ROTARY EVAPORATORS

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Contents

1. Historical Background

The evaporation of volatile solvents from industrial solutions, saline water, wastewater, etc., requires the transfer of heat to the solution usually through a heat transfer surface. The thickness of the solution layer on the heat transfer surface affects the heat transfer coefficient; the thicker the layer the lower the heat transfer coefficient and the larger the temperature difference (driving force) across the solution layer to transfer the same amount of heat. This is particularly true in the evaporation of volatile organic solvents from mildly and highly viscous solutions.

Many rotary devices have been developed and proposed to enhance the value of the heat transfer coefficient by decreasing the thickness of the solution layer. These devices were made to agitate, scrape, or wipe the solution on the heat transfer surface in order to reduce the thickness of the layer and enhance the transfer of heat as well as reduce the temperature drop across the layer. This is important to reduce energy consumption in the evaporation of solvents from slurries, concentrated brines, and viscous solutions. This is particularly vital in the evaporation of solvents from heat-sensitive solutions in the chemical and food industries because a large temperature drop across the layer may damage the solution and can result in considerable wasteful expenditure. In addition, a thinner solution layer on the evaporation side enhances the heat transfer coefficient requiring less heat transfer surface and less energy, thus resulting in savings of capital and operating costs.

A survey of patents shows that the majority of these devices use rotating heat transfer surfaces with or without scrapers or wipers applied to the solution. The patents listed at the end of this section are presented to assist interested readers to look further into this subject.

The earliest device was patented in the USA by Gilson in 1871. It used rotary drums in the manufacture of salt from brines. In this device, the rotary drums, heated by steam on the inside, were partially immersed in the brine where water was evaporated from the brine by condensing the heating steam on the inside surface of the drum. Scrapers were used to scrape and collect the salt crystals from the outside of the drums. Obviously, this device can also be used to evaporate water from saline water by using the scraper to scrape off the brine from the drum and condensing the resulting vapor into distilled water.

