DOCKET NO: 470515US

# IN THE UNITED STATES PATENT AND TRADEMARK OFFICE PATENT TRIAL & APPEAL BOARD

PATENT: 8,573,374

INVENTOR: HEIKO MAGERKURTH et al.

TITLE: HYDRODYNAMIC TORQUE CONVERTER

TRIAL NO.: IPR2017-00441

---

# DECLARATION OF DR. STEVEN SHAW

1. I, Dr. Steven Shaw, make this declaration in connection with this petition for *inter partes* review of U.S. Patent No. 8,573,374 ("the '374 patent," attached as Exhibit 1001 to the petition). I am over 21 years of age and otherwise competent to make this declaration. Although I am being compensated for my time in preparing this declaration, the opinions herein are my own, and I have no stake in the outcome of the *inter partes* review proceeding.

## I. QUALIFICATIONS

2. A detailed record of my professional qualifications, including a list of publications, awards, and professional activities, can be found

in my *curriculum vitae*, which is attached as Appendix A to this declaration. I have provided testimony by deposition within the last five years in IPR2016-00502, filed against U.S. Patent No. 8,161,740.

3. I am currently the Harris Professor of Mechanical and Aerospace Engineering at Florida Institute of Technology. I am on leave from Michigan State University ("MSU"), where I serve as a University Distinguished Professor of Mechanical Engineering and an Adjunct Professor of Physics and Astronomy. Additionally, I am involved in a small family business that makes hand and specialty tools for Snap-On, etc. as 49% owner, Vice President, and Board Member, although I am not involved in day-to-day operations.

4. Before joining the faculty at MSU in 1984, I was an Assistant Professor in the School of Engineering at Oakland University. I also served as an Associate Professor in the Department of Mechanical Engineering at the University of Michigan during 1991-93, and have held visiting professor appointments at Cornell University, the University of Minnesota, Caltech, the University of Michigan, the University of California-Santa Barbara, and McGill University.

5. During the past 32 years, I have performed research relevant to the subject matter of the ’374 patent, including on dampers, rotor systems, and centrifugal pendulum vibration absorbers. Much of my work on this subject has been fundamental in nature, supported by the U.S. National Science Foundation. I have also worked on this topic with several companies, including Ford Motor Company off and on since 1984, with Teledyne Continental Motors in 1994, with Chrysler (in its various incarnations) continually since 2006, with Honda in 2013, with Valeo starting in 2015, and with Achates Power in 2016.

6. My work on this topic has included various types of fundamental studies, design assistance, and the development of experimental methods for system characterization. This work been funded by the companies noted above and by the U.S. National Science Foundation. I have also published extensively, with over 150 technical publications. Of these, approximately 25 archival journal papers and numerous conference papers relate to this topic. I have also given professional presentations on the subject at many conferences and university seminars. I have graduated 7 Ph.D. students and 8 M.S. students working in this area, and currently have one Ph.D. student in

progress on this subject. My 1997 SAE Arch T. Colwell Merit Award and my 2013 ASME N. O. Myklestad Award, which is "presented in recognition of a major innovative contribution to vibration engineering," were based on my technical contributions to this topic.

7. In addition, I have consultation experience with torque converters, and regularly use torque converters as an example in my classes when I teach system dynamics and vibrations.

8. I hold an A.B. degree in Physics and an M.S.E. in Applied Mechanics from the University of Michigan and a Ph.D. in Theoretical and Applied Mechanics from Cornell University.

9. I have used my education and experience working in the mechanical engineering field, and my understanding of the knowledge, creativity, and experience of a person having ordinary skill in the art in forming the opinions expressed in this report, as well as any other materials discussed herein.

## II. MATERIALS CONSIDERED

10. In forming my opinions, I read and considered the '374 patent and its prosecution history, the exhibits listed in the Exhibit List

filed with the petition for *inter partes* review of the ’374 patent, as well as any other material referenced herein.

## III. LEGAL PRINCIPLES

11. For the purposes of this declaration, I have been informed about certain aspects of patent law that are relevant to my analysis and opinions, as set forth in this section of my declaration.

### A. A Person Having Ordinary Skill in the Art

12. I understand that the disclosure of patents and prior art references are to be viewed from the perspective of a person having ordinary skill in the art at the time of the alleged invention (“PHOSITA”). Unless I state otherwise, I provide my opinion herein from the viewpoint of a PHOSITA at the earliest alleged priority date for the ’374 patent, which I have been informed is July 4, 2008.

13. The ’374 patent relates to the field of hydrodynamic torque converter design. The particular technical issue that the ’374 patent purports to address is the arrangement of components within the torque converter to decrease the assembly space while maintaining functionality. I understand from my own work experience and conversations with engineers who work in the field of hydrodynamic torque converter design that torque converter design involves three

main considerations: (1) efficient transfer of torque, (2) packaging of the torque converter parts so that the torque converter fits in the space specified by the customer, and (3) reduction of noise, vibration, and harshness (called “NVH” in the industry) to meet or exceed customer requirements. A PHOSITA in the field of hydrodynamic torque converter design would be skilled in each of those three areas, although practically speaking, torque converters are designed by teams of engineers.

14. The various references that I discuss below are informative of the level of skill of a PHOSITA and are of the type that are reasonably relied upon by experts in my field to form opinions on the subject of vibration absorbers, including vibration absorbers used in hydrodynamic torque converters.

15. Long before the ’374 patent application was filed, various components used to dampen and absorb vibrations in hydrodynamic torque converters were well-known.

16. The ’374 patent acknowledges that combining (i) torsional vibration dampers positioned between the lock-up clutch and the output hub with (ii) turbine dampers positioned between the turbine and the

output hub to damp the torsional vibrations of an internal combustion engine was known prior to the filing date. (Ex. 1001, 1:23–42.)

17. Torsional vibration absorbers were also well-known. The prior art also demonstrates that companies such as DaimlerChrysler, Mannesmann Sachs/ZF Sachs, and Carl Freudenberg were already seeking patent protection on compact torque converter designs with different damper and absorber arrangements. (Ex. 1004, Figs. 1–8, 2:15–20; Ex. 1005; Ex. 1011; Ex. 1022.)

18. It was also well-known in the art to arrange these components so as to reduce assembly space as much as possible. (*See, e.g.*, Ex. 1003, 5:3–34 (teaching sharing components and benefits of reducing space); Ex. 1004, 3:9–16 (describing benefits of using existing space to decrease assembly space.)

19. Based on these factors, I have concluded that a PHOSITA was sufficiently skilled in the general design of hydrodynamic torque converters and experienced in arranging their layouts to most efficiently use available space in view of the numerous ways to connect torque converter components described in the prior art.

### B. Claim Construction

20. I understand that “claim construction” is the process of determining a patent claim’s meaning. I also have been informed and understand that the proper construction of a claim term is the meaning that a PHOSITA would have given to that term.

21. I understand that claims in *inter partes* review proceedings are to be given their broadest reasonable interpretation in light of the specification, which is what I have done when performing my analysis in this declaration. I provide comments on specific terms below.

22. Torsional Vibration Absorber (Claims 1–16): Under its broadest reasonable interpretation in light of the specification, “torsional vibration absorber” means a component or device designed to absorb torsional vibrations. As described in the ’374 patent, this includes movable masses disposed on mounting parts. (Ex. 1001, 1:43–45.) Some examples of movable masses disposed on mounting parts are compensation flywheels, frequency-tuned mass-spring devices and centrifugal-force pendulums.

23. Parallel (Claims 1–16): Under its broadest reasonable interpretation in light of the specification, “parallel” includes “does not

transfer torque generated by the engine along the power path but rotates with" the other components in the power path. This is consistent with the description of parallel components in the '374 specification and in Haller. (Ex. 1001, 5:12–16; Ex. 1004, 3:1–3.) Both documents describe absorbers with mounting parts that are parallel to the drivetrain such that they don't transfer engine torque, but they do rotate with the other components in the drivetrain.

24. Centered (Claims 2 and 11): Under its broadest reasonable interpretation in light of the specification, "centered" includes "circumferentially mounted." (Ex. 1001, Fig. 1, 2:24–28 (describing "centered" relationship between input part of first damper stage and output part of second damper stage), 3:30–33 (describing "centered" relationship between piston and output hub).)

25. In a pocket (Claim 10): Under its broadest reasonable interpretation in light of the specification, wherein the lock-up clutch is axially mounted "in a pocket" in claim 10 means "*partially* in a pocket." Claim 11 specifies that the lock-up clutch is formed out of a piston, and the piston in the '374 patent extends partially out of the pocket. Thus,

in the embodiment shown, the lock-up clutch is *partially* in the pocket. (Ex. 1001, Fig.)

### C. Anticipation

26. I understand that a patent claim is unpatentable as anticipated if a PHOSITA during the relevant timeframe would have understood a single prior art reference to teach every limitation contained in the claim. The disclosure in a reference does not have to be in the same words as the claim, but all of the requirements of the claim must be described in enough detail, or necessarily implied by or inherent in the reference, to enable a POSITA looking at the reference to make and use at least one embodiment of the claimed invention.

### D. Obviousness

27. I understand that a patent claim is invalid if the differences between the patented subject matter and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person of ordinary skill in the art.

28. When considering the issues of obviousness, I understand that I am to do the following: (i) determine the scope and content of the prior art; (ii) ascertain the differences between the prior art and the claims at issue; (iii) resolve the level of ordinary skill in the pertinent

art; and (iv) consider objective evidence of non-obviousness. Moreover, I have been informed and I understand that so-called objective indicia of non-obviousness (also known as “secondary considerations”) like the following are also to be considered when assessing obviousness: (1) commercial success; (2) long-felt but unresolved needs; (3) copying of the invention by others in the field; (4) initial expressions of disbelief by experts in the field; (5) failure of others to solve the problem that the inventor solved; and (6) unexpected results. I also understand that evidence of objective indicia of non-obviousness must be commensurate in scope with the claimed subject matter. I am not aware of any objective indicia of non-obviousness relevant to the claims of the ’374 patent.

29. Put another way, my understanding is that not all innovations are patentable. Even if a claimed product or method is not disclosed in its entirety in a single prior art reference, the patent claim is invalid if the invention would have been obvious to a person of ordinary skill in the art at the time of the invention. In particular, I understand that a patent claim is normally invalid if it would have been

a matter of "ordinary innovation" within the relevant field to create the claimed product at the time of the invention.

30. In determining whether the subject matter as a whole would have been obvious at the time that the invention was made to a person having ordinary skill in the art, I have been informed of several principles regarding the combination of elements of the prior art:

a. First, a combination of familiar elements according to known methods is likely to be obvious when it yields predictable results.

b. Second, if a person of ordinary skill in the art can implement a "predictable variation" in a prior art device, and would see the benefit from doing so, such a variation would be obvious. In particular, when there is pressure to solve a problem and there are a finite number of identifiable, predictable solutions, it would be reasonable for a person of ordinary skill to pursue those options that fall within his or her technical grasp. If such a process leads to the claimed invention,

> then the latter is not an innovation, but more the result of ordinary skill and common sense.

31. I understand that the “teaching, suggestion, or motivation” test is a useful guide in establishing a rationale for combining elements of the prior art. This test poses the question as to whether there is an explicit teaching, suggestion, or motivation in the prior art to combine prior art elements in a way that realizes the claimed invention. Though useful to the obviousness inquiry, I understand that this test should not be treated as a rigid rule. It is not necessary to seek out precise teachings; it is permissible to consider the inferences and creative steps that a person of ordinary skill in the art (who is considered to have an ordinary level of creativity and is not an “automaton”) would employ.

## IV. THE ’374 PATENT

32. The ’374 patent was filed as the national stage entry of PCT/DE2009/000819 on June 12, 2009 and issued November 5, 2013.

33. The ’374 patent discloses a hydrodynamic torque converter having good vibration damping while taking up little assembly space. More particularly, the ’374 patent describes disposing multiple damper

stages in series between a lock-up clutch and an output hub, with a torsional vibration damper between them. (Ex. 1001, 1:63–2:5.)

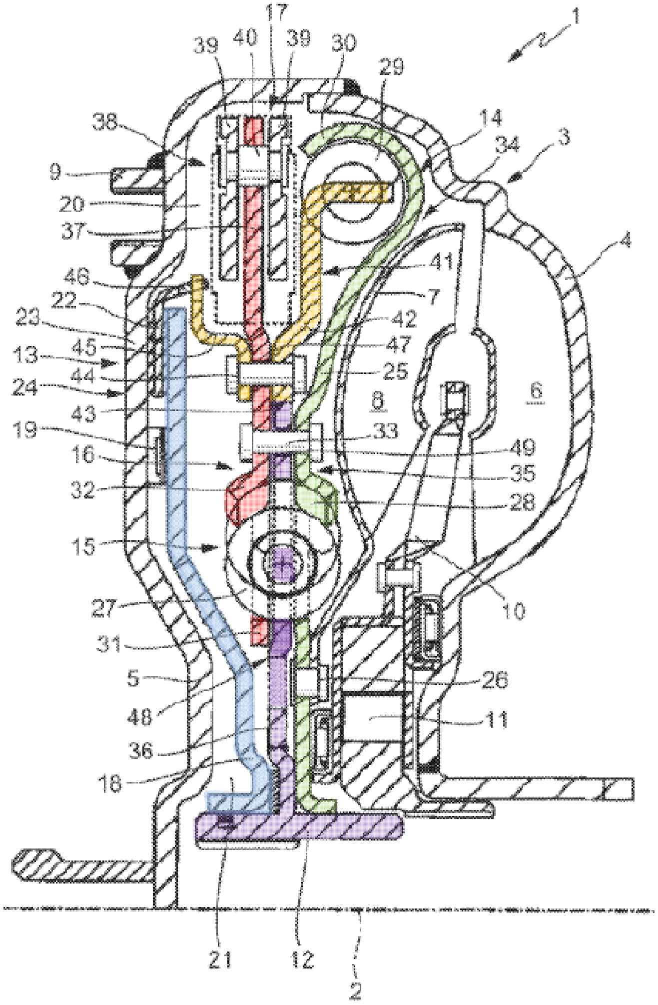
34. By integrating "both damper stages in a single damper that concurrently features a torsional vibration absorber assigned to both damper stages," the '374 patent explains that multiple components can be shared, providing a lighter and narrower torque converter. (Ex. 1001, 2:5–18.)

35. The '374 patent acknowledges that combining (i) torsional vibration dampers positioned between the lock-up clutch and the output hub and (ii) turbine dampers positioned between the turbine and the output hub to damp the torsional vibrations of an internal combustion engine was known prior to the filing date. (Ex. 1001, 1:23–42.)

36. The '374 patent also acknowledges that it was known to use vibration absorbers such as centrifugal force pendulums to reduce torsional vibrations. (Ex. 1001, 1:43–50.)

37. But the '374 patent alleges that, due to restrictive assembly space specifications in motor vehicles, a torque converter that took up less assembly space while still providing sufficient vibration damping was needed. (Ex. 1001, 1:51–59.)

38. The only Fig. in the ’374 patent, reproduced below with colored annotations, depicts a hydrodynamic torque converter 1 having a housing 3, an impeller 6, and a turbine 7 inside the housing 3. (Ex. 1001, 3:56–4:8.)



**’374 Patent Fig.**

39. Additionally, Fig. 1 shows a lock-up clutch 13 (including piston 18 in blue) mounted on the housing 3.

40. When the lock-up clutch is closed, it transmits torque from an internal combustion engine to the output hub 12 (purple) via first and second damper stages 14, 15, as follows: The input 41 (yellow) to the first damper stage receives torque from the lock-up clutch. The *output* of the first damper stage is a disk part 25 (green) that also forms a portion of the *input* of the second damper stage. (Ex. 1001, 4:38–40.)

41. The input of the second damper stage is completed by disk part 31 (red), which also forms the mounting part for the torsional vibration absorber 17. (Ex. 1001, 5:3–5.)

42. The output (purple) of the second damper stage is part of the output hub (purple). When the lock-up clutch is open, torque flows via impeller 6 to the turbine 7 which is fastened to disk part 25 (green). Because disk part 25 is the input of the second damper stage, torque is transmitted through the second damper stage 15 to the output hub (purple). (Ex. 1001, 4:8–16.)

43. The two damper stages 14, 15 are connected by a single disk part 25 (green). (Ex. 1001, 4:38–40.) The disk part 25 forms the complete output part 34 of damper stage 14 and part of the input part

35 of damper stage 15, completed by a second disk part 31 (red). (Ex. 1001, 4:53–58.)

44. The two disk parts 25 (green) and 41 (yellow) are axially spaced relative to one another by rivets 33 and accommodate flange part 36 (purple), welded to the output hub 12. (Ex. 1001, 4:58–62.)

45. Disk part 31 (together with 32 and 37, red) forms the mounting part 37 of the torsional vibration absorber 17, shown in Fig. 1 as a centrifugal force pendulum 38. (Ex. 1001, 5:3–5.)

## V. Summary of Select Prior Art

46. All the components of the ’374 claims were known in the art, as detailed below. Moreover, these components were arranged in the prior art in the same space-saving fashion taught by the ’374 patent.

### 1. Haller

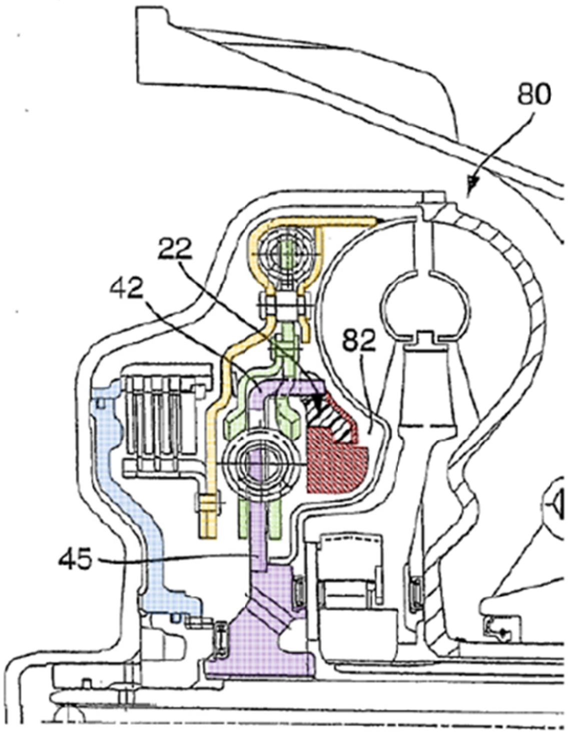
47. Like the ’374 patent, Haller (Ex. 1004) describes a hydrodynamic torque converter including a lock-up clutch and multiple damper stages disposed in series between the lock-up clutch and output hub with a torsional vibration absorber such as a spring-mass canceller installed in parallel. (Ex. 1004, 3:29–4:18.[1])

---

[1] All citations in my declaration are to the internal page numbers of the references.

48. Haller discloses a hydrodynamic torque converter including an impeller 34, a turbine 35 driven by the impeller connected with the torque converter, and a turbine torsional damper disposed between the turbine 35 and the driven side. A transfer element 42 connects the output side of a first turbine torsional damper 40 to the input side of a second turbine torsional damper 43. (Ex. 1004, 10:14–15.)

49. Fig. 8 (annotated below) shows these components;



**Haller Fig. 8 (excerpt)**

50. The spring-mass systems 22 of Haller can include centrifugal force pendulums.

51. Haller describes the spring-mass system 22 as "a translational oscillator that engages at the circumference of an element of the drive train, or as a rotational oscillator that introduces a torque into the drive train." (Ex. 1004, 8:19–20.) "The damper is any nonlinear or linear damper known per se…." (*Id.*, 4:19.) Moreover, Haller teaches that the cancellers act as rotational-speed-adaptive absorbers, characterizing its spring-mass system as possessing "a variable natural frequency" making utilization of the canceller effective "over a wider frequency band." (*Id.*, 5:17–19.) This language can describe rotational-speed-adaptive absorbers such as centrifugal force pendulums and their components.

52. Page 2:15–20 of Haller refer to several prior art documents that use a "canceller," *i.e.*, the same term that Haller uses to describe its spring-mass system 22, to attenuate torsional vibrations. (Ex. 1004, 2:15–20.) The "cancellers" in at least two of those documents (DE 199 14 871 A1,[2] Ex. 1009 and DE 196 04 160 C1,[3] Ex. 1010) are centrifugal

---

[2] There is no U.S. equivalent to this German patent, but the translation is included in the exhibit.

force pendulums of the same type disclosed in the preferred embodiments of the ’374 patent, as can be seen from the Figs. (Ex. 1001, 2:48–49; Ex. 1009; Ex. 1010.)

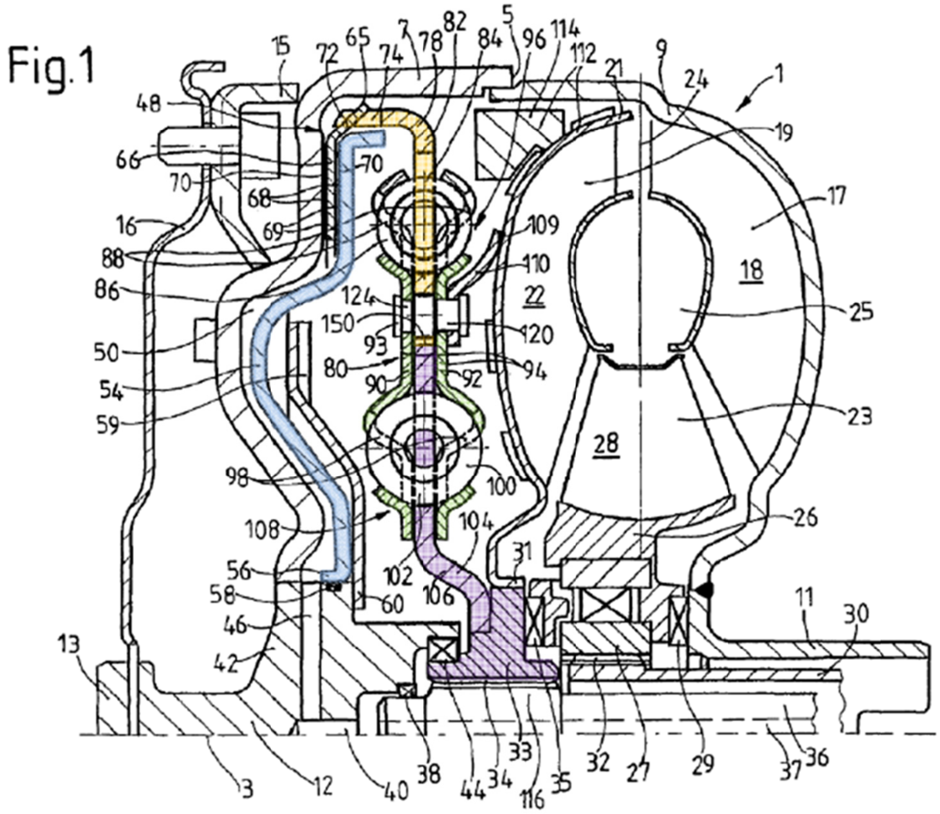
### 2. Sasse

53. Like the ’374 patent, Sasse (Ex. 1003) describes a hydrodynamic torque converter including a lock-up clutch and multiple damper stages in series between the lock-up clutch and output hub. (Ex. 1003, Figs. 1–2.)

54. Fig. 1 (annotated below), shows a clutch housing 5 permanently connected to a pump wheel shell 9, a pump wheel 17, a turbine wheel 19 (with turbine shell 21) that cooperates with the pump wheel 17, and a stator 23. (Ex. 1003, 7:21–50.)

---

[3] The translation is included, and the U.S. equivalent is U.S. Patent No. 5,884,735, Ex. 1011.



**Sasse Fig. 1**

55. Bridging/lock-up clutch 48 includes a movable piston 54 (blue) and a plate 65/friction liner carrier 66 with friction linings 68 on its opposite sides and teeth 72 at its outer circumference. (Ex. 1003, 8:14–46.) The teeth 72 engage with opposing teeth 74 on a drive-side transmission element 78 (yellow) of a torsional vibration damper 80, to allow axial motion but not relative rotation. (Ex. 1003, 8:46–48.)

