UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CoolIT Systems, Inc.
Petitioner

v.

Asetek Danmark A/S,
Patent Owner

Patent No. 10,078,355 to Eriksen

IPR Case No.: IPR2020-00522

DECLARATION OF MARC HODES, Ph.D.

Dated: February 7, 2020

Respectfully submitted,

Marc Hodes, Ph.D.

CoolIT Systems, Inc. Ex. 1003

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I, MARC HODES, PH.D., DECLARE AS FOLLOWS:

I. INTRODUCTION AND QUALIFICATIONS

1. Counsel for CoolIT Systems, Inc. ("CoolIT") has retained me as an expert to offer my opinion regarding the validity of U.S. Patent No. 10,078,355 ("'355 patent"). I submit this declaration based on my personal knowledge and in support of CoolIT's *inter partes* review petition ("Petition") against the '355 patent.

2. In 1998, I received a PhD in Mechanical Engineering (minor in Chemical Engineering) from the Massachusetts Institute of Technology.

3. In August 1998, I began working at Lucent Technologies' Bell Labs in Murray Hill, NJ as a Postdoctoral Member of Technical Staff. At Bell Labs, I was responsible for R&D in the area of thermal management of electronics and heat transfer modeling to support Lucent Technologies business units. This role included later becoming a People Manager from October 2006 to August 2008 for a Thermal Management and Acoustics Research Group as an expatriate at Bell Labs Ireland. (Alcatel and Lucent Technologies merged in April 2006.)

4. I left Bell Labs in August 2008 and began an Associate Professorship at Tufts University (Medford, MA). I was promoted to Professor in 2018. My Ph.D. thesis was entitled "Measurements and Modeling of Deposition Rates from Near-Supercritical, Aqueous, Sodium Sulfate and Potassium Sulfate Solutions to a Heated Cylinder." My area of research has been in the broad area of heat/mass/momentum

transfer. Major research has been done on thermal management of electronics, superhydrophobic surfaces, thermoelectric modules and mass transfer in supercritical fluids.

5. I have also spent extended periods in various types of positions at the National Institute of Standards and Technology (Guest Researcher), the University of Limerick (Walton Fellow, etc.) and Imperial College London (Academic Visitor).

6. I am a named inventor on 15 U.S. Patents/Patent Applications. Most of these patents are generally related to thermal management of electronics. One of them concerns enhanced liquid cooling of electronics using superhydrophobic surfaces.

7. I have over 10 years of industry experience in thermal management of electronics, with a major thrust being liquid cooling in various contexts, e.g., direct liquid metal cooling, and I have also published numerous articles and given presentations in this field. A copy of my Curriculum Vitae ("CV") is submitted herewith as **Appendix A**, which describes my education, training, and experience in greater detail. My CV includes a list of publications I have authored, as well as a list of the patents on which I am a named inventor.

8. My primary consulting client is CoolIT Systems, Inc. ("CoolIT"), acting as an expert on thermal management in general, including liquid cooling and advising on integration of pumps onto heat exchangers to cool CPUs.

9. I have not previously testified in any judicial or administrative proceeding.

10. I am billing my work in this matter at $325 per hour, with reimbursement for actual expenses. My payment is not contingent upon my testimony or the outcome of the case. I have no personal interest in the outcome of the case.

II. MATERIALS CONSIDERED

11. The analysis provided in this declaration is based on my education as well as my experience in the field. In addition to relying upon my knowledge based on written materials and other information that was known as of May 5, 2005, I have considered the exhibits to the Petition (Exs. 1001-1009), shown below.

Exhibit	Description
1001	U.S. Patent No. 10,078,355 ("'355 patent")
1002	File history of U.S. Patent No. 10,078,355 ("'355 FH")
1004	Joint Claim Construction and Pre-Hearing Statement Under Patent L.R. 4-3, filed on November 8, 2019 in *Asetek Danmark A/S v. CoolIT Systems, Inc.*, No. 3:19-cv-00410-EMC (N.D. Cal.)
1005	U.S. Patent App. Pub. No. 2006/0185830 to Qiang-Fei Duan et al. ("Duan")
1006	Certified Translation of Japanese Unexamined Patent App. Pub. No. 2002-151638 to Takayuki Shin ("Shin")
1007	U.S. Patent No. 5,731,954 to Cheon ("Cheon")

Exhibit	Description
1008	U.S. Patent No. 7,248,006 to Bail *et al.*
1009	U.S. Patent App. Pub. No. 2003/0173839 to Torii *et al.*

III. OVERVIEW AND LEGAL STANDARDS

A. Priority Date

12. Counsel for CoolIT has explained to me that I should assume the effective filing date of the ’355 patent is May 6, 2005. I have, therefore, applied this date in considering the prior art and the viewpoint of a person of ordinary skill in the art (“POSITA”).

13. I understand Petitioner may argue that the ’355 patent is not entitled to a 2005 effective filing date. Even if this were true, my opinions would not change.

B. Person Having Ordinary Skill in the Art

14. I understand that my assessment of the claims of the ’355 patent must be undertaken from the perspective of what would have been known or understood by a person having ordinary skill in the art, reading the ’355 patent on its relevant filing date and in light of the specification and file history of the ’355 patent. I will refer to such a person as a “POSITA.”

15. I understand that my analysis and opinions expressed in this declaration must be rendered based on the perspective of a POSITA as of the priority date of the Challenged Claims. I also understand that a POSITA is a hypothetical person who

is presumed to have known the relevant art at the time of the alleged invention claimed in the ’355 patent.

16. I further understand that in determining the level of ordinary skill in the art, I am to consider factors including:

(a) the type of problems encountered in the art or field of invention,

(b) prior art solutions to those problems,

(c) the rapidity with which innovations are made,

(d) sophistication of the technology, and

(e) the educational level of active workers in the field.

17. I understand that a POSITA is a person of ordinary creativity, but not an automaton, and that a POSITA can often fit multiple patents or prior art references together like pieces of a puzzle as a result of this ordinary creativity. I also understand that I may consider the inferences and creative steps that a POSITA would employ. In addition, I understand that a POSITA would necessarily have been capable of understanding the scientific and engineering principles applicable to the pertinent art. I also understand that when I consider what would have been obvious to a POSITA, I am not considering what would have been obvious to me at the time, nor to the inventors, judges, laymen, those skilled in other arts, or to geniuses in the art.

18. Based on my review and analysis of the Challenged Patent, the prior art

cited herein, and the ordinary skill factors described in this section, in my opinion, a POSITA working in the field of liquid cooling systems for computer systems as of the earliest possible effective filing date of May 6, 2005 would have been knowledgeable regarding liquid cooling systems for computer systems, would have earned at least a bachelor's degree, such as a B.S. (bachelor of science), or equivalent thereof, in electrical or mechanical engineering or a closely-related field, and would have possessed at least two or three years of specialized in liquid cooling systems for computer systems or in similar systems. A person with less education but more relevant practical experience, depending on the nature of that experience and degree of exposure to liquid cooling systems for computer systems, could also qualify as a POSITA in the field of the '355 patent.. (*See, e.g.*, Ex-1001 at 1:13-50 (describing the "Background" of the '355 patent).) A POSITA would be knowledgeable of the concepts, components, and their functions described as "prior art" in the '355 patent such as, for example, liquid pumps, heat radiators, air fans, reservoirs, and other techniques of heat dissipation and liquid cooling. (*Id.*) In addition, a POSITA would be knowledgeable about electric and electromagnetic motors and their components such as, for example, electromagnetic coils, rotors, stators, AC motors, DC motors, etc.

19. A person with less education but more relevant practical experience, depending on the nature of that experience and degree of exposure to liquid cooling

systems for computer systems could also qualify as a POSITA in the field of the ’355 patent.

C. Claim Construction

20. Based on the ’355 patent, the prosecution history, my experience with the relevant technology, and what a POSITA would know prior to the time of invention, I provide the following analysis for interpreting certain claim terms appearing in the ’355 patent.

i. “reservoir”

21. I understand that the parties have stipulated, in the pending district court action, to construe the term “reservoir,” as that term is used in claims 1, 10, and 11 of the ’355 patent, to mean “single receptacle defining a fluid flow path.” (Ex-1004 at 1.)

ii. “chamber”

22. I further understand that the parties have also stipulated to construe the term “chamber,” as that term is used in claims 1, 2, and 10 of the ’355 patent, to mean “compartment within the reservoir.” (*Id*. at 2.) I further note that the term “chamber” appears in the two claim terms “pump *chamber*” and “thermal exchange *chamber*.” These two terms should be given their plain and ordinary meaning subject to the stipulated construction for “chamber” above.

iii. <u>"impeller"</u>

23. An "impeller" is a conventional component that is well within the knowledge of a POSITA. Because the '355 patent uses "impeller" in its common usage, this term should be given its plain and ordinary meaning. Many people are familiar with propellers, which may be fans, arms, turbines, or blades that push fluid away. Impellers are similar in structure and operate in a rotational direction that creates a pressure difference to move fluids.

iv. <u>"stator"</u>

24. A "stator" is also a conventional component that is well within the knowledge of a POSITA. Stators are well-known components of rotary motors. A rotary motor includes stationary functional components that, among other things, create a force (e.g., electromotive force) and further include rotational components that rotate as a result of the force created by the stationary components. The rotating components are referred to as rotors and may include propellers and impellors. As a result, the plain and ordinary meaning of the term "stator" to a POSITA should be the stationary functional parts of a motor during its operation. In some cases, rotating components are coupled to the stator such that the rotating components rotate about an axis created by the stator. Because the '355 patent uses "stator" in its common usage, this term should be given its plain and ordinary meaning. For example, the '355 patent explains, "wherein a stationary part of the motor of the

pump, such as a stator of an electrical motor, is placed outside the reservoir." (Ex-1001 at 2:40-42.) Here, the '355 patent refers to a stator as the "stationary part of the motor of the pump."

25. When the motor is an electro-magnetic motor, a "stator" or "stator assembly" is in a fixed position as a magnetic rotor rotates as a result of magnetic fields created by stationary electro-magnetic components. These stationary electro-magnetic components include coils that receive altermatic current that create electro-magnetic fields. In this case, the stator may refer to the assembly that includes the coil as part of the stationary functional parts of a motor during its operation.

v. "an inlet … positioned below a center of the impeller"

26. The term "an inlet … positioned below a center of the impeller" should be interpreted to include the opening for fluid entrance near the center of the impeller along the axis around which the impeller rotates. For example, the '355 patent describes an "inlet" as follows: "The inlet of the pump chamber 46 is the entire opening into the cavity that the pump chamber configures, said cavity being in direct communication with the interior of the reservoir housing 14 as such." (Ex-1001 at 23:1-5.) An example of this is illustrated in FIG. 20 of the '355 patent where a red box is added to show an inlet defined by the impeller cover positioned below a center of the impeller (item 33)

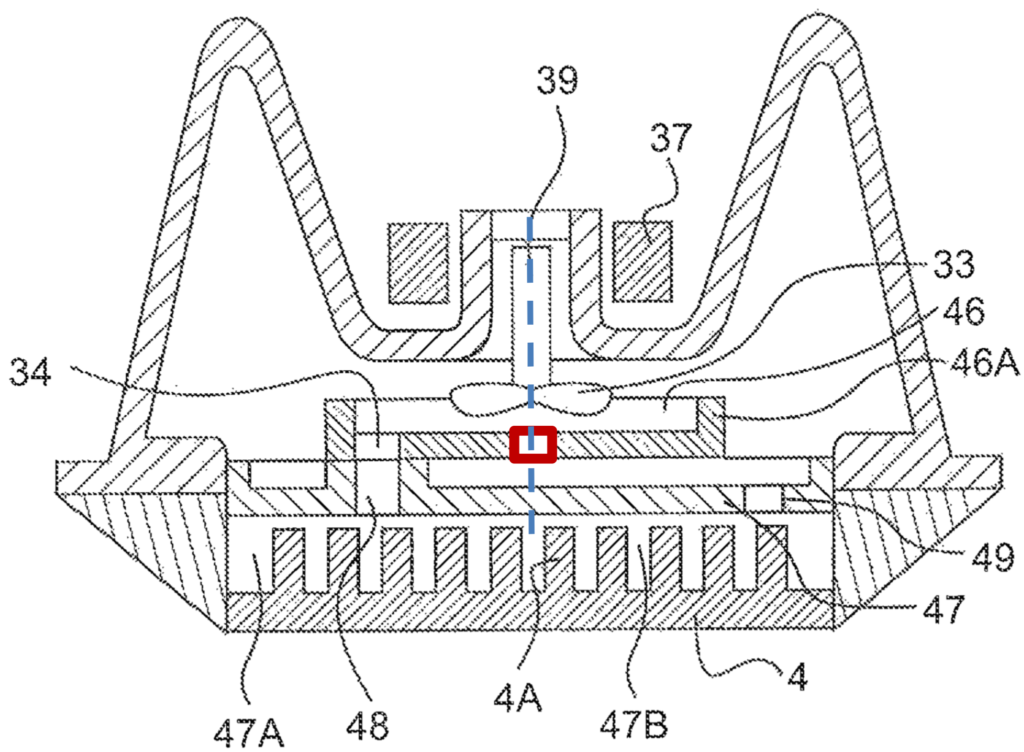


FIG. 20

I note above that the phrase “below a center of the impeller” is a relative term depending on the orientation of the impeller. Thus, if the impeller is rotated, the location of “below a center of the impeller” also moves relative to the impeller. For example, if FIG. 20 of the patent were rotated clockwise so that the impeller 33 faces to the left (instead of downward), then “an inlet defined by the impeller cover positioned below a center of the impeller” would refer to the opening to the left of the impeller. This kind of rotation is common in, for example, a tower computer case in which the motherboard is vertical as opposed to horizontal. As a result, the heat-generating processor will be installed vertically, which in turn will cause the claimed device that is cooling the processor to be accordingly rotated as exemplarily shown on the right. Such rotation would not materially alter the functioning of the device, as would have been understood and appreciated by a POSITA.

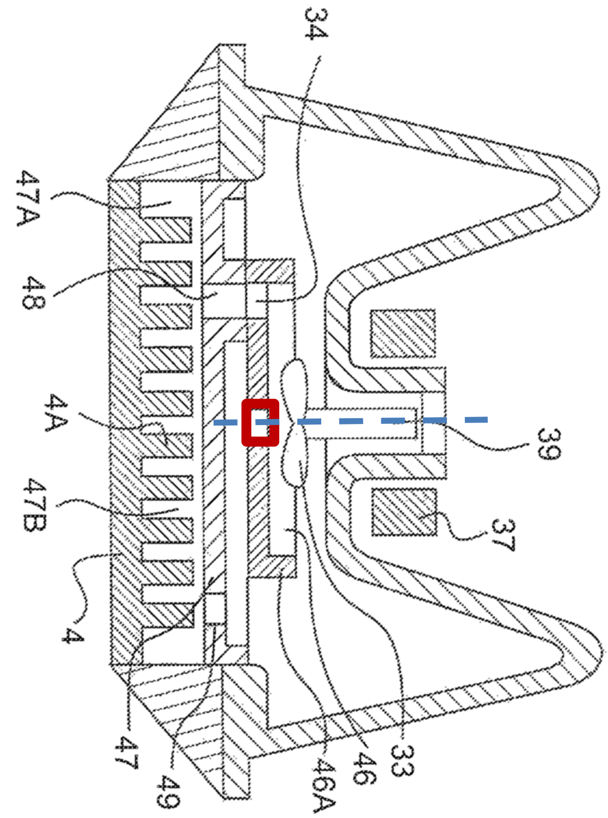


FIG. 20

This further supports the construction of this phrase to mean an opening for fluid entrance near the center of the impeller along the axis around which the impeller rotates. In sum, the term should mean the opening for fluid entrance near the center of the impeller along the axis around which the impeller rotates.

vi. <u>"heat radiator"</u>

27. A "heat radiator" is also a conventional component that is well within the knowledge of a POSITA. Heat radiators are well-known components of systems that require cooling. This concept is documented as "prior art" in the '355 patent which states that a heat radiator may serve "as a means for removing the heat from

the liquid by means of the air fan 10 blowing air through the heat radiator." (Ex.-1001 at 10:63-65 and FIG. 3.) This is consistent with the common use of the term "heat radiator." Specially, a heat radiator commonly refers to a system that transfers thermal energy (e.g., heat) by conduction/convection from one medium to another medium and may include components such as pipes or fins to transfer heat. For these reasons, this term should be given its plain and ordinary meaning.

vii. Other terms

28. As to other terms, a POSITA would have understood the plain and ordinary meaning of the term "double-sided chassis" to be "two-sided frame or base." Further, a POSITA would have understood the plain and ordinary meaning of "a first end or a second end of the thermal exchange chamber" to be "a first edge or a second edge of the thermal exchange chamber." To the extent applicable, I have rendered my opinions using these constructions. Although district court claim construction proceedings are ongoing, for purposes of these IPRs, I believe no additional specific constructions are required; I understand that the other claim terms in these IPRs will be construed according to their ordinary and customary meaning. I further understand that the claims are read in light of the patent's specification and that claims themselves often provide significant guidance as to the meaning of a particular term.

IV. LEGAL STANDARDS

29. I have been asked to opine on whether certain claims are either anticipated or rendered obvious by the prior art.

30. I have been instructed that anticipation means that a single prior art reference discloses each claim element and discloses the arrangement of each claim element. To disclose a claim element, the prior art does not have to expressly spell out the claim element as along as a POSITA, reading the reference, would at once envisage the claimed arrangement or combination

31. I have been instructed that obviousness means that one or more prior art references disclose each claim element of a claim and that there must be an apparent reason to combine the known elements to arrive at the claims. The analysis is a flexible one, accounting for the inferences and creative steps that a person of ordinary skill in the art would employ. The claims must be read as a whole when evaluating whether it is obvious.It is my understanding that a claimed invention is unpatentable under 35 U.S.C. § 103 if the differences between the invention and the prior art are such that the subject matter as a whole would have been obvious at the time the alleged invention was made to a person of ordinary skill in the art to which the subject matter pertains. This is sometimes described as "obviousness." I understand that an obviousness analysis takes into account the level of ordinary skill in the art, the scope and content of the prior art, and the differences between the prior

art and the claimed subject matter. The analysis may also consider secondary considerations, such as commercial success, unmet but long felt need and failure of others.

32. It is my understanding that the Supreme Court, in *KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398 (2007) and other cases, has recognized several rationales for combining references or modifying a reference to show obviousness of the claimed subject matter. Some of these rationales include the following: combining prior art elements according to known methods to yield predictable results; simple substitution of one known element for another to obtain predictable results; a predictable use of prior art elements according to their established functions; applying a known technique to a known device to yield predictable results; choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success; and some teaching, suggestion, or motivation in the prior art that would have led a POSITA to modify the prior art or combine prior art teachings to arrive at the claimed invention.

V. OVERVIEW OF THE '355 PATENT

33. The '355 patent characterizes its field of invention as follows:

> "The present invention relates to a cooling system for a central processing unit (CPU) or other processing unit of a computer system. More specifically, the invention relates to a liquid-cooling system for a mainstream computer system such as a PC." (Ex-1001 at 1:13-17.)

34. The ’355 patent relates to a liquid-cooling system for a computer system. The specification purports to disclose embodiments of a liquid-cooling system that is more efficient, easier to use, and more compact with integrated components than prior art cooling systems. (Ex-1001 at 1:13-2:24.)

35. The ’355 patent further states (and subsequently claims) that these purported improvements may be achieved by having an integrated element comprising the heat exchange interface, the reservoir of cooling liquid, and the pump for pumping the cooling liquid. (*Id.* at 1:54-2:36; claims 1-16.)

36. The following figures capture the main characteristics of the purported invention claimed in the Challenged Claims.

37. "FIG. 8 [which should have been FIG. 7,[1] reproduced on the right] is a perspective view of the cooling system showing the reservoir housing 14 with the heat exchanging surface (not shown) and the pump (not shown) inside the reservoir. The tube inlet connection and the tube outlet connection are connected to a heat radiator by means of connecting tubes 24 and 25 through which the cooling liquid flows into and out of the reservoir and the heat radiator, respectively. Within the heat radiator 11, the cooling liquid passes a number of channels for conducting/convecting the heat, which has been dissipated into the cooling liquid inside the reservoir, and to the surroundings of the

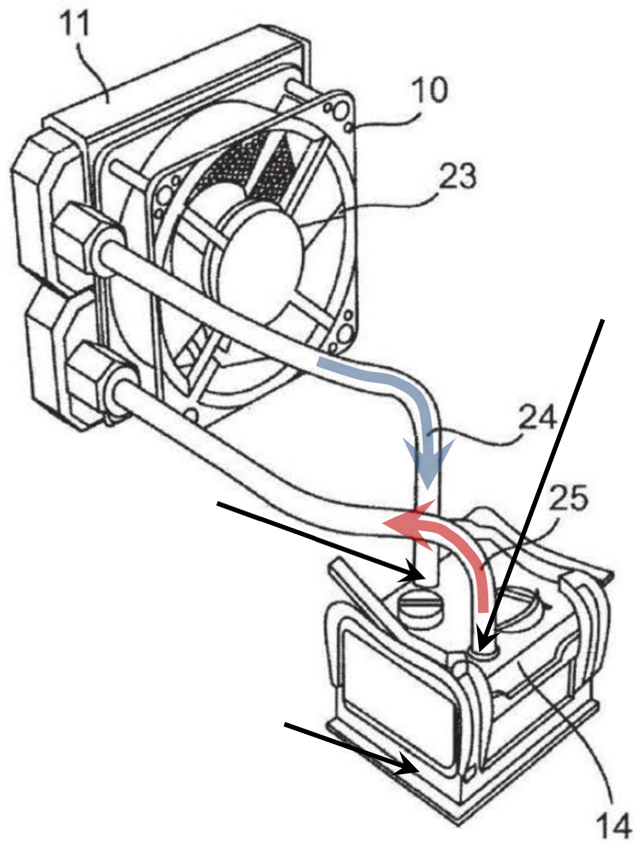


FIG. 7

[1] A POSITA would have understood the figure numbers of FIG. 7 and FIG. 8 in the patent's description are transposed. The description for FIG. 8 is actually for FIG. 7, and the description for FIG. 7 is actually for FIG. 8.

heat exchanger. The air fan 10 blows air past the channels of the heat radiator in order to cool the radiator and thereby cooling the cooling liquid flowing inside the channels through the heat radiator and back into the reservoir." (Ex. 1001 at 16:16-30.)

38. The internal structures of the claimed reservoir 14 are depicted in FIGS. 17 and 20, reproduced below. "FIG. 17 shows a preferred possible embodiment of a reservoir according to the invention. The reservoir housing 14, as shown in FIGS. 17 and 20, is in the form of a double-sided chassis configured to mount an electrical motor." (*Id.* at 21:48-52.) "The reservoir housing 14 may … be provided with an inlet (not shown [in FIGS. 17 or 20]) and an outlet (not shown [in FIGS. 17 or 20]) for the cooling liquid. The inlet and the outlet are provided along a surface of the reservoir facing downward and inwards when seen in the perspective view of the drawing. The inlet and the outlet lead to a radiator (not shown) intended for cooling the cooling liquid after having been heated by the processing unit via a heat exchanging surface[.]" (*Id.* at 22:31-38.) A POSITA would have understood that "the inlet" and "the outlet" mentioned here "are connected to a heat radiator by means of connecting tubes 24 and 25" as shown in FIG. 7 (*Id.* at 16:19-23; FIG. 7.) "The radiator may be placed nearby or distant from the reservoir housing 14, depending on the set-up of the computer system. In one possible embodiment, the radiator is placed in the immediate vicinity of the reservoir, thereby possible

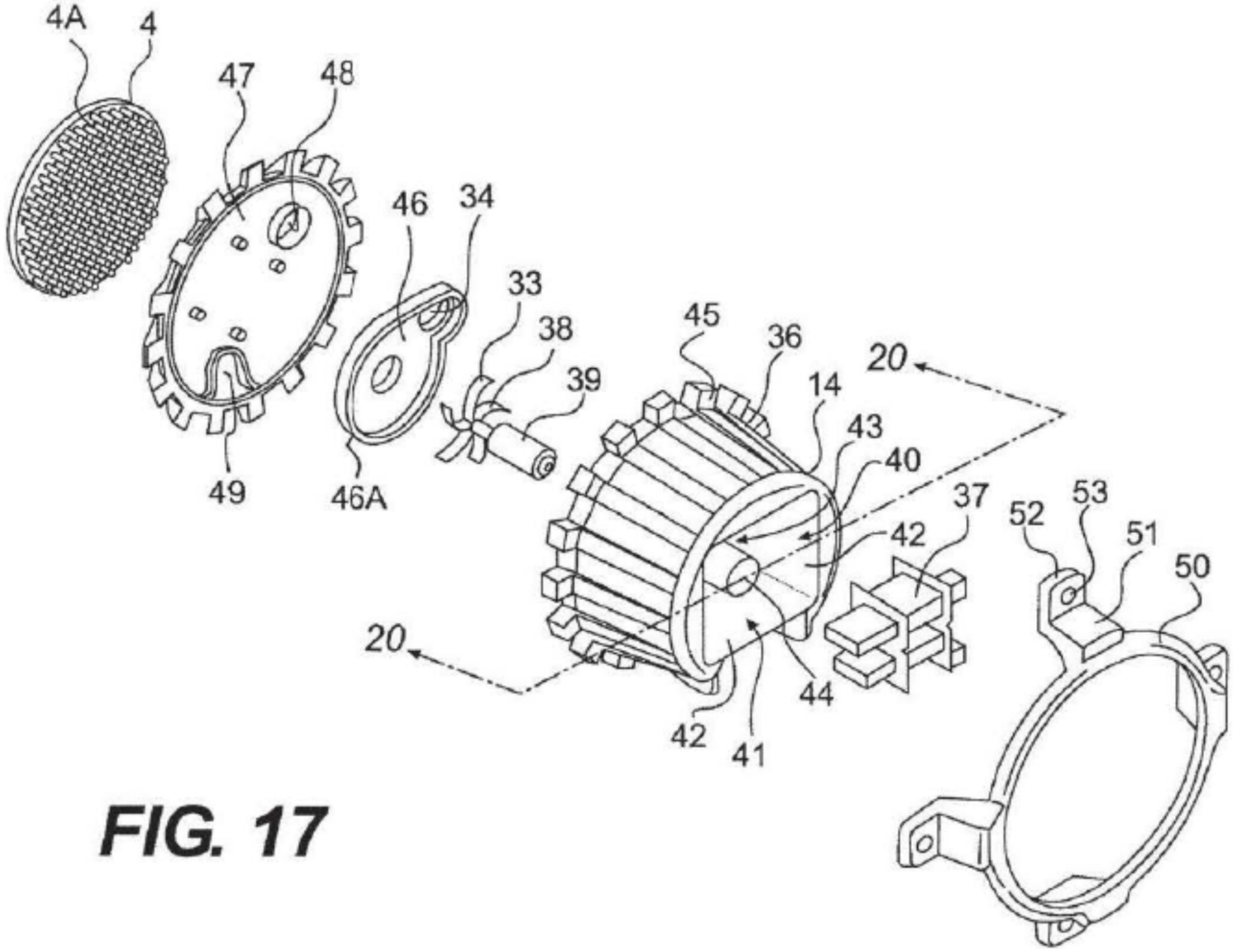


FIG. 17

excluding any tubing extending between the radiator and the inlet and the outlet, respectively. Such embodiment provides a very compact configuration of the entire cooling system, namely a monolithic configuration where all elements needed for the cooling system are incorporated in one unit." (*Id.*, 22:39-48).

39. "The reservoir housing 14 has a recess 40 in the centre on the upper side of the reservoir. The recess 40 is intended for accommodating a stator 37 of an electrical motor driving an impeller 33 of the pump, said impeller being attached to a shaft 38 of a rotor 39 of the electrical motor. The recess has an orifice 41, four sidewalls 42, a bottom 43 and a circular jacket 44 extending from the bottom 43 of

the recess 40 and outwards towards the orifice 41 of the recess 40. The interior (see FIG. 20) of the jacket 44 is intended for encompassing the rotor 39 of the pump. As shown in FIG. 20, the impeller 33 is housed in a recess on the underside of the reservoir housing 14, the recess being an extension of the interior of the jacket 44." (*Id.* at 21:58-22:9.)