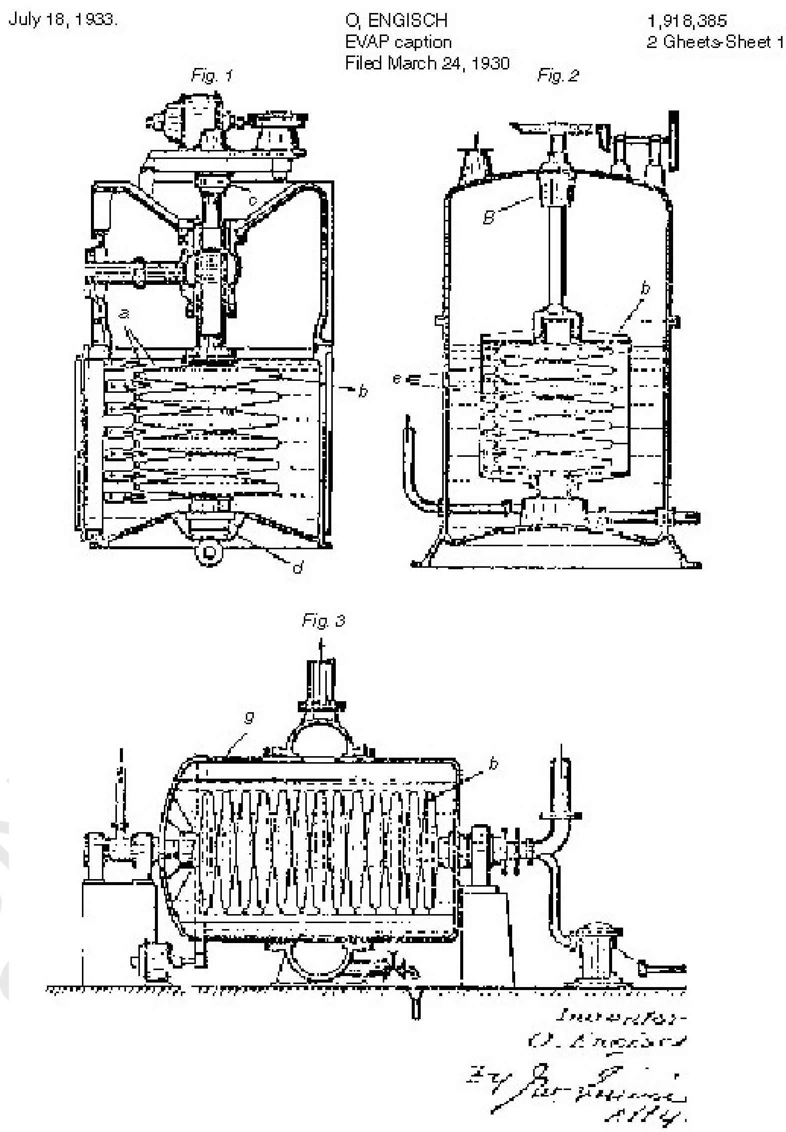

Figure 1. From Engisch, US Patent No. 1 918 385.

The earliest device specifically citing its use for desalting seawater was patented in the USA by Engisch in 1933. Figure 1 is a reproduction of one figure from this patent. This device used pairs of rotary disks forming cavities where the steam condenses on the inside surfaces of the disks and water evaporates outside with scrapers to remove the brine off the outside surfaces of the disks.

After the Second World War, research and development work was initiated and sponsored by governments for the development of processes and equipment to desalt saline waters. In the USA, this work was under the direction of the Office of Saline Water (OSW), Department of the Interior. The OSW funded many universities and research laboratories to conduct research and development to develop processes and equipment for desalting saline waters. At almost the same time in 1948, the State of California established and funded the Sea Water Conversion Laboratory (SWCL) at the University of California at Berkeley to conduct research and development work into processes and apparatus to produce fresh water from seawater economically.

Several rotary devices to desalt saline water were developed and tested. Hickman (US Patent No. 2 899 366, 11 August 1959, US Patent No. 2 894 879, 14 July 1959 and US Patent No. 3 136 707, 9 June 1964) and Hogan et al. (US Patent No. 3 200 050, 10 August 1965) obtained funds from the OSW to build and test their devices at the Badger Company. Figure 2 shows the basic system configured in the vapor compression distillation mode. Referring to Figure 2, the device consists of a pair of conically shaped disks joined together at the outside periphery to form a cavity open at one end for vapor exit and closed at the other with the pair of disks mounted on a vertical shaft to allow rotation of the unit. Here, seawater feed is introduced into the unit at 20 by stationary tubes (22) and spread by centrifugal force on the inside surfaces of the rotating disks. The residue (unevaporated brine) is picked up by a stationary tube (36) and taken out of the unit at 36. The vapor generated is withdrawn by a compressor (26) at the open end where it is compressed and is then condensed on the outside surfaces of the rotating disks with the condensate taken out from the unit at 40.

Bromley (US Patent No. 2 999 796, 12 September 1961) built and tested his rotary device at the SWCL, Richmond, California. Figure 3 shows the basic system. It is a multiple-effect unit. It consists of about 30 flat disks spaced apart to allow feed, brine, and condensate to flow in and out between the disks with the whole assembly rotating on a vertical shaft driven by an electric motor. In this unit, steam from a boiler is introduced into the unit and condensed on the bottom surface of the first disk with the feed introduced at the inside periphery of each disk and spread on the top surface of each of the disks. The vapor generated from the feed on the first disk is condensed on the bottom surface of the second disk to evaporate part of the feed spread on the top surface of the second disk. The vapor generated from the feed on the second disk is condensed on the bottom surface of the third disk and so on until the last disk where the vapor generated from the feed on the top of the last disk is condensed on tubes (106). The condensate and waste are manifolded at the outside periphery and taken out from the rotating assembly by stationary tubes (125 and 127).