56. Inward-projecting driver elements 84 (yellow) of the drive-side transmission element 80 (green) are brought into contact with first

energy-storage devices 86, which extend circumferentially and are supported between the driver element 84 (yellow) and radially outward-projecting driver element 88 of cover plates 90, 92. (Ex. 1003, 8:53–64.)

57. The cover plates 90, 92 (green) have radially inward-projecting driver elements 98 for second energy-storage devices 100, which extend circumferentially and are supported by radially outward-projecting driver elements 102 of a radially inner hub disk 104 (purple). (Ex. 1003, 9:4–10.)

58. The hub disk 104 serves as a take-off side transmission element 106 and is attached to the turbine wheel hub 33. (Ex. 1003, 9:10–12.)

59. The drive-side transmission element 78, the first energy-storage devices 86, and the intermediate transmission element 94 together form the drive-side connecting device 96 of the torsional vibration damper 80, whereas the intermediate transmission element 94, the second energy-storage devices 100, and the takeoff-side transmission element 106 together form a takeoff-side connecting device 108. (Ex. 1003, 9:13–20.)

60. The drive-side connecting device 96 acts as a standard damper, and the takeoff-side connection device 108 acts as a turbine damper. (Ex. 1003, 9:38–51.) The standard damper and turbine damper are connected in series. (Ex. 1003, 9:52–56.)

61. In Fig. 1, pin 93 at the actuation point 120 attaches a tie element 110 to the turbine wheel-side cover plate 92 of the turbine shell 21. (Ex. 1003, 9:23–25.) The opposite end of the tie element 110 is attached to the turbine wheel 19, which acts as a mass element 112 connected operatively to the intermediate transmission element 94 between the two connecting devices 96, 108. (Ex. 1003, 9:25–31.)

62. Also connected to the turbine shell 21 is a supplemental mass 114. (Ex. 1003, 9:31–37.) The embodiment in Fig. 2 is similar, except that tie element 110 is in the form of carrier 118, attaching supplemental mass 114 to plate 92, allowing supplemental mass 114 to shift circumferentially relative to the turbine wheel 19. (Ex. 1003, 9:57–67.)

63. Sasse includes numerous other embodiments with components in different orientations. Sasse states that substitutions between different embodiments may be made and that features of the

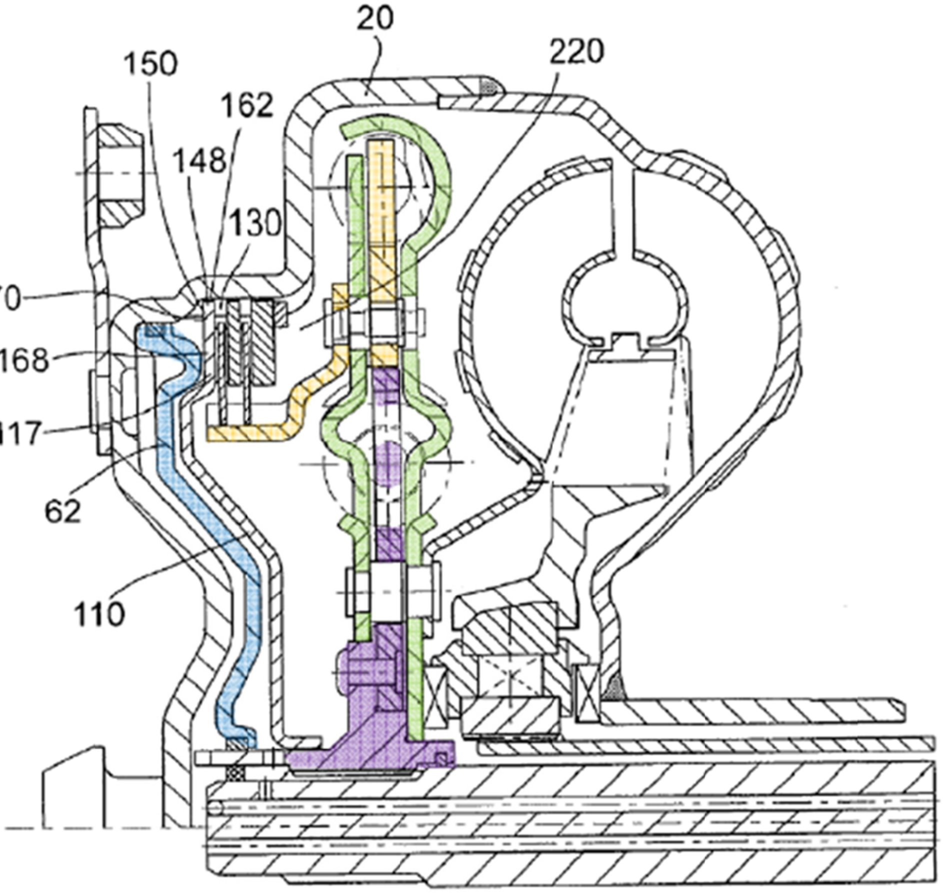
different embodiments may be incorporated into one another as a general matter of design choice. (Ex. 1003, 14:25–40.)

### 3. Heuler

64. Heuler (Ex. 1018) describes a hydrodynamic torque converter including a lock-up clutch and multiple damper stages in series between the lock-up clutch and output hub. (Ex. 1018, Fig. 11.)

65. The torque converter includes a pump, turbine, and stator. (*Id.*, [0044-45].) The lock-up clutch operates through the use of friction elements. (*Id.*, [0053].)

66. Fig. 11, annotated below, shows the piston of the lock-up clutch (blue), the input (yellow), transfer elements (green) and output of the second damper (purple):



**Heuler Fig. 11**

## VI. ANALYSIS

67. It is my opinion that claims 1-16 of the ’374 patent are obvious and/or anticipated over the prior art, as detailed below. At the request of counsel, I have divided the claims into elements denoted as [a], [b], [c], etc. to correspond to the discussion of the same elements in the petition for *inter partes* review, as follows:

**Claim 1:**

**[a]** A hydrodynamic torque converter (1)

**[b]** with a turbine (7) driven by an impeller (6) as well as housing (3)

**[c]** in which a torsional vibration damper (16) with multiple of damper stages (14, 15),

**[d]** a torsional vibration absorber (17) and

**[e]** a lock-up clutch (13) are additionally installed,

**[f]** wherein a first damper stage (14) and a second damper stage (15) are disposed between the lock-up clutch (13) and an output hub (12),

**[g]** the second damper stage (15) is disposed between the turbine (**7**) and the output hub (12)

**[h]** and the torsional vibration absorber (17) is parallel to both damper stages (14, 15).

**Claim 2:**

The hydrodynamic torque converter (1) according to claim 1, wherein an input part (41) of the first damper stage (14) and an output part (48) of the second damper stage (15) are centered on one another.

**Claim 3:**

The hydrodynamic torque converter (1) according to claim 1, wherein a disk part (25) is allocated to two damper stages (14, 15) as one piece.

**Claim 4:**

**[a]** The hydrodynamic torque converter (1) according to claim 1, wherein the torsional vibration absorber (17) comprises a plurality of absorber masses (39), and

**[b]** a mounting part (37) of the torsional vibration absorber (17) forms a disk part (31) of an input part (35) of the second damper stage (15).

**Claim 5:**

The hydrodynamic torque converter (1) according to claim 1, wherein absorber masses (39) of the torsional vibration absorber (17) and energy accumulators (29) of the first damper stage (14) disposed over the circumference are radially at the same height but axially spaced apart.

**Claim 6:**

The hydrodynamic torque converter (1) according to claim 5, wherein a middle mounting diameter of the energy accumulators (29) is disposed radially outside the turbine (7).

**Claim 7:**

The hydrodynamic torque converter (1) according to claim 5, wherein the energy accumulators (29) overlap the turbine (7) at least partially and axially.

**Claim 8:**

The hydrodynamic torque converter (1) according to claim 1, wherein energy accumulators (27) are distributed over the circumference of the second damper stage (15) based on a middle mounting diameter radially within turbine blades (8) of the turbine (7).

**Claim 9:**

The hydrodynamic torque converter (1) according to claim 8, wherein the energy accumulators (27) of the second damper stage (15) and the turbine (7) at least partially and axially overlap.

**Claim 10:**

The hydrodynamic torque converter (1) according to claim 1, wherein the lock-up clutch (13) in a closed state is axially mounted in a pocket (24) formed in a housing wall (23) radially inward of fastening means (9) provided on external part of the torque converter (1).

**Claim 11:**

**[a]** The hydrodynamic torque converter (1) according to claim 10, wherein the lock-up clutch (13) is formed out of a piston (18) centered on the output hub (12) and

**[b]** mounted non-rotatably and axially displacably on the housing (3), and axially pressurizes a friction plate (22) that can be clamped between said piston and said housing (3) to develop a frictional engagement.

**Claim 12:**

The hydrodynamic torque converter (1) according to claim 11, wherein a mounting part (37) of the torsional vibration absorber (17) is disposed axially between lock-up clutch (13) and the first damper stage (14).

**Claim 13:**

The hydrodynamic torque converter (1) according to claim 12, wherein between the friction plate (22) and an input part (41) of the first damper stage (14) transition connections (44) are formed, which reach through circular segment-shaped openings (47) of the mounting part (37).

**Claim 14:**

The hydrodynamic torque converter according to claim 1, wherein in the closed state of the lock-up clutch (13) the torsional vibration absorber (17) acts between both damper stages (14, 15).

**Claim 15:**

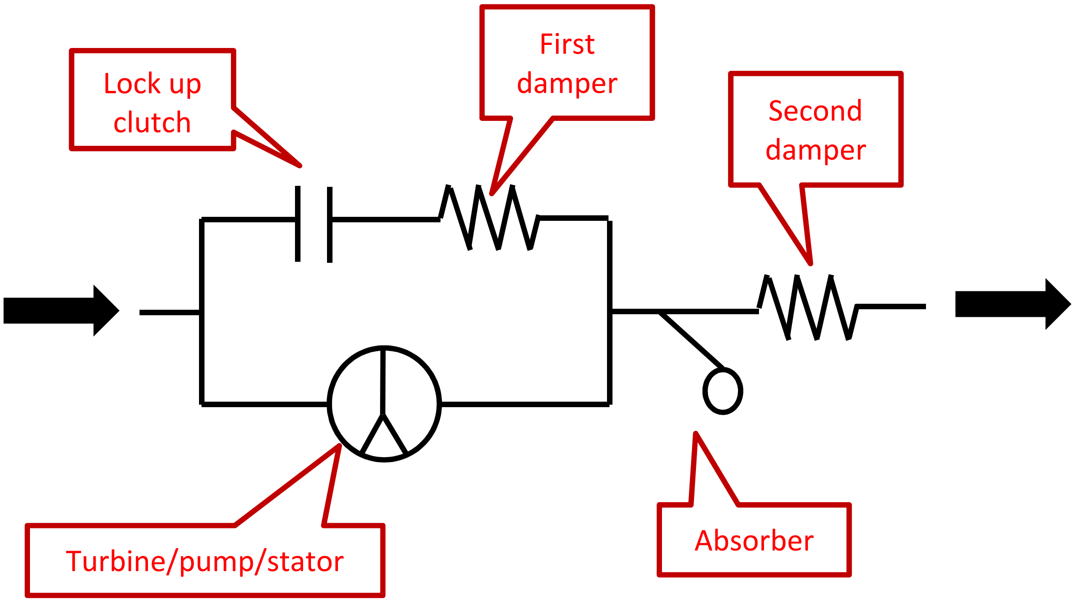
The hydrodynamic torque converter according to claim 1, wherein the torsional vibration absorber (17) is connected non-rotatably with the turbine (7).

**Claim 16:**

The hydrodynamic torque converter according to claim 15, wherein in the opened state of the lock-up clutch (13) the torsional vibration absorber (17) is connected non-rotatably with the turbine (7).

## A. Ground 1: Claims 1 and 3 Are Anticipated By Haller

68. The '374 patent describes two torque paths: (1) when the lock-up clutch is closed, torque is introduced mechanically through the lock-up clutch and transmitted via first 14 and second 15 damper stages into the output hub 12; and (2) when the lock-up clutch is open, torque flows from the turbine to the second damper stage 15 into the output hub 12. (Ex. 1001, 4:8–14.) This can be depicted as:



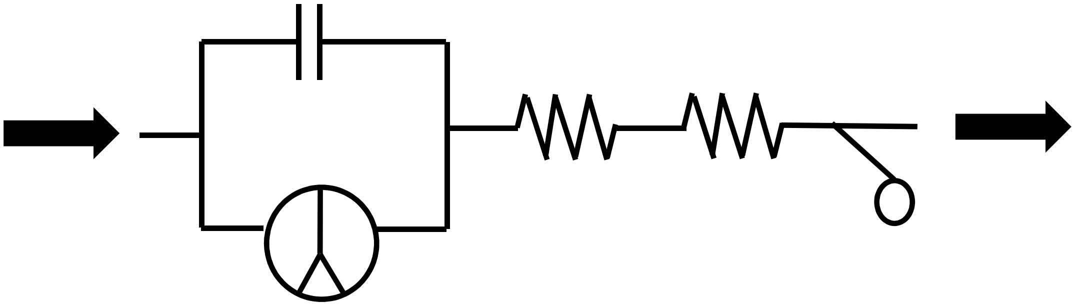
69. The same representations for lock-up clutch, turbine/pump/stator, dampers, and torsional vibration absorbers will be used throughout my declaration without labels.

70. In other words, throughout the ’374 patent and as shown in Fig. 1, the turbine is upstream from only the second damper. But, under the BRI (Broadest Reasonable Interpretation), because claim 1 only specifies “the second damper stage (15) is disposed between the turbine (7) and the output hub (12)” it may encompass situations where ***both*** damper stages are between the turbine and the output hub.

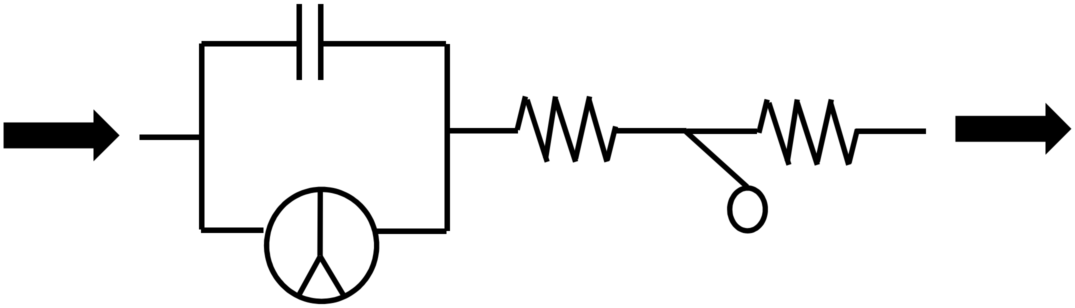
71. If claim 1 is interpreted to encompass torque converters having more than one damper stage arranged between the turbine and the output hub when the lock-up clutch is open, it is anticipated by Haller.

72. Haller Fig. 8 describes a torque converter with a turbine driven by an impeller including a torsional vibration absorber and a multi-stage torsional vibration damper disposed between a lock-up clutch and the output. (*See generally* Ex. 1004, Fig. 8.)

73. Haller describes two variations with respect to Figure 8. In the first, the mount for the absorber 22 passes through windows in the input of the second damper stage and is connected directly to support ring 45 that forms the output of the second damper stage as shown below (Ex. 1004, 12:5–6):



74. In the second variation, both damper stages are disposed between the turbine and the output hub and the absorber 22 is connected nonrotatably to transfer element 42 (corresponding to the output for the first damper stage and the input for the second damper stage), as depicted below. (Ex. 1004, (Ex. 1004, 12:5–6, Fig. 8.)



75. Haller notes that this arrangement of the absorber "between the first torsional damper stage and the second torsional damper stage … results in particularly good dynamic transfer behavior." (*Id.*, 4:4–6.)

76. In addition, Haller discloses a spring-mass system 22 that forms a torsional vibration absorber. This absorber can be connected in parallel to both dampers. (Ex. 1004, 8:24–26 and 11:22–24.)

**Claim 1[a]: A hydrodynamic torque converter (1):**

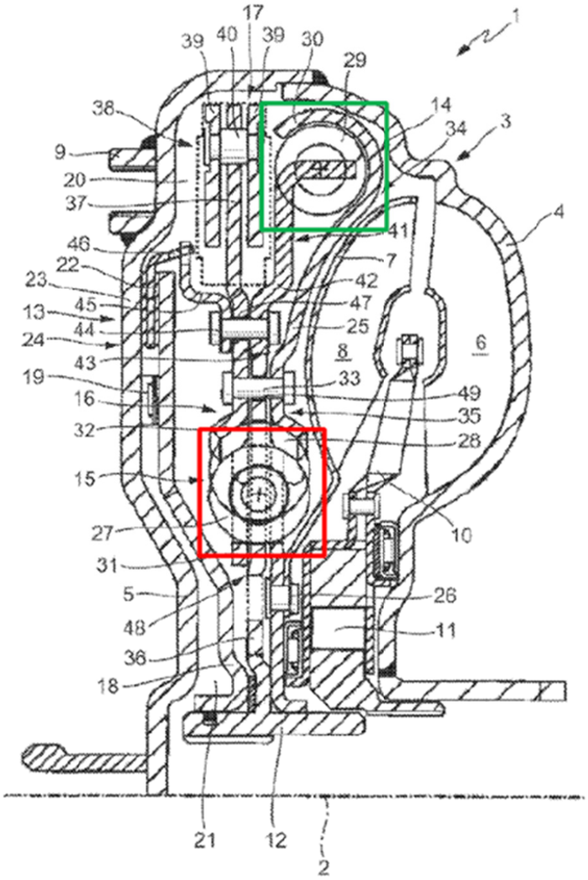
77. Haller discloses hydrodynamic torque converters. (*See, e.g.*, Ex. 1004, 3:19–20.) Thus, it is my opinion that Haller teaches claim element 1[a].

**Claim 1[b]: with a turbine (7) driven by an impeller (6) as well as housing (3)**

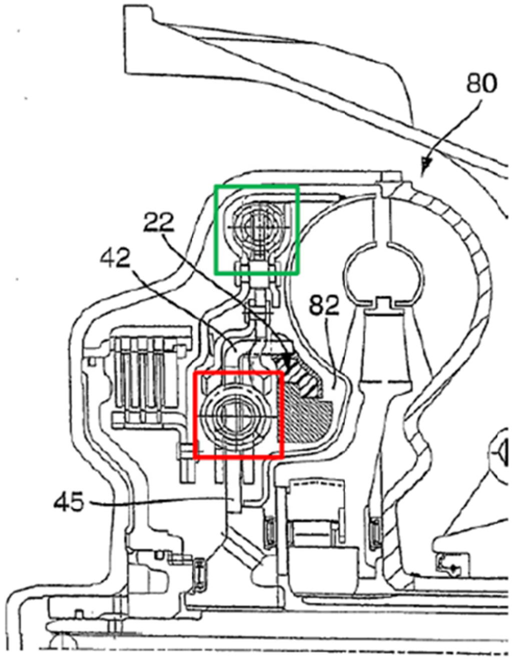
78. The hydrodynamic torque converters in Haller include a turbine driven by an impeller in a housing. (*See, e.g.*, Ex. 1004, 10:1–2.) Thus, it is my opinion that Haller teaches claim element 1[b].

**Claim 1[c]: in which a torsional vibration damper (16) with multiple of damper stages (14, 15)**

79. As acknowledged by the ’374 patent, torsional vibration dampers with multiple damper stages were well-known before the ’374 patent was filed. (Ex. 1001, 1:32–42.) The first damper stage 14 (green) and second damper stage 15 (red) of the ’374 patent in Fig. 1 below are energy accumulators such as coil springs (*id.*, 4:45–46), along with the first (green) and second (red) damper stages of Haller Fig. 8:



**’374 Patent**



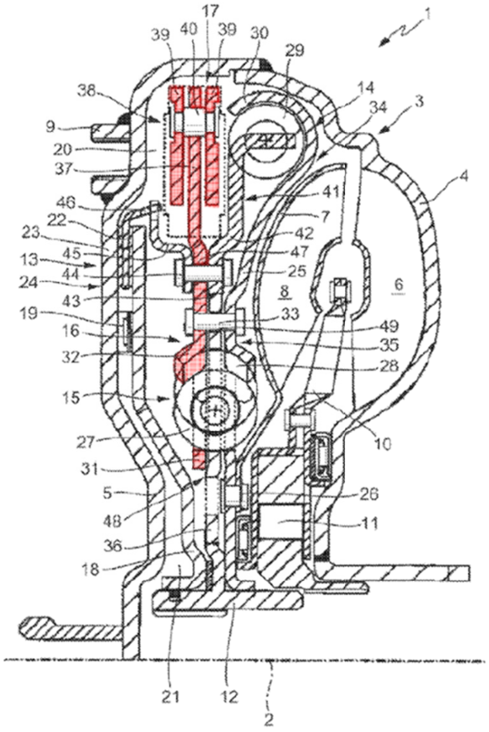
**Haller Fig. 8**

80. Haller’s two damper stages in Fig. 8 correspond with the first 14 and second 15 damper stages of the ’374 patent. Thus, it is my opinion that Haller teaches element 1[c].

**Claim 1[d]: a torsional vibration absorber (17)**

81. As acknowledged by the ’374 patent, torsional vibration absorbers were well-known when the ’374 patent was filed. (Ex. 1001, 1:43–50 (discussing absorbers in the background section).) The torsional

vibration absorber in the ’374 patent Fig. is a centrifugal pendulum absorber (*id.*, 2:48–49), shown in red:



**’374 Patent Fig.**

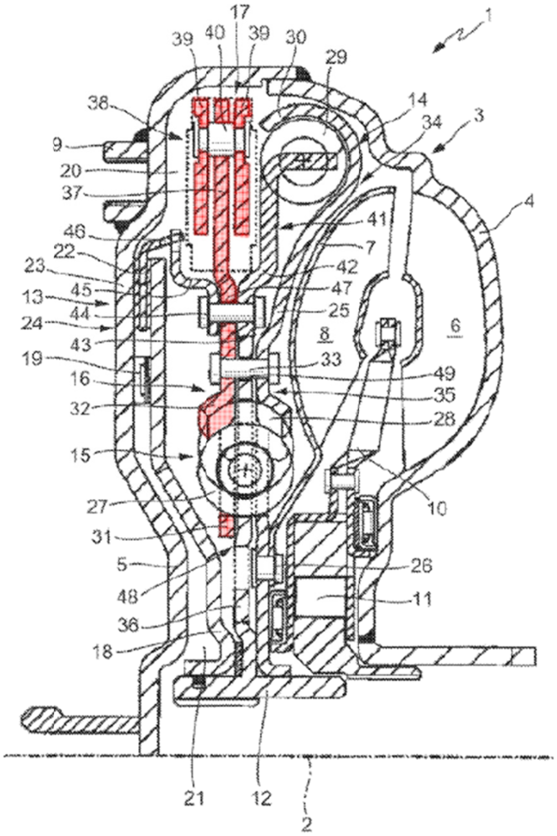
82. Haller teaches torsional vibration absorbers akin to those of the ’374 patent. The embodiments discussed in detail in Haller use frequency-tuned spring-mass devices, a type of torsional vibration absorber.

83. Moreover, Haller also discloses other types of torsional vibration absorbers, including centrifugal force pendulums, by characterizing its spring-mass system as possessing “a variable natural

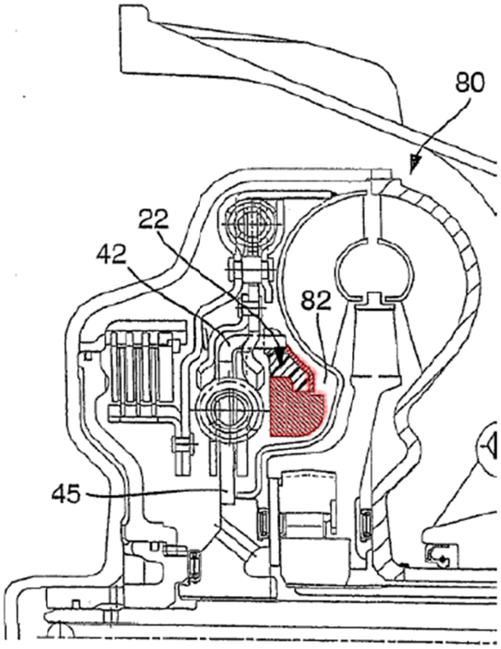
frequency" making utilization of the canceller effective "over a wider frequency band." (Ex. 1004, 5:17–19.) This language is indicative of rotational-speed-adaptive absorbers such as centrifugal force pendulums and their components.