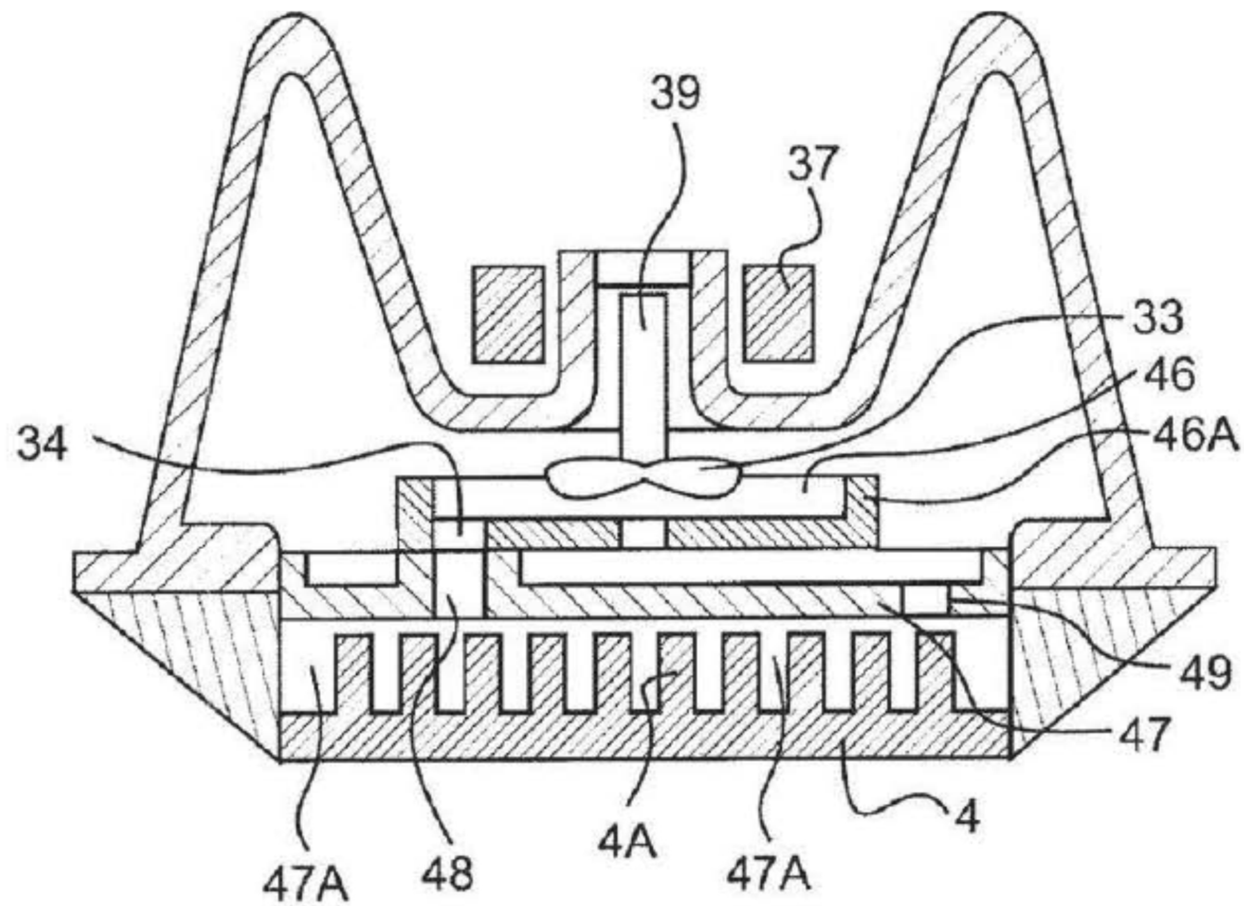


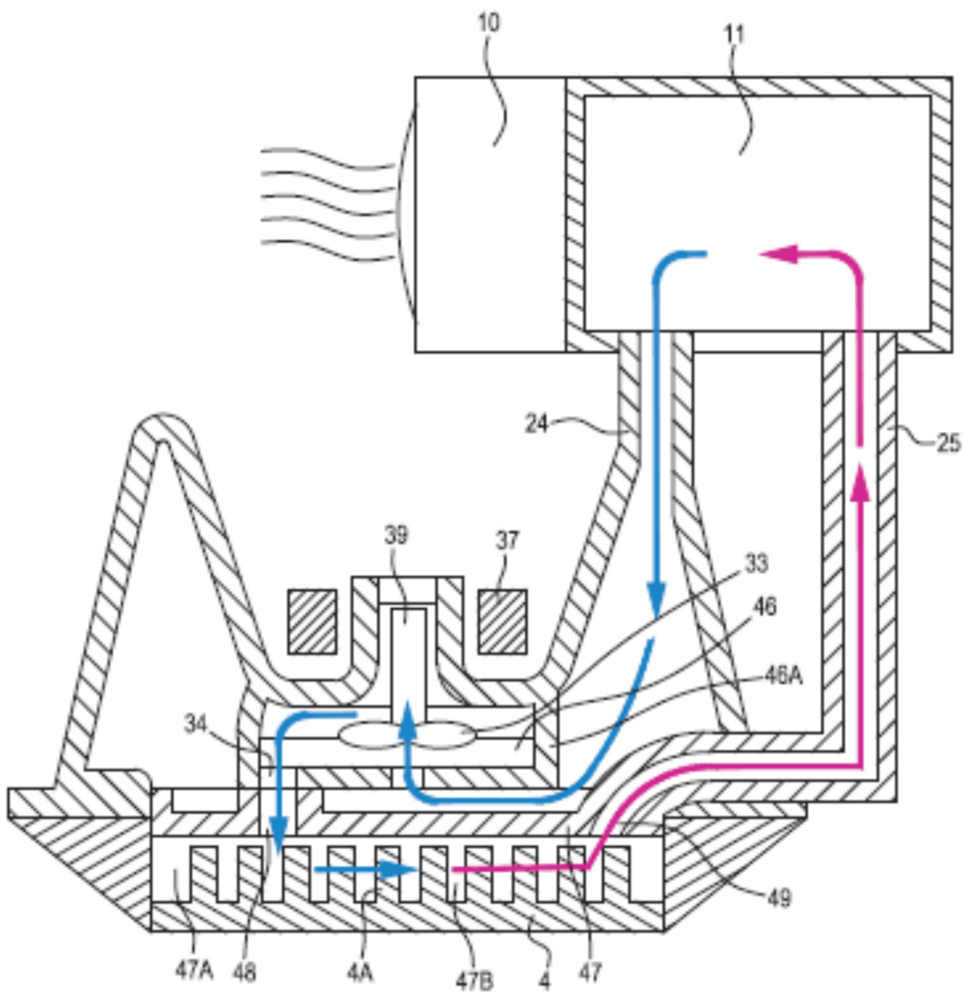
FIG. 20

40. "Thereby, a liquid-proof division is made between the rotor 39 of the

motor, said rotor 39 being placed inside the interior of the jacket 44 and being submerged in the cooling liquid, and the stator 37 of the pump, said stator 37 being positioned in the recess 40 and surrounding the exterior of the jacket 44. Accordingly, the stator 37 need not be sealed against the cooling liquid, because the recess 40 together with the jacket 44 ensures the stator staying dry from the cooling liquid, but the stator 37 still being capable of driving the rotor 39, when being supplied with electrical power from a power supply (not shown) of the computer system." (*Id.* at 22:10-20.) "Along an outer circumferential extension, the reservoir housing 14 is provided with protrusions 45 extending outwardly from the circumferential extension. The protrusions are intended for cooperating with a clip (see description below) for fastening the reservoir housing 14 to the CPU or other processing unit of the computer system. The protrusions 45 are shown as a plurality of singular protrusions. Alternatively, the protrusions may be only one continuous protrusion extending outwardly and around the circumferential extension." (*Id.* at 22:21-30.)

41. A POSITA would have understood that the resulting system looks like

the following example:



42. The cycle of the cooling liquid flows can start at the radiator 11. As shown above, the cooling liquid, already cooled by the fan 10 and the radiator 11, flows from the radiator 11 into the reservoir 14 through connecting tube 24, flows to the inlet of the pump chamber 46 and gets sucked up by the impeller 33 through the inlet of the pump chamber 46, gets spun to the circumference of the pump chamber 46, flows downward to the thermal exchange chamber 47A via the first passage 48, flows through the thermal exchange chamber 47A, flows out of the

thermal exchange chamber 47A via a second passage 49 and into the connecting tube 25, and finally flows back to the radiator 11 and fan 10 to get cooled, and the cycle continues.

VI. PRIOR ART REVIEW

A. Duan (Ex. 1005)

43. Duan was filed on February 18, 2005 and published on August 24, 2006 U.S. Patent Application Publication No. 2006/0185830. I understand that this means that Duan is prior art.

44. Duan is in the same field as the ’355 patent, as both relate to liquid-cooling systems for a heat emitting device such as a computer system. (*See* Ex-100 at [0002], [0007]-[0008].) I understand that Duan was not disclosed during the prosecution of the ’355 patent.

B. Admitted Prior Art (“APA”)

45. FIGS. 1-2 of the ’355 patent show a prior art embodiment of “the typical components in an air-cooling type CPU cooling arrangement”, and FIG. 3 shows an embodiment of “the typical components in a liquid-cooling type CPU cooling arrangement.” (Ex-1001 at 9:40-48, 10:22-67; FIGS. 1-3.)

46. The ’355 patent states that both air-cooling systems and liquid-cooling systems in the prior art included “a prior art air fan” (Ex-1001 at 10:22-67), and that in prior art liquid-cooling systems the air fan 10 is “provided together with the heat

radiator" and "blow[s] air through the heat radiator" (id. at 10:50-67). FIG. 3 of the '355 patent, showing air fan 10, is reproduced below:

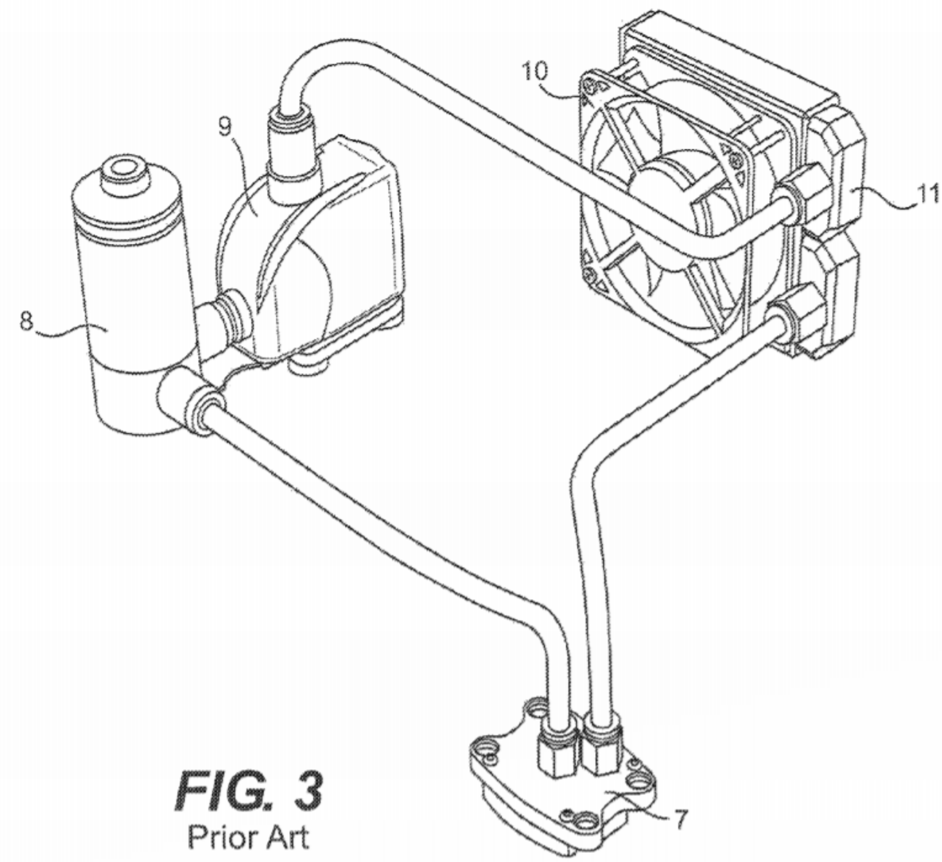


FIG. 3
Prior Art

47. Accordingly, FIGS. 1-3 of the '355 patent and the descriptions thereof are, in my opinion, an accurate description of the types of cooling and liquid cooling **<u>systems</u>** available prior to May 6, 2005.

C. Shin (Ex. 1006)

48. Shin was filed as Japanese Patent Application 2000-345470 on November 8, 2000 and published on May 24, 2002 as Japanese Unexamined Patent Application Publication No. 2002-151638 to Takayuki Shin. (Ex-1006 at (21), (22),

(11), (43).) I understand that this means that Shin is prior art.

49. Shin is in the same field as the ’355 patent, as both relate to liquid cooling systems for computer and electronic circuit systems that generate heat. (*See* Ex-1006 at [0001], [0002], [0006]-[0007].) Shin purports to solve the problem of “cooling structure for compactly mounting a liquid cooled heat sink and pump inside a case,” and does so by disclosing generally and claiming “[a] pump 5 is installed on the top part of a liquid cooled heat sink 4 and made into a structure allowing the pump 5 and liquid cooled heat sink 4 to be handled as an integral structure, making it possible to implement a liquid cooling system of high cooling performance, low noise and high reliability that can be compactly installed in an electronic equipment case without major changes to the case structure of conventional air cooled electronic equipment.” (*Id.* at [Abstract].)

50. Shin was not disclosed during the prosecution of the ’355 patent.

D. Cheon (Ex. 1007)

51. Cheon issued as U.S. Patent No. 5,731,954 on March 24, 1998. (Ex. 1007 at [11], [45].) I understand that this means that Cheon is prior art. Although Cheon was disclosed during prosecution of the ’355 patent, it was neither addressed substantively nor discussed in the context of Duan or Shin.

52. Cheon describes the problem of cooling increasingly hot microprocessors and a solution as follwos: “The cooling system of the invention has

a number of advantages. … The system may be installed either as part of original equipment or retrofitted into existing computers." (Ex-1007 at 2:44-50 ("… the system provides reliable and low-cost cooling" and "may be installed).

VII. DUAN ANTICIPATES CLAIMS 1, 2, 6, 10, 11, AND 13

53. I have been asked by counsel to analyze claims 1, 2, 5, 6, 8, 10, 11 and 13 (the "Challenged Claims") of the '355 patent and provide my opinion, rendered from the perspective of a POSITA, whether the prior art discloses the limitations of the Challenged Claims. Below, I provide my opinion with respect to each limitation of the Challenged Claims.

a. Challenged Claims

54. In my opinion, Duan anticipates every limitation of Claims 1, 2, 6, 10, 11, and 13. The elements in Duan's disclosed structure are exemplarily shown in the below annotated version of FIG. 2, which uses the following color coding scheme:

Color	Duan Element
Yellow	coil stage 221
Lime green	accommodation chamber 21
Orange	impeller stage 223
Light blue	cap 3
Dark blue	cooling plate 1
Purple	Heat-dissipating plates 12

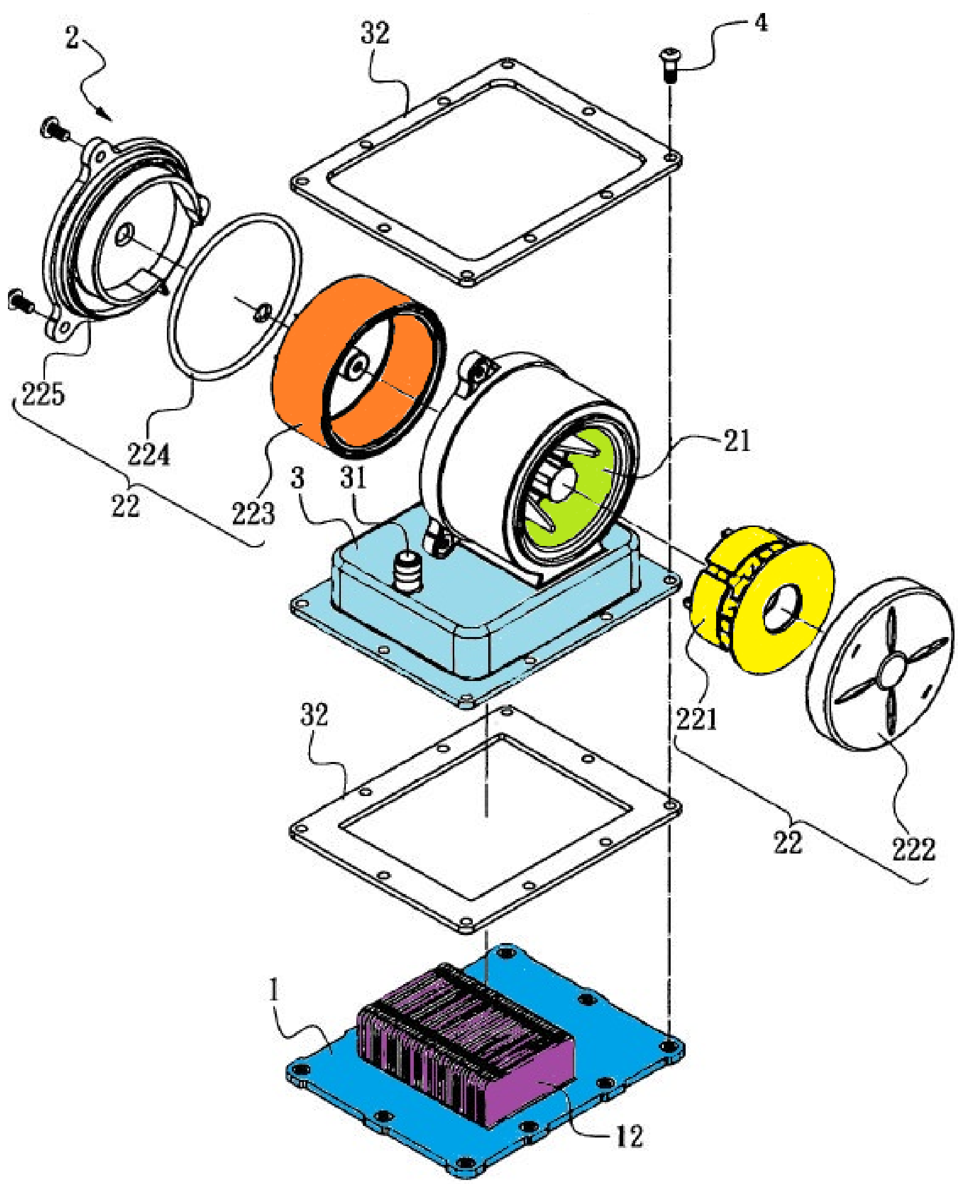


FIG. 2

(Ex. 1005 at FIG. 2.) The elements in Duan's disclosed structure above correspond to those in FIG. 17 of the '355 patent, which are exemplary of the Challenged Claims, as shown below with a similar coloring scheme:

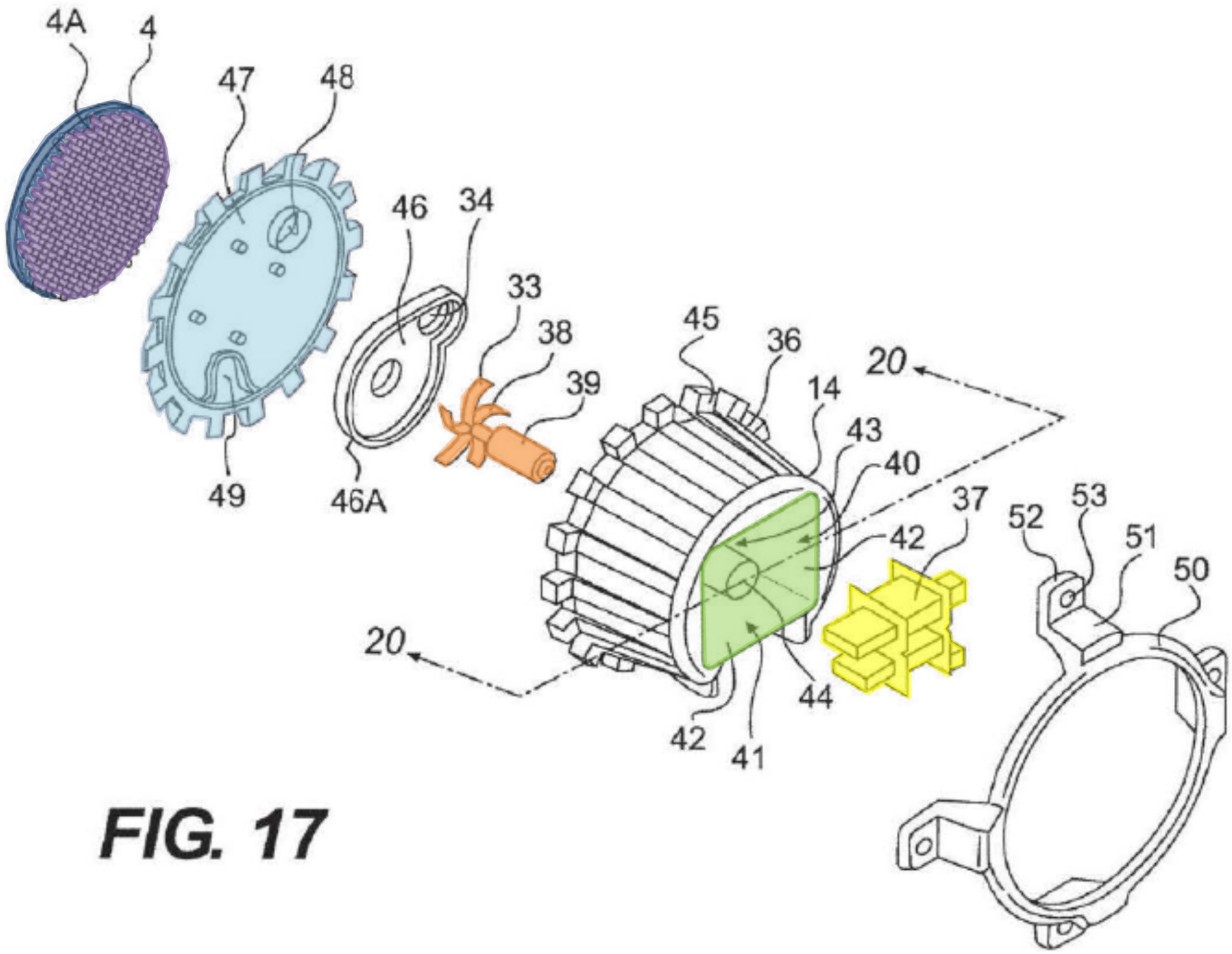


FIG. 17

As shown above, the correspondences are clear. As explained in further detail below, in my opinion, Duan discloses all limitations of Claims 1, 2, 6, 10, 11, and 13, thereby anticipating these claims.

55. I provide my analysis of the prior art with respect to these claims in the claim chart below. Unless otherwise noted, I have added emphasis to the quoted

excerpts.

(a) Claim 1

(i) **[1-PRE] 1. "A liquid cooling system for cooling a heat-generating component of a computer, comprising:"**

56. Duan discloses the preamble, regardless of whether it is a limitation. The invention disclosed or taught in Duan "relates to a cooling plate module, and more particularly to a cooling plate module used for heat emitting device such as a CPU." (Ex-1005-Duan at [0002] (emphasis added).) Duan further discloses or teaches that the described cooling plate module "includes a cooling plate and a liquid driving module." (Id. at Abstract (emphasis added).) Thus, Duan discloses the preamble.

(ii) **[1a] "a reservoir configured to circulate a cooling liquid there-through, the reservoir including;"**

57. Duan discloses or teaches this limitation. In Duan, the reservoir is the structural combination of accommodation chamber 21, cap 3, and cooling plate 1, and it is configured to pass cooling liquid there-through. Duan states:

> "With reference to FIGS. 2, 3, and 4, the liquid driving module 2 comprises an accommodation chamber 21 and a liquid driving unit 22 located in the accommodation chamber 21 and used to driving the cool liquid. The liquid driving unit 22 comprises a coil stage 221, an upper cover 222, an impeller stage 223, a sealing washer 224 and a lower cover 225. The lower cover 225 comprises a liquid inlet 23 communicated with the accommodation chamber 21. A first liquid outlet 24 is communicated to the bottom of the accommodation chamber 21 and is

> enclosed by a cap 3. A second liquid outlet 31 is defined on the cap 3. The cooling plate 1 is assembled with the cap 3 to define a closed space therein and the first liquid outlet 24 is corresponding to the heat-dissipating plates 12."

(Ex-1005 at [0023]); *see* FIGS. 2, 3.)

58. Reproduced below is a colored version of referenced FIG. 3 of Duan that uses the following color coding scheme:

Color	Duan-830 Element
Yellow	coil stage 221
Lime green	accommodation chamber 21
Orange	impeller stage 223
Light blue	cap 3
Dark blue	cooling plate 1

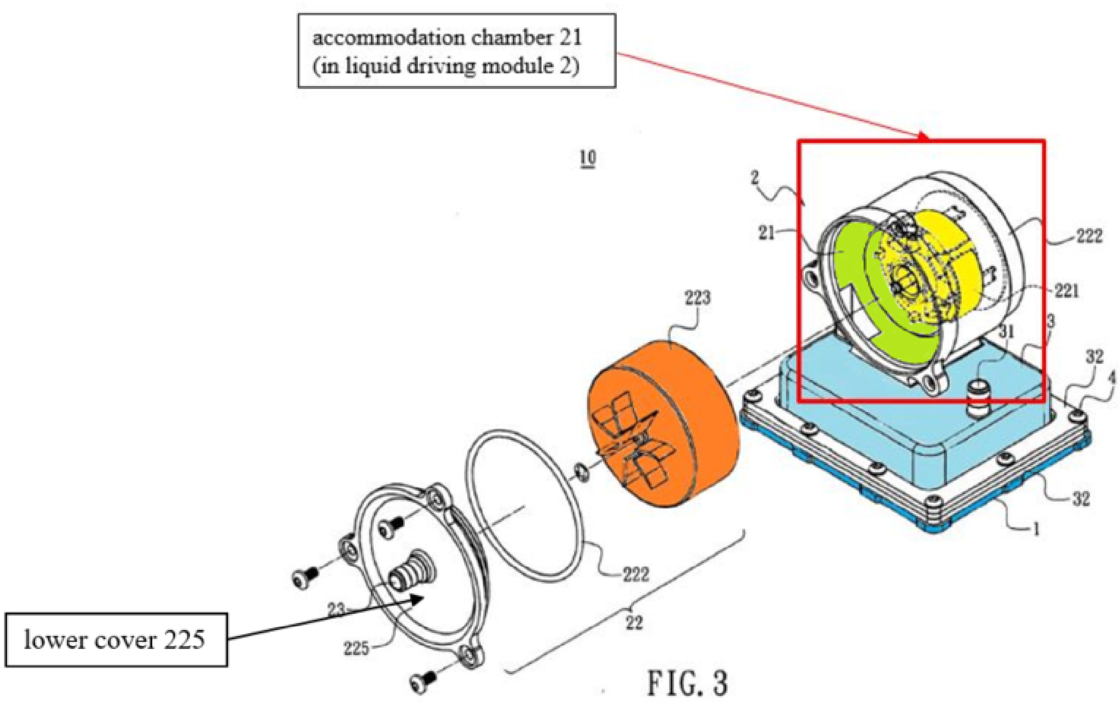


FIG. 3

59. As is clear from the above disclosures, Duan discloses or teaches this limitation.

60. To further illustrate, I present a cross sectional view of Duan where a red line is drawn around the reservoir to show a cross sectional view of the reservoir:

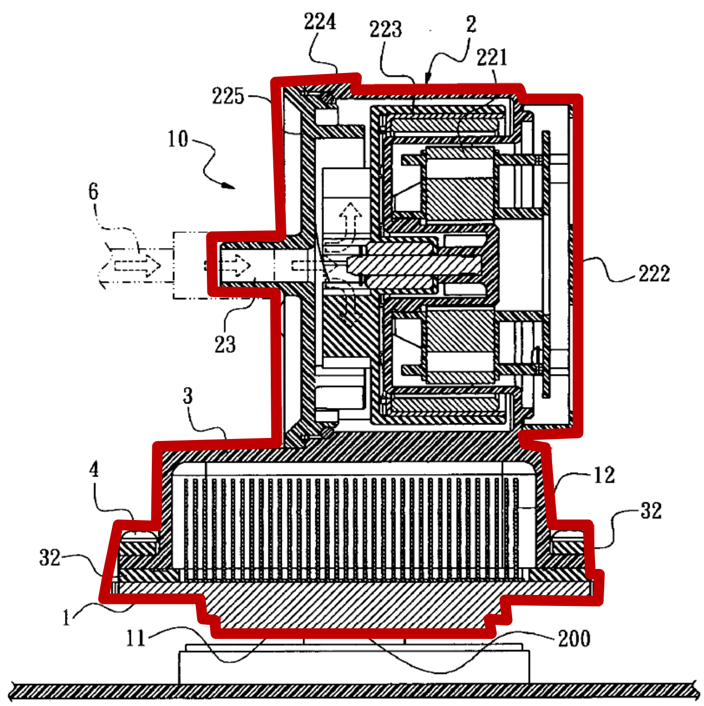


FIG. 7

61. As shown above, within the red line (denoting a reservoir), Duan includes the accommodation chamber 21, cap 3, and cooling plate 1. A POSITA would have understood that these structures together form a single receptacle defining a fluid flow path. Therefore Duan discloses this limitation.

62. In addition, it would be obvious to combine these structures as a single

receptible to achieve the claimed reservoir. I note, for example, in the embodiment in FIG. 7 that the accommodation chamber 21 and cap 3 are already combined into a single piece. Note, for example, in the embodiment in FIG. 7 that the accommodation chamber 21 and cap 3 are already combined into a single piece. Duan reiterates the need to integrate components to make them smaller as the form factor of computers become more compact. Duan describes the trend to unify components, thereby promoting integrated components as opposed to separate components. (Ex-1005 at [0006]-[0007].) Duan conveys this message by the way it characterizes the prior art as "bulky" and distributed across disparate stages. (Ex-1005 at [0006].)

(iii) **[1b] "the reservoir including: a pump chamber housing an impeller and defined at least in part by an impeller cover and a double-sided chassis, the impeller being positioned on one side of the chassis and a stator of the pump is positioned on an opposite side of the chassis"**

63. With regard to this limitation, the '355 patent explains an example of how its "reservoir housing" forms "a double-sided chassis configured to mount an electrical motor" in FIG. 17 (Ex. 1001 at FIG. 17; 21:47-56.):

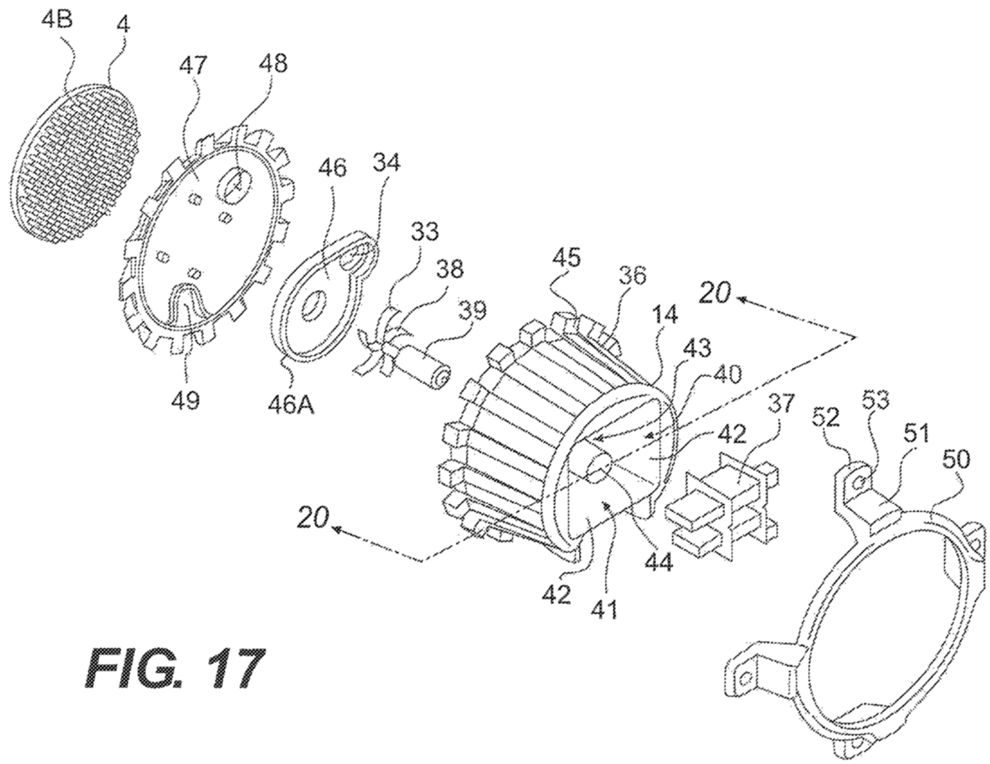


FIG. 17

64. As shown above, the "reservoir substantially has a conical, circular configuration." (*Id.*). FIG. 20 of the '355 patent provides an example of a cross section view where "the impeller 33 is housed in a recess on the underside of the reservoir housing 14" (colored in green below):

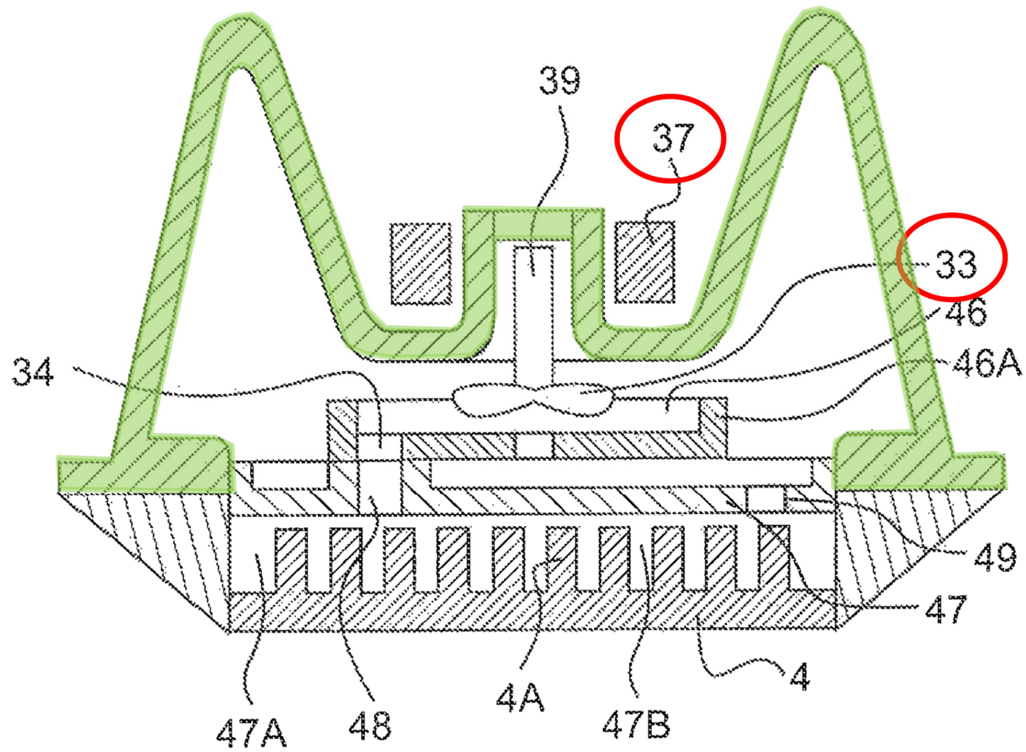


FIG. 20

(Ex. 1001 at FIG. 20; 22:6-9 (emphasis added).) Specifically, FIG. 20 depicts the impeller 33 on one side of the chassis and the stator 37 on the other side of the chassis.