Neugebauer and Lustenader (US Patent No. 3 190 817, 1961) tested their device at the facilities of General Electric Company. Figure 4 shows the basic system. It consists of a stationary vertical pipe with steam condensing on the outside surface of the pipe with feed spread into a thin film on the inside surface of the pipe by using rotating wipers and scrapers.

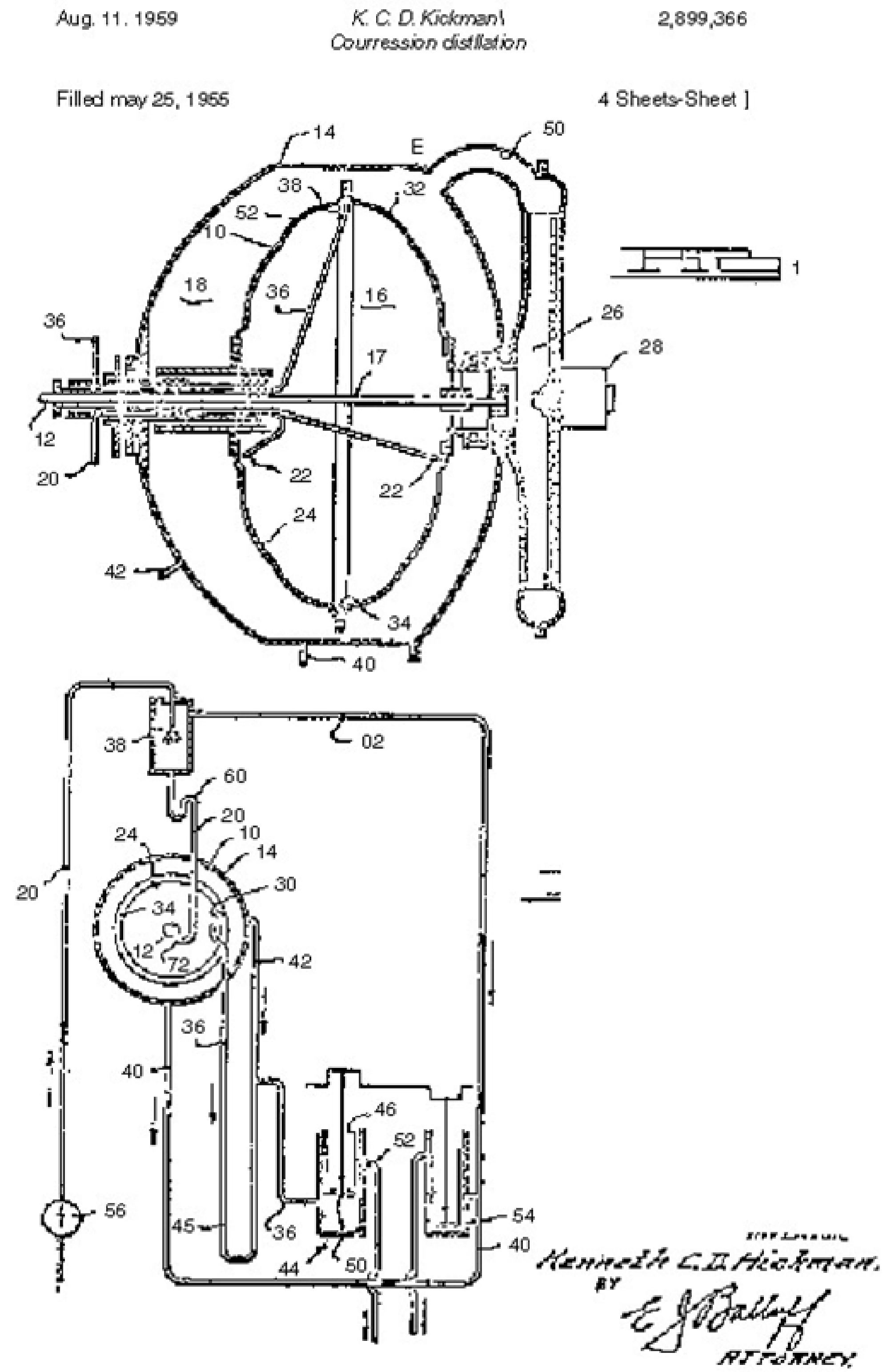

Figure 2. From Hickman, US Patent No. 2 899 366.