84. And, Haller refers to several prior art documents teaching centrifugal force pendulums as using a "canceller," *i.e.*, the same term that Haller uses to describe its spring-mass system 22, to attenuate resonance phenomena. (Ex. 1004, 2:15–20; *see* above.) As noted above, the "cancellers" in at least two of those documents (DE 199 14 871 A1, Ex. 1009 and DE 196 04 160 C1, Ex. 1010) are centrifugal force pendulums of the same type disclosed in the preferred embodiments of the '374 patent. Thus, in my opinion centrifugal force pendulums are encompassed in Haller's disclosure.

85. Haller's spring-mass system in Fig. 8 is shown in red compared with the torsional vibration absorber of the '374 patent:



**’374 Patent Fig.**



**Haller Fig. 8**

86. Thus, it is my opinion that Haller teaches claim element 1[d].

**Claim 1[e]: and a lock-up clutch (13) are additionally installed**

87. The torque converter in Haller includes a lock-up clutch, which is visible in Fig. 8 and labeled with reference numeral 46 elsewhere. (Ex. 1004, 10:25 (“Hydrodynamic torque converter 30 furthermore possesses a converter lockup clutch 46.”).) Thus, it is my opinion that Haller teaches element 1[e].

**Claim 1[f]: wherein a first damper stage (14) and a second damper stage (15) are disposed between the lock-up clutch (14) and an output hub (12),**

88. The ’374 patent describes two torque paths: (1) when the lock-up clutch is closed, torque travels through the lock-up clutch and via first 14 and second 15 damper stages into the output hub 12; and (2) when the lock-up clutch is open, torque flows from the turbine to the second damper stage 15 into the output hub 12. (Ex. 1001, 4:8–14.) Claim 1(f) describes the first torque path, *i.e.*, where torque passes through both damper stages when transferred from the lock-up clutch 14 to the output hub 12.

89. As shown above, Haller embodies torque paths similar to those described in the ’374 patent. In Fig. 8, the first and second dampers are connected in series between the lock-up clutch and the output so that when the lock-up clutch is closed, torque is transferred from the lock-up clutch, serially through both damper stages, and then to the output hub. Thus, it is my opinion that Haller teaches claim element 1[f].

**Claim 1[g]: the second damper stage (15) is disposed between the turbine (7) and the output hub (12) and**

90. As noted above, the ’374 patent describes two torque paths. Claim 1(g) describes the second torque path, *i.e.*, where torque passes through the second damper stage 15 when transferred from the turbine 7 to the output hub 12.

91. But, under the BRI, because claim 1 only specifies “the second damper stage (15) is disposed between the turbine (7) and the output hub (12)” it does not exclude situations where ***additional*** damper stages are between the turbine and the output hub.

92. Haller Fig. 8 describes such an arrangement, where *both* the first and second dampers stages are disposed between the turbine and the output hub. Both the lock-up clutch and the turbine provide input to the first damper stage, so both damper stages remain disposed between the turbine and the output hub when the lock-up clutch is open. Thus, it is my opinion that Haller teaches element 1[g].

**Claim 1[h]: the torsional vibration absorber (17) is parallel to both damper stages (14, 15).**

93. Haller describes two variations, each of which places the torsional vibration damper parallel to both damper stages. In the first variation, the mount for the absorber 22 passes through windows in the

input of the second damper stage and is connected directly to support ring 45 that forms the output of the second damper stage. (Ex. 1004, 12:5–6.) Thus, the absorber 22 is connected to the same torque flow path as the first and second damper stages, but it does not itself transfer the engine's torque along the torque flow path. Accordingly, the absorber 22 is parallel to both damper stages.

94. In the second variation, Haller states that the absorber 22 "is connected nonrotatably to transfer element 42." (Ex. 1004, 12:5–6.) The transfer element 42 corresponds to the disk 25 of the '374 patent because it forms the output for the first damper stage and the input for the second damper stage: "power flows from … springs 41, transfer element 42, springs 44 … in the aforementioned sequence." (Ex. 1004, 11:7–10.) Haller notes that this arrangement of the absorber "between the first torsional damper stage and the second torsional damper stage … results in particularly good dynamic transfer behavior." (*Id.*, 4:4–6.)

95. When Haller's absorber "is connected nonrotatably to transfer element 42," the absorber is parallel both damper stages. This is precisely the configuration of the '374 patent, with the absorber connected via rivet 33 to the disk part 25 between the damper stages.

(Ex. 1001, 5:12–16.) The disk part 25 and transfer element 42 are highlighted in green below. Accordingly, the second variation of the torque converter—described in the text of Haller—has an absorber that is parallel to both damper stages.

96. The overall disclosure of Haller also touts the advantages of connecting the spring-mass cancellers in parallel to both dampers:

> A vibration-capable spring-mass system is not connected in series with the drive train, but ***instead is located in a parallel configuration*** with respect to it. This has the advantage that the elasticity of the drive train is not modified by the action according to the present invention, so that direct influence on the agility of the vehicle is precluded.

(Ex. 1004, 3:1–5 (emphasis added), *see also* 8:24–26 and 11:22–24; Fig. 5.) In other words, installing the absorber in parallel means the absorber does not affect the torque path, and because the drive line is mainly characterized by its elasticity, the installation of the absorber does not affect this elasticity.

97. In fact, in Degler (Ex. 1006), Schaeffler admitted that Haller teaches a torsional vibration absorber parallel to the drivetrain, which includes both damper stages, and that this arrangement is beneficial:

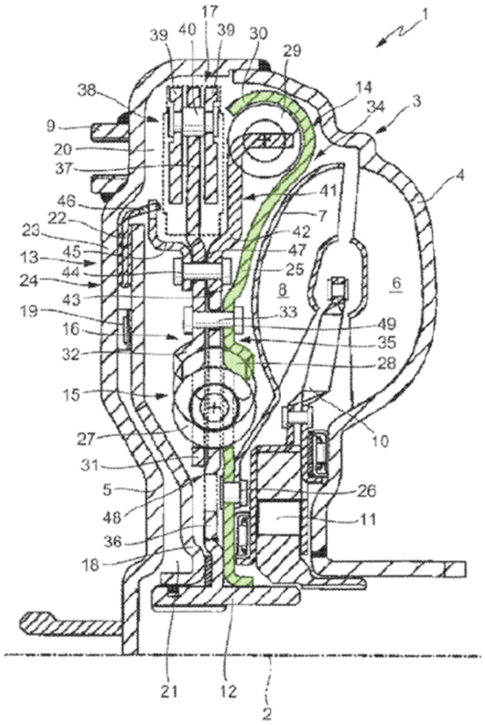
> Such an arrangement is already known, for example, from the publication DE 10236753 A1 [Haller's priority document]. Therein the drive machine is connected via at least one starting element, especially a clutch or a hydrodynamic rotational-speed/torque converter, with one or more gear-mechanism parts. This means that a spring-and-mass system capable of vibrations is not connected in series with the drivetrain but instead is disposed ***in parallel connection*** relative thereto, whereby the elasticity of the drivetrain is not impaired.

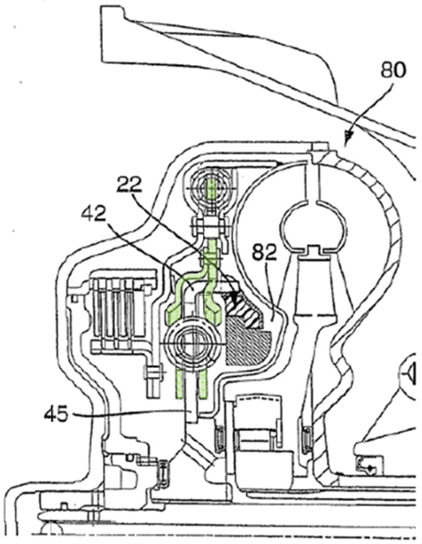
(Ex. 1006, 1 (emphasis added); *see also* Ex. 1019, 1:39–47 (similar recitation).)

98. Thus, it is my opinion that Haller teaches claim element 1[h].

**Claim 3: The hydrodynamic torque converter (1) according to claim 1, wherein a disk part (25) is allocated to two damper stages (14, 15) as one piece.**

99. Claim 3 requires that a single disk part is shared between the first and second damper stages. As shown in the '374 Fig. 1, disk part 25 (green) is a single component shared between both damper stages, and the same relationship is shown in Haller Fig. 8:





**’374 Patent** **Haller Fig. 8**

100. In Haller, Fig. 8, plates (green) form the output of the first damper stage and the input of the second damper stage. (Ex. 1004, 10:13-14.) Thus, it is my opinion that Haller teaches claim 3.

### B. Ground 2: Claim 4 is Obvious Over Haller and Eckel

101. Haller teaches a torque converter with a torsional vibration absorber, but does not expressly teach that the torsional vibration absorbers in the Figs. have multiple masses. (*See generally* Ex. 1004.)

102. In other words, Haller refers to centrifugal force pendulums as examples of cancellers but does not expressly describe the spring-mass system 22 as a centrifugal force pendulum with multiple masses.

(Ex. 1004, 2:15–20.) But, Haller specifically refers to DE 196 04 160 as a prior art canceller, and the U.S. equivalent, Eckel, teaches centrifugal force pendulums with multiple masses. (Ex. 1011, Fig. 1.)

103. It would have been obvious to a PHOSITA to apply Eckel's centrifugal force pendulum to a torque converter with multi-stage damper as in Haller Fig. 8 because the benefits of Eckel's centrifugal force pendulum could be predictably applied to any rotating machine with order excitation, such as a torque converter. In particular, incorporating Eckel's centrifugal force pendulum into a torque converter would yield the predictable result of reducing rotational vibrations. Indeed, Haller specifically suggests using Eckel as a canceller. (Ex. 1004, 2:17.) In other words, a PHOSITA would have a reasonable expectation of success in making that modification because it merely involves using Eckel's pendulum absorber for its intended purpose.

104. In view of the detailed discussion below and in light of the specification of the '374 patent, it is clear that the claims of the '374 patent simply recite prior art elements that function predictably in their known manner.

**Claim 4[a]: The hydrodynamic torque converter (1) according to claim 1, wherein the torsional vibration absorber (17) comprises a plurality of absorber masses (39), and**

105. Haller and Eckel disclose torsional vibration absorbers. Eckel's centrifugal force pendulum includes a plurality of absorber masses in the drawings. (Ex. 1011, Fig. 1.) Thus, it is my opinion that the combination of Haller and Eckel renders obvious element 4[a].

**Claim 4[b]: a mounting part (37) of the torsional vibration absorber (17) forms a disk part (31) of an input part (35) of the second damper stage (15).**

106. Claim 4[b] specifies that the mounting part of the torsional vibration absorber forms an input part of the second damper stage. Haller notes that the vibration absorber 22 can be "connected nonrotatably to transfer element 42," and that the transfer element forms the input of the second damper stage (Ex. 1004, 4:4–5, 10:13–14, 12:5–6.) In all embodiments, Haller's transfer element includes a disk part of that forms the input of the second damper stage. (*Id.* Figs. 6–8.) Thus, it is my opinion that the combination of Haller and Eckel renders obvious element 4[b].

### C. Ground 3: Claims 1–3, 8–10, and 14–16 Are Obvious Over Sasse and Haller

107. Sasse Fig. 1 describes a hydrodynamic torque converter with a turbine driven by an impeller including a multi-stage torsional vibration damper disposed between a lock-up clutch and the output. (*See generally* Ex. 1003, Fig. 1.)

108. Sasse teaches using mass elements to absorb additional vibrations, which are torsional vibration absorbers under the BRI. Haller also teaches a torque converter with a different type of torsional vibration absorber. (*See generally* Ex. 1004.)

109. Even if Sasse's mass element is not considered to be a torsional vibration absorber, it would have been obvious to a PHOSITA to apply Haller's torsional vibration absorber to a torque converter with multi-stage damper as in Sasse Fig. 1 because the benefits of Haller's torsional vibration absorbers could be predictably applied to any rotating machine with order excitation, such as a torque converter, with a reasonable expectation of success. In particular, incorporating Haller's torsional vibration absorber into a torque converter would yield the predictable result of reducing rotational vibrations (the same effects achieved by Sasse's mass element).

110. In fact, Haller states that incorporating a torsional vibration absorber between a first and second damper stage—the configuration recited in the claims of the ’374 patent—“results in particularly good dynamic transfer behavior.” (Ex. 1004, 4:4–6.)

111. As additional proof from background prior art, Speckhart notes the suitability of centrifugal pendulum vibration absorbers, a type of torsional vibration absorber, for torque converters:

> [T]here is shown in FIG. 1 a system, generally indicated 22, for absorbing vibrations in a rotatable shaft 24 associated with an internal combustion engine 20. …. ***The rotatable shaft 24 may take the form of an engine crankshaft, a flywheel, a clutch, a torque converter, or some other part which is rotatably driven by the crankshaft***. Furthermore, the system 22 may be incorporated within the shaft 24 or mounted upon the shaft 24 ….

(Ex. 1012, 3:14–19, emphasis added.)

112. Accordingly, it also would have been obvious to a PHOSITA to apply Haller’s torsional vibration absorber to a torque converter with Sasse Fig. 1’s torsional vibration damper with multiple damper stages because Haller’s torsional vibration absorber is designed to absorb rotatable shaft vibrations created by an internal combustion engine and

Haller teaches that vibration absorbers can be advantageously applied to a torque converter.

113. In view of the detailed discussion below and in light of the specification of the ’374 patent, it is clear that the claims of the ’374 patent simply recite prior art elements that function predictably in their known manner.

**Claim 1[a]: A hydrodynamic torque converter (1):**

114. Both Sasse and Haller disclose hydrodynamic torque converters. (*See, e.g.*, Ex. 1003, 3:17–29; Ex. 1004, 3:19–20.) Thus, it is my opinion that the combination of Sasse and Haller renders obvious claim element 1[a].

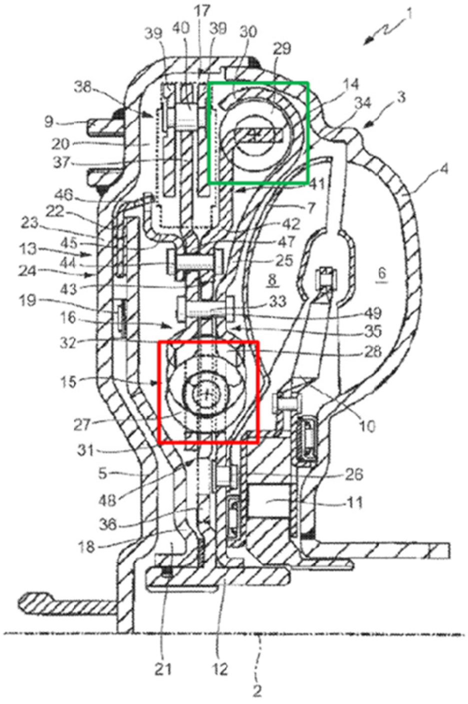
**Claim 1[b]: with a turbine (7) driven by an impeller (6) as well as housing (3)**

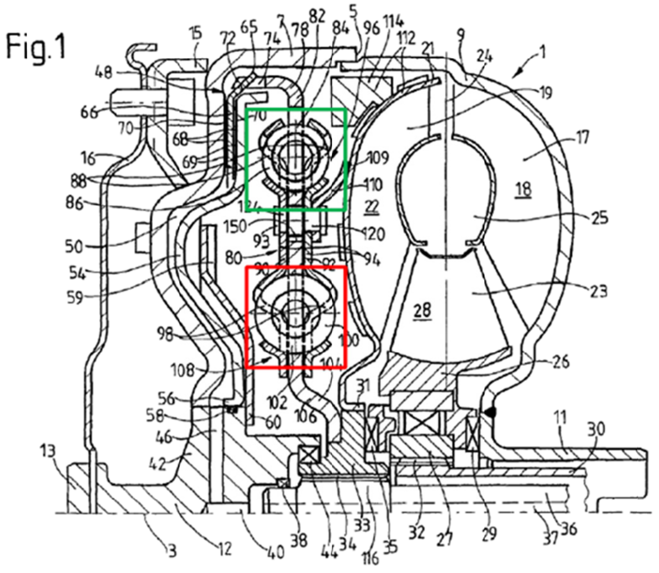
115. The torque converters in both Sasse and Haller include a turbine driven by an impeller in a housing. (*See, e.g.*, Ex. 1003, 7:21–28 and 43–50; Ex. 1004, 10:1–2.) Thus, it is my opinion that the combination of Sasse and Haller renders obvious claim element 1[b].

**Claim 1[c]: in which a torsional vibration damper (16) with multiple of damper stages (14, 15)**

116. Sasse discloses several examples of torsional vibration dampers with multiple stages. Sasse’s two damper stages (first energy-

storage devices 86 (green) and second energy-storage devices 100 (red) in Fig. 1 correspond with the first 14 and second 15 damper stages of the ’374 patent:





**’374 Patent Fig.** **Sasse Fig. 1**

117. Thus, it is my opinion that the combination of Sasse and Haller renders obvious claim element 1[c].

**Claim 1[d]: a torsional vibration absorber (17)**

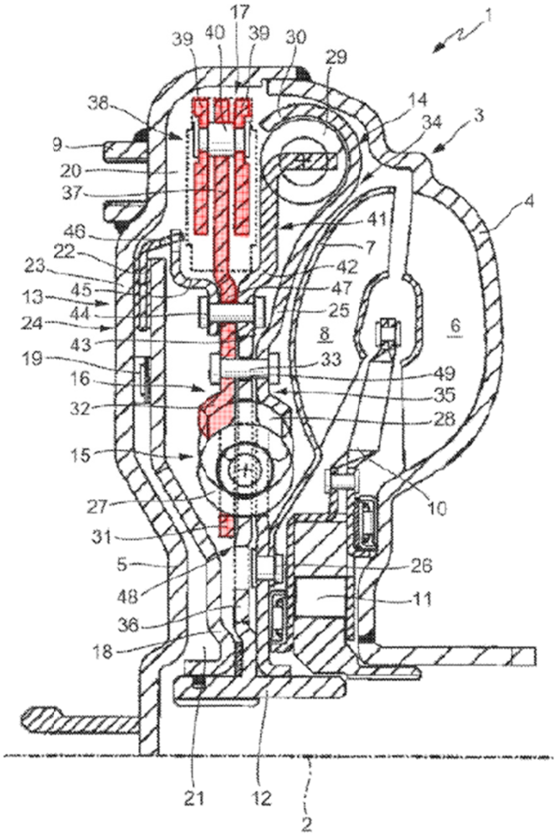
118. The discussion above provides details of the torsional vibration absorber in the ’374 patent.

119. Sasse Fig. 1 describes mass element 112 and supplemental mass 114 attached to the turbine wheel shell. (Ex. 1003, 9:27–34.)

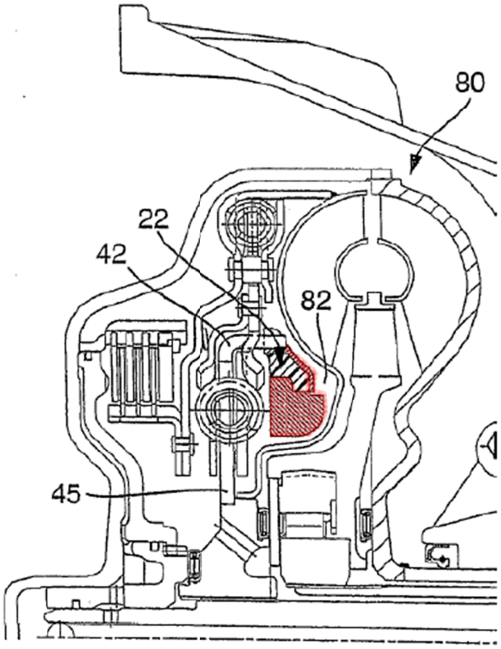
Similarly, the absorber in the ’374 patent Fig. is fixed to the turbine shell via elements 26 and 33. Because the supplemental mass in Sasse Fig. 1 dampens vibrations, it is an example of a torsional vibration absorber, *i.e.*, “a component or device designed to absorb torsional vibrations.” (*See* Ex. 1001, 1:43–45.)

120. Even if the supplemental mass in Sasse Fig. 1 is not considered a torsional vibration absorber, Haller teaches torsional vibration absorbers akin to those of the ’374 patent. Embodiments discussed in Haller use frequency-tuned spring-mass devices, a type of torsional vibration absorber. As discussed above, Haller also discloses other types of torsional vibration absorbers, including centrifugal force pendulums.

121. Haller’s spring-mass system 22 in Fig. 8 is shown in red compared with the torsional vibration absorber of the ’374 patent:



**’374 Patent**



**Haller Fig.8**

122. As discussed above, Haller also discloses other types of torsional vibration absorbers, including centrifugal force pendulums. As explained above, it would have been obvious to a PHOSITA to apply Haller’s torsional vibration absorber to a torque converter with the multi-stage damper in Sasse Fig. 1 because the benefits of Haller’s torsional vibration absorbers could be predictably applied to other torque converters.

123. In particular, incorporating Haller's torsional vibration absorber into Sasse's torque converter would yield the predictable result of reducing rotational vibrations. Thus, it is my opinion that the combination of Sasse and Haller renders obvious element 1[d].

### Claim 1[e]: and a lock-up clutch (13) are additionally installed

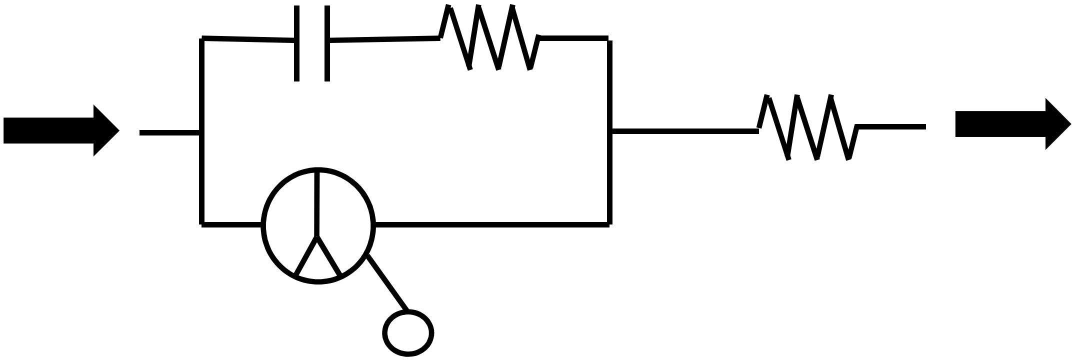
124. The torque converters in Sasse and Haller have lock-up clutches. (*See, e.g.*, Ex. 1003, 8:14–36 (describing the bridging clutch 48, *i.e.*, lock-up clutch); Ex. 1004, 10:25 ("Hydrodynamic torque converter 30 furthermore possesses a converter lockup clutch 46.").) Thus, it is my opinion that the combination of Sasse and Haller renders obvious element 1[e].

### Claim 1[f]: wherein a first damper stage (14) and a second damper stage (15) are disposed between the lock-up clutch (14) and an output hub (12),

125. Claim 1[f] describes a first torque path where torque passes through both damper stages when transferred from the lock-up clutch 14 to the output hub 12.

126. Sasse Fig. 1 embodies torque paths similar to those described in the '374 patent: the first energy-storage device 86 acts as a standard damper and the second energy-storage device 100 acts as a

turbine damper, as in the ’374 patent. (Ex. 1003, 9:13–56.) This is depicted below (with the absorber attached to the turbine):



127. The first and second energy-storage devices are connected to each other in series and are disposed between the lock-up clutch 48 and the output hub.

128. Sasse states “FIG. 1 thus shows a torsional vibration damper 80 in which a standard damper and a turbine damper form a single structural unit in which they are connected to each other in series...” (Ex. 1003, 9:52–56.) Thus, it is my opinion that the combination of Sasse and Haller renders obvious element 1[f].