65. Duan discloses or teaches this limitation. Duan states:

> "***With reference to FIGS. 2, 3, and 4, the liquid driving module 2 comprises an accommodation chamber 21 and a liquid driving unit 22 located in the accommodation chamber 21 and used to driving the cool liquid. The liquid driving unit 22 comprises a coil stage 221, an upper cover 222, an impeller stage 223, a sealing washer 224 and a lower cover 225***. The lower cover 225 comprises a liquid inlet 23 communicated with the

> accommodation chamber 21. A first liquid outlet 24 is communicated to the bottom of the accommodation chamber 21 and is enclosed by a cap 3. A second liquid outlet 31 is defined on the cap 3. The cooling plate 1 is assembled with the cap 3 to define a closed space therein and the first liquid outlet 24 is corresponding to the heat-dissipating plates 12. In the present invention, the liquid driving module 2 can be reciprocating pump or axial-flow pump."

(Ex-1005 at [0023]) (emphasis added).) These elements are also shown in the below version of FIG. 2, which uses the following color coding scheme:

Color	**Duan-830 Element**
Yellow	coil stage 221
Lime green	accommodation chamber 21
Orange	impeller stage 223
Light blue	cap 3
Dark blue	cooling plate 1
Purple	Heat-dissipating plates 12

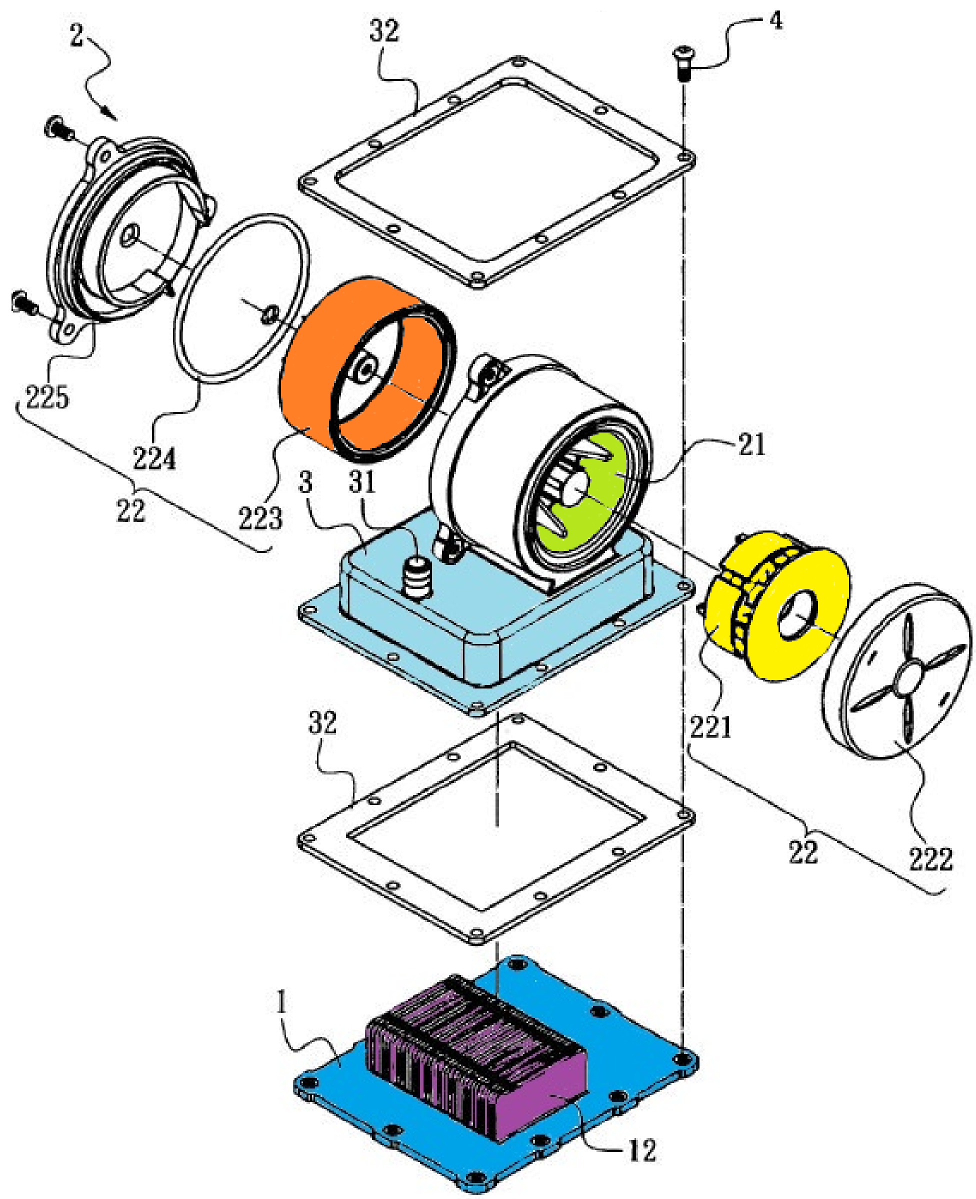


FIG. 2

(Ex-1005 at FIG. 2.) The specification and FIG. 2 of Duan thus disclose a pump chamber (e.g., accommodation chamber 21 and lower cover 225) housing an impeller (impeller stage 223) and defined at least in part by an impeller cover (the combination of the lower cover 225 and the interior cylindrical wall of the accommodation chamber 21 surrounding the impeller, further explained below) and a double-sided chassis (accommodation chamber 21), the impeller (223) being positioned on one side of the chassis and a stator (coil stage 221) of the pump (liquid driving unit 22) positioned on an opposite side of the chassis.

66. Duan's discussion of a coil stage in context of its figures discloses the claimed stator. Duan's coil stage would have been understood by a POSITA as an electro-magnetic coil or field coil. A POSITA would have understood that a coil includes several windings of a conductive wire that makes the shape of a coil. The coil is wound around a core such as, for example, an iron or other ferromagnetic metal. As current flows through the coil, the coil and core together create a magnetic field to drive a rotor such as, for example, an impeller. A POSITA would therefore know that the Duan's reference to a coil stage, in the context of a rotary motor, includes a core and that core is known to be a stator. Specifically, the core of a coil is a stationary part of the motor of the pump. Duan's "liquid driving unit 22" includes coil stage 223 as part of the rotary motor of the pump. Thus, Duan discloses a stator of a motor of a pump.

67. Duan's impeller stage discloses an impeller. As shown in FIG. 3 of Duan, the impeller stage 223 includes blades that are shaped and positioned to move fluid as the blades rotate. A POSITA would have understood that these blades of Duan's impeller stage are impellers.

68. Duan further discloses a double-sided chassis where the impeller is positioned one side of the chassis and a stator is positioned on the opposite side of the chassis. The impeller of Duan's impeller stage must be in contact with the fluid, as the primary purpose of the impeller is to move fluid. (Ex-1005 at [0023].) Duan also discloses "a sealing washer 224" to prevent liquid from leaking.

69. In addition, it is obvious to a POSITA that Duan positions the coil stage (which would have been understood by a POSITA to be included in a stator) on the opposite side of the chassis with respect to the impeller because it is the common approach to avoid inefficiencies such as leaks occurring in designs when the coils are in contact with a liquid. In fact, in FIG. 3, the coil stage 221 is drawn with dashed lines which in mechanical drawings indicates an object being behind the closest surface to the viewer. In FIG. 7, it is clear that the stator is positioned on one side of the double-side chassis indicated by the red line.

70. Duan's chassis is included in a pump chamber that is defined by the accommodation chamber 21 and the impeller cover (lower cover 22). In this respect, items 21 and 22 of Duan form a pump chamber housing a pump (e.g., the liquid driving unit 22) as shown in FIGS. 2 and 3 of Duan.

71. Duan's pump chamber is defined at least in part by an impeller cover (e.g., the *combination* of the lower cover 225 and the interior wall of the accommodation chamber 21, colored in lime green below) and a double-sided

chassis (the accommodation chamber 21, encompassed by a red rectangle below).

Color	Duan Element
Yellow	coil stage 221
Lime green	accommodation chamber 21 (interior)
Orange	impeller stage 223
Light blue	cap 3
Dark blue	cooling plate 1
Light green	Lower cover 225

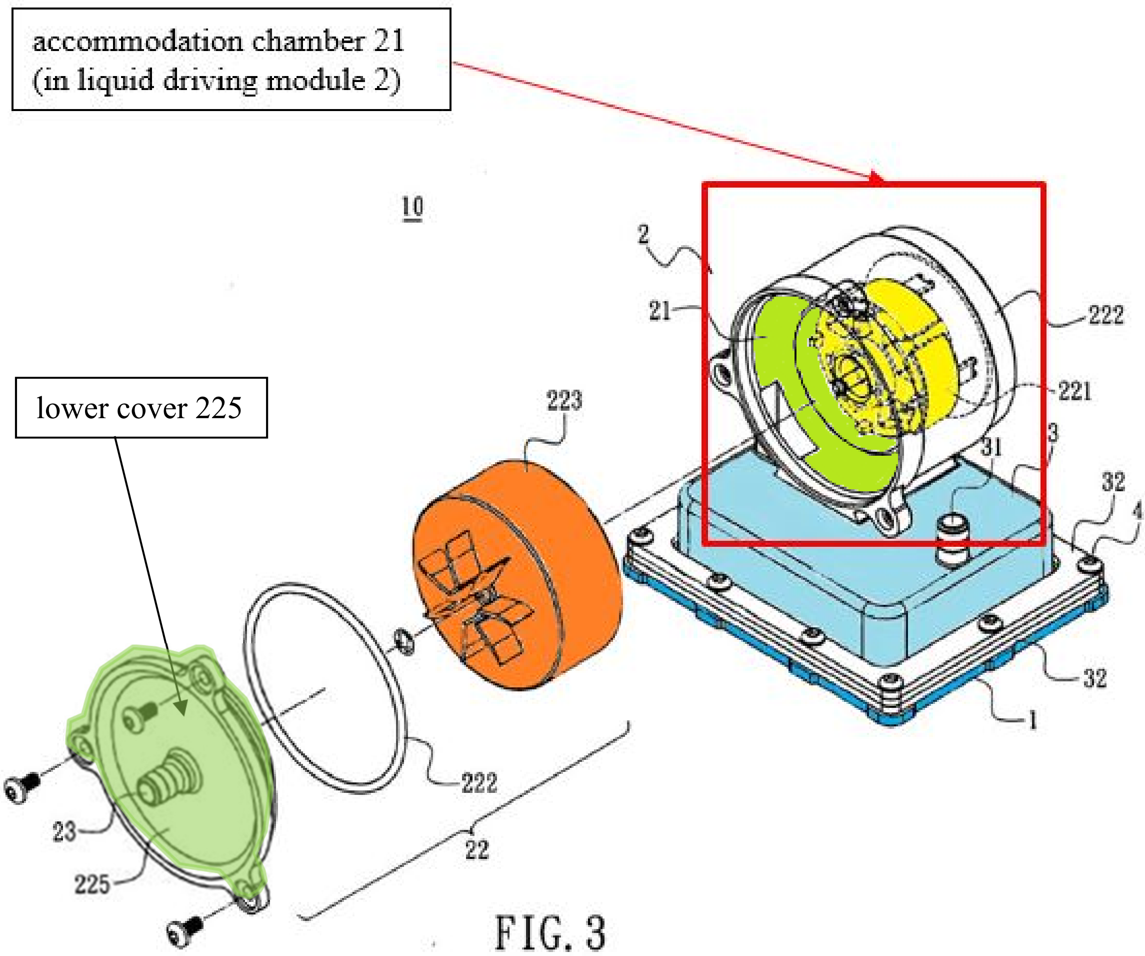


FIG. 3

72. As shown above in the color version of FIG. 2 of Duan, a lower cover 225 attaches to the accommodation chamber 21 (colored in light green above),

together in a combination with the interior cylindrical wall of the accommodation chamber 21 (colored in lime green), forms the claimed "impeller cover" to partially define an enclosure for the liquid driving unit 22, i.e., the claimed "pump chamber."

73. As further shown below in an annotated FIG. 7 of Duan, the impeller cover is indicated in light green:

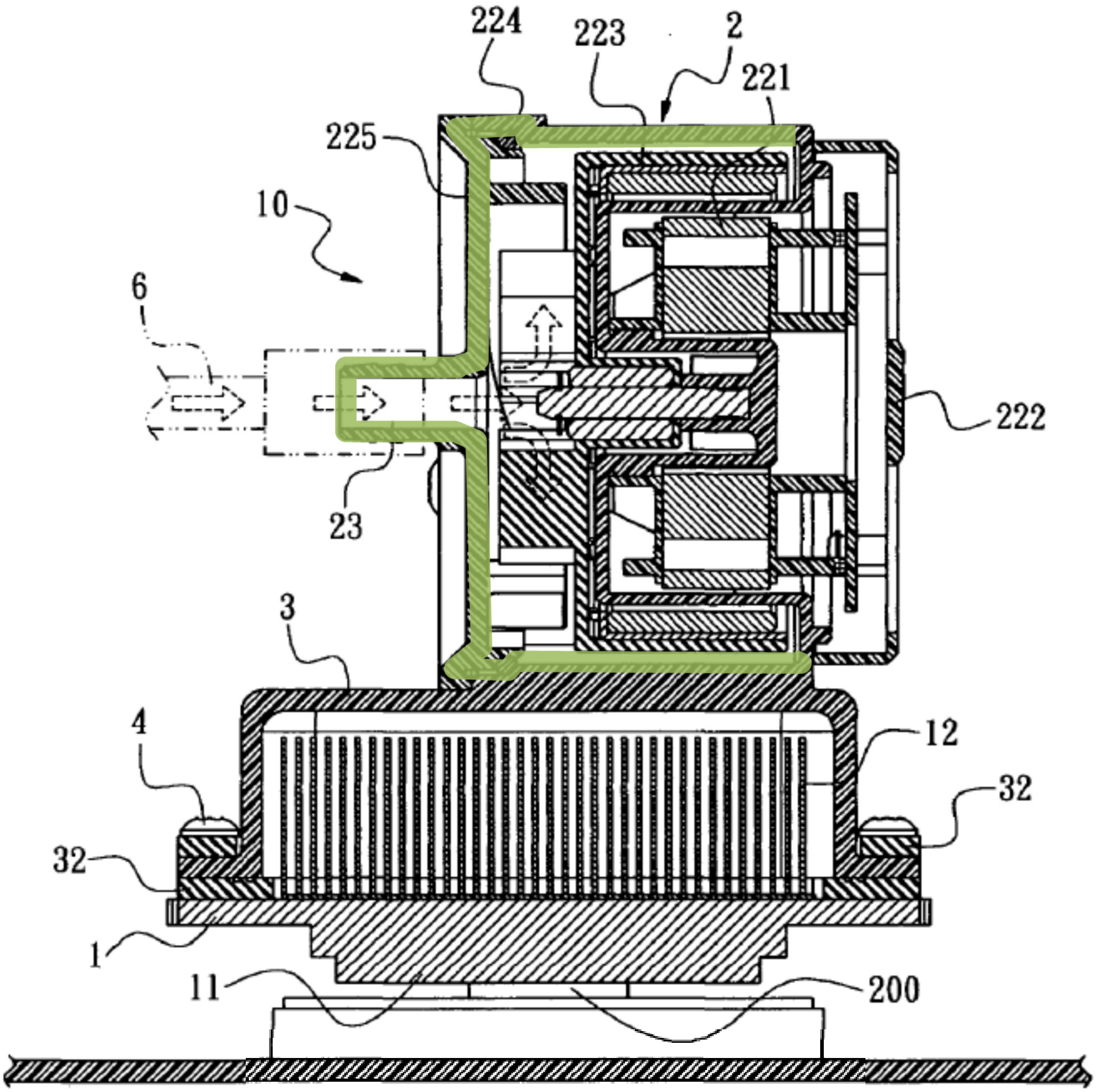


FIG. 7

74. Duan thus discloses this limitation.

75. Duan's coil stage 221 includes stationary coil and core structure having the claimed stator and structural relationships.

76. Further, Duan discloses that the impeller is positioned on one side of the chassis (e.g., the accommodation chamber 21) and a stator (e.g., the coil stage 221) of the pump (e.g., liquid driving unit 22) positioned on an opposite side of the chassis. A POSITA reading Duan would have understood that Duan's coil stage 221 is a part of an electric rotary motor, i.e., a stator, which is a common structure of a rotary motor that includes the stationary functional parts of a motor during its operation. (Ex. 1001 at 2:40-42.) Thus, Duan's disclosure of a coil stage and impeller stage further discloses the presence of a stator needed to cause the impeller to rotate about an axis for purposes of providing a fluid pump.

77. Moreover, a POSITA reading Duan would have understood that the impeller of the impeller stage is in contact with the liquid for performing the liquid pump functionality provided by Duan's liquid driving module. Specifically, Duan states that "[t]he lower cover 225 comprises a liquid inlet 23," which means that the impeller makes contact with liquid. (Ex. 1005 at [0023].) Duan also discloses the use of a "a sealing washer 224" to prevent liquid from escaping around the impeller.

78. Next, Duan's coil stage (including the stator) is not in contact with

fluid. This is shown in FIG. 2 of Duan where the impeller 223 is separated from the coil stage. In this respect, Duan protects its coil stage from the fluid that is being moved by the impeller stage. As a result, FIG. 2 of Duan shows separating the coil stage (which includes a stator) and the impeller (which is part of the impeller stage) such that former is not submerged while the latter is submerged.

79. FIG. 7 of Duan provides yet another view of a double-sided chassis that separates the impeller and stator on opposite sides of the chassis. FIG. 7, below, shows the locations of the impeller (item 223) and the coil stage that includes a stator (item 221).

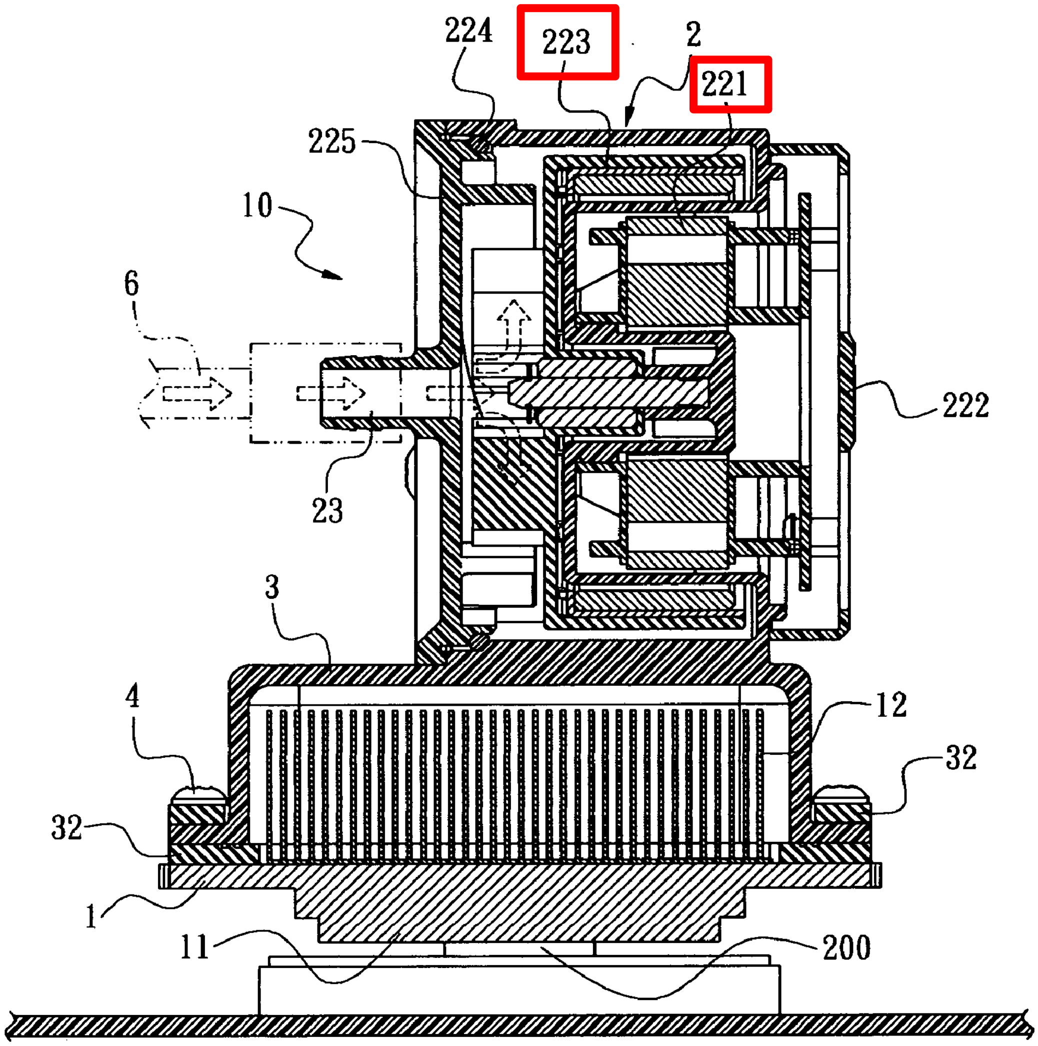


FIG. 7

(Ex. 1005 at FIG. 7 (emphasis added to show items 221 and 223).) In addition, a red line is added to FIG. 7 to show a cross-section of the chassis as it separates items 221 (on the right side of the red line) and 223 (on the left side of the red line).

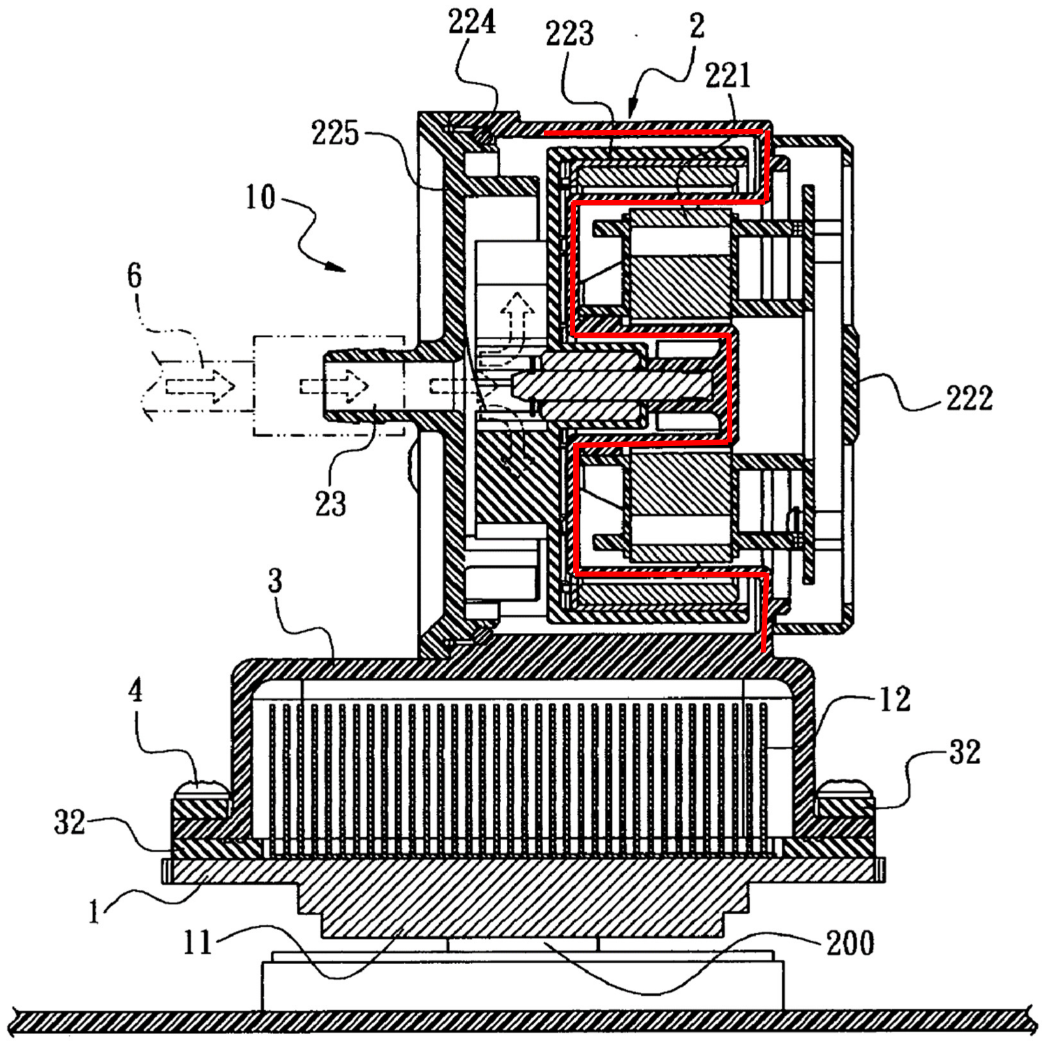


FIG. 7

(Ex. 1005 at FIG. 7 (emphasis added).) Thus, FIG. 7 of Duan further discloses an impeller being positioned on one side of the chassis (denoted partially by a red line along the cross section) and a stator of the pump positioned on an opposite side of the chassis.

(iv) **[1c] "a thermal exchange chamber disposed between the pump chamber and the heat-generating component when the system is installed on the heat-generating component,"**

80. Duan discloses this limitation. Duan states:

> "With reference to FIGS. 2 and 6, the cooling plate module 10 according to the present invention is applied to a liquid cooling cyclic mechanism 100, which is used for the heat dissipation of a CPU 200 and composed of the cooling plate module 10 and a water tank module 20 connected with the cooling plate module 10 through ducts. The cooling plate module 10 comprises a cooling plate 1 and a liquid driving module 2. ***The cooling plate 1 comprises a heat-absorbing face 11 on bottom thereof and being in contact with a heat source. A plurality of heat-dissipating plates 12 are formed on top face of the cooling plate 1 and can be arranged in longitudinal or transverse manner***. A runner is defined between the plurality of heat-dissipating plates 12 and forms a closed loop."

(Ex-1005-Duan at [0022] (emphasis added); *see also id*. at [0024] ("The cooling plate 1 is fixed to bottom of the cap 3 and the heat-dissipating plates 12 are located in the cap 3 and corresponding to the first liquid outlet 24.").) *See also* FIG. 2:

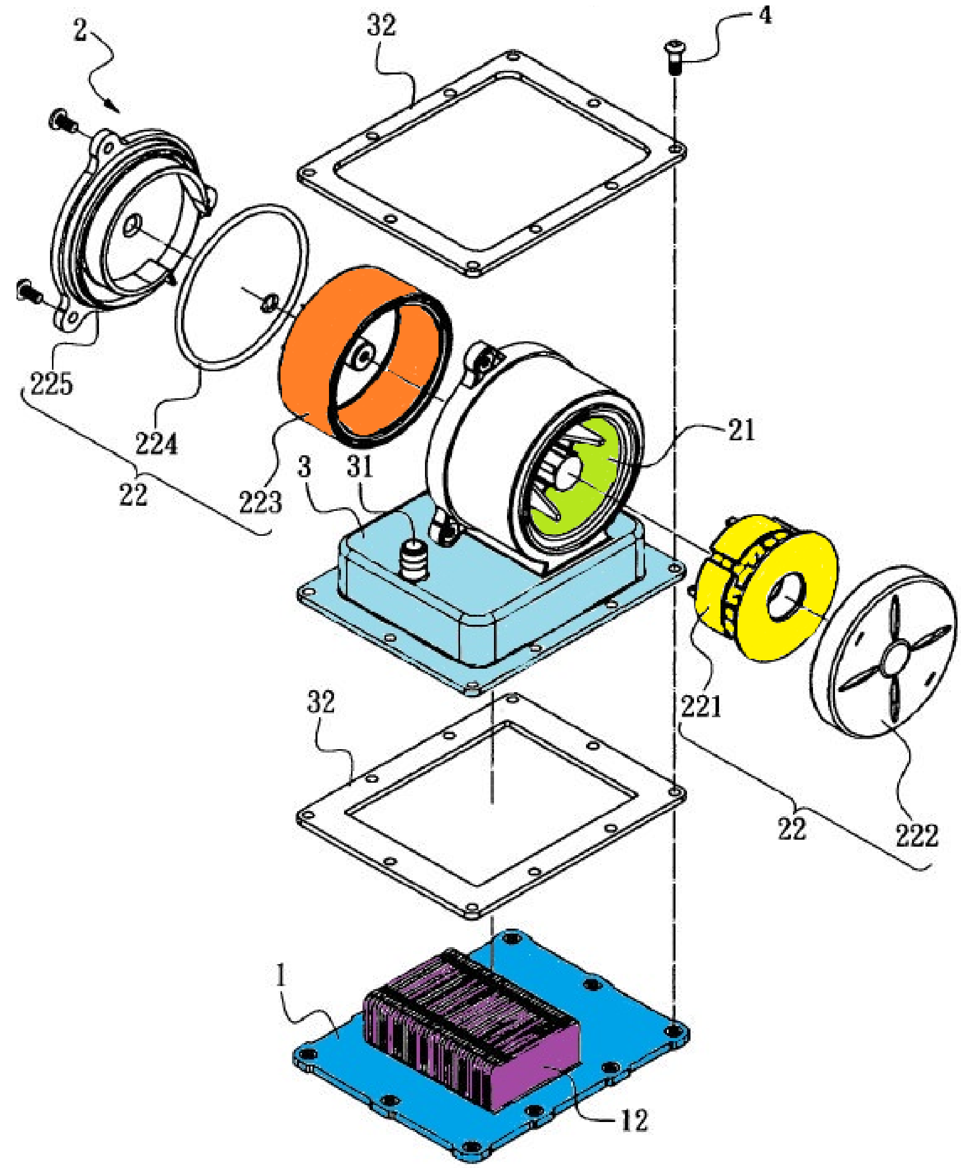


FIG. 2

81. Duan also teaches that "***the liquid cooling cyclic mechanism 100 is assembled to the CPU 200 with the heat absorbing face 11 being in contact with the CPU 200 for heat dissipating the CPU 200***." (*Id.* at [0026] (emphasis added).) And Duan further states:

> "With reference to FIGS. 7 and 8, during operation of the present invention, the cool liquid in the water tank 20 is conveyed to the accommodation chamber 21 through the duct 6 and the liquid inlet 23 of the cooling plate module 10 and driven by the liquid driving unit 22. ***The cool liquid then flows to the cap 3 through the first liquid outlet 24 for heat dissipating the heat-dissipating plates 12 in the cap 3.*** More particularly, the cool liquid is heat exchanged with the heat-dissipating plates 12 into hot liquid. The hot liquid then flows to the liquid entrance region 51 of the water tank 20 through the second liquid outlet 31 of the cooling plate module 10 and another duct 6."