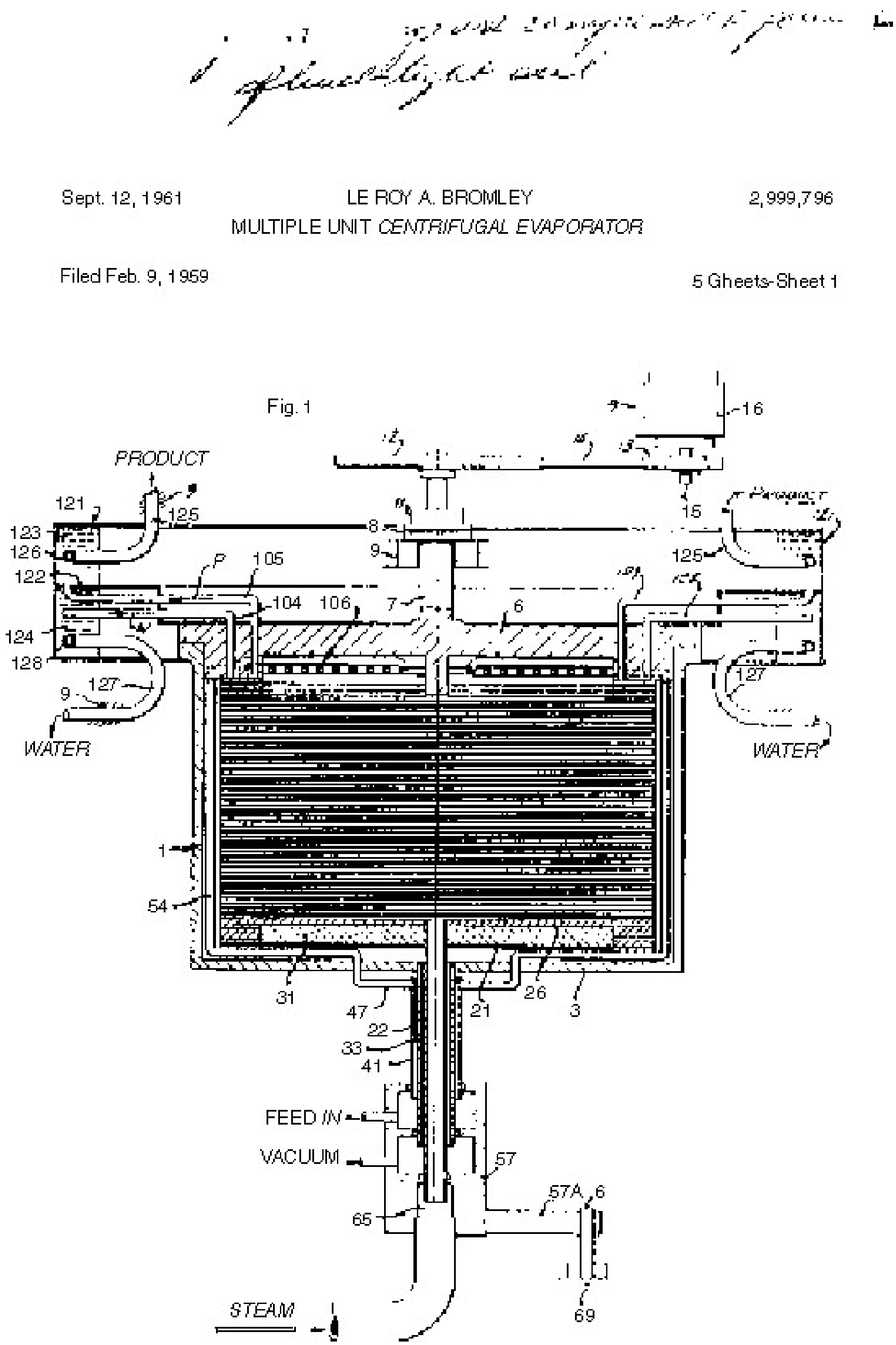

Figure 3. From Bromley, US Patent No. 2 999 796.