**Claim 1[g]: the second damper stage (15) is disposed between the turbine (7) and the output hub (12) and**

129. Claim 1[g] describes a second torque path where torque passes through the second damper stage 15 when transferred from the turbine 7 to the output hub 12.

130. Sasse Fig. 1 describes torque paths similar to those described in the ’374 patent. In Fig. 1, tie element 110 is connected to the turbine 19. The takeoff-side connecting device 108, including second energy-storage devices 100, acts as a turbine damper. (Ex. 1003, 9:48-49.) Thus, it is my opinion that the combination of Sasse and Haller renders obvious element 1[g].

### Claim 1[h]: the torsional vibration absorber (17) is parallel to both damper stages (14, 15).

131. In Sasse Fig. 1, the supplemental mass 114 is parallel to both damper stages because it is connected directly to the turbine, and the turbine is connected directly to the intermediate transmission element that acts between both damper stages. (Ex. 1003, Fig. 1.) But, if the mass in Sasse is not considered to be a torsional vibration absorber, or if parallel is interpreted more narrowly as requiring direct connection of the absorber mounting flange between two damper stages, Haller explicitly teaches that torsional vibration absorbers such as

spring-mass cancellers can be connected in parallel to the transfer element between the dampers. (Ex. 1004, 12:5–6.)

132. It would have been obvious for a PHOSITA to modify Sasse Fig. 1 with Haller's torsional vibration absorbers connected in parallel in light of the benefits in elasticity taught in Haller (*see* paragraph 100 above) and the fact that Haller also explicitly teaches that the spring-mass cancellers can be connected in parallel to the drive train components. (Ex. 1004, 3:1–5, *see also* 8:24–26 and 11:22–24.) And, the observations in Haller regarding the benefits of parallel connection are applicable to any point of connection: to a PHOSITA, as long as it is connected to the same components, it will function the same if the masses are the same distance from the axis of rotation.

133. Furthermore, incorporating Haller's torsional vibration absorber into a torque converter would yield the predictable result of reducing rotational vibrations because Haller itself teaches that the cancellers can be arranged in either a series or parallel configuration, indicating that this is simply a matter of design choice for a PHOSITA. (Ex. 1004, 8:24–26.)

134. This is supported by Sasse Fig. 2, where the supplemental mass is attached to intermediate transmission element 94, parallel to both damper stages. (Ex. 1003, Fig. 2.) Repositioning the supplemental masses 114 of Fig.1 onto a carrier 118 as taught in Fig. 2 is a general matter of design choice specifically encouraged by Sasse. (Ex. 1003, 14:25–40.)

135. Thus, it is my opinion that the combination of Sasse and Haller renders obvious element 1[h].

**Claim 2: The hydrodynamic torque converter (1) according to claim 1, wherein an input part (41) of the first damper stage (14) and an output part (48) of the second damper stage (15) are centered on one another.**

136. Claim 2 requires that an input part 41 of the first damper stage and an output part 48 of the second damper stage are centered on one another, *i.e.*, a radially outer element mounted on a radially inner element as shown in the '374 Fig. 1, where input part 41 (yellow) is circumferentially mounted on output part 48 (purple). The same relationship is shown in Sasse Fig. 1:

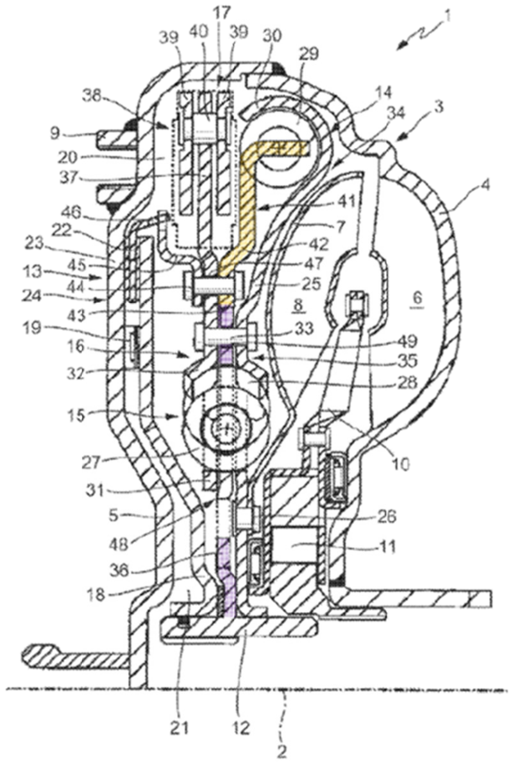
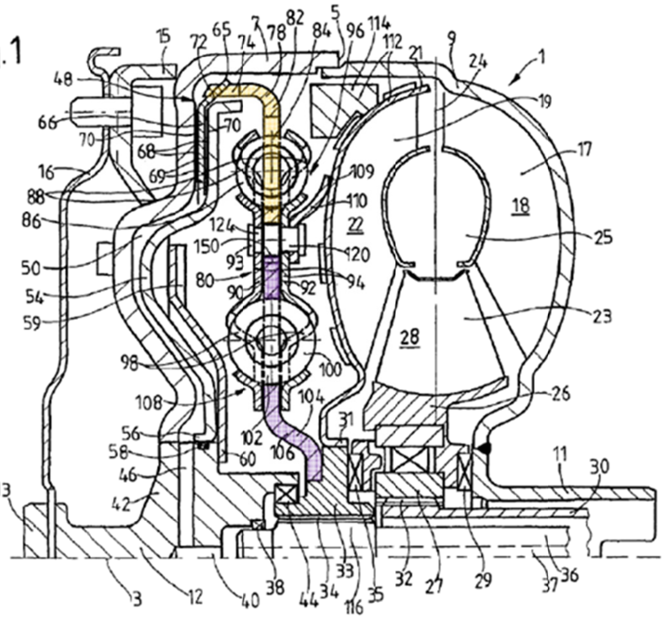


Fig.1



**’374 Patent Fig.** **Sasse Fig. 1**

137. In Sasse Fig. 1, the radially inward-projecting driver element 84 (yellow) forms an input to the first damper stage. (Ex. 1003, 8:43–58.) This input is centered on outwardly-projecting driver element 102/takeoff-side transmission element 106, which form an output of the second damper stage. (Ex. 1003, Fig. 1.)

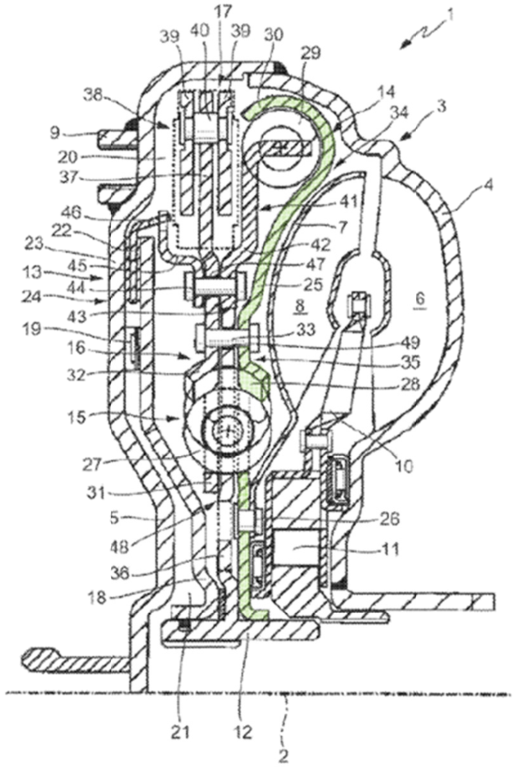
138. A PHOSITA would understand that Sasse’s element 84 is centered on element 102 because the input element 84 is not mounted to anything else, so it must be supported by output element 102 of the second damper stage. Additionally, the openings 150 are part of the

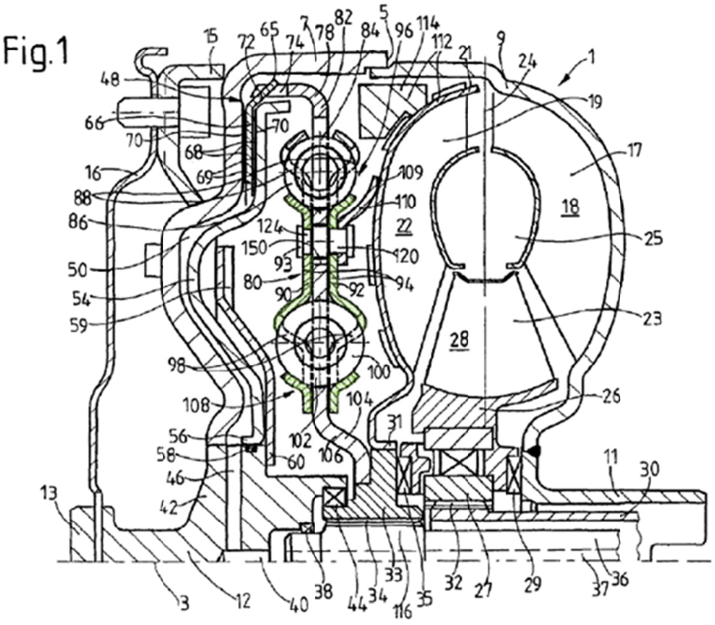
input element 84 of the first damper stage, which demonstrates that the input 84 extends below pin 93 in Sasse Fig. 1. (Ex. 1003, 8:64-67.)

139. As such, the input of the first damper stage is centered on the output of the second damper stage. Even if Sasse didn't teach that feature, a PHOSITA would recognize that centering the input 84 on output 102 would have been a convenient, and therefore obvious, way to mount the input in Sasse Fig. 1. Thus, it is my opinion that the combination of Sasse and Haller renders obvious claim 2.

**Claim 3: The hydrodynamic torque converter (1) according to claim 1, wherein a disk part (25) is allocated to two damper stages (14, 15) as one piece**

140. Claim 3 requires that a single disk part is shared between the first and second damper stages. As shown in the '374 patent, disk part 25 (green) is a single component shared between both damper stages. The same relationship is shown in Sasse Fig. 1:





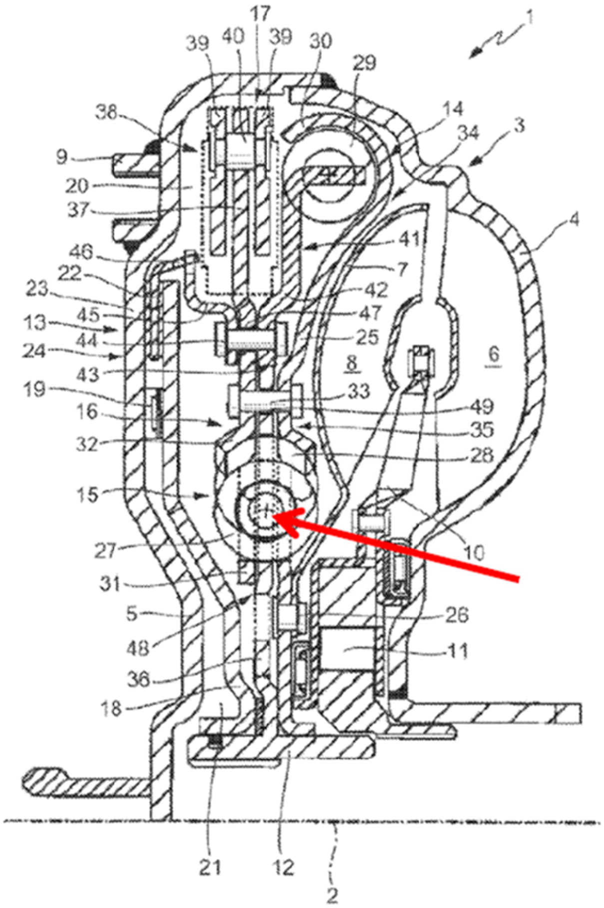
**’374 Patent** **Sasse Fig. 1**

141. In Sasse Fig. 1, cover plates 90 and 92 of the intermediate transmission element are allocated to both damper stages 86 and 100. (Ex. 1003, 8:61–64.) As such, either cover plate constitutes a single disk part that is shared between the two damper stages. Thus, it is my opinion that the combination of Sasse and Haller renders obvious claim 3.

> **Claim 8: The hydrodynamic torque converter (1) according to claim 1, wherein energy accumulators (27) are distributed over the circumference of the second damper stage (15) based on a middle mounting diameter radially within turbine blades (8) of the turbine (7).**

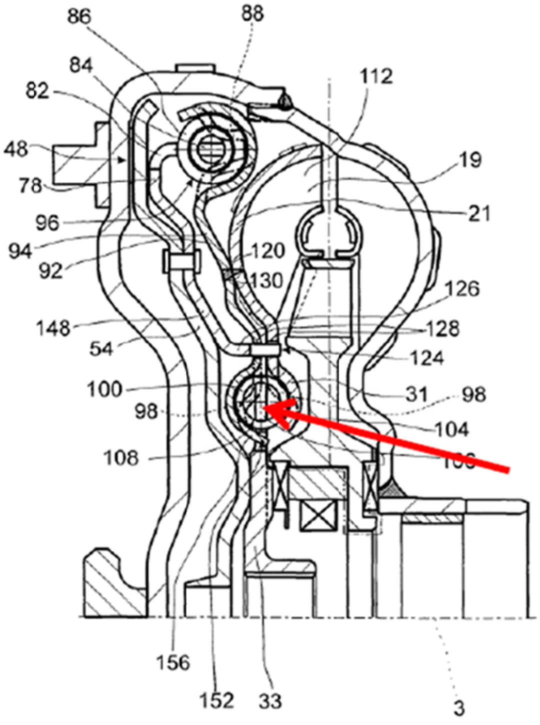
142. Claim 8 requires that the middle mounting diameter, *i.e.*, center of the springs of the second damper, be radially within (below) the turbine.

143. As shown in the ’374 patent, the center of the springs of the second damper are mounted below the turbine. The same relationship is depicted in Sasse Fig. 5, with red arrows illustrating the center of the springs of the second damper located below the turbine:



**’374 Patent**

Fig. 5



**Sasse Fig. 5**

144. It would have been obvious to a PHOSITA to combine Sasse Figs. 1 and 5 to reposition the springs of the second damper radially inward of the turbine blades as taught in Fig. 5, both as a general matter of design choice specifically encouraged by Sasse as this design would save axial space, a goal suggested by both Sasse and Haller and a desired outcome that would be recognized by a PHOSITA. (Ex. 1003, 5:32–34 ("Advantageous elaborations of the torsional vibration damper by which it can be made more compact are described in the sub claims"); *see also* 5:3–24 (reducing space and number of components a desired goal); Ex. 1004, 3:12–16 ("This on the one hand has the advantage that installation spaces present in any case between the startup element and the transmission output can be used, so that no (or only insignificant) increases in installation space result despite the placement according to the present invention of the canceller"); *see also* 12:11–13 (placing components in cavities created by other components appropriate).) Especially for transverse engines, saved space can be a big deal and thus a significant design consideration.

145. Several Figs. in Sasse and other prior art illustrate embodiments where the central area where the springs of the second

damper are mounted is radially within the turbine, illustrating the suitability of this configuration. (Ex. 1003, Figs. 4–6; Ex. 1014, Fig. 4.)

Fig. 4

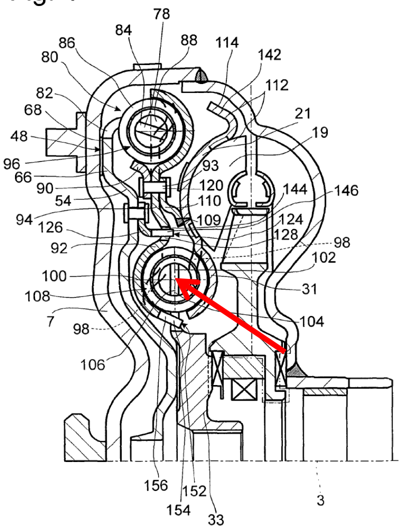


Fig. 5

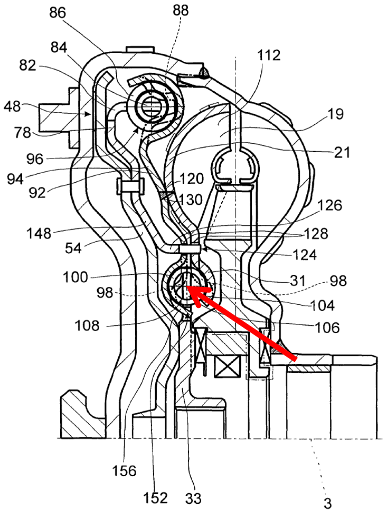
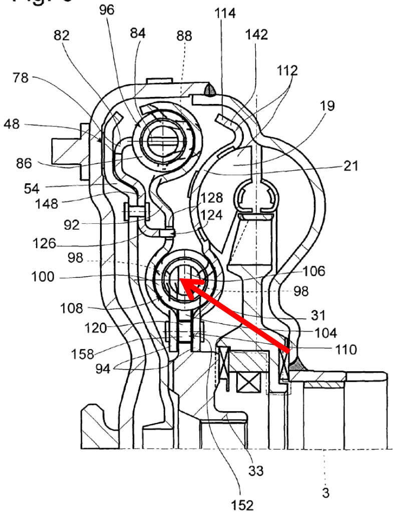


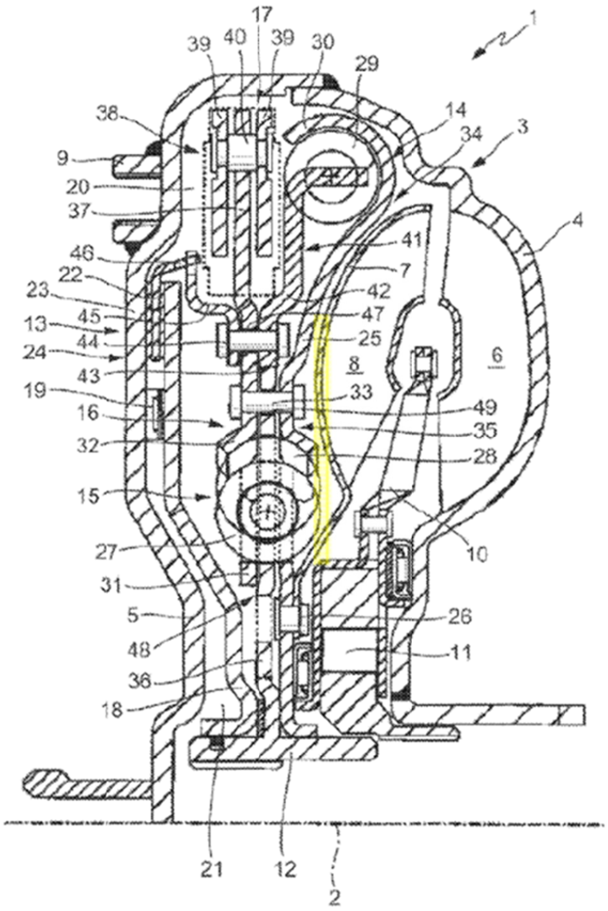
Fig. 6



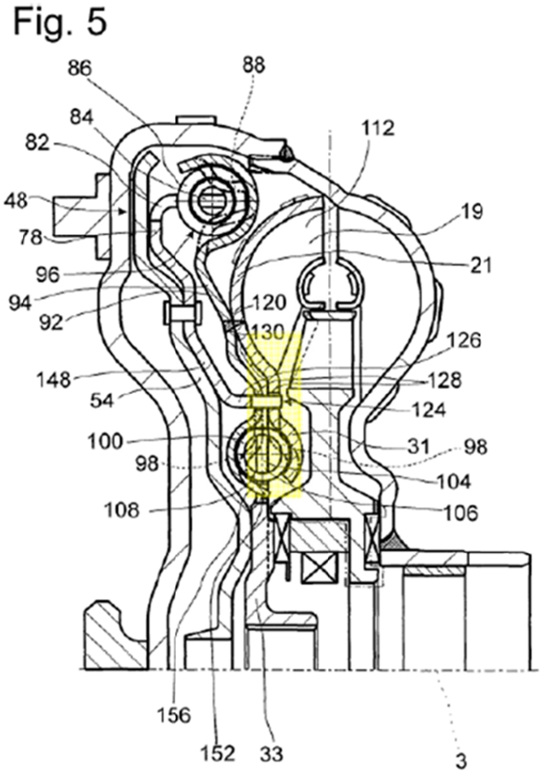
146. Thus, it is my opinion that the combination of Sasse and Haller renders obvious claim 8.

**Claim 9: The hydrodynamic torque converter (1) according to claim 8, wherein the energy accumulators (27) of the second damper stage (15) and the turbine (7) at least partially and axially overlap.**

147. Claim 9 specifies that the springs of the second damper partially overlap the turbine axially. The ’374 patent illustrates only minimal axial overlap of the springs of the second damper stage and the turbine (if any), but much more axial overlap is depicted in Sasse Fig. 5, annotated with yellow:



**’374 Patent**



**Sasse Fig. 5**

148. A PHOSITA could have easily combined Sasse Figs. 1 and 5 because repositioning the second damper to partially axially overlap with the turbine as taught in Fig. 5 is a general matter of design choice specifically encouraged by Sasse and that was known in the art. (Ex. 1003, 14:25–40; Ex. 1014, Fig. 4.)

149. And, this design would save axial space, a goal specifically suggested by both Sasse and Haller, and a desired outcome that would

be recognized by a PHOSITA. (Ex. 1003, 5:20–24 (reducing space and number of components a desired goal); Ex. 1004, 12:11–13 (placing components in cavities created by other components appropriate.)) Thus, it is my opinion that the combination of Sasse and Haller renders obvious claim 9.

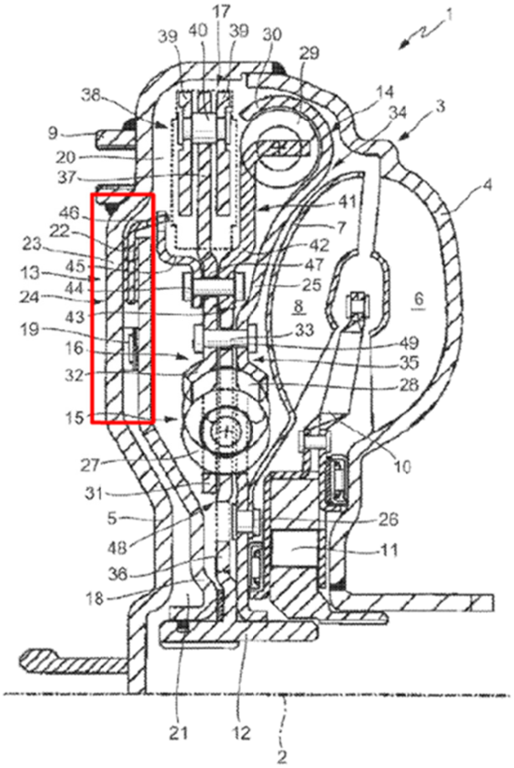
> **Claim 10: The hydrodynamic torque converter (1) according to claim 1, wherein the lock-up clutch (13) in a closed state is axially mounted in a pocket (24) formed in a housing wall (23) radially inward of fastening means (9) provided on external part of the torque converter (1).**

150. Claim 10 includes orientations that, when closed, the mounting portion of lock-up clutch is axially within a pocket in the housing wall radially inside fastening means on the housing (*i.e.*, the lock-up clutch is partially in the pocket

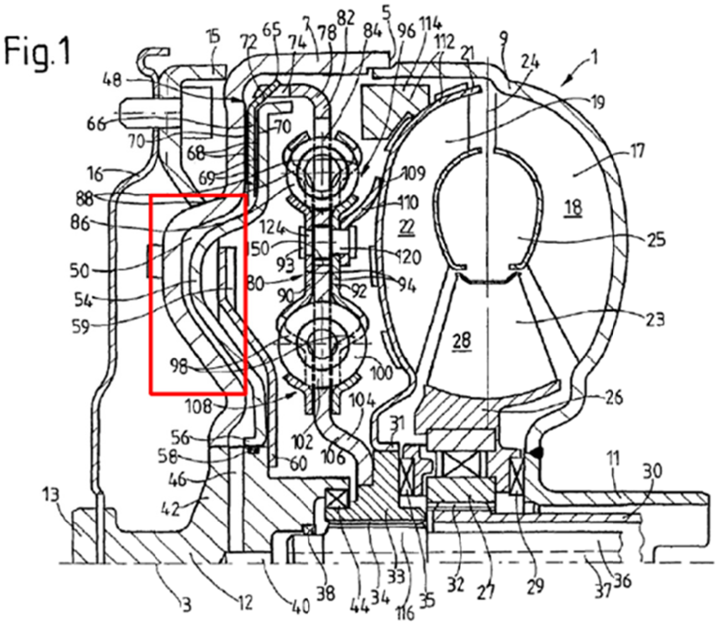
151. Additional portions of the lock-up clutch may be outside the pocket, in keeping with the ’374 patent where the teeth and the piston of the lock-up clutch extend beyond the pocket.