(Ex-1005-Duan at [0027] (emphasis added).)

82. In my opinion, based on these teachings, a POSITA would have understood that Duan discloses a thermal exchange chamber (cap 3 and cooling plate 1) disposed between the pump chamber (e.g., accommodation chamber 21 and lower cover 225) and the heat-generating component (CPU 200) when the system is installed on the heat-generating component (200). This is perhaps best illustrated in the following annotated version of FIG. 8.

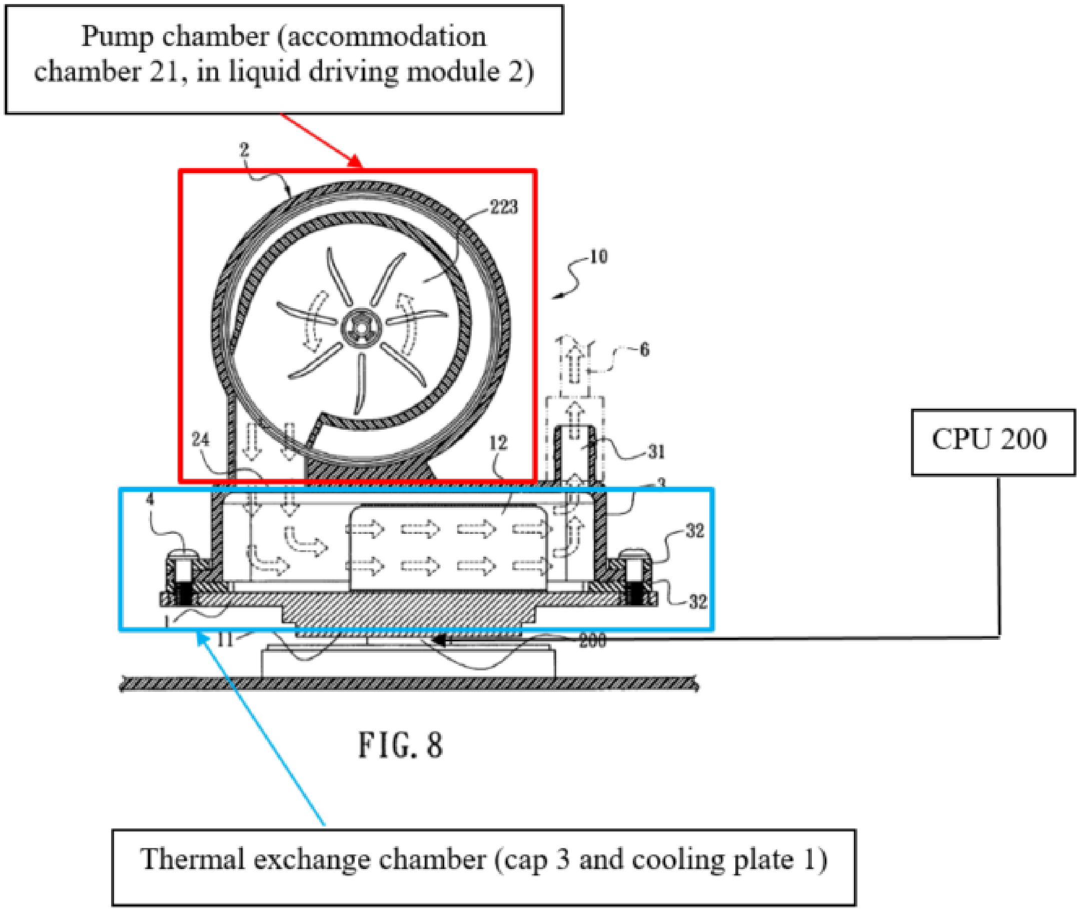


FIG. 8

(Ex-1005 at FIG. 8.)

83. Accordingly, Duan discloses this limitation.

(v) **[1d] "a heat-exchanging interface forming a boundary wall of the thermal exchange chamber, the heat-exchanging interface has an outer surface configured to be placed in thermal contact with a surface of the heat-generating component and an inner surface that direct defines a plurality of channels that direct the flow of a cooling liquid within the thermal exchange chamber;"**

84. Duan discloses, teaches or suggests this limitation. As explained below, Duan discloses that the reservoir includes a heat-exchanging interface (e.g., surface of cooling plate 1 comprising a heat absorbing face 11), the heat-exchanging

interface forming a boundary wall of the thermal exchange chamber (e.g., cap 3 and cooling plate 1), and the heat-exchanging interface further having an outer surface (e.g., heat-absorbing face 11) to be placed in thermal contact with a surface of the heat-generating component (e.g., CPU 200); and an inner surface that defines a plurality of channels (e.g., a plurality of heat-dissipating plates 12 forming channels on top face of the cooling plate 1) that direct the flow of the cool liquid within the thermal exchange chamber. Specifically, Duan describes:

> "With reference to FIGS. 7 and 8, during operation of the present invention, the cool liquid in the water tank 20 is conveyed to the accommodation chamber 21 through the duct 6 and the liquid inlet 23 of the cooling plate module 10 and driven by the liquid driving unit 22. ***The cool liquid then flows to the cap 3 through the first liquid outlet 24 for heat dissipating the heat-dissipating plates 12 in the cap 3. More particularly, the cool liquid is heat exchanged with the heat-dissipating plates 12 into hot liquid. The hot liquid then flows to the liquid entrance region 51 of the water tank 20 through the second liquid outlet 31 of the cooling plate module 10 and another duct 6***."

(Ex-1005 at [0027]; (emphasis added.)

85. Duan also teaches:

> "With reference to FIGS. 2 and 6, the cooling plate module 10 according to the present invention is applied to a liquid cooling cyclic mechanism 100, which is used for the heat dissipation of a CPU 200 and composed of the cooling plate module 10 and a water tank module 20 connected with the cooling plate module 10 through ducts. ***The cooling plate 1 comprises a heat absorbing face 11 on bottom thereof and being in contact with a heat source. A plurality of heat-dissipating plates 12 are formed on top face of the cooling plate 1 and can be arranged in***

> ***longitudinal or transverse manner. A runner is defined between the plurality of heat-dissipating plates 12 and forms a closed loop.***"

(Ex-1005 at [0022] (emphasis added).) Reproduced below is a colored version of FIG. 4 of Duan that uses the following color coding scheme and illustrates the disclosure of this limitation:

Color	Duan-830 Element
Red	heat-absorbing face 11
Light blue	cap 3
Dark blue	cooling plate 1

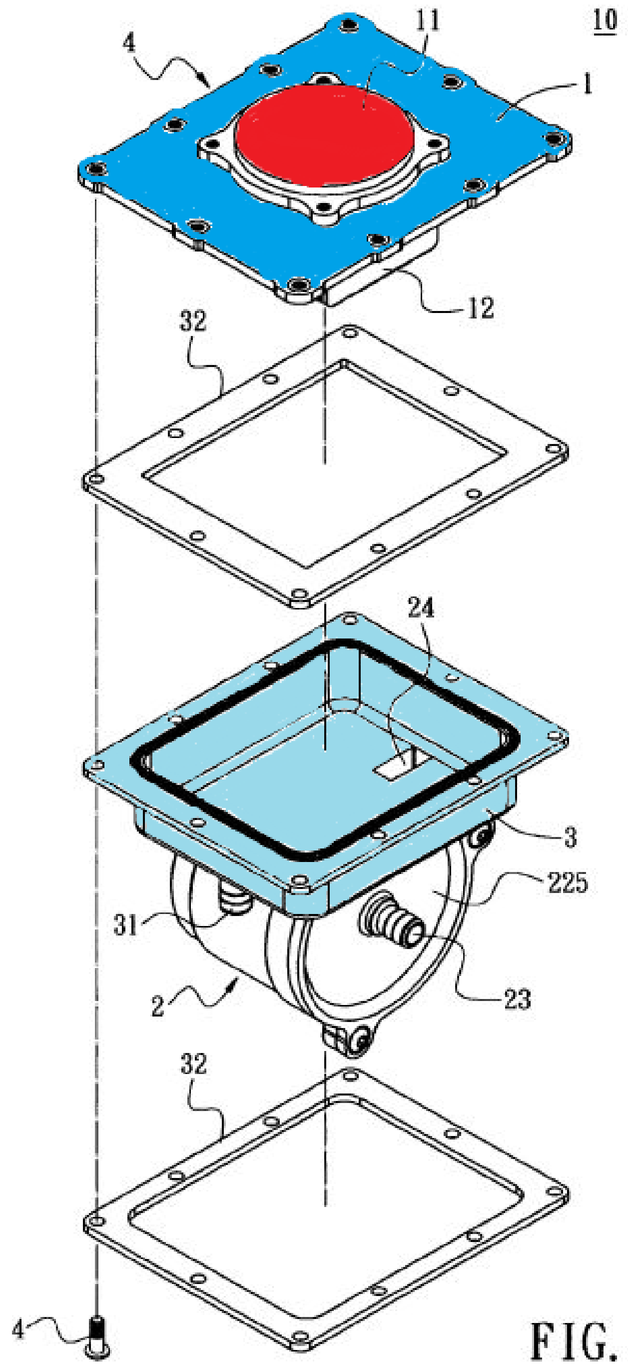


FIG. 4

(Ex-1005-Duan at FIG. 4; see also FIG. 8.)

86. Furthermore, FIG. 4 of Duan is an upside-down view of FIG. 8 that shows the components within the cap 3. Specifically, it discloses how a "plurality of heat dissipating plates 12 are formed on top face of cooling plate 1 and can be

arranged in a longitudinal or transverse manner." (Ex. 1005 at [0022].) The arrangement of the plates (longitudinal or transverse) creates a plurality of channels for liquid to flow along the surfaces of the plates. A POSITA would have understood that the greater the surface area contact between the heat dissipating plates 12 and the liquid, the greater the heat dissipation. Therefore, Duan's disclosure of arranging multiple plates teaches the use of a plurality of channels to create greater surface area and provide more contact between the liquid and the heat dissipating plates 12. Based on these teachings, in my opinion, Duan discloses a heat-exchanging interface (cooling plate 1 comprising a heat absorbing face 11), the heat-exchanging interface forming a boundary wall of the thermal exchange chamber (cap 3 and cooling plate 1), and the heat-exchanging interface further having an outer surface (heat-absorbing face 11) to be placed in thermal contact with a surface of the heat-generating component (CPU 200); and an inner surface that defines a plurality of channels that direct the flow of the cool liquid within the thermal exchange chamber (a plurality of heat-dissipating plates 12 are formed on top face of the cooling plate 1).

87. The plurality of channels formed between plates 12 are further shown in FIG. 7 of Duan, which depicts a cross-sectional view of the reservoir:

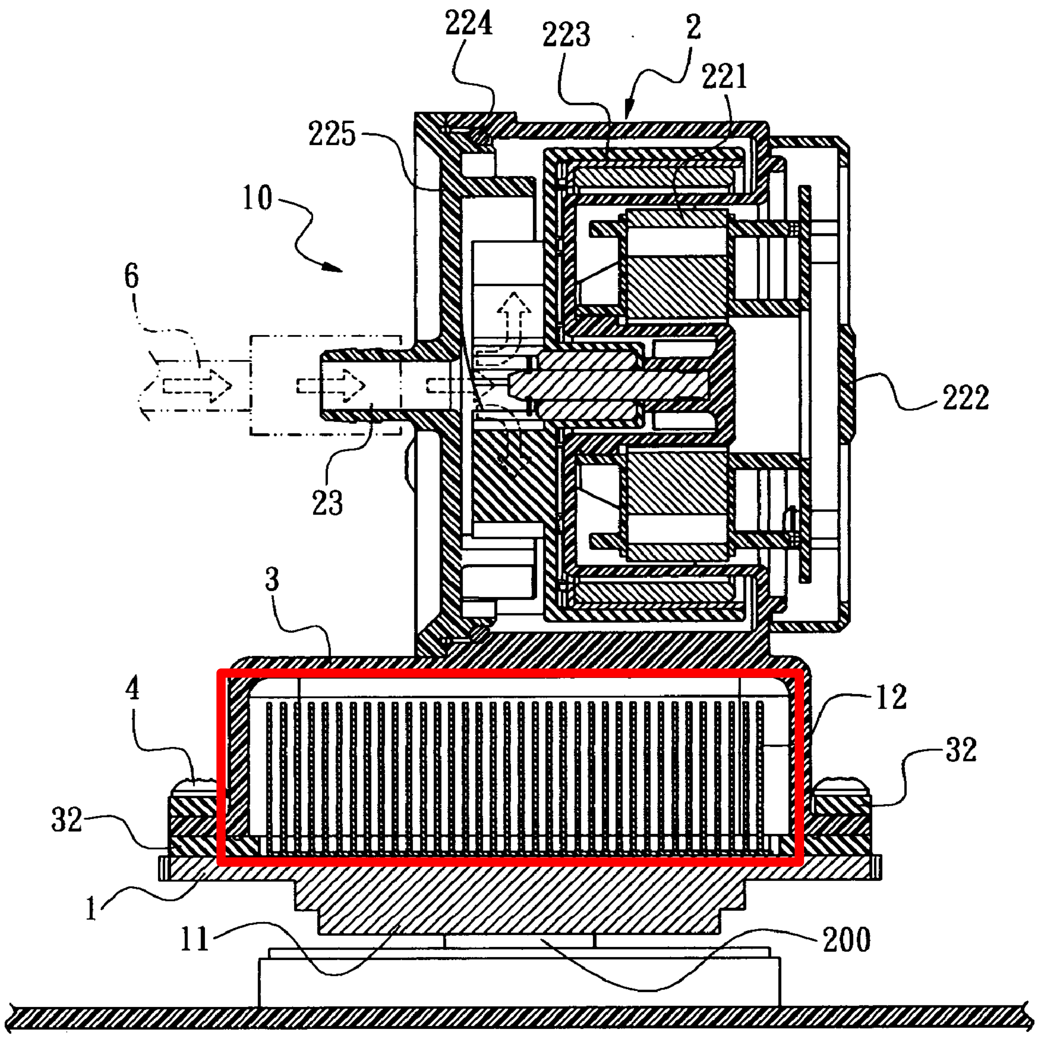


FIG. 7

(Ex. 1005 at FIG. 7) (red box added to show location of plurality of channels.)

88. Therefore, Duan discloses this limitation.

(vi) **[1e] "a heat radiator adapted to pass the cooling liquid there-through, the heat radiator being fluidly coupled to the reservoir via fluid conduits, the heat radiator being configured to dissipate heat from the cooling liquid;"**

89. Duan discloses, teaches or suggests this limitation. FIG. 6 of Duan is

reproduced below:

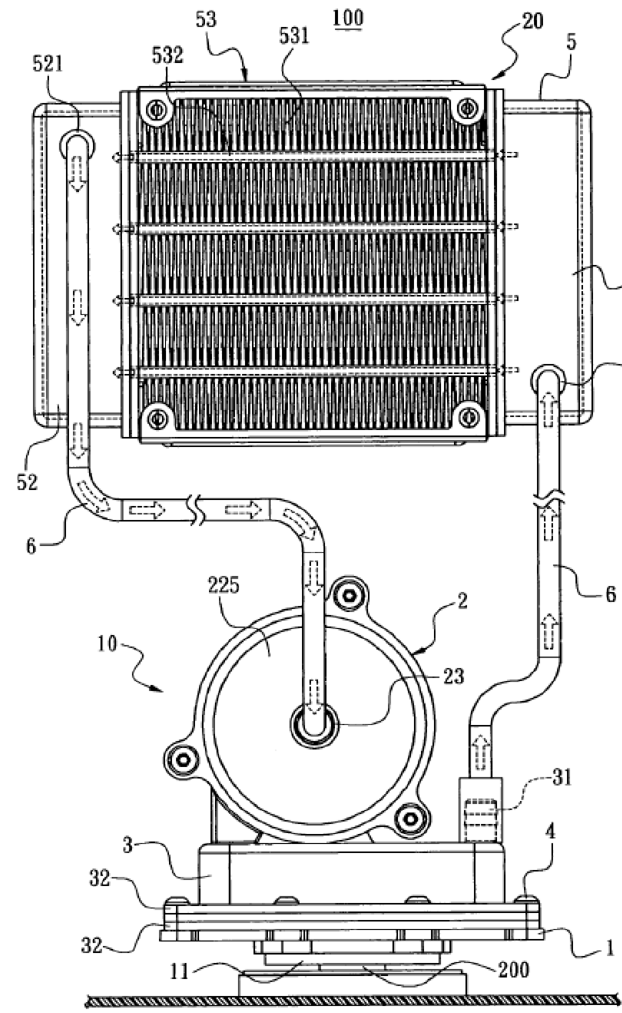


FIG. 6

90. With reference to FIG. 6, Duan states:

> "As shown in FIG. 6, ***the water tank 20 of the liquid cooling cyclic mechanism 100 comprises a box 5 with a liquid entrance region 51 and a liquid exit region 52 provided on both sides of the water tank 20, respectively. The box 5 comprises a cooling stage 53 at center thereof and composed of a plurality of stacked heat-dissipating fins 531 arranged in rows. Runners 532 are defined between rows of the heat-dissipating fins 531; both ends***

> ***of the runner 532 are communicated with the liquid entrance region 51 and the liquid exit region 52*.** When the hot liquid entrance region 51 flows to the liquid exit region 52 through the runners 532, the hot liquid is first heat exchanged with the heat-dissipating fins 531 into cool liquid and then the cool liquid flows to the liquid exit region 52."

(Ex-1005-Duan at [0025] (emphasis added).)

91. Based on these disclosures, a POSITA would have understood that Duan discloses, suggests, or teaches a heat radiator (cooling stage 53, heat-dissipating fins 531, and runners 532) fluidly coupled to the reservoir (accommodation chamber 21, cap 3, and cooling plate 1) and configured to dissipate heat from the cooling liquid (duct 6, liquid inlet 511, and liquid outlet 521).

92. Duan thus discloses this limitation.

93. Duan also teaches or suggests this limitation.

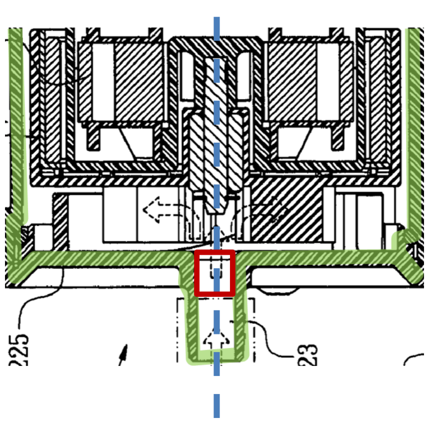
(vii) **[1f] "wherein the pump chamber further includes:"**

94. Duan discloses a pump chamber—the accommodation chamber 21, which is part of the liquid driving module 2. Notably, Duan teaches, "With reference to FIGS. 2, 3, and 4, ***the liquid driving module 2 comprises an accommodation chamber 21 and a liquid driving unit 22*** located in the accommodation chamber 21 and used to driving the cool liquid. … In the present invention, the liquid driving module 2 can be reciprocating pump, centrifugal pump or axial-flow pump." (Ex-1005 at [0023] (emphasis added); *see also* FIG. 3.)

95. Therefore, Duan discloses this limitation.

(viii) **[1g] "an inlet defined by the impeller cover positioned below a center of the impeller configured to enable the cooling liquid to flow into the center of the pump chamber;"**

96. Duan discloses this limitation. Duan discloses an inlet (liquid inlet 23) defined by the impeller cover (the cylindrical wall surrounding accommodation chamber 21 and lower cover 225 that together cover the impeller stage 223) positioned below a center of the impeller (impeller stage 223) configured to enable the cooling liquid to flow into the center of the pump chamber (e.g., accommodation chamber 21 and lower cover 225). As shown below, FIG. 7 of Duan (left) is virtually identical to FIG. 20 of the '355 patent (right) with respect to this element.



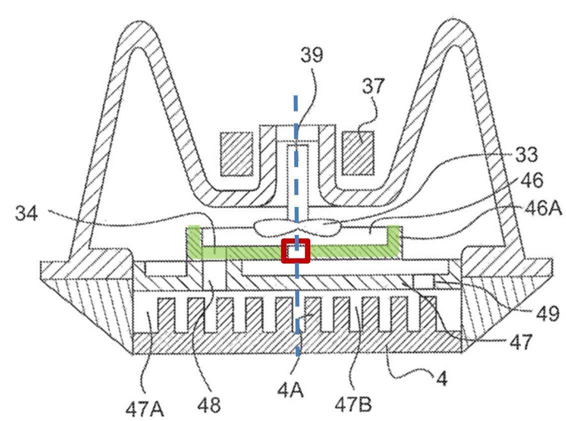
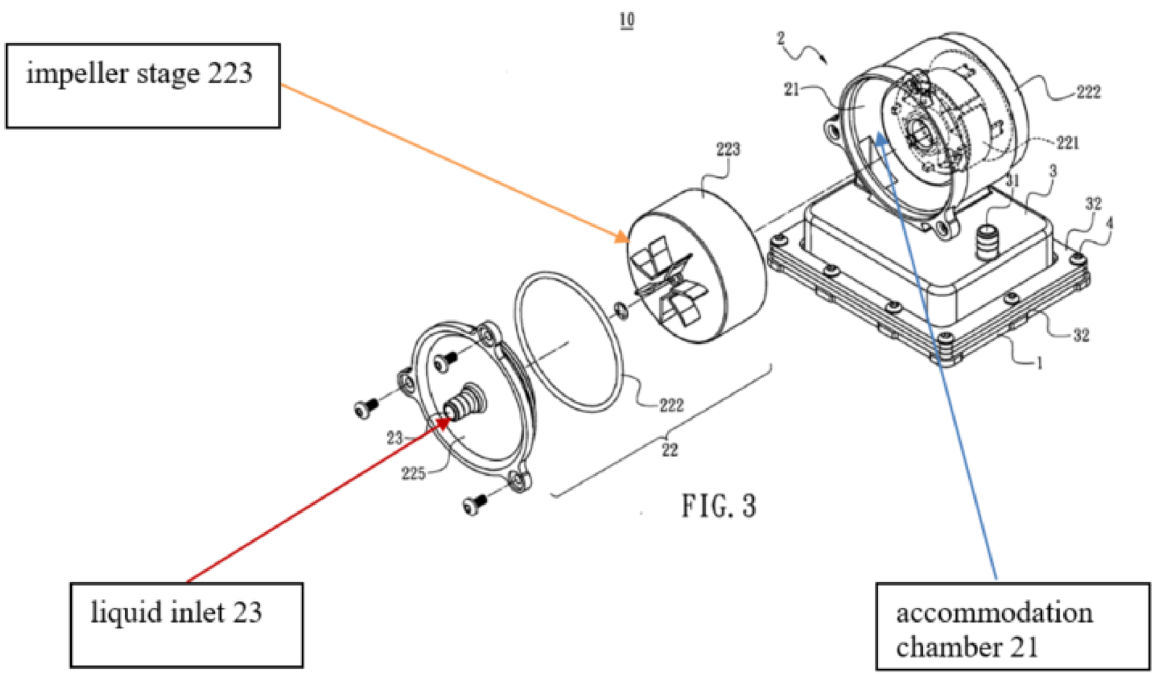


FIG. 20

(*comparing* Ex. 1005 at FIG. 7 *with* Ex. 1001 at FIG. 20.) As seen in FIG. 3, liquid inlet 23 is positioned below a center of impeller stage 223:

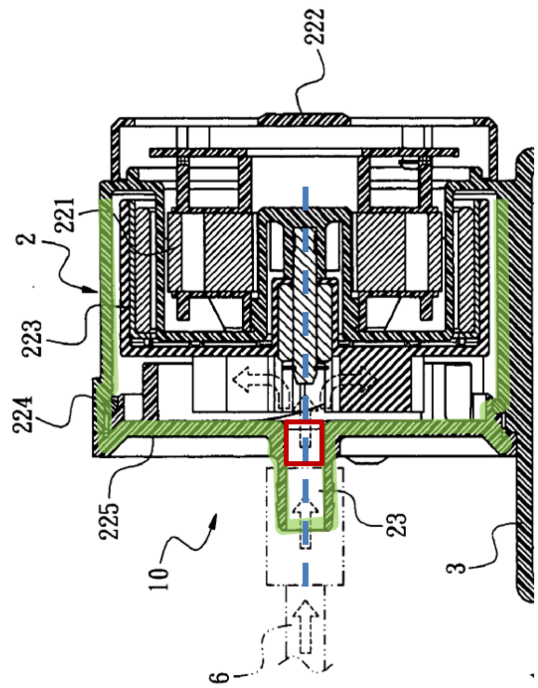


(Ex-1005 at FIG. 3.)

97. Duan further discloses that liquid inlet 23 is configured to enable the cooling liquid to flow into the center of accommodation chamber 21: "during operation of the present invention, the cool liquid in the water tank 20 is conveyed to the accommodation chamber 21 through the duct 6 and the liquid inlet 23 of the cooling plate module 10 and driven by the liquid driving unit 22." (Ex-1005 at [0027].)

98. To further illustrate this, below is an excerpt of FIG. 7 of Duan that has been rotated so that the impeller faces downward. A red box has been added to show

a location where an inlet defined by the impeller cover is positioned below a center of the impeller (the impeller of the impeller stage 223) configured to enable the cooling liquid to flow into the center of the pump chamber.



99. This is similar to FIG. 20 of the ’355 patent, shown below:

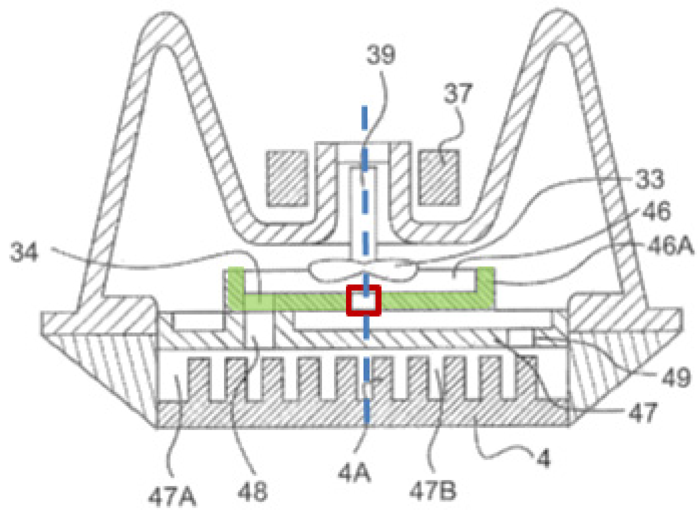


FIG. 20

100. Therefore, Duan discloses this limitation.

(ix) **[1h] "an outlet defined by the impeller cover positioned tangentially to the circumference of the impeller."**

101. Duan discloses, teaches or suggests this limitation.

102. As discussed above in element 1b, Duan discloses the impeller cover with the *combination* of the lower cover 225 (colored in light green below) and the interior cylindrical wall of the accommodation chamber 21 (colored in lime green below).

Color	Duan Element
Yellow	coil stage 221
Lime green	accommodation chamber 21 (interior)
Orange	impeller stage 223

Light blue	cap 3
Dark blue	cooling plate 1
Light green	Lower cover 225

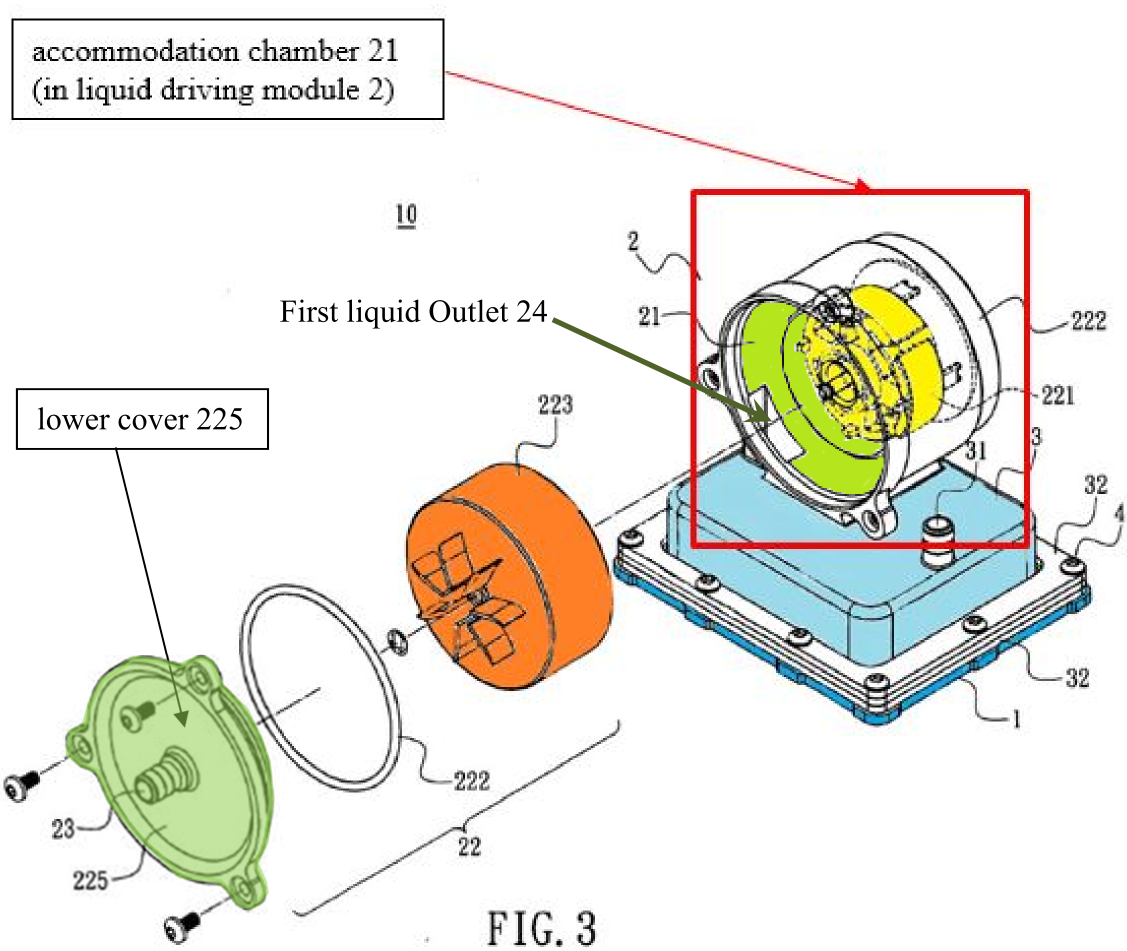


FIG. 3

103. As shown above in the color version of FIG. 3 of Duan, a lower cover 225 attaches to the accommodation chamber 21 (colored in light green), *<u>together</u> in a combination with the interior cylindrical wall of the accommodation chamber 21* (colored in lime green), forms the claimed "impeller cover," which also defines the first fluid outlet 24.