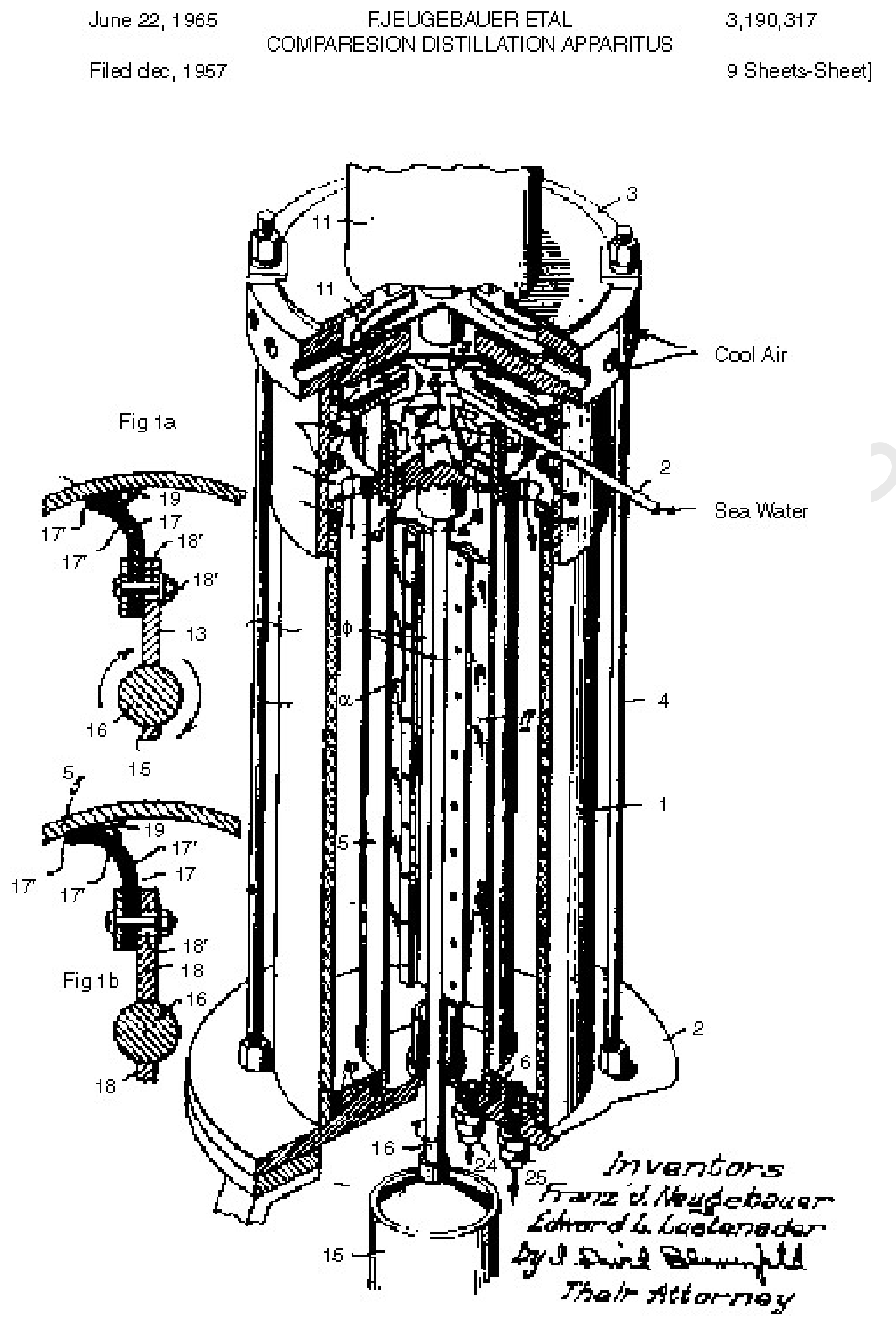

Figure 4. From Neugebauer et al., US Patent No. 3 190 817.