152. The hydrodynamic torque converter in Sasse Fig. 1 has a fastening bracket 15 on the housing of the torque converter for attaching the housing 5 to a drive. (Ex. 1003, 7:34–36.)

153. When closed, the lock-up clutch 48 is axially mounted in a pocket formed by chamber 50 in the housing wall 7. The pocket is radially inside the fastening bracket 15. Below, the ’374 patent and Sasse Fig. 1 illustrate the mounting portion of the lock-up clutch within the pocket, with the portions of the lock-up clutch within the pocket highlighted in red:



**’374 Patent**



**Sasse Fig. 1**

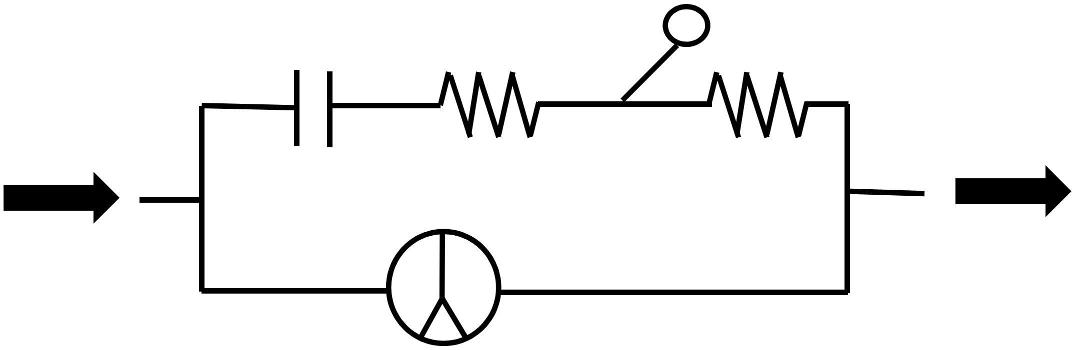
154. Thus, it is my opinion that the combination of Sasse and Haller renders obvious claim 10.

**Claim 14: The hydrodynamic torque converter (1) according to claim 1, wherein in the closed state of the lock-up clutch (13) the torsional vibration absorber (17) acts between both damper stages (14, 15).**

155. Claim 14 requires that the torsional vibration absorber act between both damper stages when the lock-up clutch is closed.

156. In Sasse Fig. 1, the mass 114 acts between the first and second dampers via the tie element 110, so that the intermediate transmission element 94 for the two dampers, the turbine, and the mass 114 all rotate together as one unit (*i.e.*, they are connected non-rotatably).

157. If in claim 14 "acts" is interpreted narrowly to require the mass to be connected to the dampers separately from the turbine, this feature is shown in Sasse Fig. 2. There, the supplemental mass 114 is connected with tie element 110 to the intermediate transmission element 94, located between the first and second energy-storage devices 86, 100. (Ex. 1003, Fig. 2.) Accordingly, when the lock-up clutch is closed, the supplemental mass 114 acts between both damper stages, as depicted below (with the absorber connected between the damper stages and with weld 31 connecting the turbine directly to the output):



158. As noted previously, it would have been obvious to a PHOSITA to mount the mass 114 to the tie element because repositioning the supplemental mass as taught in Fig. 2 is a general matter of design choice specifically encouraged by Sasse and no particular benefits are associated with either configuration. (Ex. 1003, 14:25–40.)

159. Moreover, Haller specifically states that a torsional vibration absorber can be "arranged between the first torsional damper stage and the second torsional damper stage." (Ex. 1004, 4:4–5.) Thus, it is my opinion that the combination of Sasse and Haller renders obvious claim 14.

**Claim 15: The hydrodynamic torque converter (1) according to claim 1, wherein the torsional vibration absorber (17) is connected non-rotatably with the turbine (7).**

160. Sasse Fig. 1 describes mass element 112 and supplemental mass 114 attached to the turbine wheel shell. (Ex. 1003, 9:27–34.)

161. Because the supplemental mass in Sasse Fig. 1 dampens vibrations, it meets the broadest reasonable interpretation of torsional vibration absorber described above, *i.e.*, "a component or device designed to absorb torsional vibrations." (*See* Ex. 1001, 1:43–45.) And, the supplemental mass in Sasse Fig. 1 is connected so that it cannot rotate relative to, *i.e.*, non-rotatably with, the turbine. (Ex. 1003, 9:27–34.)

162. As discussed above for claim 1, if the supplemental mass in Sasse Fig. 1 is not considered a torsional vibration absorber, Haller teaches torsional vibration absorbers akin to those of the '374 patent. Thus, it is my opinion that the combination of Sasse and Haller renders obvious claim 15.

> **Claim 16: The hydrodynamic torque converter (1) according to claim 15, wherein in the opened state of the lock-up clutch (13) the torsional vibration absorber (17) is connected non-rotatably with the turbine (7).**

163. Sasse Fig. 1 describes mass element 112 and supplemental mass 114 attached to the turbine wheel shell. (Ex. 1003, 9:27–34.) Because the supplemental mass in Sasse Fig. 1 dampens vibrations, it

meets the broadest reasonable interpretation of torsional vibration absorber described above.

164. And, the supplemental mass in Sasse Fig. 1 is fixed to the turbine and thus connected non-rotatably with the turbine when the lock-up clutch is open. (Ex. 1003, 9:27–34.)

165. As discussed above for claims 1 and 15, if the supplemental mass in Sasse Fig. 1 is not considered a torsional vibration absorber, it would have been obvious to a PHOSITA to substitute the mass for any of the cancellers described in Haller. Thus, it is my opinion that the combination of Sasse and Haller renders obvious claim 16.

### D. Ground 4: Claims 4–7 Are Obvious Over Sasse, Haller, and Eckel

166. Sasse Fig. 1 describes a hydrodynamic torque converter with a turbine driven by an impeller including a multi-stage torsional vibration damper disposed between a lock-up clutch and the output. (*See generally* Ex. 1003, Fig. 1.)

167. Sasse teaches using at least one mass element to absorb additional torsional vibrations. (Ex. 1003, 4:7–12.)

168. Haller teaches a torque converter with a torsional vibration absorber, but does not expressly teach that the torsional vibration

absorbers in the Figs. have multiple masses. As discussed above, Haller refers to centrifugal force pendulums as examples of cancellers but does not expressly describe the spring-mass system 22 as a centrifugal-force pendulum with multiple masses (although virtually all implementations of centrifugal-force pendulum systems use multiple masses for balancing, so it is inherent that multiple masses are involved). (*See generally* Ex. 1004.)

169. Regardless, Eckel, teaches centrifugal force pendulums with multiple masses. (Ex. 1011, Fig. 1.)

170. It would have been obvious to a PHOSITA to apply Eckel's centrifugal force pendulum to a torque converter with multi-stage damper as in Sasse Fig. 1 because the benefits of Eckel's centrifugal force pendulum could be predictably applied to any rotating machine with order excitation, such as a torque converter.

171. Particularly, incorporating Eckel's centrifugal force pendulum into a torque converter would yield the predictable result of attenuating rotational vibration. And, a PHOSITA would have a reasonable expectation of success in making that modification because it merely involves using Eckel's pendulum absorber for its intended

purpose. In view of the detailed discussion below and in light of the specification of the ’374 patent, it is clear that the claims of the ’374 patent simply recite prior art elements that function predictably in their known manner.

**Claim 4[a]: The hydrodynamic torque converter (1) according to claim 1, wherein the torsional vibration absorber (17) comprises a plurality of absorber masses (39), and**

172. Sasse describes that the mass element has multiple “supplemental masses” and that the torsional vibration absorber in Fig.1 includes a plurality of absorber masses, noting that “mass element 112 can also have a supplemental mass 114.” (Ex. 1003, 4:57–58, 9:31–32.)

173. Even if Sasses’ supplemental mass is not considered a torsional vibration absorber, Haller and Eckel disclose torsional vibration absorbers, and Eckel’s centrifugal force pendulums include a plurality of absorber masses 2. (Ex. 1011, Figs. 1–3).

174. Thus, it is my opinion that the combination of Sasse, Haller, and Eckel renders obvious element 4[a].

**Claim 4[b]: a mounting part (37) of the torsional vibration absorber (17) forms a disk part (31) of an input part (35) of the second damper stage (15).**

175. Claim 4[b] specifies that the mounting part of the torsional vibration absorber forms an input part of the second damper stage.

176. As explained above for claim 1[h], it would have been obvious to modify the embodiment of Sasse's Fig. 1 by mounting a torsional vibration absorber on carrier 118, as shown in Sasse Fig. 2. Carrier 118 attaches the vibration absorber to plate 92 through actuation point 120. (Ex. 1003, 9:57–67.) Thus, carrier 118 and actuation point 120 are part of the disk part plate 92 that functions as an input part of the second damper stage 100.

177. It would have been obvious for a PHOSITA to combine Sasse Figs. 1 and 2 because Sasse states that substitutions between different embodiments may be made, and that features of the different embodiments may be incorporated into one another as a general matter of design choice. (Ex. 1003, 14:25–40.)

178. And, if "disk part" is interpreted as requiring a single component, it would have been obvious to a PHOSITA to combine carrier 118 and plate 92 into an integral piece because Sasse itself teaches that it is desirable to combine components, meeting the goals of reducing cost and complexity. (*See, e.g.*, Ex. 1003, 5:3–8.)

179. Also, Sasse Fig. 6 shows the mounting part for the supplemental mass 114 integral with an input of the second damper, which supports the obviousness of making the same modification to the Fig. 1 embodiment and confirms that there would have been a reasonable expectation of success in doing so. (Ex. 1003, Fig. 6.)

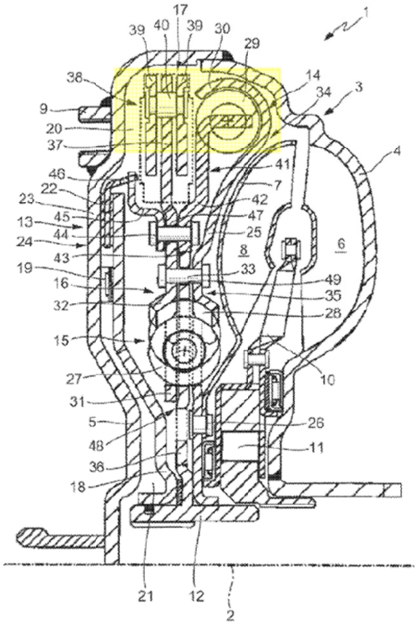
180. Still further, Haller suggest such a modification by noting that the vibration absorber 22 can be "connected nonrotatably to transfer element 42," which includes a disk part forming the input of the second damper stage. (Ex. 1004, 12:5–6.)

181. Thus, it is my opinion that the combination of Sasse, Haller, and Eckel renders obvious element 4[b].

> **Claim 5: The hydrodynamic torque converter (1) according to claim 1, wherein absorber masses (39) of the torsional vibration absorber (17) and energy accumulators (29) of the first damper stage (14) disposed over the circumference are radially at the same height but axially spaced apart.**

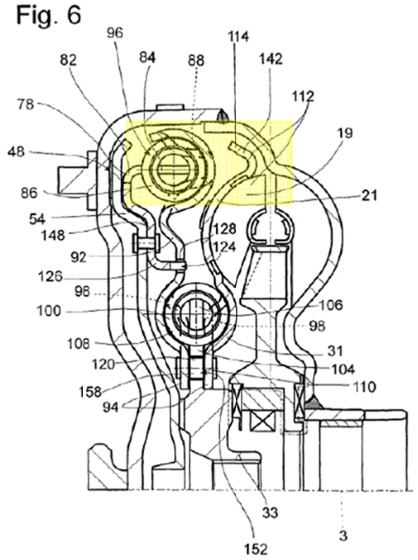
182. Claim 5 specifies that the absorber masses (see discussion above for claim 4[a] for discussion of absorber masses) and the springs of the first damper stage are axially spaced apart but radially at the same height, as illustrated in the '374 patent.

183. This orientation is a simple matter of design choice seen in the prior art, such as in Sasse Fig. 6 with yellow highlighting the absorber masses and springs of the first damper stage at the same radial height while spaced apart axially:



**’374 Patent**

Fig. 6



**Sasse Fig. 6**

184. As noted above, it would have been obvious for a PHOSITA to combine Sasse Figs. 1 and 6 because Sasse states that substitutions between different embodiments may be made, and that features of the different embodiments may be incorporated into one another as a general matter of design choice. (Ex. 1003, 14:25–40.)

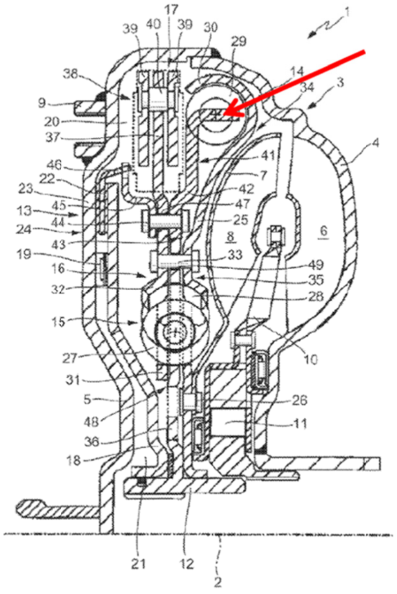
185. Haller Figs. 6–7 also show embodiments with the dampers and absorbers overlapping radially, illustrating that this was known in

the art as a way to package components of a torque converter. (Ex. 1004, Figs. 6–7.) Thus, it is my opinion that the combination of Sasse, Haller, and Eckel renders obvious claim 5.

> **Claim 6: The hydrodynamic torque converter (1) according to claim 5, wherein a middle mounting diameter of the energy accumulators (29) is disposed radially outside the turbine (7).**

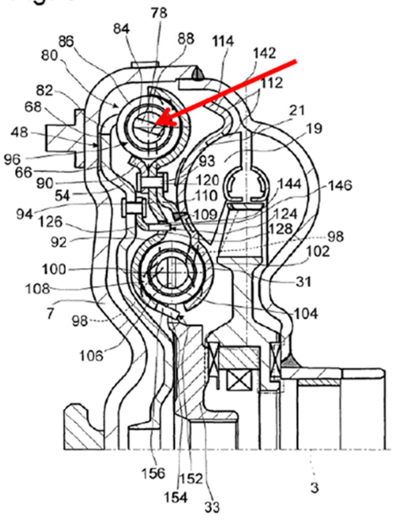
186. Claim 6 requires that the middle mounting diameter, *i.e.*, center of the springs of the first damper, be radially above the turbine.

187. As shown in the ’374 Fig. 1, the center of the springs of the first damper are mounted above the turbine. The same relationship is depicted in Sasse Fig. 4, annotated with red arrows illustrating the central area of the springs of the first damper located above the turbine:



**’374 Patent**

Fig. 4



**Sasse Fig. 4**

188. It would have been obvious to a PHOSITA to modify Sasse Fig. 1 to reposition the first damper to be radially above the turbine, as taught in Fig. 4, because it is a design choice specifically encouraged by Sasse. (Ex. 1003, 14:25–40.) And, this design would save axial space, a goal specifically suggested by both Sasse and Haller, and a desired outcome recognizable by a PHOSITA because saving space is extremely important. (Ex. 1003, 5:3–34; Ex. 1004, 3:12–16 and 12:11–13.)

189. In fact, Sasse Figs. 4–7 all illustrate embodiments where the center of the springs of the first damper are mounted radially above the turbine, illustrating the suitability of this configuration. (Ex. 1004, Figs. 4–7.) Thus, it is my opinion that the combination of Sasse, Haller, and Eckel renders obvious claim 6.

**Claim 7: The hydrodynamic torque converter (1) according to claim 5, wherein the energy accumulators (29) overlap the turbine (7) at least partially and axially.**

190. Claim 7 specifies that the springs of the first damper partially overlap the turbine axially, as shown in the ’374 patent.

191. The same relationship is depicted in Sasse Fig. 4 where the springs overlap the turbine housing, annotated with a yellow box illustrating the axial overlap:

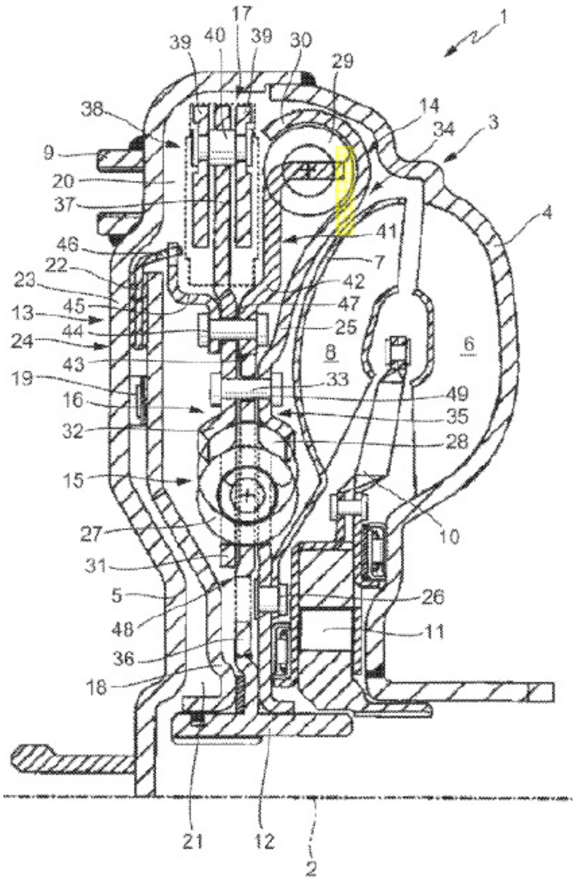
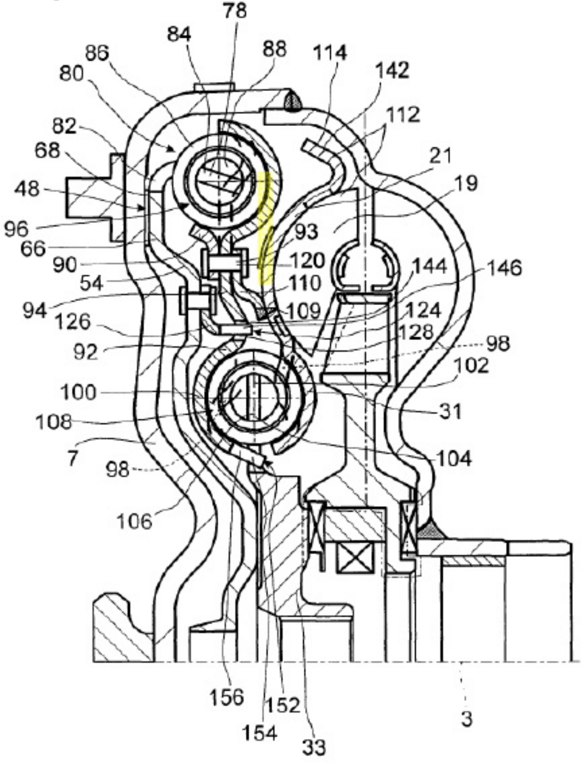


Fig. 4



**’374 Patent Fig.** **Sasse Fig. 4**

192. It would have been obvious to a PHOSITA to modify Sasse Fig. 1 to reposition the first damper to partially axially overlap with the turbine, as taught in Fig. 4, because it is a design choice specifically encouraged by Sasse. (Ex. 1003, 14:25–40.)

193. Indeed, other embodiments in Sasse show even more overlap. (Ex. 1003, Fig. 5.) And, overlap would save axial space, a goal specifically suggested by both Sasse and Haller and a desired outcome

that would be recognized by a PHOSITA. (Ex. 1003, 5:20–24 (reducing space and number of components a desired goal); Ex. 1004, 12:11–13 (placing components in cavities created by other components appropriate).) Thus, it is my opinion that the combination of Sasse, Haller, and Eckel renders obvious claim 7.

### E. Ground 5: Claims 11–13 Are Obvious Over Sasse, Haller, and MacDonald

194. Sasse Fig. 1 describes a hydrodynamic torque converter with a turbine driven by an impeller including a multi-stage torsional vibration damper disposed between a lock-up clutch and the output. (*See generally* Ex. 1003, Fig. 1.)

195. As noted above, it would have been obvious to a PHOSITA to incorporate Haller's torsional vibration absorbers into Sasse's torque converter. Although Sasse and Haller do not show a lock-up clutch mounted on the housing of the torque converter as recited in claim 11, in general there are a number of lock-up clutch mounting designs, and it was well-known that they could be substituted for one another with known trade-offs.

196. Broadly speaking, the available hydrodynamic torque converter designs include two-way and three-way hydrodynamic torque

converters with either single-faced or two-faced friction plates. The '374 patent uses a two-way hydrodynamic torque converter with a two-faced friction plate so the piston is connected to the housing, an orientation well-known in the art.

197. For example, MacDonald demonstrates a lock-up clutch design with a welds (72, 73) mounting the piston (60) of the lockup clutch to the housing (12). (Ex. 1026, Fig. 1.) Similarly, Ex. 1027 shows a piston attached to the housing through piston mount 53. (Ex. 1027, [0029].) Ex. 1028 uses tongues to mount the piston to the housing while maintaining axial movement. (Ex. 1028, [0051] and [0060]). Moreover, the leaf spring connection used in the '374 patent was well known, and documented in the prior art. (Ex. 1029, [0014] ("attachment can be carried out with leaf springs which are flexible enough to allow axial displacement of the piston plate").)

198. A PHOSITA would have been motivated to modify the lock-up clutch in Sasse with the mounted-type of lock-up clutch in MacDonald because the benefits of MacDonald's lock-up clutch could be predictably applied to any torque converter. Particularly, incorporating MacDonald's lock-up clutch into a torque converter would yield

predictable results and a PHOSITA would have a reasonable expectation of success in making that modification because it merely involves using MacDonald's lock-up clutch for its intended purpose.

> **Claim 11[a]: The hydrodynamic torque converter (1) according to claim 10 wherein the lock-up clutch (13) is formed out of a piston (18) centered on the output hub (12) and mounted non-rotatably and axially displacably on the housing (3), and**

199. Claim 11 specifies that the lock-up clutch is formed out of a piston centered on the output hub and that the piston is mounted non-rotatably and axially displacably on the housing.

200. The lock-up clutch in Sasse Fig. 1 is formed out of a piston 54 connected to the wheel hub 33 via the journal hub 12 and axial bearing 44. (Ex. 1003, 8:22–32 and Fig. 1.) The axis of the piston is centered on the axis of the wheel hub, which forms an output hub for the torque converter.

201. If "centered" is interpreted as requiring that the piston be ***directly*** mounted on the output hub, then this configuration is taught by MacDonald. In MacDonald Fig. 1, piston 60 is mounted on turbine hub 38 which is adapted to engage with the transmission input shaft.

(Ex. 1026, 2:43–48[4] and 57–59, Fig. 1.) Thus, MacDonald's turbine hub is an output hub.

202. It would have been obvious to a PHOSITA to combine the arrangement from MacDonald with Sasse Fig. 1 because mounting the piston 60 of MacDonald on the output hub 33 would beneficially provide a more compact design, and providing compact designs was a recognized goal. (Ex. 1003, 5:3–34; Ex. 1004, 3:12–16.) In fact, this type of centering design is known in the art. (*See, e.g.*, Ex. 1005, Fig. 1.)