104. As further shown below in an annotated FIG. 7 of Duan, the impeller

cover is indicated in light green:

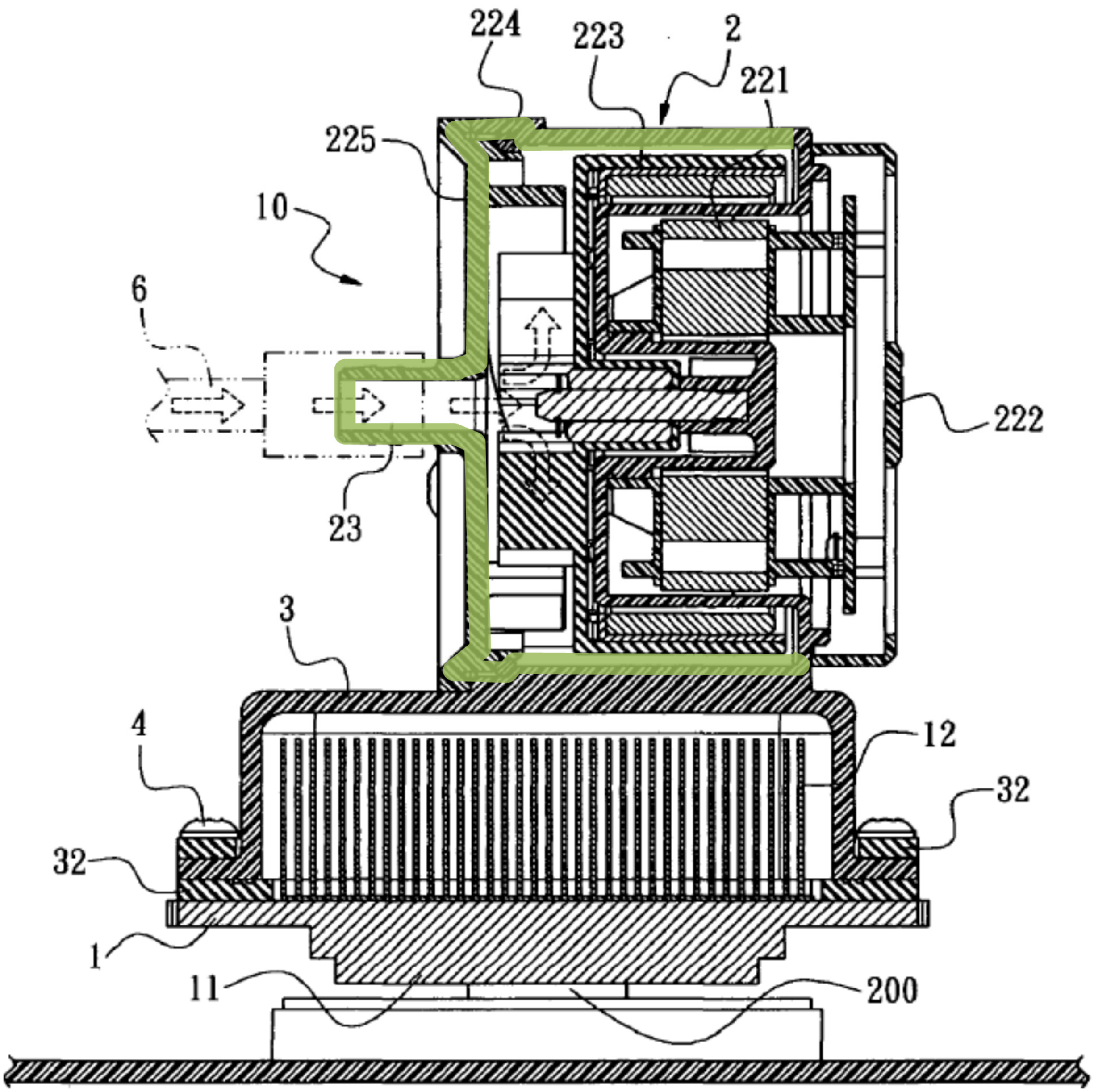
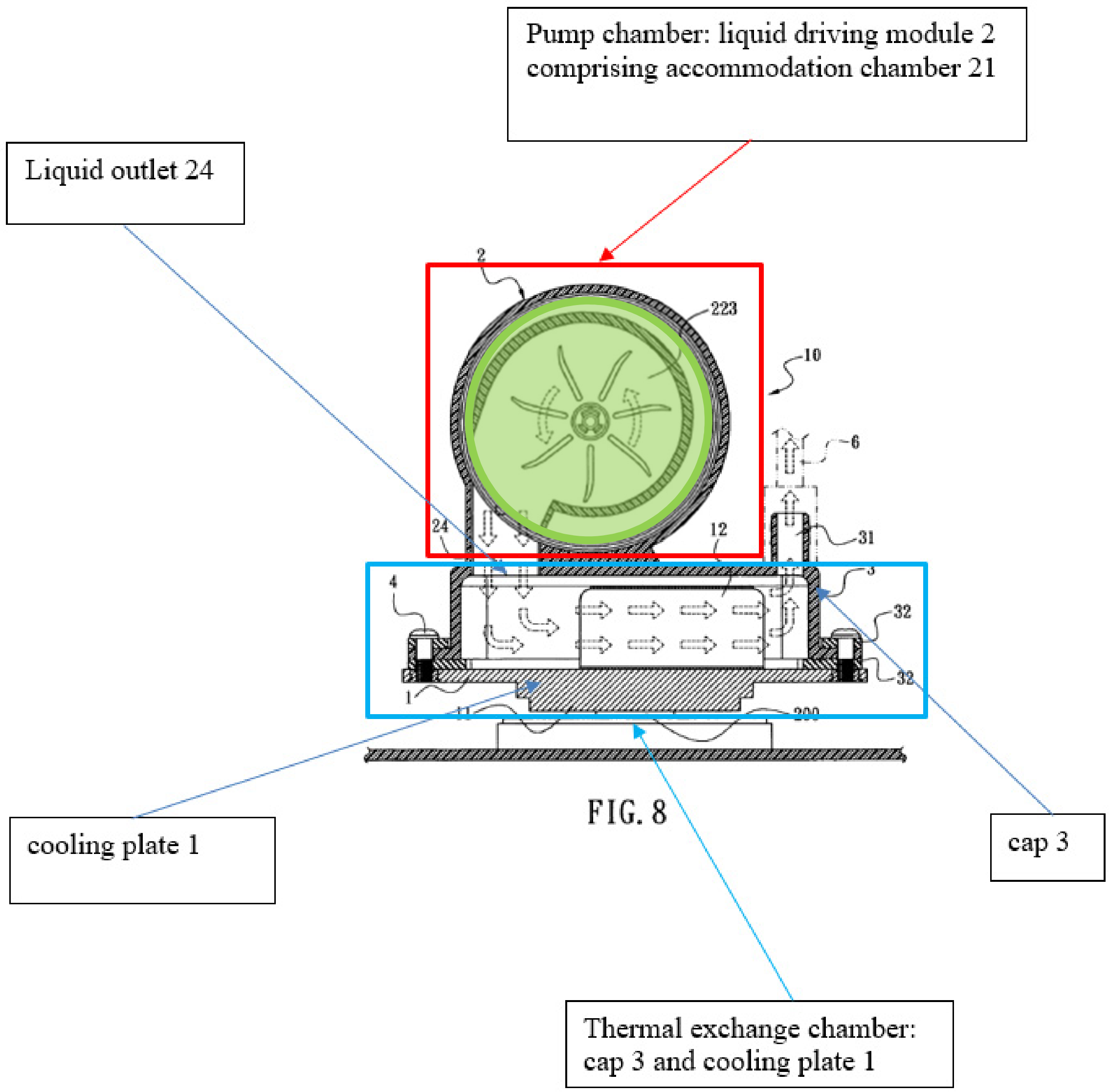


FIG. 7

(Ex. 1005 at FIG. 7 (annotation added).)

105. With respect to outlet 24, Duan states, "cool liquid flowing into the

accommodation chamber 21 will directly flow out of the first liquid outlet 24 and flush the heat-dissipating plates 12 to heat dissipate the heat-dissipating plates 12 with enhanced efficiency." (Ex. 1005 at [0029].) Duan's outlet is depicted in the following colored and annotated version of FIG. 8, which discloses the claimed "outlet" at item 24, with the impeller cover indicated in green:



106. Further, annotated FIG. 3 below also shows the pump cover (e.g., the

combination of the lower cover 225 (colored in light green below) and the interior wall of the accommodation chamber 21 (colored in lime green below)) defines an outlet (e.g., liquid outlet 24) to the pump chamber positioned tangentially to the circumference of the impeller (e.g., impeller stage 223):

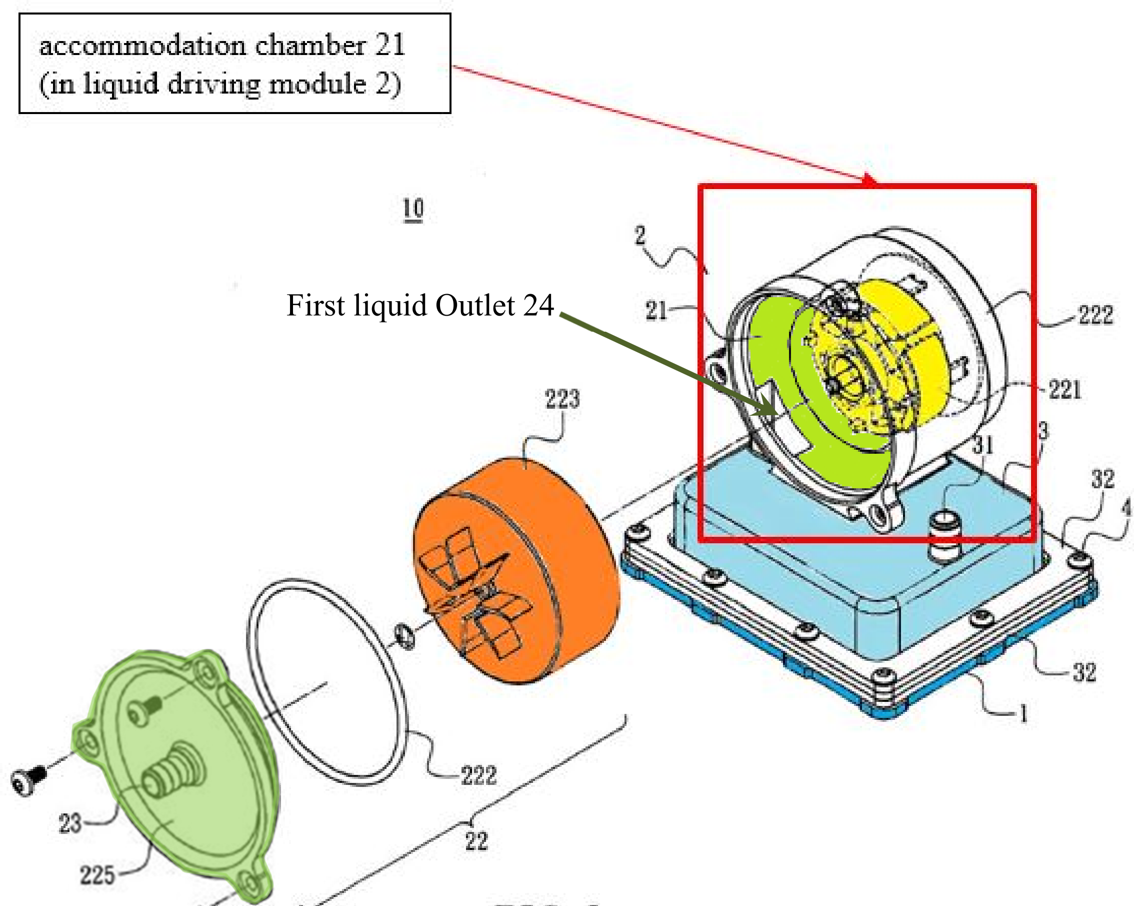


FIG. 3

107. Thus, as can be seen above, the outlet 24 is defined by the impeller cover positioned tangentially to the circumference of the impeller in Duan. (Ex-

1005 at FIG. 8.) Thus, Duan discloses this limitation.

(b) <u>Claim 2</u>: "The cooling system of claim 1, wherein the thermal exchange chamber includes at least one second passage configured to direct the cooling liquid out of the thermal exchange chamber, the at least one second passage is positioned at either a first end or a second end of the thermal exchange chamber."

108. Duan discloses, teaches or suggests this limitation. Specifically, Duan teaches:

> "In the present invention, during the assembling of the liquid cooling cycle mechanism 100, the liquid inlet 23 of the cooling plate module 10 is communicated to the liquid outlet 521 of the liquid exit region 52 of the water tank 20 through duct 6. ***Moreover, the second liquid outlet 31 of the cooling plate module 10 is communicated to the liquid inlet 511 of the liquid entrance region 51 of the water tank 120 through duct 6***, thus forming the liquid cooling cycle mechanism 100 with continuous cycles. Thereafter, the liquid cooling cyclic mechanism 100 is assembled to the CPU 200 with the heat absorbing face 11 being in contact with the CPU 200 for heat dissipating the CPU 200."

Ex-1005 at [0026] (emphasis added).)

109. These teachings are also illustrated in the following annotated version of FIG. 6 with the below color coding scheme:

Color	Duan-830 Element
Pink	second liquid outlet 31
Light blue	cap 3
Dark blue	cooling plate 1

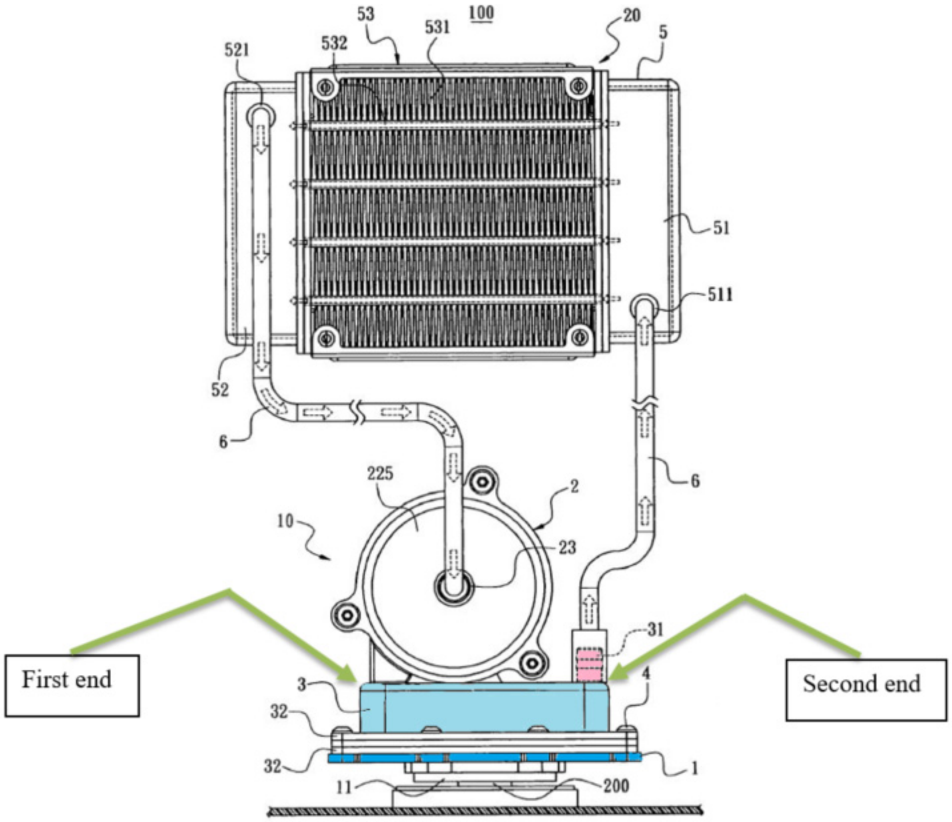


FIG. 6

(Ex-1005-Duan at FIG. 6.)

110. Duan further states:

> "With reference to FIGS. 7 and 8, during operation of the present invention, the cool liquid in the water tank 20 is conveyed to the accommodation chamber 21 through the duct 6 and the liquid inlet 23 of the cooling plate module 10 and driven by the liquid driving unit 22. The cool liquid then flows to the cap 3 through the first liquid outlet 24 for heat dissipating the heat-dissipating plates 12 in the cap 3. More particularly, the cool liquid is heat exchanged with the heat-dissipating pates 12 into hot liquid. ***The hot liquid then flows to the liquid entrance region 51 of the water tank 20 through the second liquid outlet 31 of the cooling plate module 10 and another duct 6.***"

Ex-1005 at [0025] (emphasis added).)

111. The following annotated version of FIG. 8, referenced above, further

illustrates these teachings:

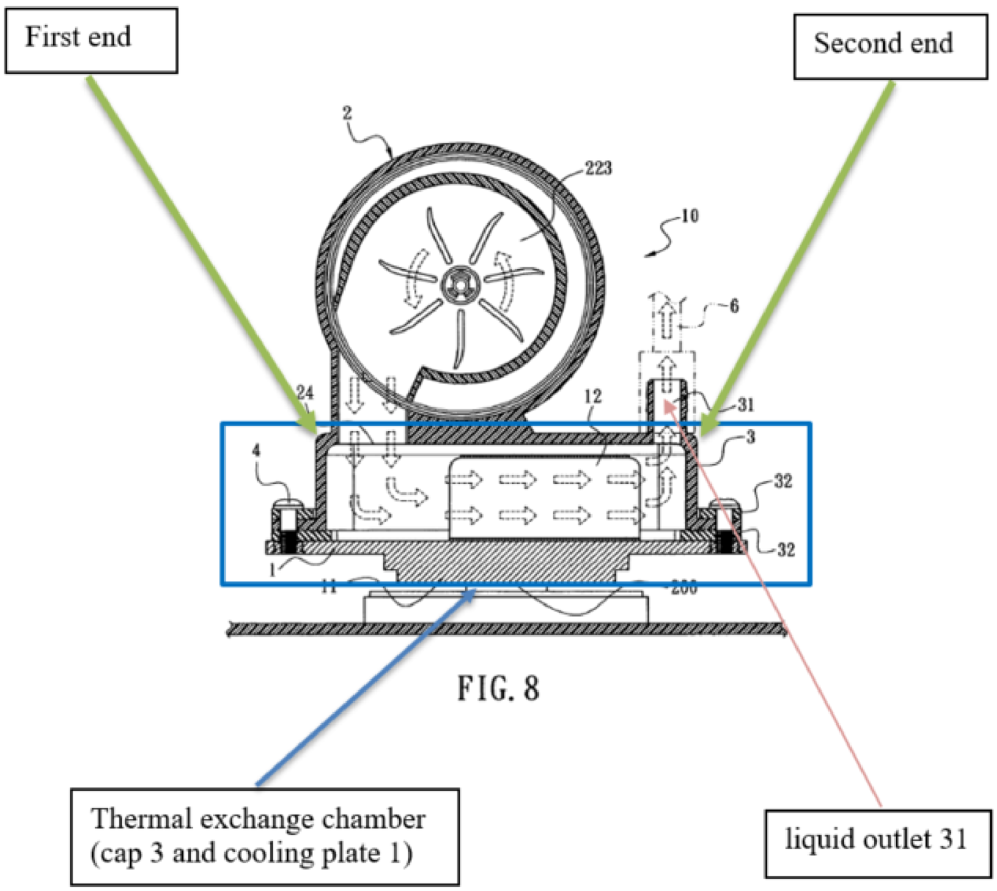


FIG. 8

(Ex-1005 at FIG. 8.)

112. In my opinion, based on these teachings, a POSITA would have understood that Duan discloses a thermal exchange chamber (cap 3 and cooling plate 1) that includes at least one second passage (second liquid outlet 31) configured to direct the cooling liquid out of the thermal exchange chamber (via duct 6), the at least one second passage is positioned at the second end of the thermal exchange chamber (cap 3 and cooling plate 1).

113. Accordingly, Duan discloses all limitations of Claim 2.

(c) <u>Claim 6</u>: "The liquid cooling system of claim 1, wherein the double-sided chassis defines a recess configured to house the stator."

114. Duan discloses this limitation. In my opinion, Duan discloses a double-sided chassis housing (accommodation chamber 21) that defines a recess (on top side of accommodation chamber 21) configured to house the stator (coil stage 221). (See Ex-1005 at [0023] ("With reference to FIGS. 2, 3, and 4, the liquid driving module 2 comprises an accommodation chamber 21 and ***a liquid driving unit 22 located in the accommodation chamber 21 … The liquid driving unit 22 comprises a coil stage 221***") (emphasis added).)

115. These elements are best shown in FIG. 3, where the stator (coil stage 221) is in yellow:

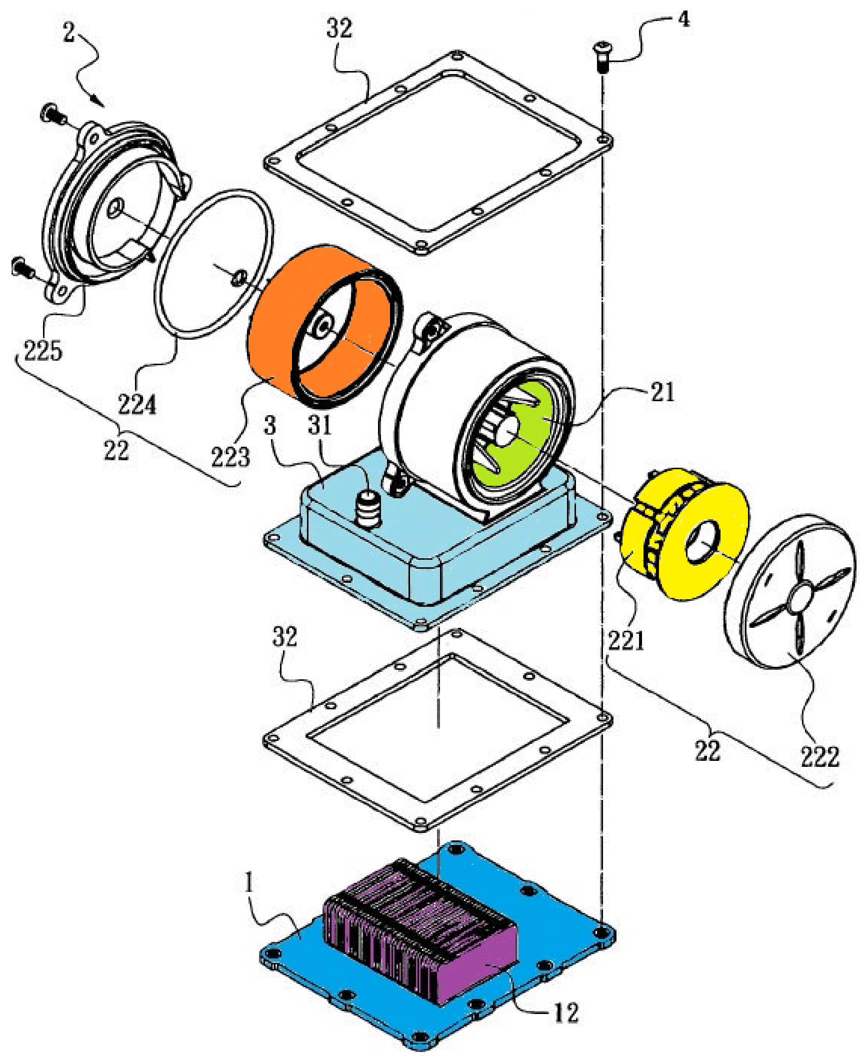


FIG. 2

(Ex-1005 at FIG. 2; *see also* FIG. 3.)

116. FIG. 7 of Duan also shows a recess configured to house the stator:

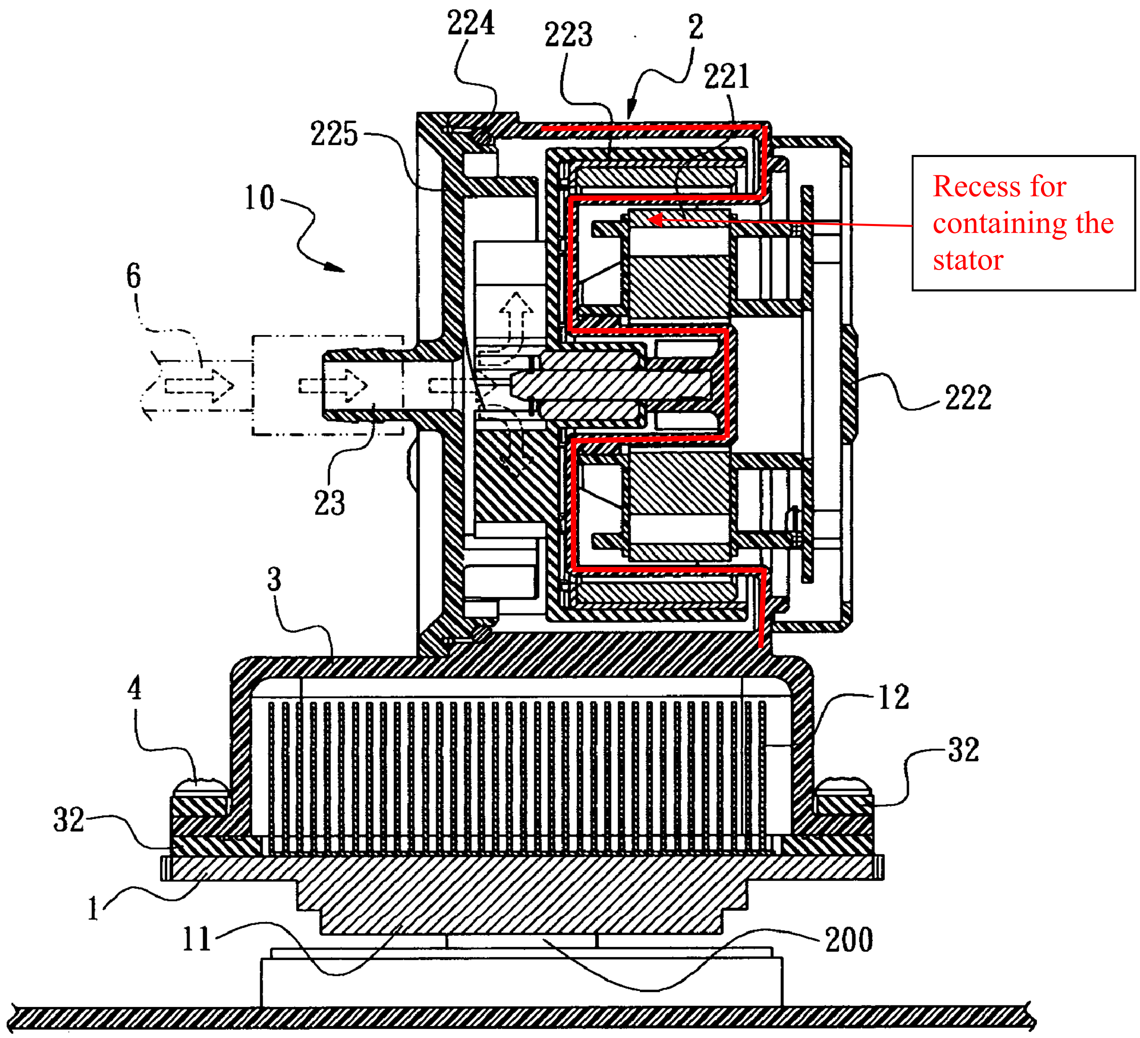


FIG. 7

(Ex. 1005 at FIG. 7 (emphasis added).)

117. Thus, Duan discloses all limitations of Claim 6, and anticipates and renders obvious Claim 6.

(d) Claim 10

(i) [10-PRE] **"A liquid cooling system for cooling a heat-generating component of a computer, comprising:"**

118. Duan discloses the preamble, regardless of whether it is a limitation. The invention disclosed in Duan "relates to ***a cooling plate module, and more particularly to a cooling plate module used for heat emitting device such as a CPU***." (Ex-1005 at [0002] (emphasis added).) Duan further teaches that the disclosed cooling plate module "includes a cooling plate and a ***liquid driving module***." (*Id.* at Abstract (emphasis added).) Therefore, Duan discloses the preamble.

(ii) **[10a] "a double-sided chassis adapted to mount a pump configured to circulate a cooling liquid, the pump comprising a stator and an impeller, the impeller being positioned on a first side of the chassis and the stator being positioned on the opposite side of the chassis;"**

119. Duan discloses this limitation. Reproduced below is a colored version of referenced FIG. 3 of Duan that uses the following color coding scheme:

Color	Duan-830 Element
Yellow	coil stage 221
Lime green	accommodation chamber 21
Orange	impeller stage 223
Light blue	cap 3
Dark blue	cooling plate 1

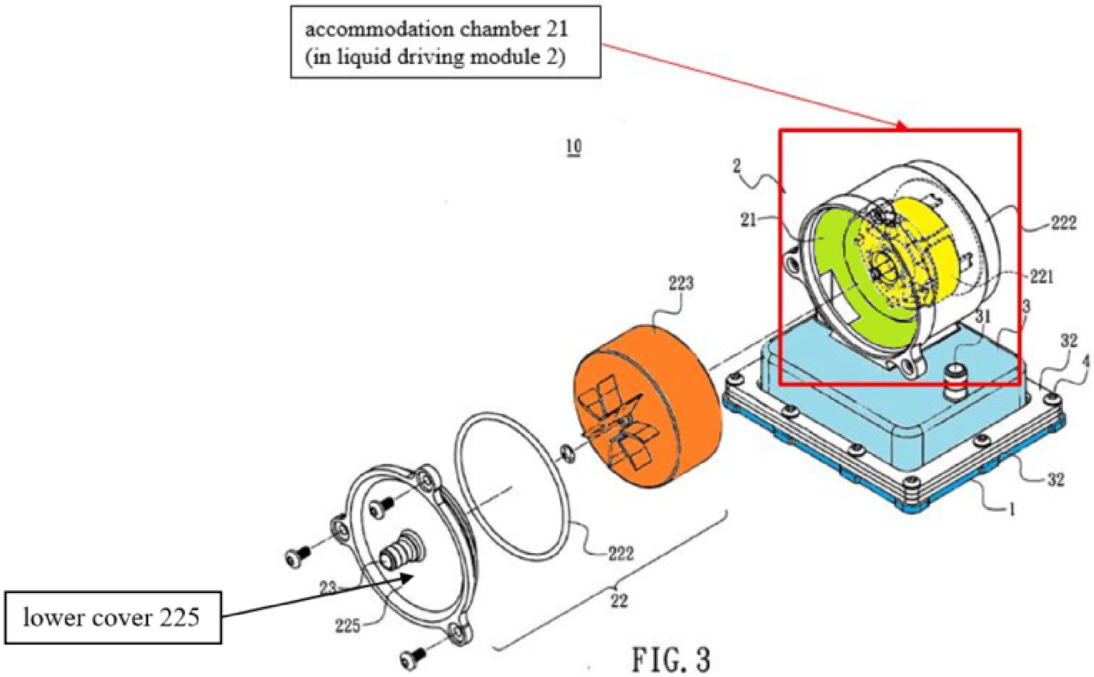


FIG. 3

120. As illustrated above, Duan discloses a double-sided chassis (accommodation chamber 21) adapted to mount a pump (liquid driving unit 22) configured to circulate a cooling liquid. (*See id.* at [0023] ("With reference to FIGS. 2, 3, and 4, the liquid driving module 2 comprises an accommodation chamber 21 and a liquid driving unit 22 located in the accommodation chamber 21 and used to driving the cool liquid").)

121. Duan also discloses that the pump (liquid driving unit 22) comprises a stator (coil stage 221) and an impeller (impeller stage 223). (*Id.* at [0023] ("The liquid driving unit 22 comprises a coil stage 221, an upper cover 222, an impeller stage 223, a sealing washer 224 and a lower cover 225.") (*See id.* at [0023].)