Tleimat (US Patent No. 3 764 483, 1973) tested his device at the SWCL, Richmond, California. Figure 5 shows the basic system. The device consists of a rotor and a housing. The rotor consists of pairs of disks joined together at the outside and inside peripheries to form cavities, the assembly being closed at one end and open at the other end to admit heating vapor, with the disk assembly supported on bearings and driven through a pulley. Heating vapor is introduced into the cavities where it condenses on the inside surfaces of the rotating disks (12) and collected at the periphery where it is withdrawn by stationary scoops (24) into a manifold (25) and taken out of the evaporator. The feed solution enters the evaporator where it is spread on the outside surfaces of the rotating disks by stationary wipers forming a very thin hydrodynamic film between the wipers and the disks. The unevaporated portion is slung out onto the inside surfaces of the housing and drains into the bottom at 14 where it is taken out as residue.

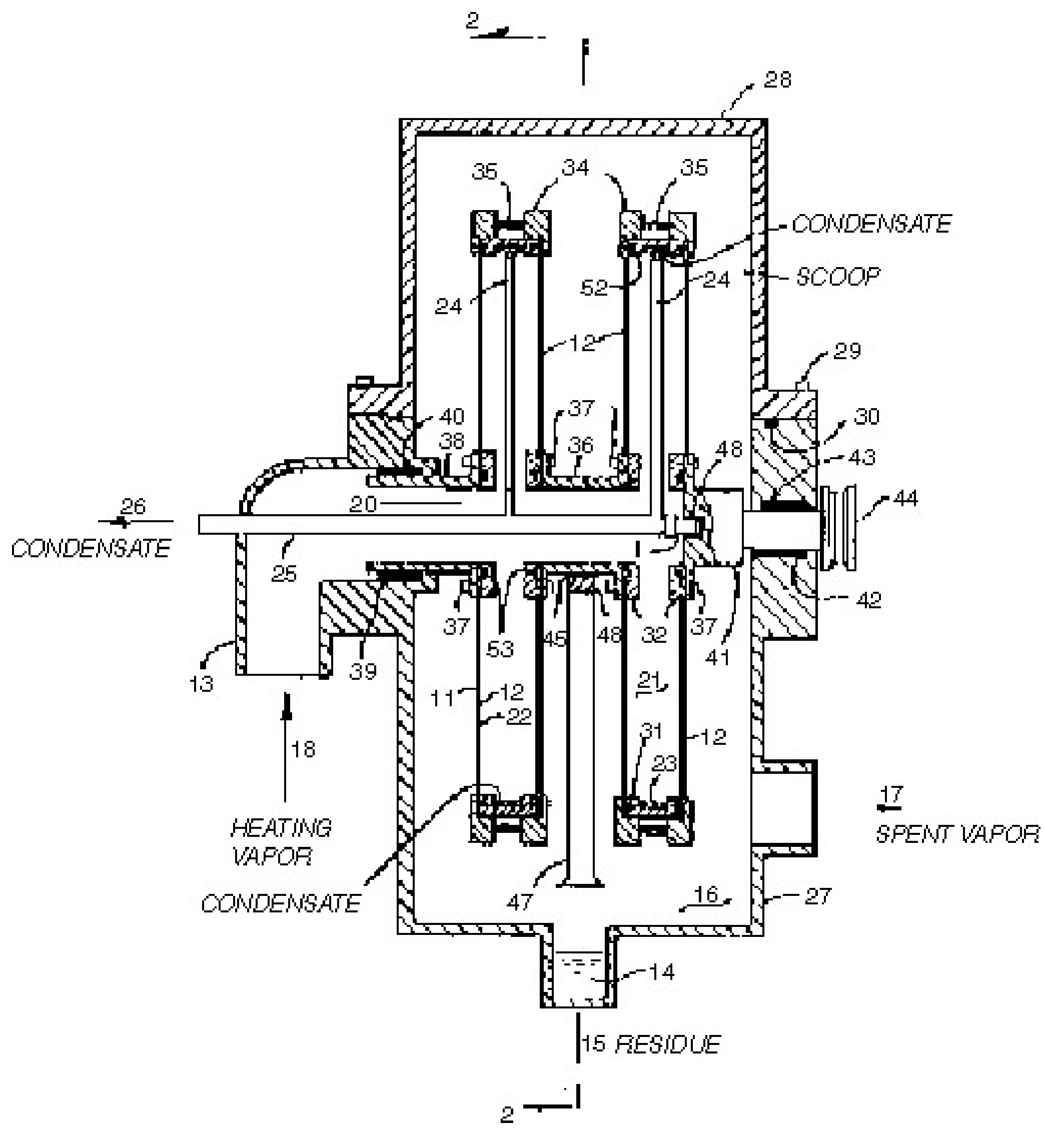