203. Furthermore, MacDonald teaches that the lock-up clutch can mounted non-rotatably and axially displacably on the housing, an obvious modification of Sasse as discussed above. (Ex. 1026, Fig. 1 (welds (72, 73) mounting the piston (60) of the lockup clutch to the housing (12)); 3:44–46 (noting axial movement).) Thus, it is my opinion that the combination of Sasse, Haller, and MacDonald renders obvious element 11[a].

**Claim 11[b]: axially pressurizes a friction plate (22) that can be clamped between said piston and said housing (3) to develop a frictional engagement.**

---

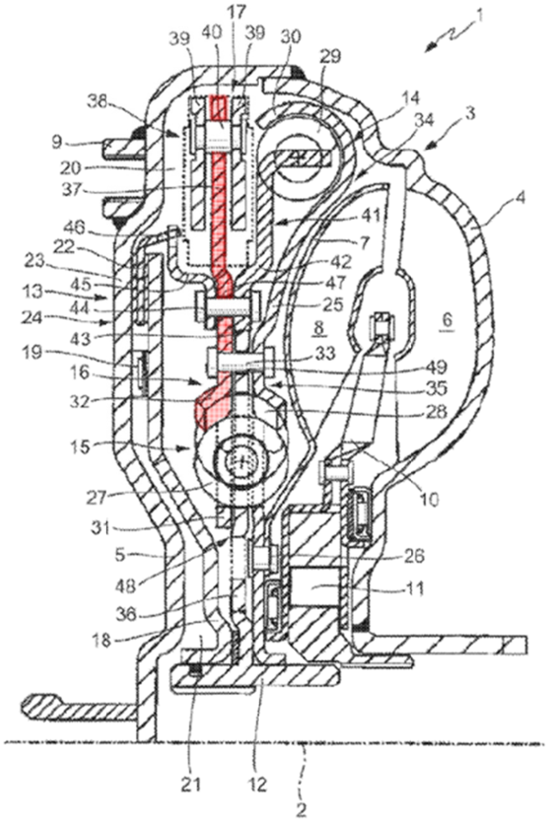
[4] I note there appears to be a typo in MacDonald: the "retainer 97" at 2:43/44 should be "retainer 84."

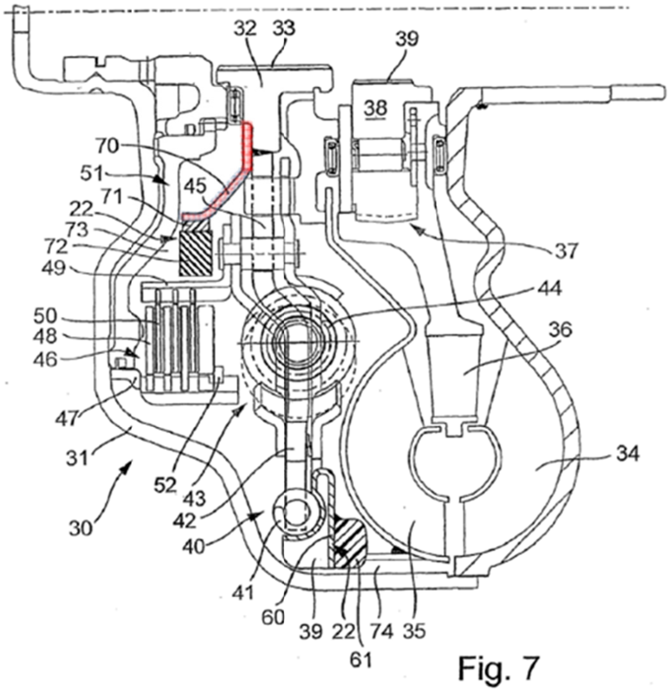
204. The bridging clutch 48, *i.e.*, lock-up clutch, in Sasse Fig. 1 axially pressurizes a friction plate between the piston and housing to develop a frictional engagement. (Ex. 1003, 8:37–43 and Fig. 1.) Thus, it is my opinion that the combination of Sasse, Haller, and MacDonald renders obvious element 11[b].

**Claim 12: The hydrodynamic torque converter (1) according to claim 11, wherein a mounting part (37) of the torsional vibration absorber (17) is disposed axially between lock-up clutch (13) and the first damper stage (14).**

205. Claim 12 specifies that the mounting part of the torsional vibration absorber is located axially between the lock-up clutch and the first damper stage, as shown in the ’374 patent.

206. Haller teaches that a mounting part of a vibration absorber can be located at different locations in a torque converter, including between the lock-up clutch and the damper stages in Fig. 7. Mounting parts of the ’374 patent and Haller are annotated in red to illustrate their location axially between the lock-up clutches and the damper stages:





**’374 Patent Fig.** **Haller Fig. 7**

207. As noted above, it would have been obvious for a PHOSITA to apply Haller’s torsional vibration absorber to a torque converter with a multi-stage damper as in Sasse Fig. 1 because the benefits of Haller’s torsional vibration absorbers could be predictably applied to a torque converter with two damper stages.

208. In particular it would have been obvious for a PHOSITA to move the mounting part of the absorber between the damper stages and the lock-up clutch, as shown in Haller Fig. 7, because Haller and Sasse

both teach that the components from their various embodiments can be combined and the absorber would function the same irrespective of whether it is mounted on the left or right side of the dampers in Sasse Fig. 1. (Ex. 1003, 14:35-40; Ex. 1004, 12:18–19.)

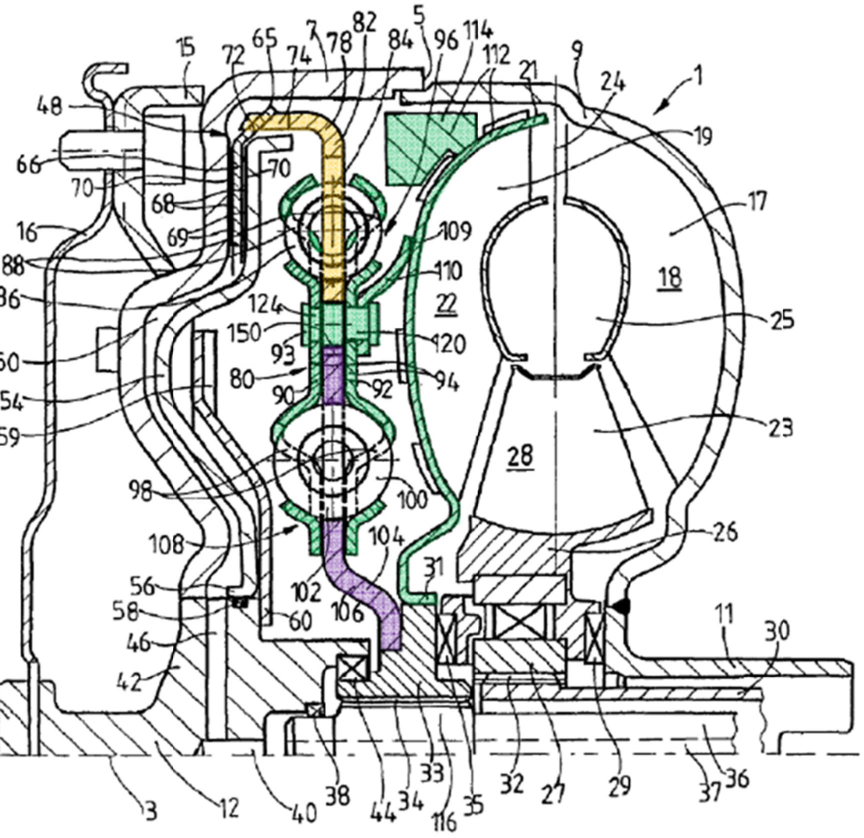
209. Haller also teaches that it is desirable to use empty installation space between the damper stages. (Ex. 1004, 3:12–16.) If Sasse Fig. 1 were modified, as taught by Haller (see following discussion), to move the absorber from the turbine side to the lock-up clutch side, the dampers could be shifted to the right, creating installation space between the lock-up clutch and the dampers.

210. Also, disposing the absorber axially between the lock-up clutch and the first damper does not achieve any particular advantages and it still simply functions as an absorber, *i.e.*, to reduce vibrations.

211. Consistent with Haller's various examples where the absorber could be mounted, a PHOSITA would understand that it does not matter where the absorber is placed: as long as it is connected to the same components, it will function in the same manner if the masses are the same distance from the axis of rotation.

212. This concept can be explained by looking in more detail at Sasse Fig. 1, where the components annotated in green will all rotate together:

Fig.1



**Sasse Fig. 1**

213. Because the components in green all rotate together, masses 112/114 (from the Sasse Figs. 1 and 2 combination) could be connected to the actuation point 120 from either side and would function identically.

214. A PHOSITA would have a reasonable expectation of success in making this modification because Sasse Fig. 2 confirms that the absorber can be mounted on a carrier instead of the turbine. A PHOSITA would recognize that if Sasse Fig. 1 were modified to remove the supplemental mass from the turbine side, the dampers could be shifted to the right, creating installation space between the lock-up clutch and the dampers.

215. Thus, it is my opinion that the combination of Sasse, Haller, and MacDonald renders obvious claim 12.

> **Claim 13: The hydrodynamic torque converter (1) according to claim 12, wherein between the friction plate (22) and an input part (41) of the first damper stage (14) transition connections (44) are formed, which reach through circular segment-shaped openings (47) of the mounting part (37).**

216. Claim 13 specifies that transition connections are formed between the friction plate of the lockup clutch and the input of the first damper, and that these transition connections pass through circular segment-shaped openings in the mounting part of the torsional vibration absorber.

217. The ’374 patent explains that these openings are provided to ensure that the mounting part of the torsional vibration absorber is

rotatable relative to the input of the first damper stage. (Ex. 1001, 5:26–29.)

218. Haller teaches that windows can be formed in the rotating plates of a torque converter to provide transition connections. A PHOSITA would recognize that these transition connections advantageously permit one rotating part to “pass through” another rotating part, as shown in Fig. 8 of Haller, and allow the parts to rotate relative to each other.

219. It would be obvious for a PHOSITA to modify the combination of Sasse, Haller, and MacDonald, as described above for claim 12, to provide windows in the mounting plate of the absorber to allow the input of the first damper to pass through the mounting part of the absorber.

220. Creating these openings would have been an obvious modification for a PHOSITA because using openings in hydrodynamic torque converter elements to permit the input of the first damper stage to pass through such elements and provide freedom of movement was known in the art and commonplace. (Ex. 1003, 8:64–9:3; Ex. 1018, Fig. 11 (torque transmission components extend through openings provided

on a flange acting between the damper stages); Ex. 1016, Fig. 5 (same); Ex. 1017, Fig. 1 (same).)

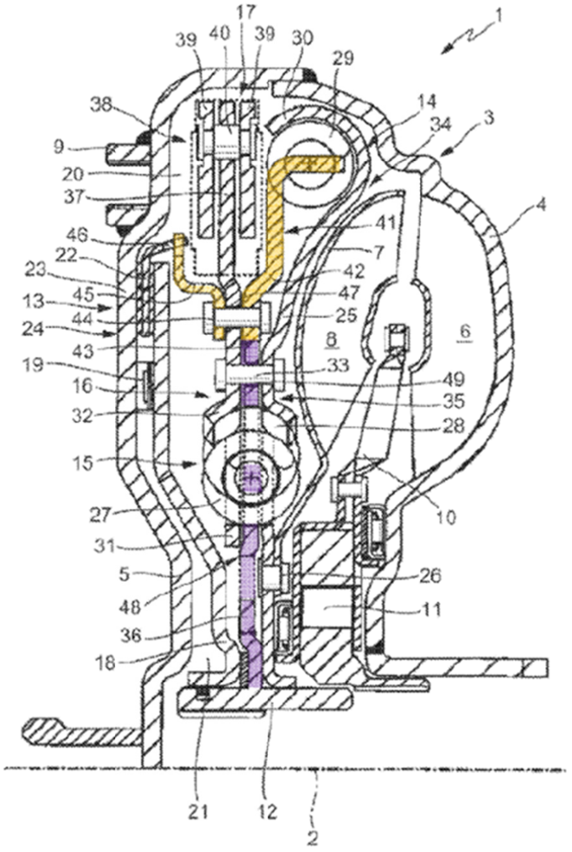
221. A PHOSITA could have easily designed the openings in any appropriate shape, including circular segment-shaped, which would have been the obvious choice of window shape for circular parts that rotate around the same axis. (*See* Ex. 1003, Figs. 8 and 10 (circular-segment shaped openings).) Thus, it is my opinion that the combination of Sasse, Haller, and MacDonald renders obvious claim 13.

### F. Ground 6: Claims 2 and 10 Are Obvious Over Sasse, Haller, and Heuler

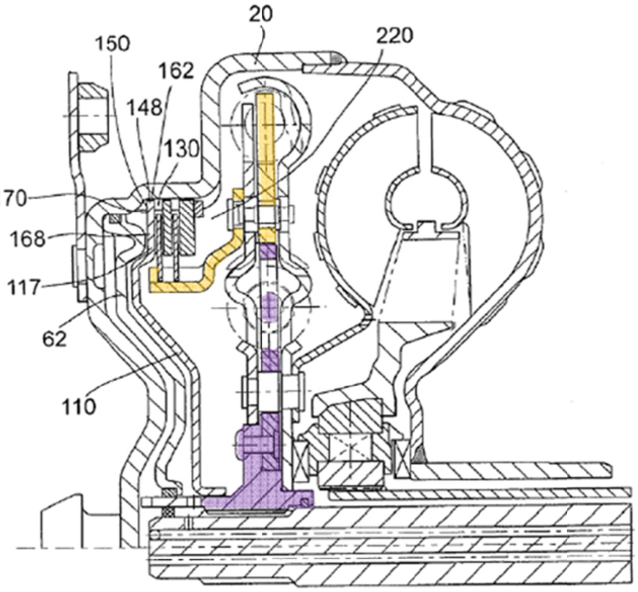
**Claim 2: The hydrodynamic torque converter (1) according to claim 1, wherein an input part (41) of the first damper stage (14) and an output part (48) of the second damper stage (15) are centered on one another.**

222. Section VI.C above explains how claim 2 would have been obvious over Sasse and Haller. Claim 2, which depends from claim 1, requires that an input part 41 of the first damper stage and an output part 48 of the second damper stage are centered on one another.

223. Even if Sasse Fig. 1 is not considered to teach centering, centering the input of a first damper stage and the output of a second damper stage was well-known, as shown in Fig. 11 of Heuler:



**’374 Patent**



**Heuler Fig. 11**

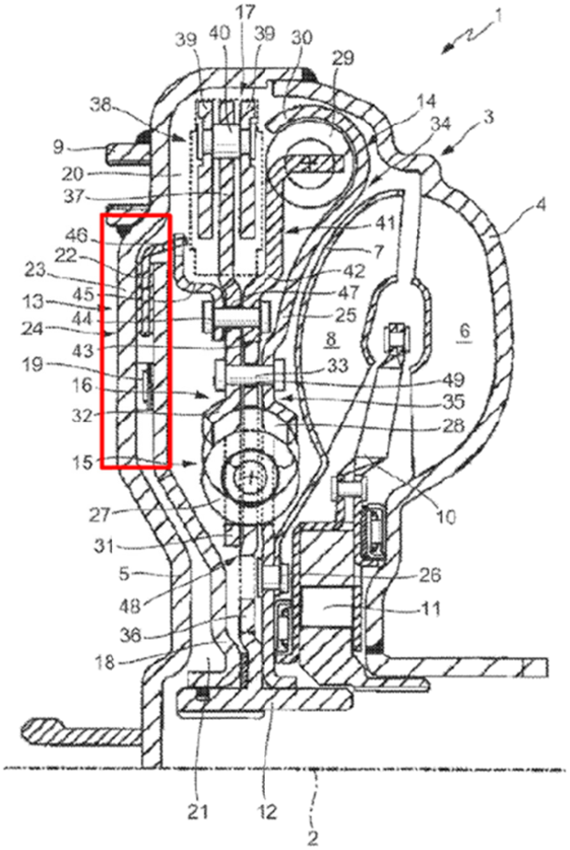
224. A PHOSITA would have been motivated to modify Sasse Fig. 1 to center the input of the first damper and the output of the second damper as taught by Heuler because this is a simple matter of design choice, well-known in the art, for mounting parts in a torque converter. (*See* Ex. 1016, Fig. 5; Ex. 1017, Fig. 1.) Thus, it is my opinion that the combination of Sasse, Haller, and Heuler renders obvious claim 2.

**Claim 10: The hydrodynamic torque converter (1) according to claim 1, wherein the lock-up clutch (13) in a closed state is axially mounted in a pocket (24) formed in a**

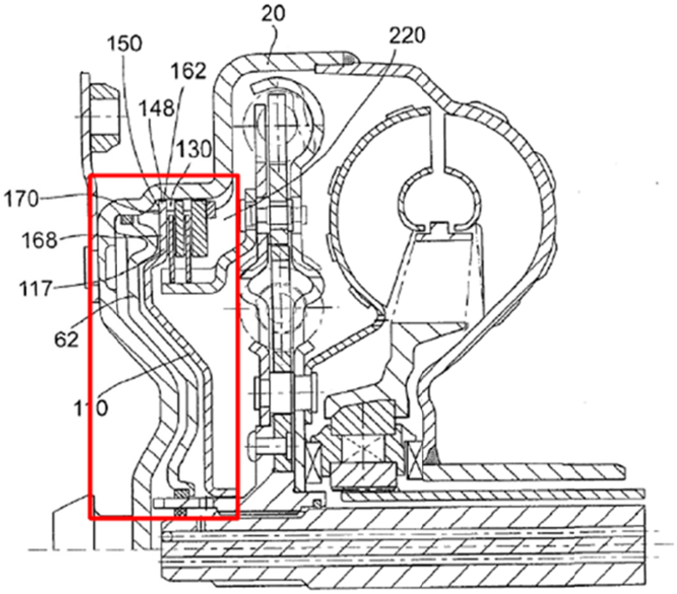
**housing wall (23) radially inward of fastening means (9) provided on external part of the torque converter (1).**

225. Section VI.C above explains how claim 10 would have been obvious over Sasse and Haller. If claim 10 is interpreted more narrowly, requiring the entire lock-up clutch to be disposed within a pocket formed in a housing wall, this feature would have been obvious to a PHOSITA in view of Heuler.

226. The hydrodynamic torque converter in Heuler Fig. 11 has a fastening bracket on the housing of the torque converter for attaching the housing to a drive. (Ex. 1018, Fig. 11.) And, as shown in Fig. 11, when closed, the clutch is axially mounted in a pocket formed in the housing wall radially inside of the fastening bracket. Moreover, in contrast to Fig. 1 of the '374 patent, in Heuler Fig. 11 all components of the lock-up clutch are disposed within the pocket:



**’374 Patent**



**Heuler Fig. 11**

227. A PHOSITA would have been motivated to modify Sasse Fig. 1 to include the entire lock-up clutch in the pocket as taught by Heuler because this is a simple matter of design choice, and no particular benefits are associated with either configuration. Indeed, this orientation was well-known. (*See, e.g.*, Ex. 1015, Fig. 1; Ex. 1016, Fig. 5; Ex. 1017, Fig. 1.) Thus, it is my opinion that the combination of Sasse, Haller, and Heuler renders obvious claim 10.

### G. Ground 7: Claims 1–3, 10, and 14–16 Are Obvious Over Heuler and Haller

228. Heuler Fig. 11 describes a hydrodynamic torque converter with a turbine driven by an impeller including a multi-stage torsional vibration damper disposed between a lock-up clutch and the output. (*See generally* Ex. 1018, Fig. 11.)

229. Heuler does not disclose torsional vibration absorbers, but Haller teaches a torque converter with torsional vibration absorbers. (*See generally* Ex. 1004.)

230. It would have been obvious to a PHOSITA to apply Haller's torsional vibration absorber to a torque converter with a multi-stage damper as in Heuler Fig. 11 because the benefits of Haller's torsional vibration absorbers could be predictably applied to any rotating machine with order excitation, such as a torque converter.

231. In particular, incorporating Haller's torsional vibration absorber into a torque converter would yield the predictable result of reducing rotational vibrations.

232. In fact, Haller states that incorporating a torsional vibration absorber in parallel with the drivetrain components—the configuration recited in the claims of the '374 patent—"results in particularly good

dynamic transfer behavior." (Ex. 1004, 4:4–6.)

233. Accordingly, it also would have been obvious to a PHOSITA to apply Haller's torsional vibration absorber to a torque converter with Heuler Fig. 11's torsional vibration damper with multiple damper stages because Haller's torsional vibration absorber is designed to absorb rotatable shaft vibrations created by an internal combustion engine and Haller teaches that vibration absorbers can be advantageously applied to a torque converter.

234. In view of the detailed discussion below and in light of the specification of the '374 patent, it is clear that the claims of the '374 patent simply recite prior art elements that function predictably in their known manner.

**Claim 1[a]: A hydrodynamic torque converter (1):**

235. Both Heuler and Haller disclose torque converters. (*See, e.g.*, Ex. 1018, [0044]; Ex. 1004, 3:19–20.) Thus, it is my opinion that the combination of Heuler and Haller render obvious element 1[a].

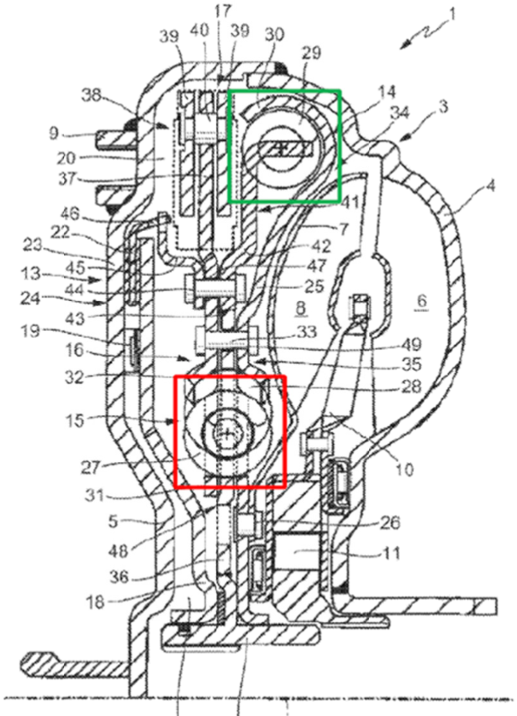
**Claim 1[b]: with a turbine (7) driven by an impeller (6) as well as housing (3)**

236. The hydrodynamic torque converters in both Heuler and Haller include a turbine driven by an impeller in a housing. (*See, e.g.*,

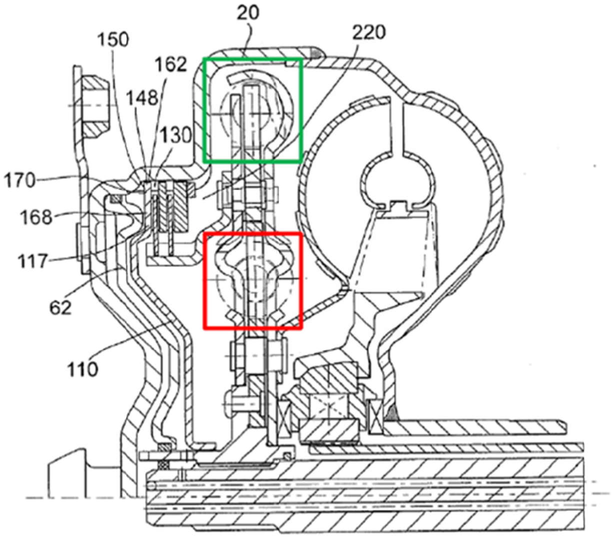
Ex. 1018, [0044–45]; Ex. 1004, 10:1–2.) Thus, it is my opinion that the combination of Heuler and Haller renders obvious element 1[b].