122. In addition, Duan discloses the impeller (impeller stage 223) being

positioned on a first side of the chassis (accommodation chamber 21) and the stator (coil stage 221) being positioned on the opposite side of the chassis. These elements are also shown in FIG. 2:

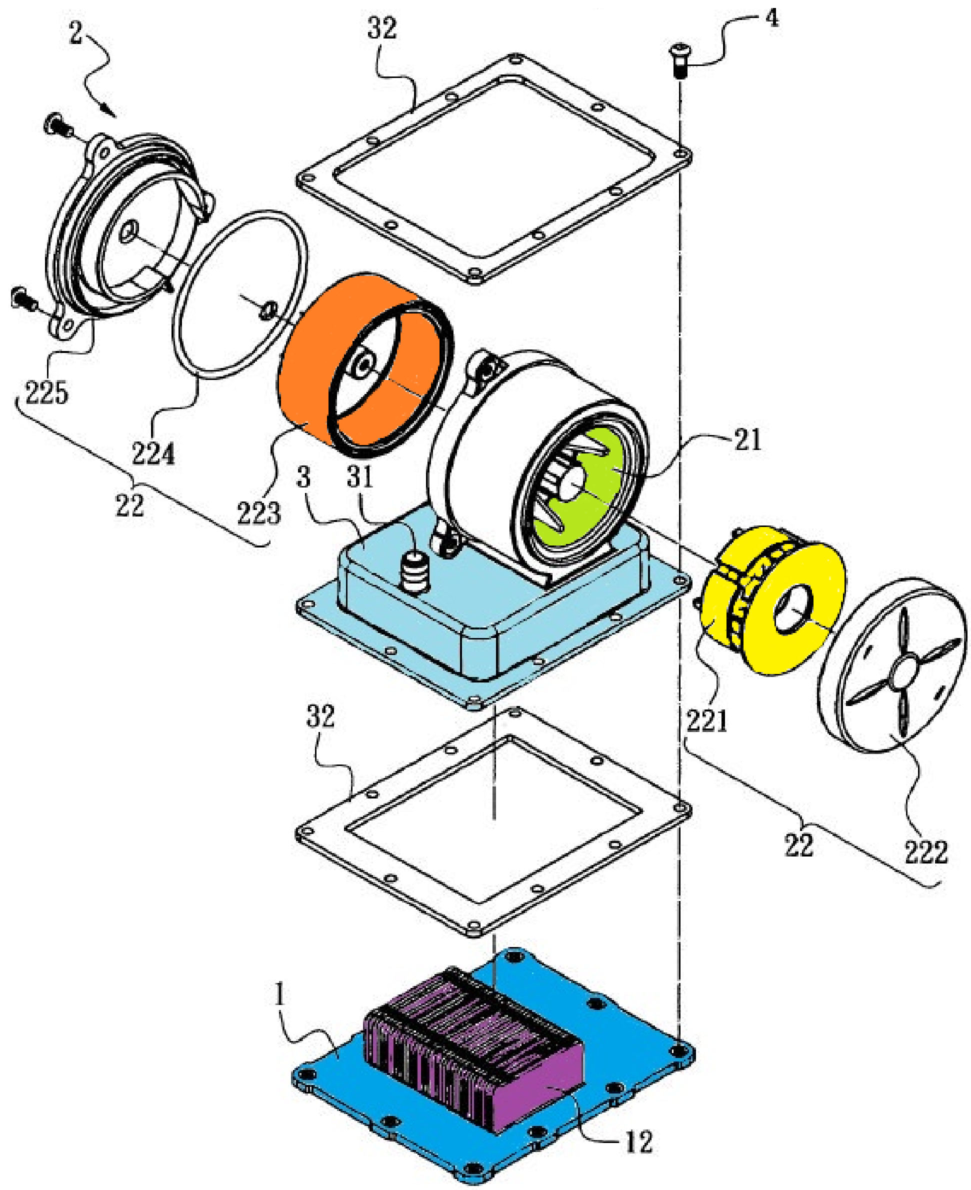


FIG. 2

123. As seen in FIG. 2, the stator (coil stage 221) is positioned on a first side

of the chassis (accommodation chamber 21) and the impeller (impeller stage 223) is positioned on the opposite side.

124. Accordingly, Duan discloses this limitation.

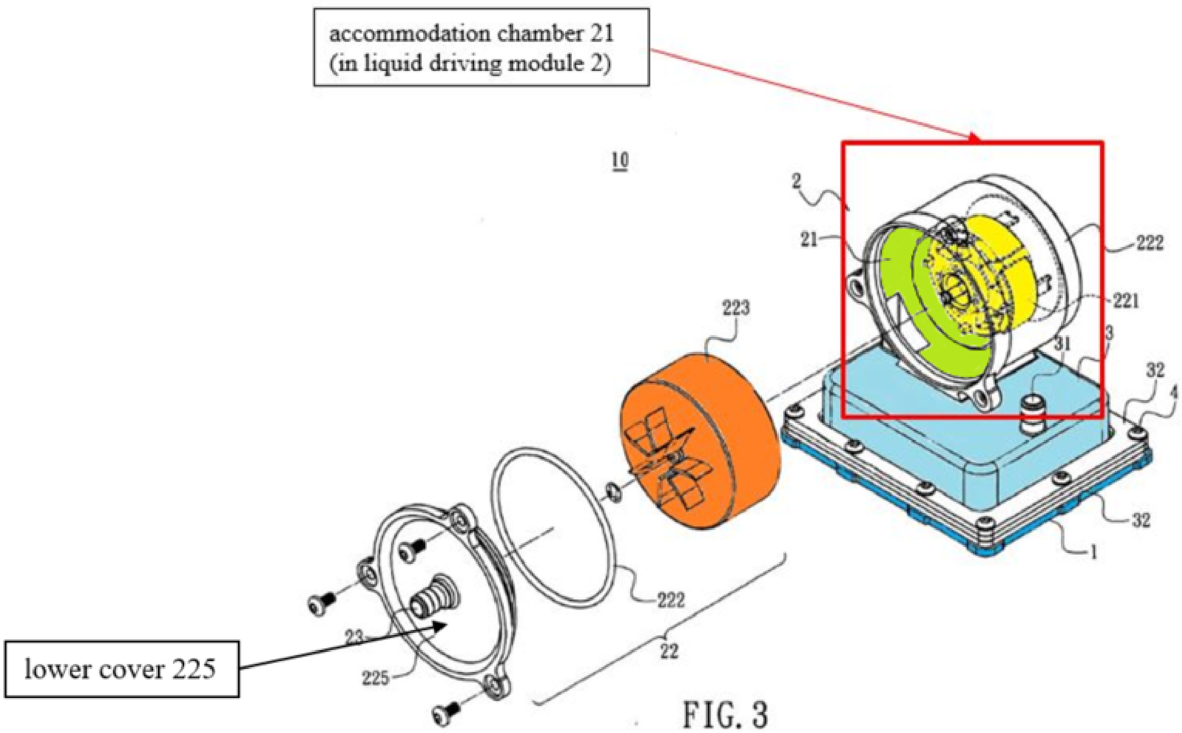
(iii) **[10b] "a reservoir configured to circulate a cooling liquid there-through, the reservoir comprising:"**

125. Duan discloses this limitation. In Duan, the reservoir is the accommodation chamber 21, cap 3, and cooling plate 1, and it is configured to pass cooling liquid there-through. Duan states:

> "With reference to FIGS. 2, 3, and 4, the liquid driving module 2 comprises an accommodation chamber 21 and a liquid driving unit 22 located in the accommodation chamber 21 and used to driving the cool liquid. The liquid driving unit 22 comprises a coil stage 221, an upper cover 222, an impeller stage 223, a sealing washer 224 and a lower cover 225. The lower cover 225 comprises a liquid inlet 23 communicated with the accommodation chamber 21. A first liquid outlet 24 is communicated to the bottom of the accommodation chamber 21 and is enclosed by a cap 3. A second liquid outlet 31 is defined on the cap 3. The cooling plate 1 is assembled with the cap 3 to define a closed space therein and the first liquid outlet 24 is corresponding to the heat-dissipating plates 12."

(Ex-1005-Duan at [0023]).

126. These elements are also shown in FIG. 3:



(Ex-1005 at FIG. 3; *see also* FIG. 2.)

127. As is clear from the above disclosures, Duan discloses this limitation.

(iv) **[10c] "a pump chamber and a thermal exchange chamber, wherein the pump chamber and the thermal chamber are vertically displaced fluid-containing chambers;"**

128. Duan discloses this limitation, particularly in FIG. 8, of which an annotated version follows:

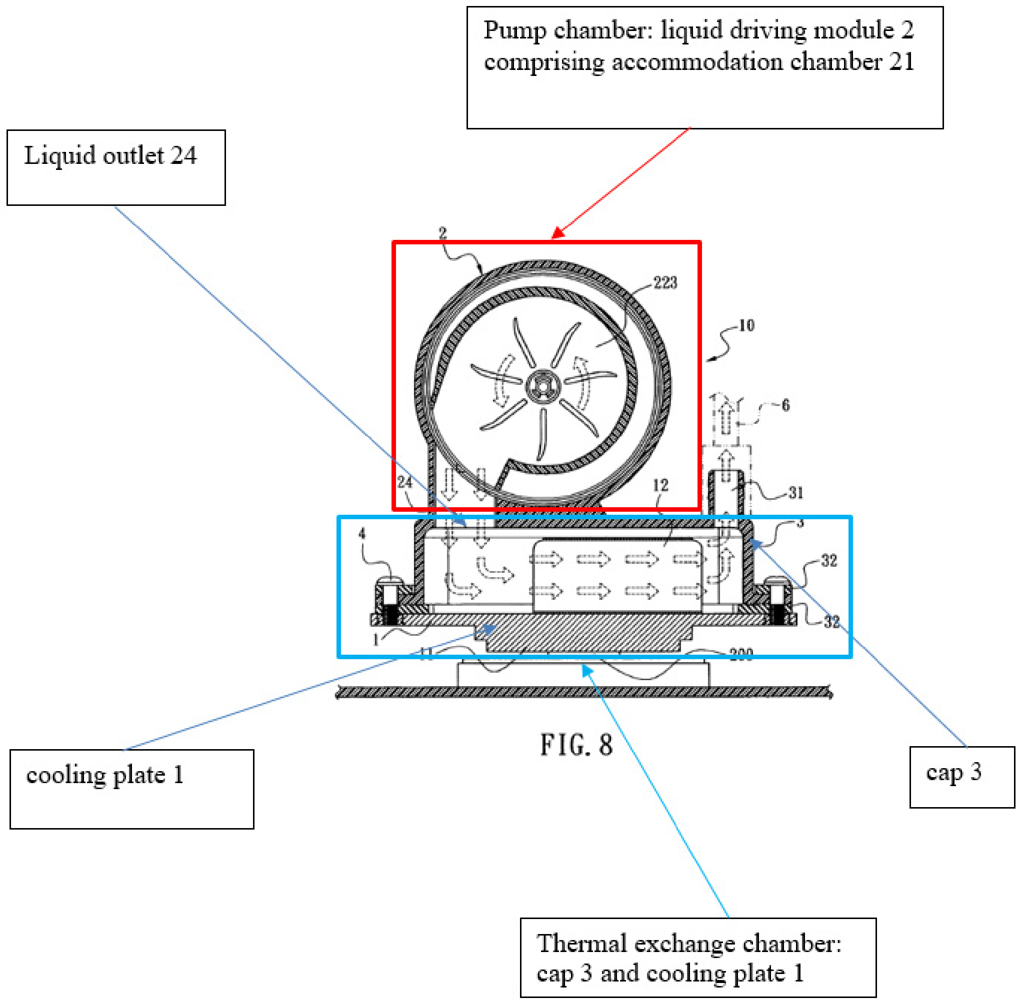


FIG. 8

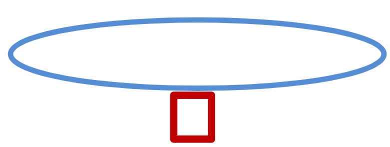
(Ex-1005 at FIG. 8.)

129. As shown in this figure by the orientation of the superimposed red and blue boxes, as well as the arrows indicating the flow of liquid within the cooling system, Duan discloses a pump chamber (e.g., accommodation chamber 21 and lower cover 225) and a thermal exchange chamber (cap 3 and cooling plate 1), wherein the pump chamber (21) and the thermal exchange chamber (cap 3 and cooling plate 1) are vertically displaced fluid-containing chambers.

130. For these reasons, Duan discloses this limitation.

(v) **[10d] "wherein the pump chamber includes an inlet to the pump chamber positioned concentric to the impeller and an outlet to the pump chamber positioned tangentially to the circumference of the impeller;"**

131. Duan discloses this limitation for reasons similar to those discussed above with respect to limitations [1g] and [1h]. To further explain, I present a side-by-side comparison below showing the inlet in a red circle which is concentric with respect to the impeller in the blue circle. Duan is on the left while FIG. 20 of the '355 patent is on the right:



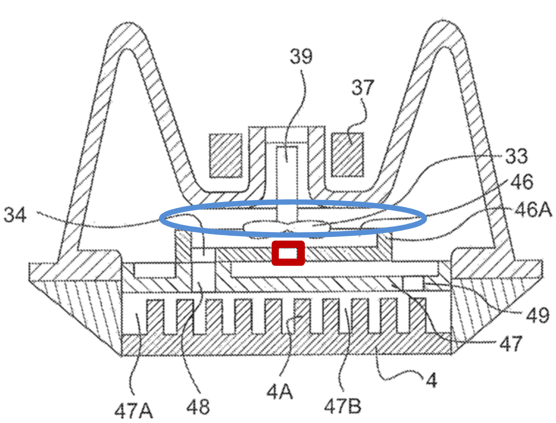


FIG. 20

(*Comparing* Ex. 1005 at FIG. 7 *with* Ex. 1001 at FIG. 20.). While the above shows cross-sectional views, moving the view so that the view faces the impeller would show that Duan discloses an inlet to the pump chamber positioned concentric to the impeller. This is shown below in FIG. 8 of Duan.

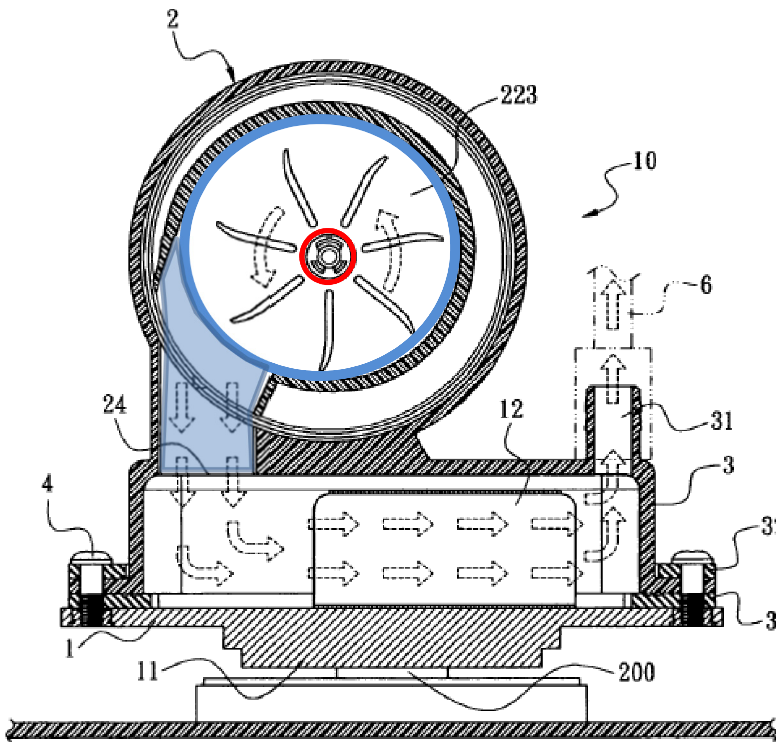


FIG. 8

(Ex. 1005 at FIG. 8 (showing the inlet in a red circle which is concentric with respect to the impeller in the blue circle).) FIG. 8 above also shows an outlet 24 that is positioned tangentially to the circumference of the impeller. Further, annotated FIG. 3 below also shows the pump chamber includes an inlet (e.g., liquid inlet 23) to the pump chamber (e.g., accommodation chamber 21 and lower cover 225) positioned concentric to the impeller and an outlet (e.g., liquid outlet 24) to the pump chamber positioned tangentially to the circumference of the impeller (e.g., impeller stage 223):

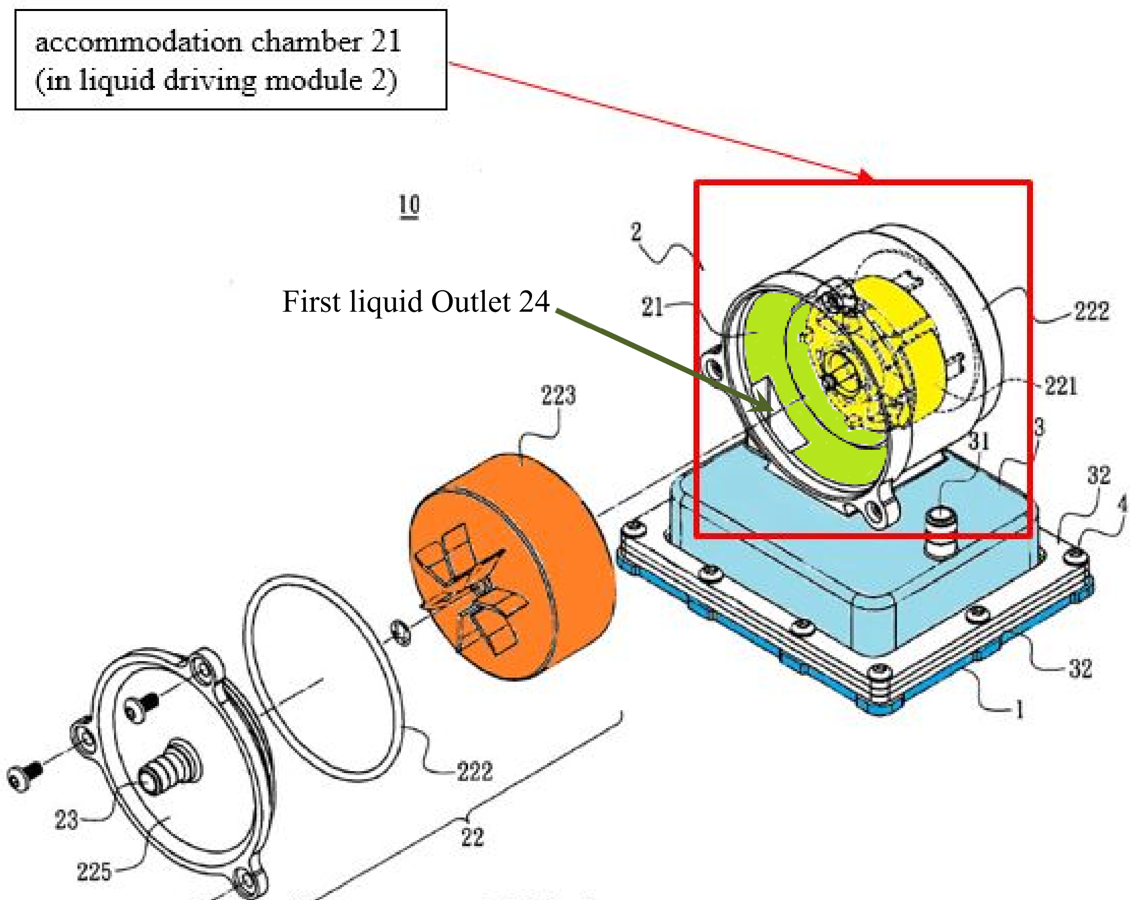


FIG. 3

132. Accordingly, Duan discloses this limitation.

(vi) **[10e] "a first passage fluidly coupling the pump chamber and the thermal exchange chamber, wherein the first passage directs the cooling liquid in the thermal exchange chamber between a first end and a second end of the thermal exchange chamber;"**

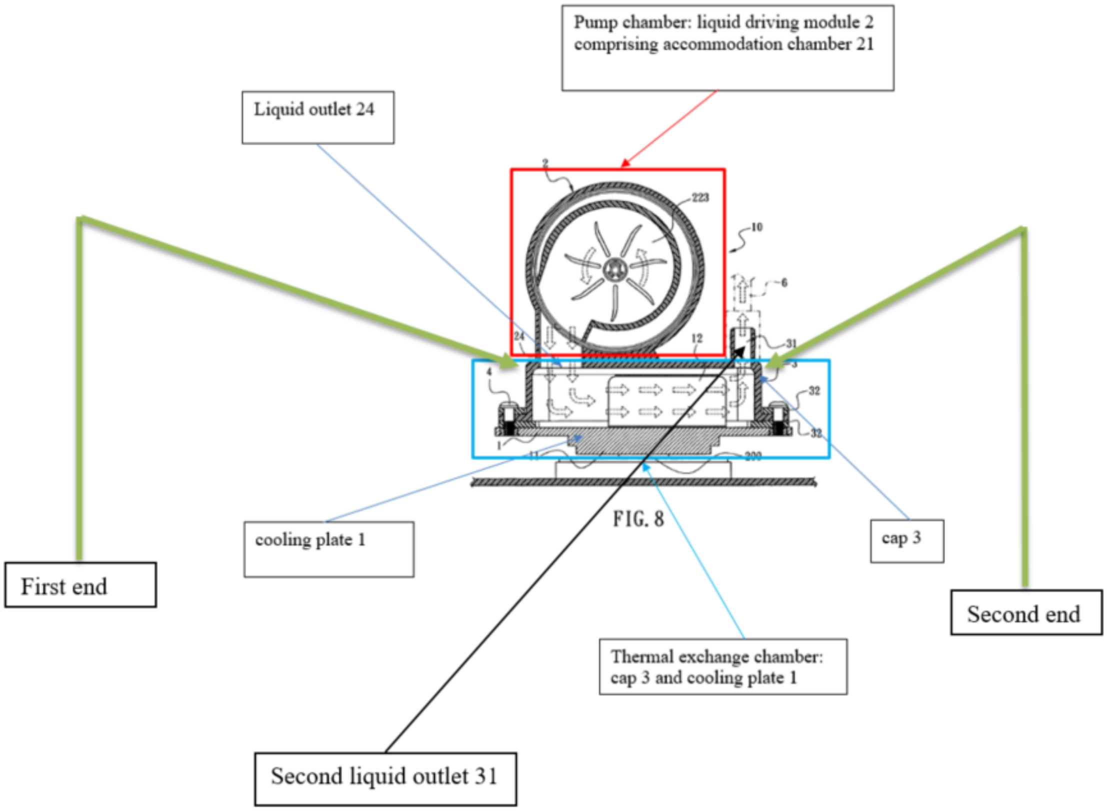
133. Duan discloses, teaches or suggests this limitation. Specifically, Duan

describes:

> "With reference to FIGS. 7 and 8, during operation of the present invention, the cool liquid in the water tank 20 is conveyed to the accommodation chamber 21 through the duct 6 and the liquid inlet 23 of the cooling plate module 10 and driven by the liquid driving unit 22. ***The cool liquid then flows to the cap 3 through the first liquid outlet 24 for heat dissipating the heat-dissipating plates 12 in the cap 3. More particularly, the cool liquid is heat exchanged with the heat-dissipating plates 12 into hot liquid. The hot liquid then flows to the liquid entrance region 51 of the water tank 20 through the second liquid outlet 31 of the cooling plate module 10 and another duct 6***."

(Ex-1005 at [0027] (emphasis added.)

134. Further, as shown in the following colored and annotated version of FIG. 8, Duan discloses a first passage (first liquid outlet 24) fluidly coupling the pump chamber (e.g., accommodation chamber 21 and lower cover 225) and the thermal exchange chamber (cap 3 and cooling plate 1), wherein the first passage (24) directs the cooling liquid into the thermal exchange chamber (cap 3 and cooling plate 1) between a first end (at first liquid outlet 24) and a second end (at second liquid outlet 31) of the thermal exchange chamber (cap 3 and cooling plate 1), which ends are shown below with the green arrows:



(*Id.* at FIG. 8.) Thus, Duan discloses this limitation. Further, regarding the limitation of "between a first end and a second end of the thermal exchange chamber," Duan discloses this limitation as explained below. To the extent the limitation is interpreted to mean the "first passage directs the cooling liquid … between a first end and a second end of the thermal exchange chamber," it can be seen above that at least a (right) portion of the first liquid outlet 24 is located between the first and second ends of the thermal exchange chamber (e.g., cap 3 and cooling plate 1), thus directing the fluid as claimed. On the other hand, to the extent the limitation is interpreted to mean "the network of channels [is] between a first end and a second end of the thermal exchange chamber," Duan's heat dissipating plates

12 are located between the first and second ends of the thermal exchange chamber (e.g., cap 3 and cooling plate 1), as shown above. Thus, Duan discloses this limitation under either interpretation.

(vii) **[10f] "a heat-exchanging interface forming a boundary wall of the thermal exchange chamber, the heat-exchanging interface has an outer surface configured to be placed in thermal contact with a surface of the heat-generating component and an inner surface that defines a plurality of channels that direct the flow of the cooling liquid within the thermal exchange chamber;"**

135. Duan discloses, teaches or suggests this limitation. Duan states:

> "With reference to FIGS. 2 and 6, the cooling plate module 10 according to the present invention is applied to a liquid cooling cyclic mechanism 100, which is used for ***the heat dissipation of a CPU 200*** and composed of the cooling plate module 10 and a water tank module 20 connected with the cooling plate module 10 through ducts. ***The cooling plate 1 comprises a heat absorbing face 11 on bottom thereof and being in contact with a heat source. A plurality of heat-dissipating plates 12 are formed on top face of the cooling plate 1 and can be arranged in longitudinal or transverse manner. A runner is defined between the plurality of heat-dissipating plates 12 and forms a closed loop.***"

(Ex-1005-Duan at [0022] (emphasis added).)

136. FIGS. 2, 4 and 8, reproduced below in colored and annotated format, are also particularly relevant to this limitation:

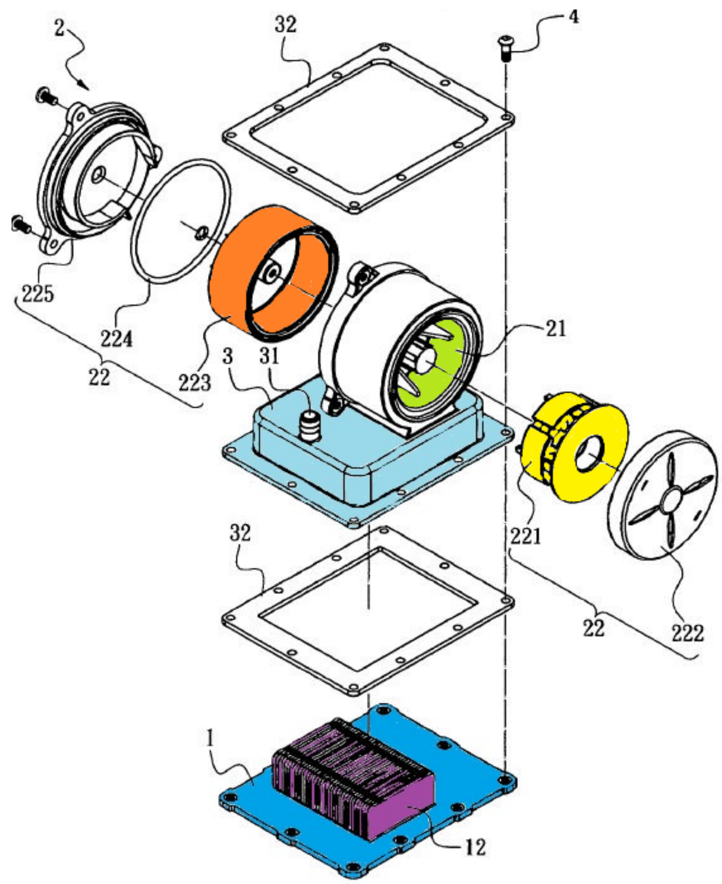

2
32
4
225
224
22
223
3
31
21
221
22
222
32
1
12

FIG. 2

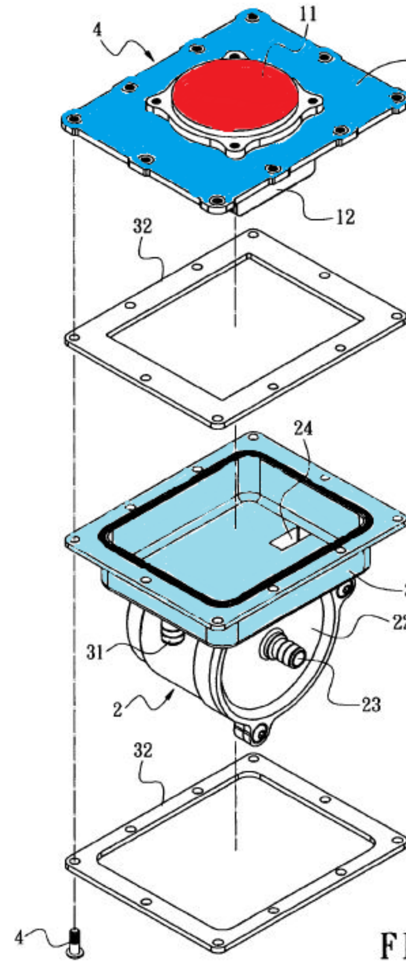
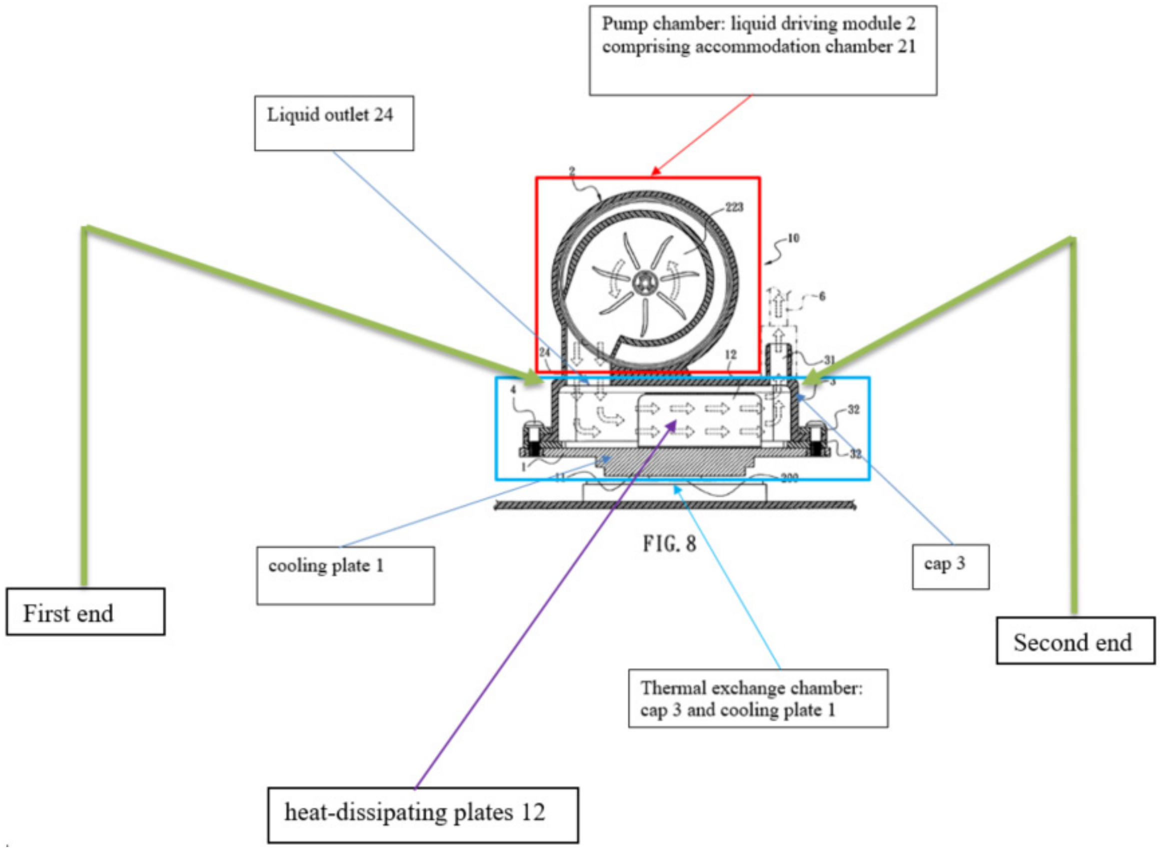

4
11
10
1
12
32
24
3
225
31
23
2
32
4

FIG. 4



(Ex-1005 at FIGS. 2, 4, 8.)

