction or pressure drop across the elementary section varies as the square of the velocity and as the length of the elementary section. Expressing this mathematically we have:

$$\triangle F = \frac{k^2}{a^2} L^2 \triangle L$$

If this equation is integrated to obtain the total friction drop we obtain:

$$F = \frac{k^2 L^3}{3a^2}$$

Since the friction drop is the same in the several lanes, due to the common inlet and outlet, the value

$$\frac{k^2 L^3}{3a^2}$$

will be constant for the different lanes. If this value for different lanes is equated, it will be found that the widths of the lanes vary as the

$$\frac{3}{2}$$

powers of the lengths of the lanes. Expressing this mathematically, with reference to lanes A and B in Fig. 1:

$$\frac{a_A}{a_B} = \frac{L_A^{\frac{3}{2}}}{L_B^{\frac{3}{2}}}$$

Thus, having given the width of one lane, it is possible to calculate the widths of the other lanes to find the values which will result in the lanes receiving varying amounts of steam proportional to their condensing capacities with equal friction drops through the lanes.

It is to be understood that the above calculation does not apply to all condensers but has been worked out for condensers having the rows arranged vertically in parallel. However, by using the fundamentals underlying the above calculation, it should be possible to work out the proper relation for any condenser.

While the condenser shown in Fig. 1 is not of circular section, it will be seen that the same considerations would apply if the cross-section of the shell were circular and the tubes were arranged in vertical rows.

In Figs. 2 and 3 I have shown the invention applied to a condenser of the type having converging lanes. The shell of the condenser is designated 10. A plurality of longitudinally extending cooling tubes extend within the shell and are supported at their ends and suitably fixed in tube sheets 12 and 13. Cooling fluid such as water is adapted to enter the condenser through the inlet water box 14 and, after passing through the tubes 11, to leave the condenser through outlet water box 15. Vapors enter the condenser through vapor inlet 16 and the condensate which collects in the bottom of the condenser passes through an opening 17 into a trap 18 which is connected by a conduit 19 to a suitable tail

pump, not shown. Gaseous fluid is removed from the condenser through conduit 20 which is connected to a suitable air pump, not shown. The lower portion of the condenser may be considered as an air cooler, cooled by the tubes 21.

The arrangement of the tubes 11 is in accordance with the present invention. The tubes are arranged in rows which radiate from a common point O. The rows are arranged at different angles relative to each other to alter the widths of the lanes so that the total resistances of the respective lanes shall be in inverse relation to their lengths as in the arrangement shown in Fig. 1. As shown in the drawings the lateral lanes which are shorter are narrower so that their resistance to flow is greater.

The angularity, that is, the angle between any two adjacent rows, which differs in all the lanes, can be determined mathematically along the same lines as above indicated with reference to Fig. 1. The lengths of the lanes are the lengths from their inlets to the beginning of the air cooler section indicated by the dash-and-dot line A′—C′. Since the width of any lane varies as it goes downwardly, this factor must be taken into account. Width is then a function of the distance from the point O. Working this out mathematically I obtain the following equation for the relative angularities of the lanes:

$$\frac{a_1}{a}=\frac{\left(\frac{L_1^2-d^2}{L_1}-2d\log\frac{L_1}{d}\right)^{\frac{1}{2}}}{\left(\frac{L^2-d^2}{L}-2d\log\frac{L}{d}\right)^{\frac{1}{2}}}$$

In this equation L is the distance from the generating point O to the point where the steam path begins, and d is the distance from the generating point to the end of the lane, that is, to the line A′—C′. This formula is based on the assumption that the distance between tubes in any row is the same and that the pressure at the inlets and outlets of the lanes is the same.

It will be seen that in accordance with the invention the rows are arranged so that the total resistances of any two lanes are in inverse relation to the lengths of the lanes, and that the width of a longer lane is increased with respect to the width of a shorter lane beyond the point where the total resistance is the same and to a point where the resistance of the shorter lane is so much greater than the resistance of the longer lane that a smaller quantity of steam flows into the shorter lane than into the longer lane and so that the proportion of steam entering the respective lanes is in accordance with the condensing capacities of the lanes so that the steam penetration in the lines will be equal.