**Claim 1[c]: in which a torsional vibration damper (16) with multiple of damper stages (14, 15)**

237. Section VI.A above details the damper stages in the ’374 patent. Heuler discloses several examples of torsional vibration dampers with multiple stages. Heuler’s two damper stages—annotated with red and green in Fig. 11—correspond with the first 14 and second 15 damper stages of the ’374 patent:

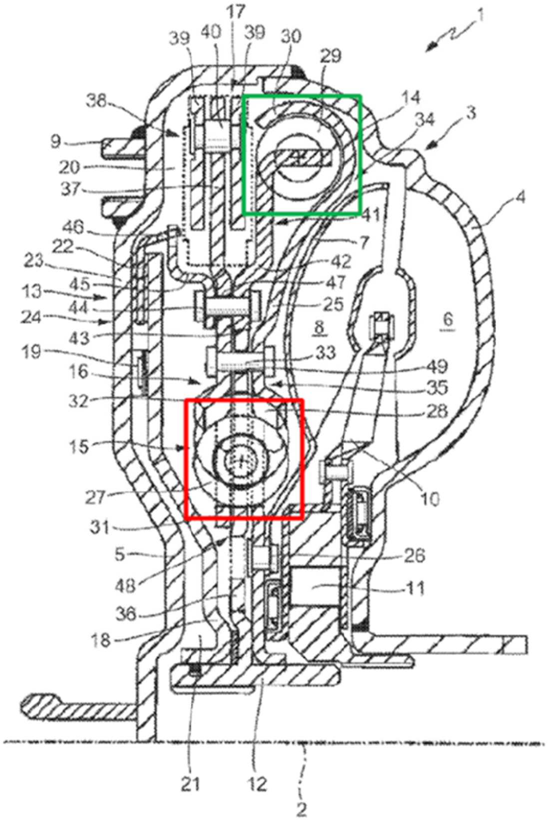


**’374 Patent**

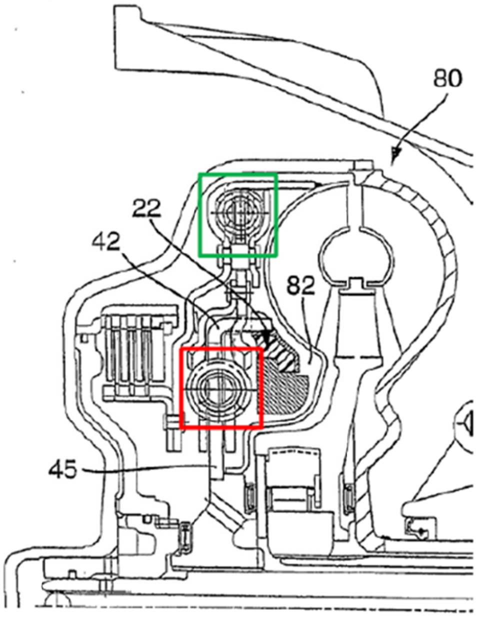


**Heuler Fig. 11**

238. Haller also discloses several examples of torsional vibration dampers with multiple stages, as shown in this portion of Fig. 8 with the damper stages identified in green and red:



**’374 Patent**



**Haller Fig. 8**

239. Haller’s two damper stages in Fig. 8 correspond with the first 14 and second 15 damper stages of the ’374 patent.

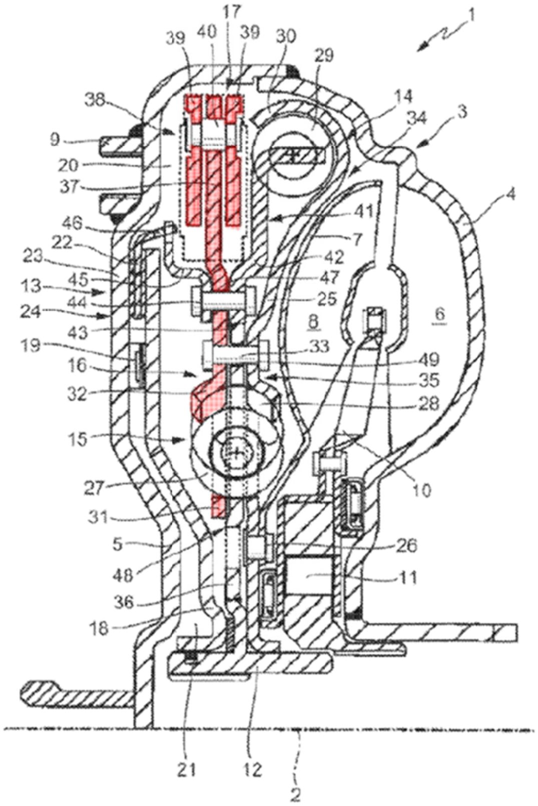
240. Thus, it is my opinion that the combination of Heuler and Haller renders obvious element 1[c].

**Claim 1[d]: a torsional vibration absorber (17)**

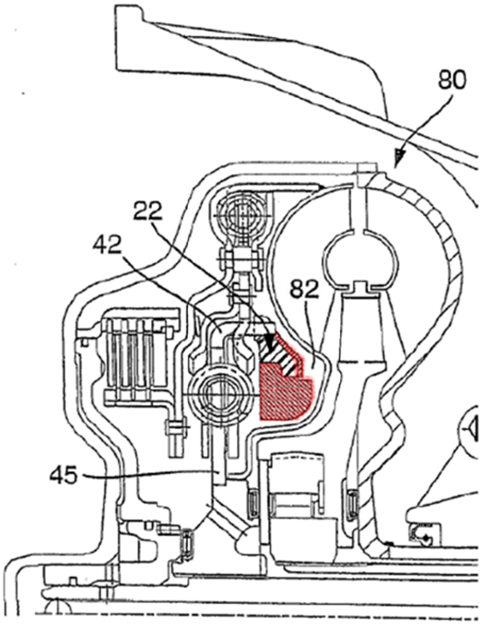
241. Heuler does not disclose torsional vibration absorbers. But,

as discussed above in Section VI.A, Haller discloses torsional vibration absorbers, including centrifugal force pendulums.

242. Haller's spring-mass system in Fig. 8 is shown in red compared with the torsional vibration absorber of the '374 patent:



**'374 Patent**



**Haller Fig. 8**

243. As explained above, it would have been obvious to a PHOSITA to apply Haller's torsional vibration absorber to a torque converter with the multi-stage damper in Heuler Fig. 11 because the benefits of Haller's torsional vibration absorbers could be predictably applied to other torque converters.

244. In particular, incorporating Haller's torsional vibration absorber into Heuler's torque converter would yield the predictable result of reducing rotational vibrations. Thus, it is my opinion that the combination of Heuler and Haller renders obvious element 1[d].

### Claim 1[e]: and a lock-up clutch (13) are additionally installed

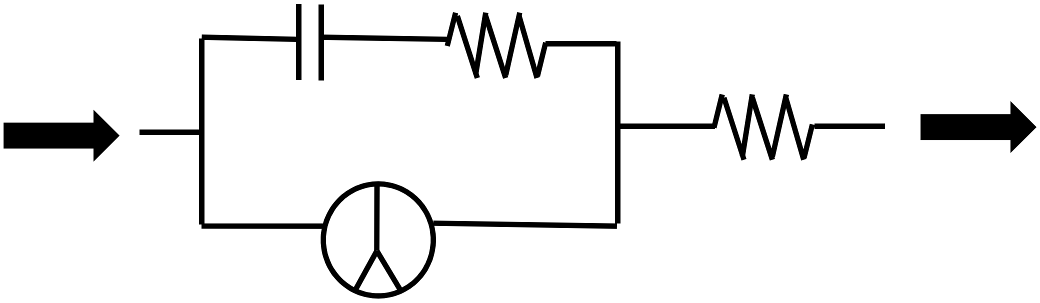
245. The torque converters in Heuler and Haller both include a lock-up clutch. (*See, e.g.*, Ex. 1018, [0017] (describing bridging clutch, *i.e.*, lock-up clutch); Ex. 1004, 10:25 ("Hydrodynamic torque converter 30 furthermore possesses a converter lockup clutch 46.").) Thus, it is my opinion that the combination of Heuler and Haller renders obvious element 1[e].

### Claim 1[f]: wherein a first damper stage (14) and a second damper stage (15) are disposed between the lock-up clutch (14) and an output hub (12),

246. Claim 1[f] describes a first torque path where torque passes through both damper stages when transferred from the lock-up clutch 14 to the output hub 12.

247. Heuler Fig. 11 embodies torque paths similar to those described in the '374 patent: the first and second energy-storage devices

are connected to each other in series and are disposed between the lock-up clutch 48 and the output hub as depicted below:



248. Thus, it is my opinion that the combination of Heuler and Haller renders obvious element 1[f].

**Claim 1[g]: the second damper stage (15) is disposed between the turbine (7) and the output hub (12) and**

249. Claim 1[g] describes a second torque path where torque passes through the second damper stage 15 when transferred from the turbine 7 to the output hub 12.

250. As noted above, Heuler Fig. 11 describes torque paths similar to those described in the ’374 patent. In Heuler Fig. 11, when the lock-up clutch is open, torque travels from the turbine to the output hub through the second damper stage. Thus, it is my opinion that the combination of Heuler and Haller renders obvious element 1[g].

**Claim 1[h]: the torsional vibration absorber (17) is parallel to both damper stages (14, 15).**

251. Haller explicitly teaches that torsional vibration absorbers such as spring-mass cancellers can be connected directly to the transfer element between the damper stages. (Ex. 1004, 12:5–6.)

252. It would have been obvious for a PHOSITA to modify Heuler Fig. 11 to add a torsional vibration absorber connected to Heuler's plates between the damper stages because Haller teaches that such parallel connections are beneficial, for example, by reducing elasticity. (Ex. 1004, 3:1–5.)

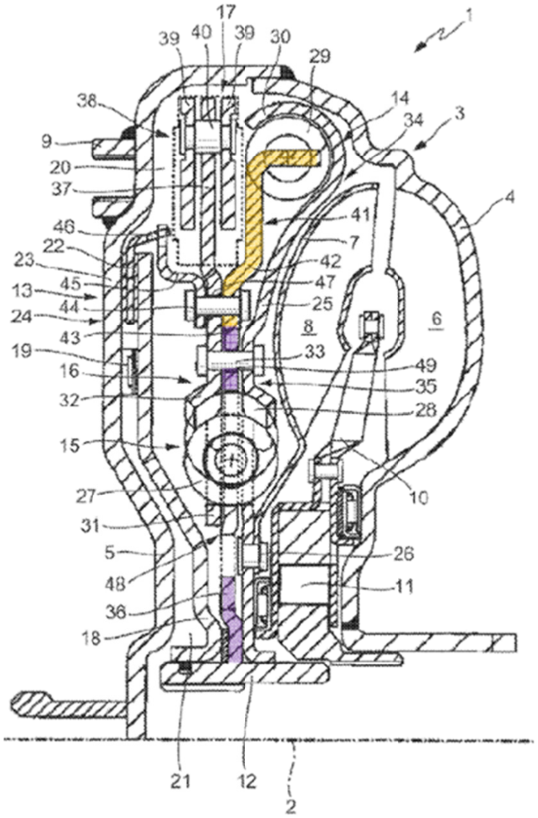
253. And, the observations in Haller regarding the benefits of parallel connection are applicable to any point of connection: to a PHOSITA, it does not matter where the absorber is placed: as long as it is connected to the same components, it will function in the same manner if the masses are the same distance from the axis of rotation.

254. Furthermore, incorporating Haller's torsional vibration absorber into a torque converter would yield the predictable result of reducing rotational vibrations because Haller itself teaches that the cancellers can be arranged in either series or parallel, indicating that this is simply a matter of design choice for a PHOSITA. (Ex. 1004, 8:24–

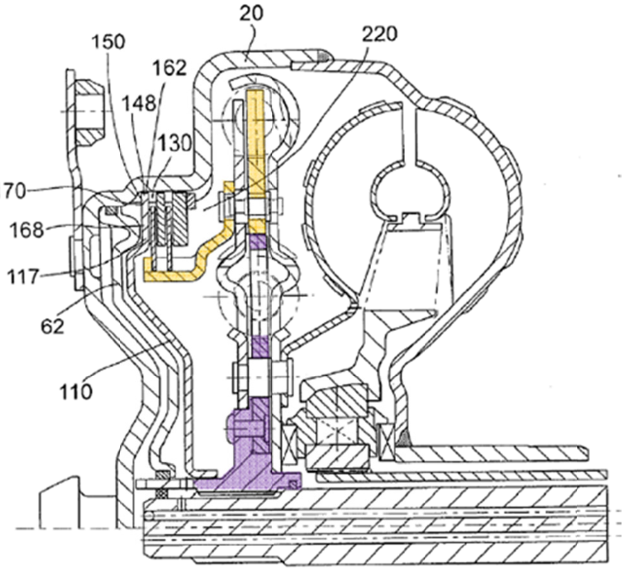
26.) Thus, it is my opinion that the combination of Heuler and Haller renders obvious element 1[h].

> **Claim 2: The hydrodynamic torque converter (1) according to claim 1, wherein an input part (41) of the first damper stage (14) and an output part (48) of the second damper stage (15) are centered on one another.**

255. Heuler's torque converter, as modified in view of Haller to include a torsional vibration absorber mounted on the transfer element, has an input part of the first damper stage concentrically mounted on the output of the second damper stage:



**'374 Patent**

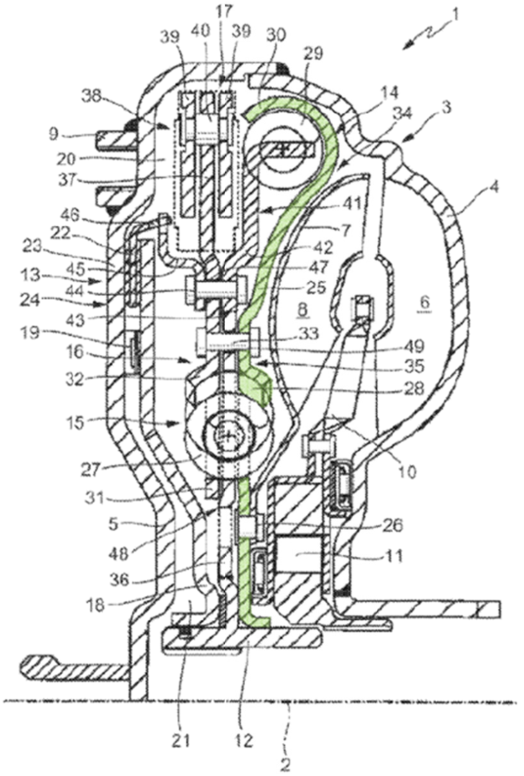


**Heuler Fig. 11**

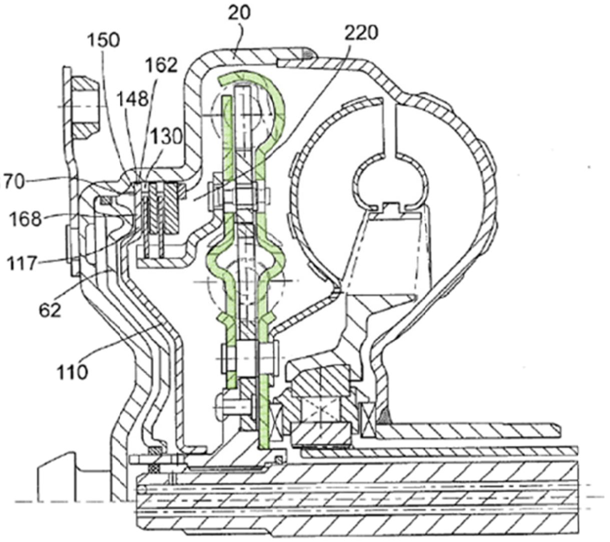
256. Thus, it is my opinion that the combination of Heuler and Haller renders obvious claim 2.

> **Claim 3: The hydrodynamic torque converter (1) according to claim 1, wherein a disk part (25) is allocated to two damper stages (14, 15) as one piece.**

257. Heuler's torque converter, as modified in view of Haller to include a torsional vibration absorber mounted on the transfer element, has a disk part allocated to two damper stages:



**'374 Patent**



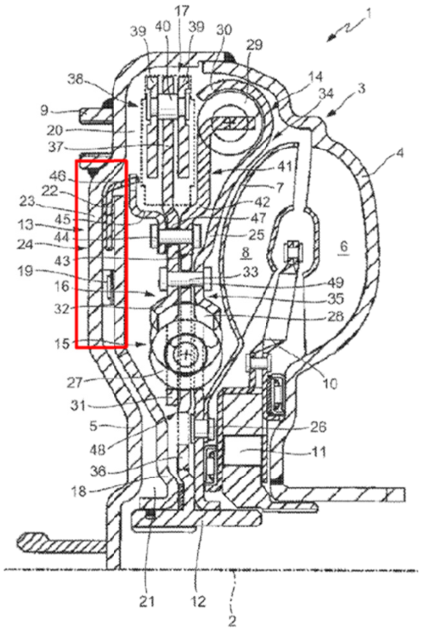
**Heuler Fig. 11**

258. Thus, it is my opinion that the combination of Heuler and Haller renders obvious claim 3.

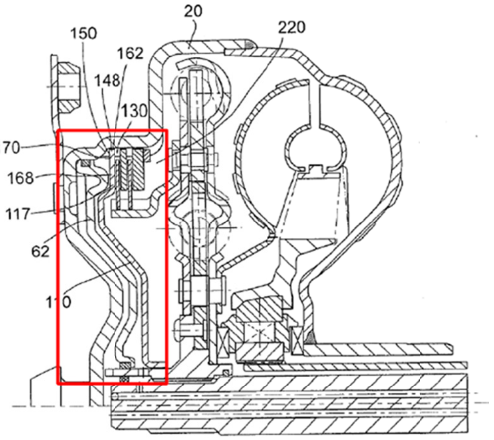
> **Claim 10: The hydrodynamic torque converter (1) according to claim 1, wherein the lock-up clutch (13) in a closed state is axially mounted in a pocket (24) formed in a housing wall (23) radially inward of fastening means (9) provided on external part of the torque converter (1).**

259. Heuler's torque converter, as modified in view of Haller to include a torsional vibration absorber mounted on the transfer element, has a clutch axially mounted in a pocket formed in the housing wall radially inside of the fastening bracket.

260. Moreover, in Heuler Fig. 11, it appears that substantially all components of the lock-up clutch are disposed within the pocket:



**'374 Patent**



**Heuler Fig. 11**

261. Indeed, this orientation was well-known. (*See, e.g.*, Ex. 1015, Fig. 1; Ex. 1016, Fig. 5; Ex. 1017, Fig. 1.) Thus, it is my opinion that the combination of Heuler and Haller renders obvious claim 10.

**Claim 14: The hydrodynamic torque converter (1) according to claim 1, wherein in the closed state of the lock-up clutch (13) the torsional vibration absorber (17) acts between both damper stages (14, 15).**

262. Claim 14 requires that the torsional vibration absorber act between both damper stages when the lock-up clutch is closed.

263. Heuler's torque converter, as modified in view of Haller (claim 1 discussion) teaches two damper stages in series and a torsional vibration absorber connected between them. Haller specifically suggests that arrangement, stating that the spring-mass system "is arranged between the first torsional damper stage and the second torsional damper stage." (Ex. 1004, 4:4–5.)

264. With that arrangement, when the lock-up clutch is closed, the torsional vibration absorber acts between both damper stages. Thus, it is my opinion that the combination of Heuler and Haller renders obvious claim 14.

**Claim 15: The hydrodynamic torque converter (1) according to claim 1, wherein the torsional vibration absorber (17) is connected non-rotatably with the turbine (7).**

265. Heuler's torque converter, as modified in view of Haller (claim 1 discussion) teaches this feature because the turbine is connected non-rotatably with Heuler's transfer elements (green plates in claim 3 discussion), and the absorber would be connected to these transfer elements. Thus, it is my opinion that the combination of Heuler and Haller renders obvious claim 15.

**Claim 16: The hydrodynamic torque converter (1) according to claim 15, wherein in the opened state of the lock-up clutch (13) the torsional vibration absorber (17) is connected non-rotatably with the turbine (7).**

266. Heuler's torque converter, as modified in view of Haller (claim 1 discussion) teaches this feature because the turbine is connected non-rotatably with Heuler's transfer elements (green plates in claim 3 discussion) when the lock-up clutch is opened, and the absorber would be connected to these transfer elements. Thus, it is my opinion that the combination of Heuler and Haller renders obvious claim 16.

### H. Ground 8: Claim 4 Is Obvious Over Heuler, Haller and Eckel

267. Heuler as modified by Haller, includes a torsional vibration absorber (Section VI.G). Haller refers to centrifugal force pendulums as examples of cancellers but does not expressly describe the spring-mass system 22 as a centrifugal force pendulum with multiple masses. (Ex. 1004, 2:15–20.) Haller specifically refers to DE 196 04 160 as a prior art canceller, and the U.S. equivalent, Eckel, teaches centrifugal force pendulums with multiple masses. (Ex. 1011, Fig. 1.)

268. It would have been obvious to a PHOSITA to apply Eckel's centrifugal force pendulum to a torque converter with multi-stage damper as in Heuler and Haller because the benefits of Eckel's centrifugal force pendulum could be predictably applied to any rotating machine with order excitation, such as a torque converter.

269. In particular, incorporating Eckel's centrifugal force pendulum into a torque converter would yield the predictable result of reducing rotational vibrations. Indeed, Haller specifically suggests using Eckel as a canceller. (Ex. 1004, 2:17.) And, Haller teaches using absorbers at various locations. (Ex. 1004, Figs.)

270. In view of the detailed discussion below and in light of the specification of the ’374 patent, it is clear that the claims of the ’374 patent simply recite prior art elements that function predictably in their known manner.

**Claim 4[a]: The hydrodynamic torque converter (1) according to claim 1, wherein the torsional vibration absorber (17) comprises a plurality of absorber masses (39), and**

271. Haller and Eckel disclose torsional vibration absorbers. Eckel’s centrifugal force pendulum includes a plurality of absorber masses. (Ex. 1011, Fig. 1.) Thus, it is my opinion that the combination of Heuler, Haller and Eckel renders obvious element 4[a].

**Claim 4[b]: a mounting part (37) of the torsional vibration absorber (17) forms a disk part (31) of an input part (35) of the second damper stage (15).**

272. When Heuler’s torque converter in Fig. 11 is modified as discussed above for claim 1 to connect a torsional vibration absorber to Hueler’s transfer element, the mounting part of the torsional vibration absorber is a disk of the transfer element. And the transfer element is the output of the first damper stage and the input of the second damper stage. Thus, it is my opinion that the combination of Heuler, Haller and Eckel renders obvious element 4[b].

### I. Ground 9: Claims 11–13 Are Obvious Over Heuler, Haller, MacDonald, and Schierling

273. As noted above, it would have been obvious to a PHOSITA to incorporate combine Heuler and Haller. Although these documents do not illustrate a lock-up clutch mounted on the housing of the torque converter as recited in claim 11, there are a number of lock-up clutch mounting designs, and it was well-known to those skilled in the art that they could be substituted for one another with known trade-offs.

274. The ’374 patent uses a two-way hydrodynamic torque converter with a two-faced friction plate so the piston is connected to the housing, an orientation well-known in the art as shown in MacDonald. (Ex. 1026, Fig. 1.) (*See also* (Ex. 1027, [0029]; Ex. 1028, Fig. 1, [0051] and [0060]; Ex. 1029, [0014].)

275. A PHOSITA would have been motivated to modify the lock-up clutch in Heuler with the mounted type of lock-up clutch in MacDonald because the benefits of MacDonald’s lock-up clutch design could be predictably applied to any torque converter and a PHOSITA would have a reasonable expectation of success in making that modification because it merely involves using MacDonald’s lock-up clutch design for its intended purpose.

**Claim 11[a]: The hydrodynamic torque converter (1) according to claim 10, wherein the lock-up clutch (13) is formed out of a piston (18) centered on the output hub (12) and mounted non-rotatably and axially displacably on the housing (3), and**

276. The lock-up clutch in Heuler Fig. 11 is formed out of a piston 62 centered on the output, as is apparent from comparing Heuler Fig. 11 with Heuler Fig. 12, which shows "centering of the piston on the drive-side housing hub". (Ex. 1018, Fig. 11, Fig. 12, [0033].)

277. And, MacDonald teaches a lock-up clutch design with a weld (73) mounting the piston (60) of the lockup clutch to the housing (12). (Ex. 1026, Fig. 1).) Thus, it is my opinion that the combination of Heuler, Haller, and MacDonald renders obvious element 11[a].