137. In my opinion, the above figures and excerpt from the specification of Duan disclose a heat-exchanging interface (cooling plate 1) forming a boundary wall of the thermal exchange chamber (cap 3 and cooling plate 1), the heat-exchanging interface (cooling plate 1) having an outer surface (heat absorbing face 11) configured to be placed in thermal contact with a surface of the heat-generating component (CPU 200) and an inner surface that defines a plurality of channels (heat-dissipating plates 12) that direct the flow of the cooling liquid within the thermal exchange chamber (cap 3 and cooling plate 1).

138. Thus, Duan discloses this limitation.

(viii) **[10g] "a heat radiator adapted to pass the cooling liquid there-through, the heat radiator being fluidly coupled to the reservoir via fluid conduits, the heat radiator being configured to dissipate heat from the cooling liquid."**

139. Duan discloses, teaches or suggests this limitation. FIG. 6 of Duan is reproduced below:

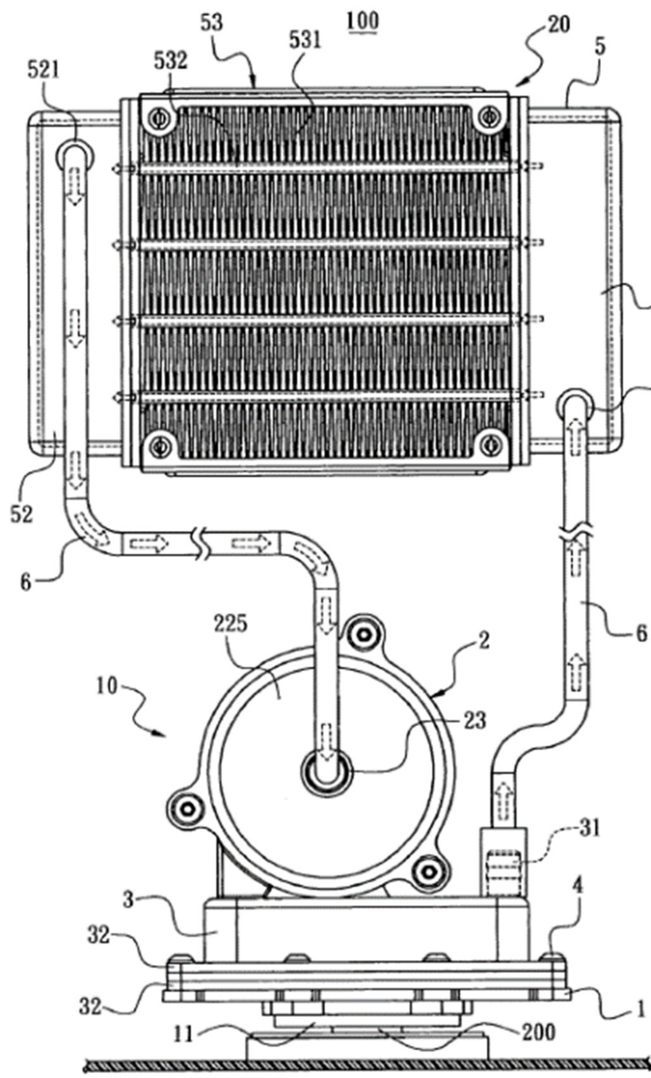


FIG. 6

140. With reference to FIG. 6, Duan states:

> "As shown in FIG. 6, ***the water tank 20 of the liquid cooling cyclic mechanism 100 comprises a box 5 with a liquid entrance region 51 and a liquid exit region 52 provided on both sides of the water tank 20, respectively. The box 5 comprises a cooling stage 53 at center thereof and composed of a plurality of stacked heat-dissipating fins 531 arranged in rows. Runners 532 are defined between rows of the heat-dissipating fins 531; both ends of the runner 532 are communicated with the liquid entrance region 51 and the liquid exit region 52.*** When the hot liquid entrance region 51 flows to the liquid exit region 52 through the runners 532, the hot liquid is first heat exchanged with the heat-dissipating fins 531 into cool liquid and then the cool liquid flows to the liquid exit region 52."

(Ex-1005 at [0025] (emphasis added).)

141. It is my opinion that, based on these disclosures, a POSITA would have understood that Duan discloses, suggests, or teaches a heat radiator (cooling stage 53, heat-dissipating fins 531, and runners 532) adapted to pass the cooling liquid there-through (duct 6, liquid inlet 511, and liquid outlet 521), fluidly coupled to the reservoir (accommodation chamber 21, cap 3, and cooling plate 1) via conducts (ducts 6), and configured to dissipate heat from the cooling liquid (duct 6, liquid inlet 511, and liquid outlet 521).

142. Thus, Duan teaches, discloses, or suggests all limitations of Claim 10.

(e) <u>Claim 11</u>: "The cooling system of claim 10, wherein the double-sided chassis shields the stator from the cooling liquid in the reservoir."

143. Duan discloses this limitation. FIGS. 2 and 3, of which a colored and annotated version is reproduced below, are most relevant:

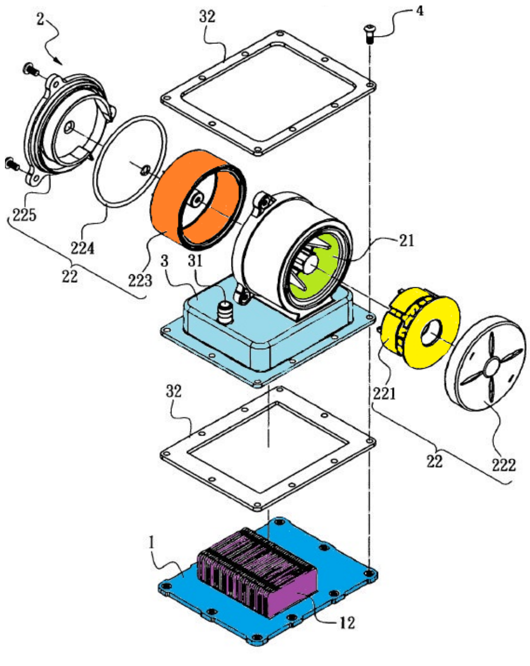


FIG. 2

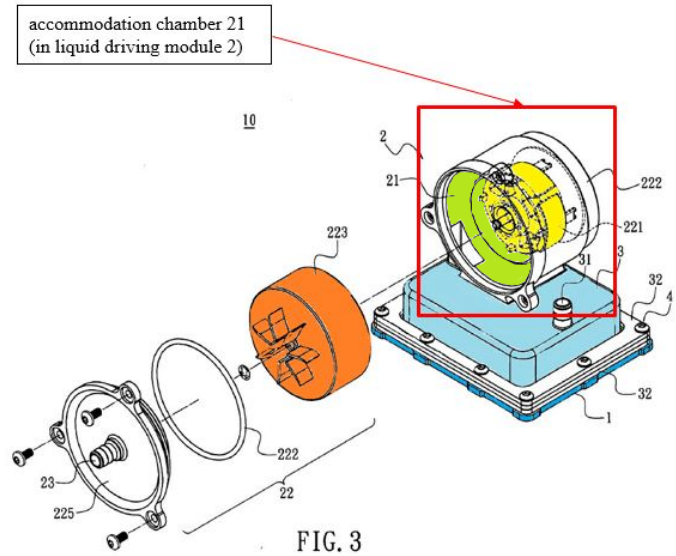


FIG. 3

144. Referring to these figures, Duan also states:

> "With reference to FIGS. 2, 3, and 4, the liquid driving module 2 comprises an accommodation chamber 21 and a liquid driving unit 22 located in the accommodation chamber 21 and used to driving the cool liquid. The liquid driving unit 22 comprises a coil stage 221, an upper cover 222, an impeller stage 223, a sealing washer 224 and a lower cover 225. The lower cover 225 comprises a liquid inlet 23 communicated with the accommodation chamber 21. A first liquid outlet 24 is communicated to the bottom of the accommodation chamber 21 and is enclosed by a cap 3. A second liquid outlet 31 is defined on the cap 3. The cooling plate 1 is assembled with the cap 3 to define a closed space therein and the first liquid outlet 24 is corresponding to the heat-dissipating plates 12."

(Ex-1005 at [0023].)

145. Based on these disclosures, a POSITA would have understood that Duan discloses a double-sided chassis (accommodation chamber 21) that shields the

stator (coil stage 221) from the cooling liquid of the reservoir (accommodation chamber 21, cap 3, and cooling plate 1).

146. Accordingly, Duan teaches, discloses, or suggests all limitations of Claim 11.

(f) Claim 13: "The liquid cooling system of claim 10, wherein the double-sided chassis defines a recess configured to house the stator."

147. Duan discloses this limitation. Duan discloses a double-sided chassis housing (accommodation chamber 21) that defines a recess (on the top side of the accommodation chamber 21) configured to house the stator (coil stage 221). (*See* Ex-1005 at [0023] ("With reference to FIGS. 2, 3, and 4, the liquid driving module 2 comprises an accommodation chamber 21 and a liquid driving unit 22 located in the accommodation chamber 21 … The liquid driving unit 22 comprises a coil stage 221") (emphasis added).)

148. These elements are best shown in FIGS. 2 and 3:

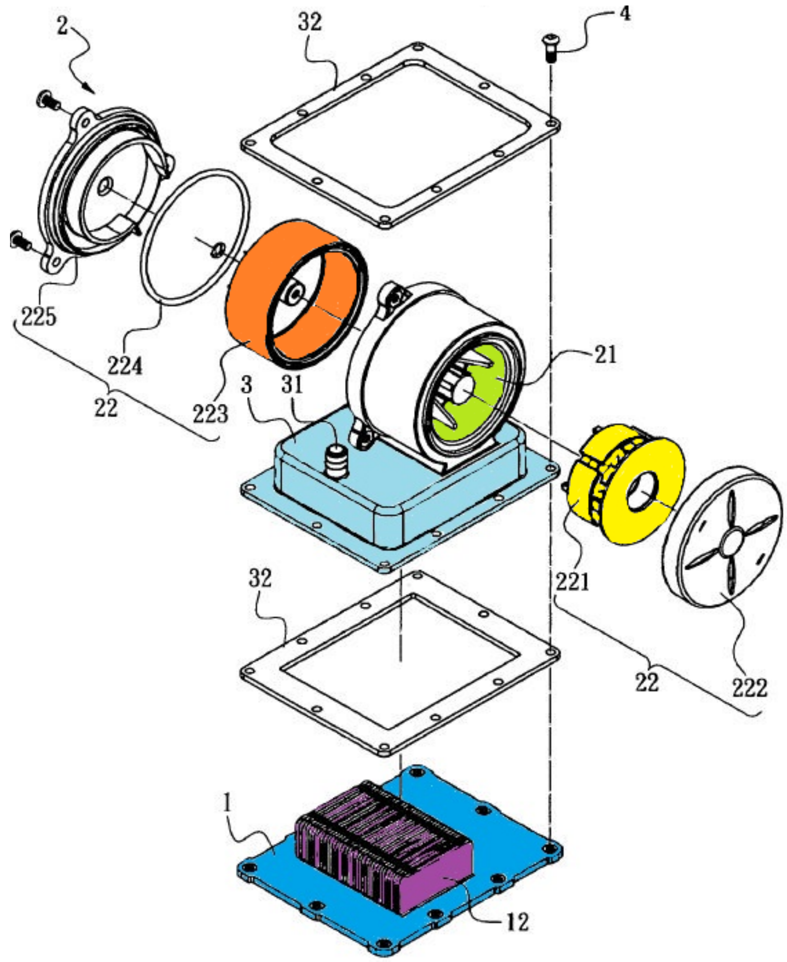


FIG. 2

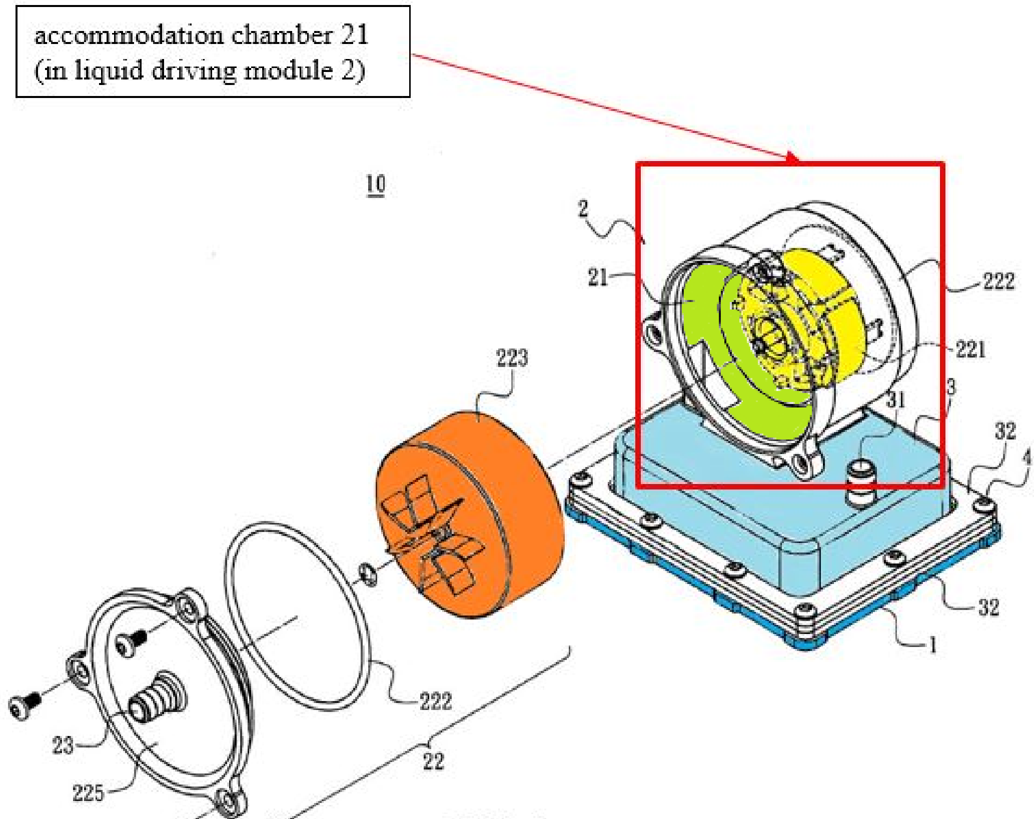


FIG. 3

149. Thus, Duan discloses all limitations of Claim 13, and anticipates and renders obvious Claim 13.

VIII. DUAN RENDERS OBVIOUS CLAIMS 1, 2, 10, 11 AND 13

150. Duan does not directly use the word "reservoir." But as discussed above, Duan discloses the reservoir by describing a structure formed by an accommodation chamber 21, cap 3, and cooling plate 1 configured to pass cooling liquid there-through. It would have been obvious to a POSITA to combine these structures as a single receptible to achieve the claimed reservoir. Duan emphasized the need for "integrally formed" components to track to the "compact trend of

computer[s]"). (Ex.1005 at [[0006]-[0007]). Duan teaches that modifications can be made to integrate components to "minimize space." (*Id.*) Thus, a POSITA would be motivated to minimize the number of components to form singular integrated components for more compact computing applications. In addition, the accommodation chamber 21, cap 3, and cooling plate 1 of Duan perform the same functions and purpose as the claimed "reservoir" as discussed in Ground 1. Thus, integrating these components into a single receptible would disclose the claimed "reservoir."

151. As to the heat radiator, Duan does not directly use the word "radiator," but a POSITA would have understood to the extent Duan does not expressly disclose a "heat radiator," Duan teaches this limitation with its teaching as described in Sections [1e] and [10g] above. Thus, this limitation is obvious from a POSITA's point of view.

152. As to the stator, Duan does not directly use the word, but a POSITA would find the presence of a stator obvious based on the teachings of the coil stage 221, as explained in Section [1b] above.

IX. THE COMBINATION OF DUAN AND CHEON RENDERS OBVIOUS CLAIM 5

153. Below, I provide my opinion with respect to Claim 5.

A. Motivation/Rationale to combine the teachings of Duan and Cheon

154. Duan describes: "As downsize of form factor and increasing processing speed, the heat dissipation for central processing unit (CPU) is also an important issue to solve." (Ex-1005 at [0004].) Duan further states that a problem to be solved is that prior art liquid-cooling dissipation systems are "***bulky and hard to assemble***. This is adverse to the ***compact*** trend of computer." (*Id.* at [0006] (emphasis added).)

155. The invention in Duan, therefore, "provides a cooling plate module wherein the cooling plate is integrally formed with the liquid driving module ***such that the layout of the cooling plate module can be minimized to reduce space***." (*Id.* at [0007] (emphasis added).)

156. Cheon describes a similar problem and solution: "The cooling system of the invention has a number of advantages. … The system may be installed either as part of original equipment or retrofitted into existing computers." (Ex-1007 at 2:44-50 ("… the system provides reliable and low cost cooling" and "may be installed).

157. Duan and Cheon therefore attempt to solve similar issues—how to cool, with liquids, the increasing temperature of increasingly powerful semiconductor

devices. Further, as shown above, these references also attempt to disclose compact solutions that will be compatible with then-existing cooling solutions. In my opinion, a POSITA would have been motivated to combine the teachings of Duan and Cheon because they have a similar overall approach to solving the same problems.

158. In addition, because these two references disclose inventions that can readily be used with then-existing liquid cooling devices, they generally teach the use of similar components in a liquid cooling system for a computer system, including without limitation a heat-generating processing unit, a pump, cooling liquid, heat-exchanging elements or surfaces, and conduits for circulating cooling liquid. In other words, in my opinion, they combine familiar elements according to known methods to yield predictable results.

159. Further, Duan teaches ensuring contact between a heat-generating component (e.g., CPU 200) to a heat-exchanging interface (e.g., heat absorbing face 11). (Ex. 1005 at [0026].) A POSITA would have understood there are only a finite number of mechanisms to have two surfaces maintain contact such that they are secured to each other. Cheon's clip having legs (spring clip 16) provides a mechanism that accomplishes the "securing" disclosed in Duan. The essential purpose of Cheon's spring clip is to secure a heat-generating component (e.g., CPU 200) to a heat-exchanging interface (e.g., heat absorbing face 11). (Ex. 1007 at 4:7-

19 and FIG. 1.) Therefore, using Cheon's spring clip in Duan's disclosed system is one of a finite number of predictable solutions well within the grasp of a POSITA for maintaining intimate heat contact. (*Id.*)

160. Consequently, a POSITA, when reading these two references together, would have been motivated to combine Duan and Cheon.

B. Challenged Claims

161. In my opinion, Duan in view of Cheon renders obvious every limitation of Claim 5. I provide my analysis of the prior art with respect to this claim in the claim chart below. Unless otherwise noted, I have added emphasis to the quoted excerpts.

(a) Claim 5: "The liquid cooling system of claim 1, further comprising a clip having legs configured to secure the double-sided chassis, and the heat-exchanging interface to the heat-generating component."

162. Duan in view of Cheon discloses this limitation. Cheon discloses:

> "In accordance with the invention a ***heat transfer device 12 is mounted on the chip 8 to remove excess heat from the chip 8***. In order to accomplish heat transfer from the chip 8 to the device 12, ***the device 12 has an outer surface in intimate contact with a complementary outer surface of the chip 8***. In the illustrated configuration ***the device 12 has a lower surface that is in contact with a flat upper surface of the chip 8 along an interface 14. The intimate contact between the two surfaces is maintained by a spring clip 16***."

(Ex-1007 at 3:40-49 (emphasis added).)

163. Cheon further teaches:

> "A heat transfer device 30 is mounted on the heat sink 26 to cool the component 26, 28. The heat sink 26 has a flat horizontal top to which the heat transfer device 30 is attached and opposite downwardly depending legs to which rectifiers 28 are attached. As in the case of the first heat transfer device 12 discussed above, the second heat transfer device 30 has a flat heat-transferring interface 32 with the top of the heat sink 26. Intimate contact between the heat sink 26 and device 30 may be maintained by a heat transfer adhesive. ***Alternatively, a spring clip, such as one of the type 16 shown in connection with the chip 8, may be used for maintaining the intimate heat-transferring contact*.**"

(Ex-1007 at 4:7-19 (emphasis added).)

164. Spring clip 16 is colored blue in the following colored and annotated version of FIG. 1 of Cheon:

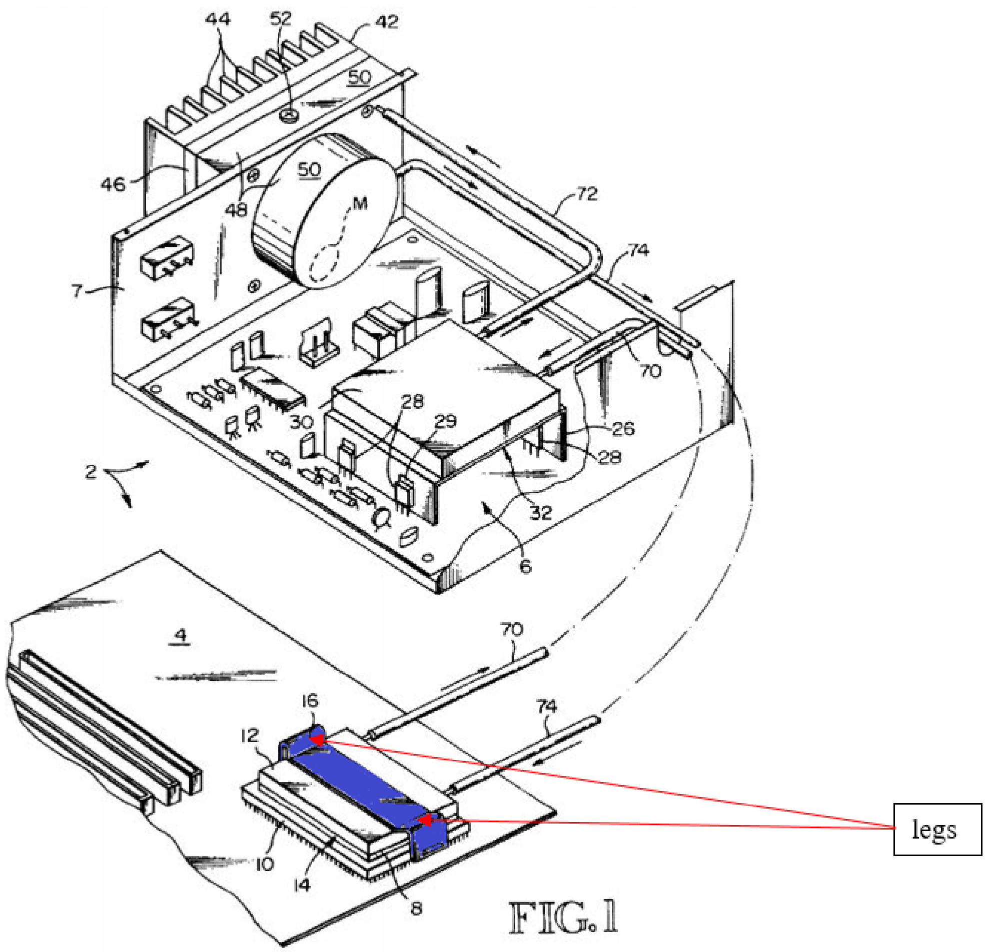


FIG. 1

165. As seen from the quoted text and FIG. 1 of Cheon, in that reference the heat exchanging interface (interface 14) is secured onto the heat generating component (chip 8) using a clip with legs (spring clip 16). To a POSITA, Cheon's interface 14 is a heat exchanging interface and thus a wall of the thermal chamber as claimed in the '355 patent.

166. As such, it would be obvious to a POSITA that in the case of a thermal chamber disposed between the pump chamber and the heat generating component (chip 8), where the pump chamber is comprised of an impeller cover and a double

sided chassis, and the heat exchanging interface (interface 14) is mounted on the heat generating component (chip 8) using a clip having legs (spring clip 16) as taught by Cheon, by design the double-sided chassis is also secured onto the heat generating component (chip 8) by that clip having legs (spring clip 16).

167. Therefore, Claim 5 is rendered obvious over Duan in view of Cheon.

X. CLAIM 8 IS RENDERED OBVIOUS OVER DUAN IN VIEW OF SHIN

168. Below, I provide my opinion with respect to Claim 8.

A. Motivation/Rationale to combine the teachings of Duan and Shin

169. Duan describes: "As downsize of form factor and increasing processing speed, the heat dissipation for central processing unit (CPU) is also an important issue to solve." (Ex-1005 at [0004].) Duan further states that a problem to be solved is that prior art liquid-cooling dissipation systems are "***bulky and hard to assemble***. This is adverse to the ***compact*** trend of computer." (*Id.* at [0006] (emphasis added).) The invention in Duan, therefore, "provides a cooling plate module wherein the cooling plate is integrally formed with the liquid driving module ***such that the layout of the cooling plate module can be minimized to reduce space***." (*Id.* at [0007] (emphasis added).)

170. Shin similarly discloses:

> "The present invention pertains to a cooling structure for liquid cooling of heat generating electronic circuit components … relating in

> particular to a cooling structure for compactly mounting a liquid cooled heat sink and pump. … ***In recent years, the amount of heat generated by electronic equipment, as represented by computers, communication equipment, multimedia equipment, etc., has tended to increase markedly***. In particular, ***the cooling of CPUs***, which perform centralized computation processing, image processing LSI chips, power amplifiers and the like, ***has become a very important problem***."

(Ex-1007 at [0001] – [0002] (emphasis added).)

171. Shin also states: "It is an object of the present invention to provide a cooling structure for electronic devices which is ***compact***, has low noise, ***superior cooling performance and high reliability***." (*Id.* at [0006] (emphasis added); *see also id.* at [Abstract] (the invention "can be compactly installed in an electronic equipment case without major changes to the case structure of conventional air cooled electronic equipment").)

172. In my opinion, Duan and Shin therefore attempt to solve similar issues—how to cool, with liquids, the increasing temperature of increasingly powerful semiconductor devices. Further, as shown above, these references also attempt to disclose compact solutions that will be compatible with then-existing cooling solutions. In my opinion, a POSITA would have been motivated to combine the teachings of Duan and Shin because they have a similar overall approach to solving the same problems.

173. In addition, because both references disclose inventions that can readily be used with then-existing liquid cooling devices, they generally teach the use of similar components in a liquid cooling system for a computer system, including without limitation a heat-generating processing unit, a pump, cooling liquid, heat-exchanging elements or surfaces, and conduits for circulating cooling liquid.

174. That is also a rationale for combining the teachings of Duanwith Shin. Specifically, the ’355 patent admits that then-existing liquid cooling systems containing air fans, to blow air through the heat radiator, are prior art: “FIG. 3 shows an embodiment of “the typical components in a liquid-cooling type CPU cooling arrangement.” (Ex-1001 at 7:7-9, 8:1-18; FIG. 3 (air fan 10).) “The heat radiator 11 serves as a means of removing heat from the liquid by means of the air fan 10 blowing air through the heat radiator.” (*Id.* at 10:63-65.) I am informed that prior art admissions made in the specification of a patent application are binding on a Patent Owner, and may be used as prior art against the patent.

175. Shin similarly teaches the use of an air fan in the liquid cooling systems disclosed therein. (Ex-1006 at [0025].)

176. In other words, in my opinion, using an air fan in a liquid cooling system to blow air through the heat radiator, with a known air cooling effect and potential associated noise, would have represented nothing more than the use of a known feature, used in an entirely predictable and conventional fashion (to achieve

desired air cooling of components) and in the same way that is used in the prior art to improve conventional liquid cooling systems for computer systems.

177. Ultimately, a POSITA would have recognized that hot air will build up around a radiator such as, for example, the components of box 5 of Duan. This is because the purpose of Duan's heat-dissipating fins 531 is to remove heat from one system and transfer it to the air. (Ex. 1005 at [0025]). The solution of using a fan to disperse heat build-up is an obvious one because it was well known prior to the time of invention (Ex. 1001 at FIG. 3) and a fan's primary purpose is to move air, *i.e.*, to circulate air at higher velocities than possible with pure natural convection (buoyancy driven flow) and thus reduce thermal resistance from a radiator to the surroundings. Moreover, because Duan's radiator is positioned away from the liquid driving module 2 (Ex. 1005 at [0023] and FIG. 6), the fan would be driven by a motor separate from the motor of the pump. Thus, a POSITA would have been motivated to solve Duan's issues with the solutions provided in Shin.

178. Consequently, a POSITA, in my opinion, when reading these references together, would have been motivated to combine Duan and Shin.

B. Challenged Claims

179. In my opinion, Duan in view of Shin renders obvious every limitation of Claim 8. I provide my analysis of the prior art with respect to this claim below. Unless otherwise noted, I have added emphasis to the quoted excerpts.

(a) Claim 8: "The liquid cooling system of claim 1, further comprising a fan configured to direct air through the heat radiator, the fan being driven by a motor separate from the motor of the pump."

180. Duan discloses, teaches or suggests this limitation in view Shin.

181. As discussed above, Duan discloses a radiator (cooling stage 53, heat-dissipating fins 531, and runners 532), which are components in box 5 of Duan. A POSITA reading FIG. 6 of Duan would have understood that the heat-dissipating fins 531 release heat through air. The air around the fins warm up as heat is drawn from the fins to the surrounding air. Without proper circulation, the surrounding air around the fins will stagnate.

182. As discussed above, Patent Owner admits that prior art liquid-cooling systems included an air fan "provided together with the heat radiator" and for "blowing air through the heat radiator." (Ex-1001 at 10:50-65 & FIG. 3.) This would be within the knowledge of a POSITA. Specifically, a POSITA would have known that fans are used to disperse hot air as the '355 patent suggests.

183. In my opinion, a POSITA thus would have found it obvious, based on admitted prior art teachings, to add a fan to the liquid-cooling system disclosed in Duan to direct air through the heat radiator. A POSITA would have further found it obvious, as a matter of basic design of a liquid-cooling system, that such a prior art air fan would need to be driven by a motor separate from the motor of the pump because this would allow for the individual operation of the fan and the pump, which

is advantageous to independently regulate the airflow and the liquid flow to achieve an optimal efficiency of the system while reducing noise.