Figure 5. From Tleimat, US Patent No. 3 764 483.

Li (US Patent No. 4 230 529, 28 October 1980) built and tested his device at his facilities in Lincoln, Massachusetts. Figure 6 shows the basic system. It consists of a vertical long tube assembly mounted such that the assembly moves in an orbital motion by virtue of items 21, 23, 24, and 51 with hanging rod assemblies (20) into tubes (7). Due to the orbital motion of the assembly, the rods (20) press against the inside surfaces of the tubes (7). Here, feed is spread on the inside surfaces of the tubes (7) and steam is condensed on the outside surfaces. Due to the orbital motion of the tubes and the action of the rods, the feed is squeezed into a thin film between the rods and the tubes. The centrifugal force generated by the orbital motion of the assembly assists in creating a condensate film thinner than that which would form on a stationary vertical tube.

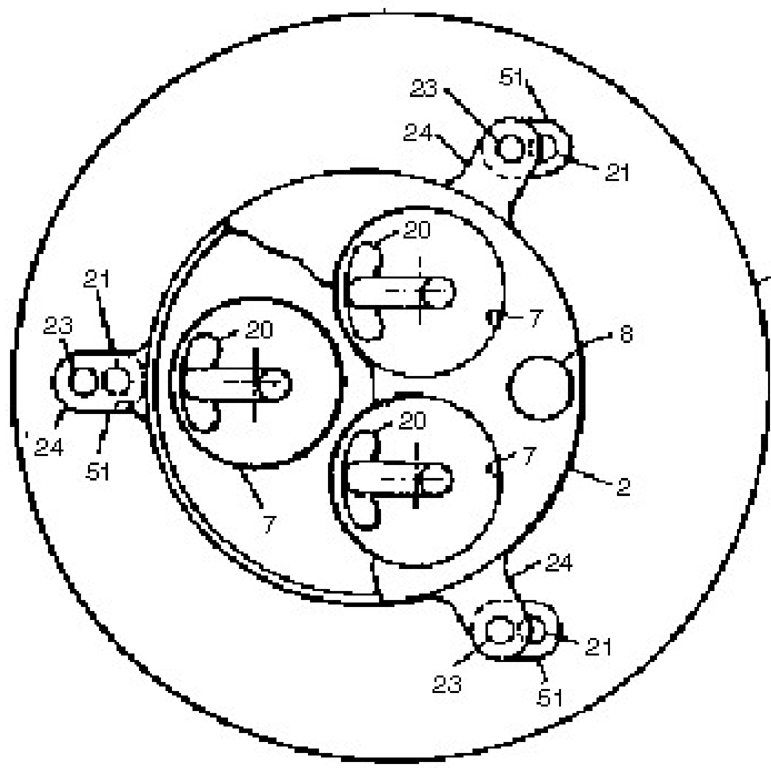

Figure 6. From Li, US Patent No. 4 230 529.

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