It will be clear that the invention is not limited to the particular types of condensers indicated.

Furthermore, my invention, which provides transverse equalization of steam penetration, may be combined with any known arrangements for providing longitudinal equalization of steam penetration. In case of using a condenser having a number of compartments, the steam penetration may be equalized longitudinally as well as transversely, for example, by the arrangement shown in the application of Ernest L. Cahoon, Serial No. 484,732, filed September 27th, 1930.

While I have shown only condensers having straight rows of tubes, it will be understood that the tubes of the vertically or substantially vertically extending rows may be staggered. That is, the lanes may not be straight but may zig-zag. The invention will apply to such structure, it being necessary to determine the effective widths of the lanes. With equal spacing of tubes in irregular rows, the rows bordering a shorter lane should, in accordance with the invention, be closer together than the rows bordering a longer lane. Furthermore, the rows may be of uniform curvature and either parallel converging or otherwise related.

What I claim is:

1. A condenser comprising a shell having a steam inlet and an outlet and a plurality of tubes extending in the same general direction to carry a cooling medium through the shell, the flow of steam being generally transverse to the tubes, the tubes being arranged in rows to provide lanes in which the steam flows, the form of the shell and the arrangement of tubes being such as to provide lanes of different lengths, and said rows being spaced different distances apart to provide lanes of different widths along the lengths thereof, the width of a relatively long lane being greater than the width of a relatively short lane.

2. A condenser comprising a shell having a steam inlet and an outlet and a plurality of tubes extending in the same general direction to carry a cooling medium through the shell, the flow of steam being generally transverse to the tubes, the tubes being arranged in rows to provide lanes in which the steam flows, the form of the shell and the arrangement of tubes being such as to provide lanes of different lengths, and said rows being spaced different distances apart to provide lanes of different widths, the width of a relatively long lane being greater than the width of a relatively short lane by an amount beyond that at which the total resistance to flow in the lanes is equal and to an amount where the total resistance of the shorter lane is so much greater than the total resistance of the longer lane that a smaller quantity of steam flows into the shorter lane than into the longer lane.

3. A surface condenser having rows of

tubes forming lanes of different lengths, the rows bordering a shorter lane being closer together along the lengths thereof than the rows bordering a longer lane.

4. A surface condenser having rows of tubes forming lanes of different lengths, the rows being arranged different distances apart, the width of a relatively long lane being greater than the width of a relatively short lane and the relation of widths being such that the lanes will receive steam in accordance with their condensing capacities.

5. A surface condenser having rows of tubes forming lanes of different lengths, the rows being arranged different distances apart, and the spacing of the rows being such that the total resistance to flow in different lanes is in inverse relation to their condensing capacities.

6. A condenser comprising a shell having a steam inlet and an outlet and a plurality of tubes extending in the same general direction to carry a cooling medium through the shell, the flow of steam being generally transverse to the tubes, the tubes being arranged in rows to provide lanes in which the steam flows, said rows having intersecting lines, the form of the shell and the arrangement of tubes being such as to provide lanes of different lengths, and said rows being spaced at different degrees of angularity to provide lanes of different widths at corresponding radial distances, the width of a relatively long lane being greater than the width of a relatively short lane.

7. A condenser comprising a shell having a steam inlet and an outlet and a plurality of tubes extending in the same general direction to carry a cooling medium through the shell, the flow of steam being generally transverse to the tubes, the tubes being arranged in rows to provide lanes in which the steam flows, said rows being arranged in intersecting lines, the form of the shell and arrangement of tubes being such as to provide lanes of different lengths, and said rows being spaced at different degrees of angularity to provide lanes of different widths at corresponding radial distances, the width of a relatively long lane being greater than the width of a relatively short lane by an amount beyond that at which the total resistance to flow in the lanes is equal and to an amount where the total resistance of the shorter lane is so much greater than the total resistance of the longer lane that a smaller quantity of steam flows into the shorter lane than into the longer lane.

In testimony whereof I hereunto affix my signature.

DION K. DEAN.