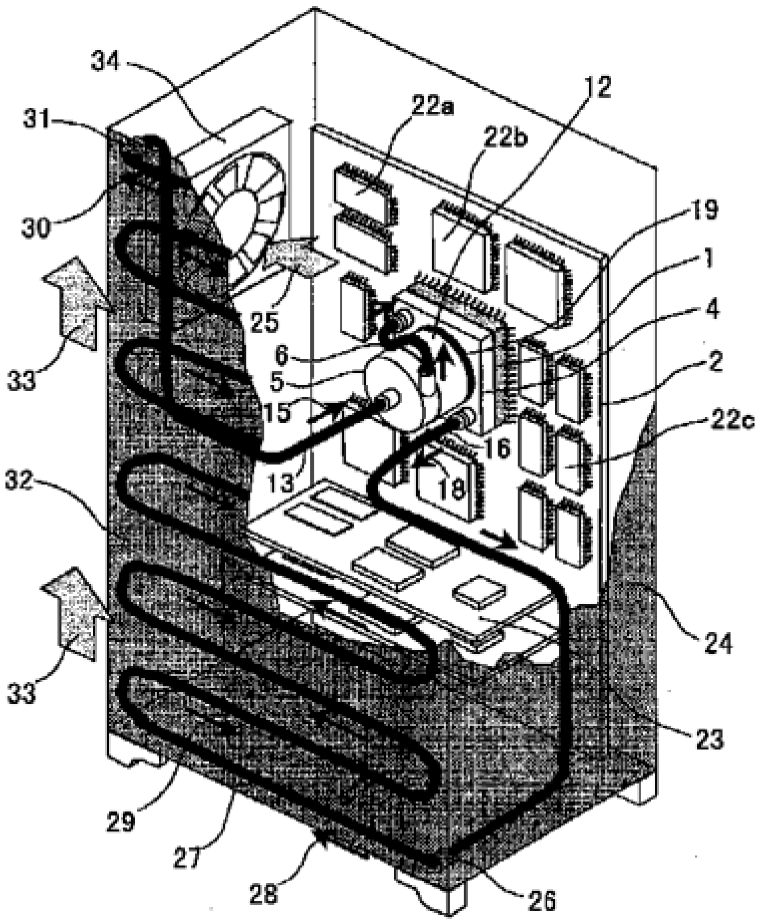
184. Shin teaches: "Using a DC motor ***allows the motor speed to be easily changed by changing the DC voltage, thus enabling control of cooling power***." (Ex-1006 at [0019] (emphasis added).) Shin also states with respect to the embodiment in FIG. 3:

> "Besides the heat generating element 1, heat generating elements 22a, 22b, 22c, such as memory LSI and driver LSI chips, ***which can be cooled by air cooling***, as well as an IO card, memory card, hard disk or other card mounting board 23 are also installed on the wiring board 2. The wiring board 2 is housed inside case 24, which is an electronic equipment case. ***An air cooling fan 34 is installed in the case 24, and the aforementioned multiple air cooled components are air-cooled by cooling air 25***."

(Id. at [0023]-[0024] (emphasis added).)

185. These elements are also shown in FIG. 3:

FIG. 3



(Id. at FIG. 3.)

186. Thus, Shin confirms the conventional practice of using a fan to disperse and blow away accumulating hot air.

187. In my opinion, based on these teachings, a POSITA would have understood that Shin discloses or suggests an air fan (34) configured to direct air through the heat radiator, the fan being driven by a motor separate from the motor of the pump, for the same reasons discussed above in regards to the APA.

188. Accordingly, Claim 8 is rendered obvious over Duan in view of Shin.

i. Motivation/Rationale for combining the teachings of Duan with Shin

189. Duan describes: "As downsize of form factor and increasing processing speed, the heat dissipation for central processing unit (CPU) is also an important issue to solve." (Ex. 1005 at [0004].) Duan further states that a problem to be solved is that prior art liquid-cooling dissipation systems are "***bulky and hard to assemble***. This is adverse to the ***compact*** trend of computer." (*Id.* at [0006] (emphasis added).) The invention in Duan, therefore, "provides a cooling plate module wherein the cooling plate is integrally formed with the liquid driving module ***such that the layout of the cooling plate module can be minimized to reduce space***." (*Id.* at [0007] (emphasis added).)

Shin similarly discloses:

> "The present invention pertains to a cooling structure for liquid cooling of heat generating electronic circuit components … relating in particular to a cooling structure for compactly mounting a liquid cooled heat sink and pump. … ***In recent years, the amount of heat generated by electronic equipment, as represented by computers, communication equipment, multimedia equipment, etc., has tended to increase markedly***. In particular, ***the cooling of CPUs***, which perform centralized computation processing, image processing LSI chips, power amplifiers and the like, ***has become a very important problem***."

(Ex. 1006 at [0001] – [0002] (emphasis added).) Shin also discloses: "It is an object of the present invention to provide a cooling structure for electronic devices which is ***compact***, has low noise, ***superior cooling performance and high reliability***." (*Id.* at [0006] (emphasis added); *see also id.* at [Abstract] (the invention "can be compactly installed in an electronic equipment case without major changes to the case structure of conventional air cooled electronic equipment").)

190. In my opinion, based on these teachings, Duan and Shin therefore attempt to solve similar issues—how to cool, with liquids, the increasing temperature of increasingly powerful semiconductor devices. Further, as shown above, these references also attempt to disclose compact solutions that will be compatible with then-existing cooling solutions. (*Id.*) A POSITA would have been motivated to combine the teachings of Duan and Shin because they have a similar overall approach to solving the same problems. *See KSR Int'l Co. v. Teleflex, Inc.*, 550 U.S. 398, 401, 419-21 (2007).

191. In addition, because both references disclose inventions that can readily be used with then-existing liquid cooling devices, they generally teach the use of similar components in a liquid cooling system for a computer system, including without limitation a heat-generating processing unit, a pump, cooling liquid, heat-exchanging elements or surfaces, and conduits for circulating cooling liquid. That is also a rationale for combining the teachings of Duan with those of Shin.

Specifically, the ’355 patent admits that then-existing liquid cooling systems containing air fans, to blow air through the heat radiator, are prior art: “FIG. 3 shows an embodiment of “the typical components in a liquid-cooling type CPU cooling arrangement.” (Ex. 1001 at 7:7-9, 8:1-18; FIG. 3 (air fan 10).) “The heat radiator 11 serves as a means of removing heat from the liquid by means of the air fan 10 blowing air through the heat radiator.” (*Id.* at 10:63-65.) Prior art admissions made in the specification of a patent application are binding on a Patent Owner, and may be used as prior art against the patent. *PharmaStem Therapeutics, Inc. v. ViaCell, Inc.*, 491 F.3d 1342, 1362 (Fed. Cir. 2007) (“Admissions in the specification regarding the prior art are binding on the patentee for purposes of a later inquiry into obviousness.”). *See also In re Cohen*, 767 Fed. Appx. 985, 987-89 (Fed. Cir. 2019) (affirming an examiner’s reliance on the disclosure of a “typical” technique in the “Background” section of a patent as applicant-admitted prior art). Shin similarly teaches the use of an air fan in the liquid cooling systems disclosed therein. (Ex. 1006 at [0025].)

192. In other words, using an air fan in a liquid cooling system to blow air through the heat radiator, with a known air cooling effect and potential associated noise, would have represented nothing more than the use of a known feature, used in an entirely predictable and conventional fashion (to achieve desired air cooling of components) and in the same way that is used in the prior art to improve conventional

liquid cooling systems for computer systems. *KSR Int'l Co. v. Teleflex, Inc.*, 550 U.S. 398, 401 (2007) ("a combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results.").

193. In my opinion, based on these teachings, a POSITA would have recognized that hot air will build up around a radiator such as, for example, the components of box 5 of Duan. This is because the purpose of Duan's heat-dissipating fins 531 is to remove heat from one system and transfer it to the air. (Ex. 1005 at [0025]). The solution of using a fan to disperse heat build-up is an obvious one because it was well known prior to the time of invention (Ex. 1001 at FIG. 3) and a fan's primary purpose is to move air. Moreover, because Duan's radiator is positioned away from the liquid driving module 2 (Ex. 1005 at [0023] and FIG. 6), the fan would be driven by a motor separate from the motor of the pump. The solutions to these issues are provided in Shin, so a POSITA would have been motivated to use Shin's solutions to solve Duan's issues.

194. Consequently, a POSITA, when reading these references together, would have been motivated to combine Duan and Shin.

XI. SECONDARY CONSIDERATIONS

195. I am not aware of any secondary considerations that would overcome the showing of obviousness provided by the Petition and above. Further, in my opinion,

any attempt by Patent Owner to rely on alleged secondary considerations cannot overcome the showing of obviousness detailed above.

XII. CONCLUDING STATEMENT

196. I reserve the right to offer opinions relevant to the invalidity of the '355 patent claims at issue and/or offer testimony in support of the Declaration.

197. In signing this Declaration, I recognize that the Declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in the case. If required, I will appear for cross-examination at an appropriate and convenient place and time.

198. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and, further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 28 U.S.C. § 1001.

APPENDIX A

MARC HODES

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TUFTS UNIVERSITY

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http://engineering.tufts.edu/me/people/hodes/

AREA OF INTEREST: TRANSPORT PHENOMENA

- Analysis of Transport Phenomena in the Presence of Apparent Slip.
- Mass Transfer in Supercritical Fluids.
- Thermal Management of Electronics.
- Analysis and Design of Thermoelectric Modules and Assemblies.

EDUCATION

Massachusetts Institute of Technology **Cambridge, MA**
PhD Mechanical Engineering (Chemical Engineering Minor) 1998

- Thesis: *Measurements and Modeling of Deposition Rates from Near-Supercritical, Aqueous, Sodium Sulfate and Potassium Sulfate Solutions to a Heated Cylinder*.
- Advisor: Kenneth A. Smith, Emeritus Professor of Chemical Engineering. Co-Advisor: Peter Griffith, Emeritus Professor of Mechanical Engineering.

University of Minnesota **Minneapolis, MN**
MS Mechanical Engineering 1994

- Thesis: *Gas Assisted Evaporative Cooling in Downflow through Vertical Channels*.
- Advisor: Avram Bar-Cohen, Distinguished University Professor of Mechanical Engineering (University of Maryland).

University of Pittsburgh **Pittsburgh, PA**
BS Mechanical Engineering (magna cum laude) 1990

EXPERIENCE

Tufts University **Medford, MA**
Professor of Mechanical Engineering & Director of Graduate Studies Sept 2018-present
Associate Professor of Mechanical Engineering (tenured 5/19/14) Aug 2008-Aug 2018

- Lead and directly contribute to research currently focused on analysis of convection in the presence of apparent slip, supercritical CO_2-based drying of aerogels and thermal management of electronics. See https://engineering.tufts.edu/me/research/hodes for representative past and current research projects.
- Teach Fluid Mechanics and Heat Transfer at the undergraduate level and Thermal Management of Electronics, Fluid Mechanics, Heat Transfer and Analytical Transport Phenomena at the graduate level.
- Service to the Department, University and Heat Transfer community.

Transport Phenomena Technologies, LLC – http://www.tptechcorp.com/ **Medford, MA**
Co-Founder and Chief Technology Officer Oct 2017–present

- Technical and business activities related to hybridization of computational fluid dynamics, flow network modeling and multi-variable optimization to enable simultaneous optimization of the geometry of arrays of heat sinks as per Phase I NSF SBIR funding.
- Consulting on transport phenomena.

Imperial College **London, UK**
Academic Visitor in Department of Mathematics Jan-July 2015, May-July 2016, May-July 2017, June-July 2018, ...

- Analysis of transport phenomena in the presence of apparent slip.
- Analysis of thermal contact resistance for rough surfaces.

University of Limerick **Limerick, Ireland**
E.T.S. Walton Award Visitor June 2012-Aug 2012

- Analysis of convection in the presence of apparent slip.

Bell Laboratories **Murray Hill, NJ**
Manager (expatriate) Oct 2006-Aug 2008

- Managed externally-funded Thermal Management Research Group at newly-founded Bell Labs Ireland.
- Participated in research on superhydrophobic nanostructured surfaces, "three-dimensional" heat sinks, etc.

Member of Technical Staff July 1998-Sept 2006

- Developed algorithms to maximize the performance and efficiency of thermoelectric modules used for the precision temperature control of photonic components.
- Developed thermal management technologies, e.g., mechanical replacements for elastomeric gap fillers, for Lucent Technologies products.

Postdoctoral Member of Technical Staff Aug 1998-July 2000

- Experiments on transient thermal management and analysis of multi-dimensional heat conduction.
- Developed numerical models for heat transfer in Lucent Technologies products, e.g., power conversion modules and handsets.

Massachusetts Institute of Technology **Cambridge, MA**
Research Assistant in Department of Mechanical Engineering Sept 1993-June 1998

- Modeled fouling due to precipitation of insoluble salts during Supercritical Water Oxidation (SCWO), an emerging technology to remediate hazardous organic wastes. Models predicted whether salts nucleated homogeneously or heterogeneously and rates of deposition of salt on walls of SCWO reactors by double-diffusive natural convection mass transfer.

National Institute of Standards and Technology (NIST) **Gaithersburg, MD**
Visiting Scientist and NSF Fellow Jan 1994-Aug 1997

- Performed solubility, deposition rate and nucleation experiments in salt-containing supercritical water.

University of Minnesota **Minneapolis, MN**
Research Assistant Sept 1990-Aug 1993

- Investigated transition to annular flow by addition of non-condensable gas to enhance evaporative cooling of microelectronics.
- Designed, constructed and commissioned γ-ray densitometer to identify two-phase flow regimes.

Teaching Assistant Sept 1990-Aug 1993

- Teaching Assistant for Thermodynamics, Applied Thermodynamics, Heat Transfer and Boiling Heat Transfer and Multiphase Flow.

Ford Motor Company **Redford, MI**
Summer Intern Jun 1990-Aug 1990

- Performed simulations in Patran/Nastran to evaluate reliability of metal matrix composites in automobiles.

University of Notre Dame **South Bend, IN**
NSF REU Fellow Jun 1989-Aug 1989

- Experimental quantification of energy savings achievable in household refrigerators using Phase Change Material (PCM).

AWARDS

- 2014: IEEE SEMI-THERM Conference. Best Paper Award
- 2013: Tufts ASME Student Chapter. Award of Excellence
- 2012: Science Foundation Ireland. Walton Visitor Award
- 2011: ASME *Journal of Electronics Packaging*. Invited Contribution to Special Issue
- 2009: ASME InterPACK 2009. Best Poster Award in System Air and Liquid Cooling Track
- 2008: ASME ICNMMC 2008. Best Paper Nomination
- 2004: IEEE ITherm 2004. Best Paper Nomination
- 2002: Bell Laboratories. Teamwork Award
- 1997: NSF. NSF/NIST Graduate Student Fellowship
- 1994: MIT. Sigma Xi Honors Society

- 1989: NSF. REU Award to spend summer at University of Notre Dame
- 1989: University of Pittsburgh. Pi Tau Sigma Honors Society (Chapter President)

REPRESENTATIVE PROFESSIONAL ACTIVITIES

- External Examiner of undergraduate curriculum, Department of Mechanical, Aeronautical and Biomedical Engineering, University of Limerick, Limerick, Ireland, 2013-2017.
- Associate Editor of *IEEE Transactions on Components, Packaging and Manufacturing Technology*, 2013-.
- Guest Editor of *IEEE Transactions on Components, Packaging and Manufacturing Technology*, 2010-13.
- Consultant on Thermal Management of DC-DC Power Converters, Altera Inc., San Jose, CA, 2012-13.

JOURNAL PUBLICATIONS

Submitted

[51] Kirk, T., Karamanis, G., Crowdy, D., Hodes, M., "Thermocapillary Stress and Meniscus Curvature Effects on Slip Lengths in Ridged Microchannels." Submitted to *J. Fluid Mech.*

Published

[50] Game, S., Hodes, M., Papageorgiou, D., 2019, "Effects of Slowly-Varying Meniscus Curvature on Internal Flows in the Cassie State," *J. Fluid Mech.*, **872**, pp. 272-307

[49] Karamanis, G., Hodes, M., 2019, "Conjugate Nusselt Numbers for Simultaneously-Developing Flow through Rectangular Ducts," *ASME J. Heat Transfer*, **141**.

[48] Kane, D., Hodes, M., 2019, "Isoflux Nusselt Number Expression for Combined Poiseuille and Couette Flow Capturing Asymmetry and Slip," *Heat Transfer Research*, **50**(15).

[47] Karamanis, G., Hodes, M., 2019, "Simultaneous Optimization of an Array of Heat Sinks," *ASME J. Electronic Packaging*, **141**(2).

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[43] Karamanis, G., Hodes, M., Kirk, T., Papageorgiou, D., 2018, "Solution of the Extended Graetz-Nusselt Problem for Liquid Flow over Isothermal Parallel Ridges." *ASME J. Heat Transfer*, **140**.

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[36] Karamanis, G., Hodes, M., 2016, "Longitudinal-Fin Heat Sink Optimization Accounting for Non-Uniform Heat Transfer Coefficient under Fully-Developed Conditions," *ASME J. Thermal Sci. Eng. Appl.*, **8**.

[35] Zhang, R., Hodes, M., Wilcoxon, R., Lower, N., 2015, "Water-Based Microchannel and Galinstan-Based Minichannel Cooling beyond 1000 W/cm^2 Heat Flux," *IEEE Trans. Compon., Packag., Manuf. Technol.*, **5**(6).

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[31] Brownell, E. and Hodes, M., 2014, "Optimal Design of Thermoelectric Generators Embedded in Thermal Resistance Networks," *IEEE Trans. Compon., Packag., Manuf. Technol.*, **4**(4), pp. 612-621.

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[28] Hodes, M., Zhang, R., Lam, L., Wilcoxon, R., and Lower, N., 2014, "On the Potential of Galinstan-Based Minichannel and Minigap Cooling," *IEEE Trans. Compon., Packag., Manuf. Technol.*, **4**(1), pp. 46-56.

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EXTERNAL FUNDING AWARDS AS PI OR INSTITUTIONAL PI

- Tufts University's Tufts Collaborates Program for "Elimination of Surfactant-Induced Flow Resistance in Superhydrophobic Microchannels." PI. July 2018-June 2019, $30,500.
- National Science Foundation grant #CBET-1805179 for "Electrowetting-assisted Dropwise Condensation on Hybrid Superhydrophobic-Hydrophilic Surfaces." Co-PI. September 2018-August 2021, $354,742 ($118,900 to Tufts University).
- Massachusetts Clean Energy Center (Catalyst Program) grant for "Heat Sink Optimization for Reduction of Energy Consumption in Data Centers." PI. August 2016-July 2017, $39,604.
- National Science Foundation grant #CMMI-1530603 for "SNM: Low-Cost, Large-Scale Nanomanufacturing of Superinsulating Aerogels and Lightweight, Mechanically-Strong Aerogels." PI. January 2016-December 2019, $1,499,309.
- Google, Google Faculty Research Award for "Beyond 1 kW/cm^2 Microchannel Cooling of Microelectronics Enabled by Structured Surfaces and Liquid Metal." PI. June 2015-July 2016, $55,040.
- National Science Foundation grant #CBET-1402783 for "Analysis of Convection in the Presence of Apparent Thermal Slip." PI. September 2014-August 2017, $255,630.
- Futurewei Technologies, Inc. for "Low Flow Resistance 3D Heat Sinks for Enhanced Air Cooling of Telecommunications Equipment." PI. July 2014-June 2015, $106,620.
- Science Foundation Ireland grant #11/W.1I2072 for "Analytical Models Relevant to Evaporation-Induced Shear Stress-Driven Heat Spreaders." PI. June 2012-August 2012. $52,044.

- Byrne Thermodynamic Systems, LLC, for "A Calculation Model of a Thermosyphon Operating at -150^{o}C for Attachment to a Cold Finger on a Stirling Cooler." PI. January 2012 - April 2012, $12,000.
- DARPA grant #W31P4Q-11-1-0011 for "Liquid Metal Cooling of Microelectronics." PI. August 2011-August 2013. $250,000.
- Wittich Energy Sustainability Research Initiation Fund Grant for "Thermoelectric Module-Liquid Metal Substrate Assemblies for Reduced Power Precision Temperature Control." PI. June 2010-August 2011. $57,771.
- Aspen Aerogel Inc. Subcontract #310264 from for "Aerogel Blanket Manufacture." (DoE Contract DE-EE0000266 to Aspen Aerogel, Inc.). Institutional Co-PI in Year I and Institutional PI in Year 2. May 2009-May 2011. $486,632.00.

INVITED PRESENTATIONS & SHORT COURSES (2007-)

- "Diabatic Flow of Liquids in the Cassie State," National Fuel Cell Research Center, University of California, Irvine, CA, 2019 .
- "New Nusselt Number Expression for an Internal Liquid Flow in the Cassie State over Parallel Ridges," Mini Symposium on Transport Phenomena and Textured Sufaces: Modeling and Applications, International Conference on Industrial and Applied Mathematics, Valencia, Spain, 2019 .
- "Diabatic, Internal Liquid Flow in the Cassie State," the Mathematical Instsitute, University of Oxford, Oxford, UK, 2019 .
- "Modeling Transport Phenomena in Diabatic Internal Flows in the Cassie State," ASME International Conference on Nanochannels, Microchannels and Minichannels (ICNMM) Keynote, St. Johns, Newfoundland, Canada, 2019.
- "Effect of Surface Curvature on Contact Resistance," Department of Mechanical and Aerospace Engineering, Brunel University, London, UK, 2019.
- "Effect of Thermocapillary Stress and Meniscus Curvature on Internal Liquid Flows in the Cassie State," Department of Mechanical Engineering, Purdue University, West Lafayette, IN, 2019.
- "Effect of Surface Curvature on Contact Resistance," Department of Mechanics, Tianjin University, Tianjiin, China, 2018.
- "Design and Optimization of Heat Sinks" Professional Development Course, Co-located IEEE Electronic Components & Technology Conference and Intersociety Thermal & Thermomechanical in Electronic Systems Conference, San Diego, CA, 2018. (with Georgios Karamanis)
- "Towards Rigorous Measurements and Modeling of Supercritical Carbon Dioxide Drying of Sol Gels ," MRS Spring Meeting and Exhibit, Phoenix, AZ, 2017.
- "Effect of Thermocapillary Stress on Slip Length for a Channel Textured with Parallel Ridges ," Condensed Matter Physics Seminar Series, Tufts University, Department of Physics, 2017.
- "Effect of Thermocapillary Stress on Slip Length for a Channel Textured with Parallel Ridges ," *The Red Lotus Project Workshop* (Sponsored by the Royal Society), Chicheley, England, 2016.
- "Effect of Thermocapillary Stress on Slip Length for a Channel Textured with Parallel Ridges ," Numerical Methods for Partial Differential Equations Seminar Series, Department of Mathematics, MIT, 2016.
- "Analysis of Convection in the Presence of Apparent Slip," Department of Mechanical Engineering Seminar Series, IIT Bombay, 2015.
- "Analysis of Convection in the Presence of Apparent Slip," Department of Mechanical Engineering Seminar Series, University of Connecticut, 2015.
- "Convection in the Presence of Apparent Slip and Its Implications on Microchannel Cooling," Department of Mechanical Engineering Seminar Series, University College Dublin (UCD), 2015.
- "Effects of Evaporation and Condensation on Apparent Thermal Slip," First International Applied and Computational Complex Analysis (ACCA) UK-JP Workshop, Imperial College London, 2015.
- "Analysis of Convection in the Presence of Apparent Slip," Thermofluids Division Seminar Series, Department of Mechanical Engineering, Imperial College London, 2015.
- "3D Heat Sinks for Enhanced Air Cooling," 6th International Electronic Cooling Technology Workshop, Yokohama, Japan, 2014.
- "Galinstan-Based Cooling of Microelectronics: Beyond Tuckerman and Pease?," Keynote Lecture, Eurotherm Seminar 102, Limerick, Ireland, 2014.

- "Analysis of Convection in the Presence of Apparent Slip," ACCA-UK Group, Imperial College, London, England, 2014.
- "Galinstan-Based Cooling of Microelectronics: Beyond Tuckerman and Pease?," State of Maine IEEE Chapter, South Portland, ME, 2014.
- "Supercritical CO_2 Drying of Silica Alcogel: State-of-the-Art and Outstanding Needs," Invited Lecture, NSF Workshop on Supercritical Fluids, Campinas, Brazil, 2013.
- "Galinstan-Based Cooling of Microelectronics: Beyond Tuckerman and Pease?," Keynote Lecture, Cooling Zone-13, eConference, 2013.
- "Galinstan-Based Liquid Cooling of RF MMIC PAs: Beyond Tuckerman and Pease?," DARPA-organized Panel on "Embedded Thermal Management," IEEE Compound Semiconductor IC Symposium, Monterey, CA, 2013.
- "Analysis of Convection in the Presence of Apparent Slip," Mechanical Engineering Seminar Series, University of Houston, 2013.
- "Continuous Extraction Rate Measurements during Supercritical CO_2 Drying of Silica Alcogel," Empa Swiss Federal Laboratories for Materials Science and Technologies, Dubendorf, Switzerland, 2012.
- "Emerging Thermal Management Technologies," University of Limerick, Limerick, Ireland, 2012.
- "Emerging Thermal Management Technologies," ABB Inc., Zurich, Switzerland, 2012.
- "Ethanol Extraction Rates During Supercritical CO_2-Based Drying of Alcogels," Union College Aerogel Group, Schenectady, NY, 2011.
- "Reduced Power Consumption Precision Temperature Control of Photonic Components," Lindbergh Lecture Series, Department of Mechanical Engineering, University of Wisconsin, Madison, WI, 2010
- "Thermoelectricity-Based Technologies for Thermal Management: Present and Future." Keynote presentation at NSF Cooling Technologies Research Center/Huawei, Inc. Workshop on Thermal Management in Telecommunication Systems and Data Centers, Dallas, TX, 2010.
- "Thermoelectricity-Based Technologies for Thermal Management: Present and Future," Thermal Management Seminar cum Panel Discussion, National University of Singapore, 2010.
- "Thermal Management of Electronics (Semester Long Course)," Lytron Inc., Woburn, MA, 2010.
- "Thermoelectric Modules: Principles and Research," Guest lecture in ME597G (later ME51100) - Heat Transfer in Electronic Systems at Purdue University, West Lafayette, IN, 2006, 2008, 2019.
- "Thermoelectric Modules: Principles and Research," short course at InterPACK 2005, 2007 and 2011 and ITherm 2006, 2008.
- "Optimized Pellet Geometry for Thermoelectric Power Generation," University of Cardiff, Cardiff, Wales, 2007.

PhD THESES EXTERNALLY EXAMINED

- Belal Al-Khamaiseh, 2018, *Analytical Solutions of 3D Heat Conduction in Flux Channels with Nonuniform Properties and Complex Structures*, Memorial University of Newfoundland.
- Seye Masood Razavi, 2016, *Advanced Thermal Analysis of Microelectronics Using Spreading Resistance Models*, Memorial University of Newfoundland.
- Mehdi Ghobadi, 2014, *Experimental Measurement and Modelling of Heat Transfer in Spiral and Curved Channels*, Memorial University of Newfoundland.
- Tamanna Alam, 2012, *Characteristics Investigation and Parametric Study of Flow Boiling in a Microgap Heat Sink*, National University of Singapore.
- Karthik Balasubramanian, 2012, *Experimental Study of Flow Boiling Characteristics and Instabilities in Straight, Expanding and Stepped Fin Microchannels*, National University of Singapore.
- Yong-Jiun Lee, 2011, *Enhanced Thermal Transport in Microchannel Heat Sink Using Oblique Fins*, National University of Singapore.
- David McGuire, 2006, *On the Interferometric Measurements of Convective Mass Transfer*, University of Limerick.
- Noel Sirr, 2008, *On Continuous Flow Discretized DNA Amplification*, University of Limerick.
- Cormac Eason, 2005, *Measurement of Pressure Drop and Heat Transfer Analysis of Microchannels*, University of Limerick.

RESEARCH GROUP ALUMNI

Postdoctoral

- Martin Cleary, 2010-2011. Currently at GMZ Energy, Inc.

PhD

- Georgios Karamanis, 2018, "Nusselt Numbers for Superhydrophobic Microchannels and Shrouded Longitudinal-Fin Heat Sinks." Currently at Transport Phenomena Technologies, LLC.
- Lisa Lam, 2014, "Convection Heat Transfer in the Presence of Apparent Slip."
- Rui Zhang, 2014, "Water-Based Microchannel and Galinstan-Based Minichannel Cooling." Currently at ACS Material Inc.
- Martin Cleary, 2011, "An Experimental Investigation on the Operation of Variable Conductance Heat Pipes and Gas-Loaded Thermosyphons." Co-advised with Dr. Ronan Grimes. Currently at Shell TechWorks.

Master's of Science

- Michael Mayer, 2018, "Effect of Surface Curvature on Contact Resistance between Abutting Cylinders."
- Daniel Kane, 2017, "On Spreading Resistances and Apparent Slip Lengths for Rectangular and Elliptic Pillars," Currently an intern at Bell Labs Ireland.
- Georgios Karamanis, 2015, "Optimized Longitudinal-Fin Heat Sinks Accounting for Non-Uniform Heat Transfer Coefficient," Currently pursuing PhD at Tufts University.
- Ryan Nelson, 2014, "Effects of Pressure, Temperature, Solvent and Gel Thickness on the Kinetics of Supercritical CO2 Drying of Silica Alcogel." Currently at Aerogel Technologies.
- Justin Griffin, 2013, "Continuous Extraction Rate Measurements During Supercritical CO_2 Drying of Silica Alcogels." Currently at Aerogel Technologies.
- Elizabeth Brownell, 2013, "Optimal Design of Thermoelectric Generators Embedded in a Thermal Resistance Network." Currently at Yankee Scientific.
- Rui Zhang, 2011, "Optimized Thermoelectric Module-Heat Sink Assemblies for Precision Temperature Control." Currently at ACS Material Inc.
- Drew Mills, 2011, "Apparatus to Measure Ethanol Extraction Rates During Supercritical CO_2-Based Drying of Alcogels." Currently at Ocean Spray Inc.
- Yinzhen Liu, 2011, "Numerical Modeling of Peltier-Cooled Current Leads." Currently at American Chrome Company. Co-advised with Luisa Chiesa.
- Stuart Mueller, 2011, "Enhanced Heat Sink Performance Utilizing Capillary-Driven Evaporation." Currently at General Electric Company.
- David A. Brooks, 2011, "Experimental Characterization of Thermoelectric Module-Variable Conductance Heat Pipe Assemblies for Reduced Power Precision Temperature Control." Currently at Raytheon Corporation.
- George J. Chan, 2011, "Variable-Speed Compressor Enabled Energy Efficient Cooling of Blade Servers," Currently at General Electric Company.
- Douglas Hwang, 2009, "Data Center Power Consumption Reductions Achievable with Liquid Cooling: A Case Study." Currently at Etsy. Co-advised with Vincent Manno.

Master's of Engineering

- Michael Eskowitz, 2014, "Optimal Design of Vapor Chamber-Heat Sink Assemblies." Currently at Lincoln Labs.

HOBBIES

- Reading, including the collected works of James A. Michener.
- Jogging, especially in newly-visited cities.
- Walking tours, including 210 through *London Walks*.
- Travel, including visiting all 7 continents in 2006 & 79 countries in total.
- Restaurants, from €5 meals at *Urbani* in the Jewish Ghetto in Rome to $500 meals at *per se* in NYC.
- Films, especially at the *Film Forum* in Greenwich Village.
- Theatre, especially in the West End and elsewhere in London.
- Japan: language, travel, performing arts, arts, cuisine, etc.
- National Historic Sites, Parks, Monuments, etc. run by the National Park Serivce.