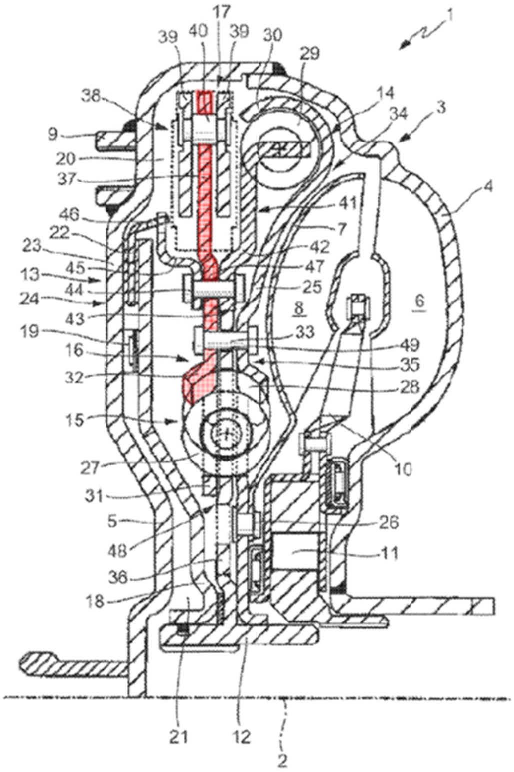
**Claim 11[b]: axially pressurizes a friction plate (22) that can be clamped between said piston and said housing (3) to develop a frictional engagement.**

278. The bridging clutch 48, *i.e.*, lock-up clutch, in Heuler Fig. 11 axially pressurizes a friction plate between the piston and housing to develop a frictional engagement. (Ex. 1018, Fig. 11, [0053] (describing friction linings and surfaces interacting).) Thus, it is my opinion that the combination of Heuler, Haller, and MacDonald renders obvious element 11[b].

**Claim 12: The hydrodynamic torque converter (1) according to claim 11, wherein a mounting part (37) of the torsional vibration absorber (17) is disposed axially between lock-up clutch (13) and the first damper stage (14).**

279. Claim 12 specifies that the mounting part of the torsional vibration absorber is located axially between the lock-up clutch and the first damper stage, as shown in Fig. 1 of the ’374 patent.

280. Heuler Fig. 11, as modified by Haller in the discussion of claim 1[d] above and by MacDonald for claim 11, renders obvious a torque converter that combines a torsional vibration absorber with a multi-stage damper. And, Haller informs a PHOSITA that the mounting part of the absorber can be disposed at different locations within the torque converter, including between the lock-up clutch and the damper stages in Fig. 7. Below, the absorber mounting parts of the ’374 patent and Haller are annotated in red to illustrate their location axially between the lock-up clutches and the damper stages:



**’374 Patent**

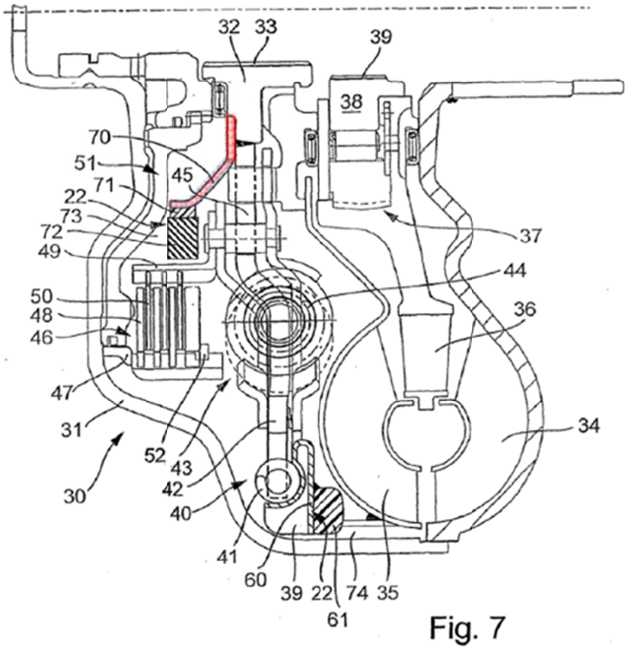
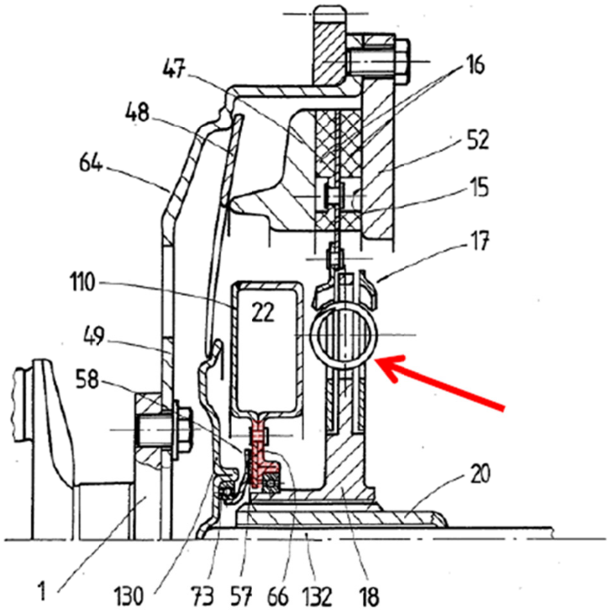


Fig. 7

**Haller Fig. 7**

281. In addition, the Schierling references teach that it was known to mount a torsional vibration absorber on the output of a damper stage. Although the Schierling references are directed to a manual transmission rather than an automatic transmission, Schierling Fig. 6 from Ex. 1022 shows that the housing (partially red in the figure below) of the compensating inertial mass 22 (a type of torsional vibration absorber – see below) is located axially between the pressure spring 48 and release element 130 and the damper stage (indicated by red arrow).

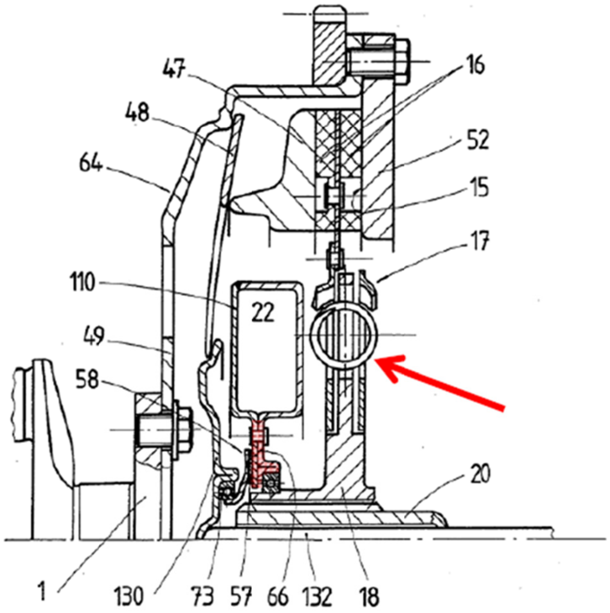


**Schierling ’894 Fig. 6**

282. And, it was well-known to a PHOSITA that pendulum-type torsional vibration absorbers can be used in both manual transmissions as well as in automatic transmissions. In further support of this combination, background reference Speckhart explicitly describes using absorbers in all types of internal combustion engines, noting that the absorber can be used with components from either type of engine, as long as it is rotatably driven by a crankshaft. (Ex. 1012, 3:4–21.) In other words, the function of the pendulum is the same in both environments.

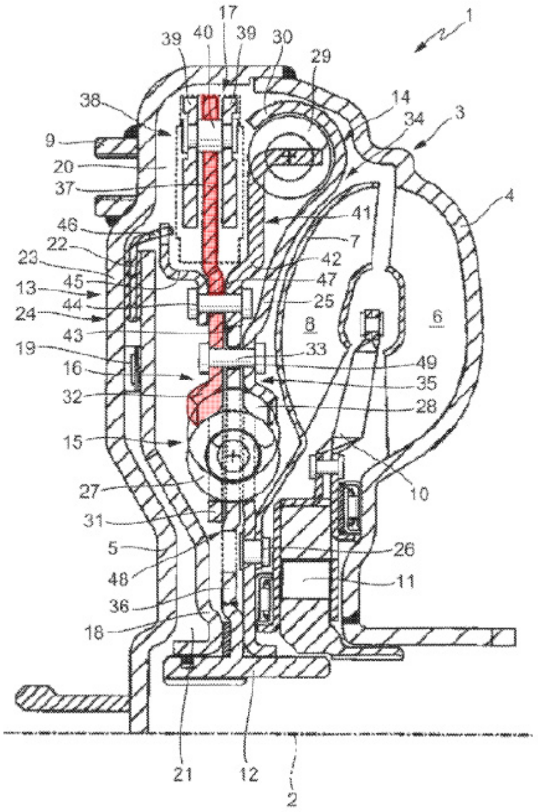
283. The Schierling references are all based on the same internal priority application, Schierling ’553, which includes the disclosures that were divided into the Schierling ’894 and ’915 published applications. Thus, it is my opinion that it would have been obvious to PHOSITA that their teachings are combinable and should be considered together.

284. Like Haller, Schierling also teaches that a torsional vibration absorber can be mounted in the axial space on either side of a damper 8. (Ex. 1022, Figs. 3, 6; Ex. 1024, Figs. 5, 12.) Schierling’s absorber—compensating inertial mass 22—is a pendulum absorber. (Ex. 1023, Fig. 1; Ex. 1024, Figs. 1, 2.) As shown in Schierling ’894 (Ex. 1022) Fig. 6 (corresponding to Schierling ’553 (Ex. 1024) Fig. 12), mounting part (red) for the absorber 22 is located axially between (A) the clutch 58, pressure spring 48, and release element 130, all located on the crankshaft side, and (B) the damper 8 (indicated by red arrow), located on the output side:

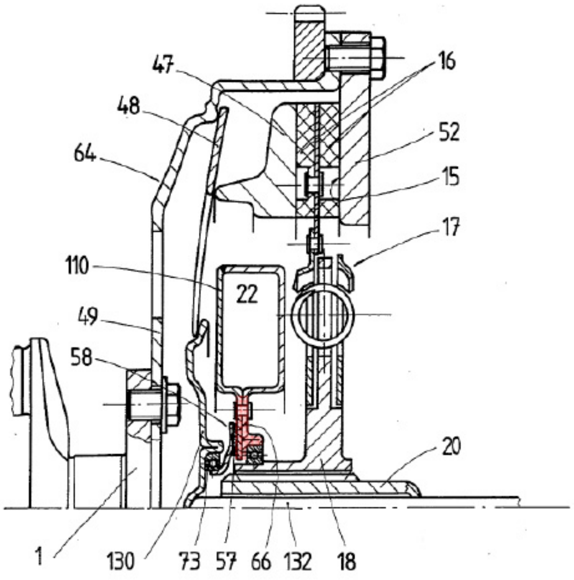


**Schierling '894 Fig. 6**

285. That location of the pendulum in Schierling Fig. 6 in Ex. 1022 corresponds to the axial space between the lock-up clutch and the damper stage in an automatic transmission, which is the same orientation recited in claim 12 as can be seen in this comparison of the manual transmission of Schierling and the '374 patent:



**’374 Patent**



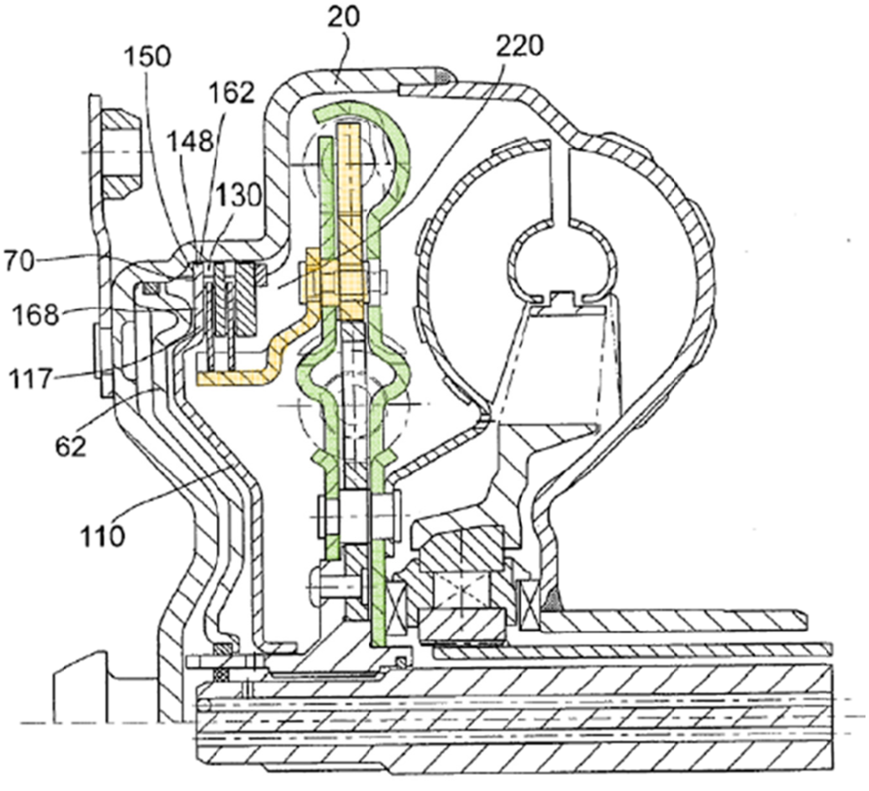
**Schierling ’894 Fig. 6**

286. As evidenced by Haller and Schierling, disposing the absorber axially on one side of a damper or the other does not affect the function or performance of the absorber—the choice is simply a matter of where to place the absorber in the torque converter. Indeed, Ex. 1025 provides further proof that a tuned-mass damper 30 (such as the absorber used in Haller) can be located in different places in a driveline with a clutch disk, either axially upstream the clutch disk or axially downstream the clutch disk. (Ex. 1025, Fig. 5, page 13.)

287. Consistent with Haller's and Schierling's various examples of where the absorber can be mounted, a PHOSITA would understand that it does not matter where the absorber is placed: as long as it is connected to the same components, it will function in the same manner if the masses are the same distance from the axis of rotation. Thus, it is my opinion that the combination of Heuler, Haller, MacDonald, and Schierling renders obvious claim 12.

> **Claim 13: The hydrodynamic torque converter (1) according to claim 12, wherein between the friction plate (22) and an input part (41) of the first damper stage (14) transition connections (44) are formed, which reach through circular segment-shaped openings (47) of the mounting part (37).**

288. When Heuler is modified in view of Haller and Schierling as discussed above for claim 12, the green flange on the left forms the mounting part for the absorber. Heuler teaches that the input (yellow) between the lock-up clutch and first damper stage extends through openings provided in a flange (green) shared by the two damper stages:



**Heuler Fig. 11**

289. As a result, the mounting part (green) has the openings for the input (yellow) of the first damper stage, as recited in claim 13. (*See also* Ex. 1022, 5 (cover plates 36, 37 have axial expansion forming housing for compensating flywheel), Fig. 2.)

290. And, a PHOSITA could have easily designed the openings in any appropriate shape, including circular segment-shaped, which would have been the obvious choice of window shape for circular parts that rotate around the same axis. (*See* Ex. 1003, Figs. 8 and 10 (circular-

segment shaped openings).) Thus, it is my opinion that the combination of Heuler, Haller, MacDonald, and Schierling renders obvious claim 13.

## VII. CONCLUDING STATEMENTS

291. In signing this declaration, I understand 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 acknowledge that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

292. I declare that all statements made herein of my 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 knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. § 1001.

293. I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

Executed on 12/5/2016

Steven Shaw

# APPENDIX A

**STEVEN W. SHAW** 12/05/2016

Mechanical and Aerospace Engineering Department
Florida Institute of Technology
150 W. University Blvd.
Melbourne, FL 32901

Phone: (321) 674-8698
E-mail: sshaw@fit.edu

## EDUCATION

Ph.D., Theoretical and Applied Mechanics, Cornell U., Ithaca, NY, 1983, Advisor: P. J. Holmes
M.S.E., Applied Mechanics, U. of Michigan, Ann Arbor, MI, 1979
A.B., Physics, U. of Michigan, Flint, MI, 1978

## PROFESSIONAL EXPERIENCE

*Academic Employment*

Jan. 2016-present, Harris Professor, Department of Aerospace and Mechanical Engineering, Florida Institute of Technology (Florida Tech), Melbourne, FL
2011-present, University Distinguished Professor, Department of Mechanical Engineering, Michigan State University (MSU), East Lansing, MI (on leave in 2016)
2014-present, Adjunct Professor of Physics and Astronomy, MSU
1994-2011, Professor, Department of Mechanical Engineering, MSU
1991-93, Associate Professor, Department of Mechanical Engineering, University of Michigan
1987-1991, Associate Professor, Department of Mechanical Engineering, MSU
1990, Acting Associate Chairperson, Department of Mechanical Engineering, MSU
1984-1987, Assistant Professor, Department of Mechanical Engineering, MSU
1983-1984, Assistant Professor, School of Engineering, Oakland University, Rochester, MI

*Visiting Positions*

July-August 2008, Visiting Professor, Department of Mechanical Engineering, McGill University, Montreal, QC, Canada
January-June 2004, Visiting Professor, Department of Mechanical Engineering, University of California-Santa Barbara, CA
Summers 2000, 2002-05, Visiting Research Scientist, Department of Mechanical Engineering, University of Michigan, Ann Arbor, MI
January-June, 1989, Visiting Associate Professor, Applied Mechanics, California Institute of Technology, Pasadena, CA
July 1984, Visiting Assistant Professor, Department of Aerospace Engineering and Mechanics, University of Minnesota, Minneapolis, MN
June 1983, Visiting Assistant Professor, Department of Theoretical and Applied Mechanics, Cornell University, Ithaca, NY

*Other Positions*

August 2015-January 2016, Research Professor, Florida Tech, Melbourne, FL
1992-present, Vice-President and Board Member, SE Tools, Lapeer, MI (family business)
1991-present, President, Steven W. Shaw and Associates, Inc. (consulting company)

*Consulting* (through Steven W. Shaw and Associates, Inc., unless otherwise indicated)

2016, pendulum vibration absorbers, for Valeo through Florida Tech Consulting
2015-present, technical expert, IP issues for vibration absorbers
2013, technical expert, NineSigma, machine design brainstorming
2003-2008, technical expert for legal firms on design IP issues
1984-1986, 1993-2002, consultant, Ford Motor Company, assist with the design of dynamic vibration absorbers, and analytical support for noise and vibration issues

*Teaching Experience*

dynamics, vibrations, controls, dynamical systems, design projects, engineering analysis, statics, machine design, strength of materials

*Research Interest Areas*

Fundamental: nonlinear dynamics and vibrations, exploitation of nonlinear behavior in the design of mechanical systems, nonlinear resonances, effects of noise in nonlinear oscillations
Applications: resonant micro/nano-electromechanical systems for sensing and signal processing, vibration absorbers for rotating machinery, nonlinear normal modes, mode localization, structural vibration and control, chaotic motions in mechanical systems, vibro-impact dynamics, mechanism dynamics, vehicle dynamics and stability

## HONORS AND AWARDS

N. O. Myklestad Award, ASME Design Division, “Presented in recognition of a major innovative contribution to vibration engineering,“ 2013
Promoted to University Distinguished Professor, MSU, 2011
University Distinguished Faculty Award, MSU, 2008
Withrow Distinguished Senior Scholar Award, College of Engineering, MSU, 2002
Certificate of Appreciation, “Rattle Severity Detection Using Spectral Data,“ Intellectual Property Group, Visteon Corporation, 2000
Arch T. Colwell Merit Award, SAE, 1997, for the paper marked + in the publication list below.
Fellow, ASME, elected 1995
Westinghouse Distinguished Lecturer, Department of Mechanical Engineering and Applied Mechanics, University of Michigan, Ann Arbor, MI, September, 1990
Henry Ford Customer Satisfaction Award, Ford Motor Company, with 5 others, for “Development of CAE Tools for Squeak and Rattle Prevention,” 1986
Henry Hess Award, ASME, for the two -part paper marked * in the publication list below, for best paper by an author under 31 years of age, 1986
James B. Angell Scholar, College of Literature Science & Arts, U. of Michigan, 1976, 1978

## SPECIAL LECTURES

Advanced School, 6 lectures for The Art of Modeling Mechanical Systems, International Centre for Mechanical Sciences (CISM), Udine, Italy, 2015
Invited Tutorial, “Nonlinear Modal Interactions,” IMAC XXXIII and XXXIV, Orlando, FL, 2015, 2016
N. O. Myklestad Award Keynote Lecture, 25th ASME Conference on Vibration and Noise, IDETC,

Portland, OR, 2013

Keynote Lecture, 1st Annual Review Meeting for EPSRC Project: Engineering Nonlinearity, Jesus College, Cambridge University, UK, 2013

Keynote Lecture, AUTOMATION 2012, Chang Gung University, Taiwan, 2012

Keynote Lecture, 24th ASME Conference on Vibration and Noise, IDETC, Chicago, IL, 2012

Keynote Lecture, 4th International Conference on Localization, Energy Transfer and Nonlinear Normal Modes in Mechanics and Physics, Haifa, Israel, 2012

Advanced School, 6 lectures for Modal Analysis of Nonlinear Mechanical Systems, International Centre for Mechanical Sciences (CISM), Udine, Italy, 2012

Plenary Lecture, International Modal Analysis Conference XXVIII, Jacksonville, FL, 2010

Advanced School, 6 lectures for Exploiting Nonlinear Behaviour in Structural Dynamics, CISM, Udine, Italy, 2010

Keynote Lecture, First ASME Dynamic Systems and Control Conference, Ann Arbor, MI, 2008

Symposium Invited Speaker, First ASME Conference on Smart Materials, Adaptive Structures, and Intelligent Systems, Symposium on Nonlinear Dynamics and Passive/Adaptive Controls, Ellicott City, MD, 2008

Symposium Invited Speaker, 42$^{nd}$ Meeting, Society of Engineering Science, Symposium on Nonlinear Localization and Targeted Energy Transfer Phenomena in Dynamical Systems, Champaign-Urbana, IL, 2008

Plenary Lecture, Advanced Problems in Mechanics – APM2008, St. Petersburg, Russia, 2008

Engineer's Edge Learning Series, Chrysler Technology Center, Auburn Hills, MI, joint with A. G. Haddow and B. Geist, 2007

Keynote Lecture, 2nd International Conference on Nonlinear Normal Modes and Localization in Vibrating Systems, Samos, Greece, 2006

Symposium Invited Speaker, Minisymposium on Reduced-Order Modeling, Fifth Euromech Nonlinear Dynamics Conference, ENOC2005, Eindhoven, 2005

Keynote Lecture, JSME Minisymposium on Nonlinear Dynamics and Chaos in Mechanical Systems, Tokyo, Japan, 2001

Keynote Lecture, IUTAM Symposium on Nonlinear Dynamics and Chaos in Mechanics, Ithaca, NY, 1997

Inaugural Sethna Lecture, Department of Aerospace Engineering and Mechanics, University of Minnesota, Minneapolis, MN, 1994

Westinghouse Distinguished Lectures, Department of Mechanical Engineering and Applied Mechanics, two lectures, University of Michigan, Ann Arbor, MI, September, 1990

Chaos: Applications in Engineering and Science, one of six invited speakers for a one-day Workshop at University College London, 1990

## PROFESSIONAL AFFILIATIONS AND ACTIVITIES

*Society Memberships*

The American Society of Mechanical Engineers (ASME), 1982-present

The Society for Experimental Mechanics, 2011-present

The Society for Industrial and Applied Mathematics (SIAM), 1983-2000, 2009-2013

The Society of Automotive Engineers (SAE), 1995-2010

The American Academy of Mechanics (AAM), 1983-2002

*Professional Committee Activities*

Member, Steering Committee, EPSRC Engineering Nonlinearity Grant; oversight of a £4.5M grant Involving five universities and eight companies in the UK, 2013-2017
Member, Technical Committee on Vibration and Sound, Design Division, ASME, 2006-2012
Vice Chair, SIAM Dynamical Systems Activity Group, 2010-2011

*Editorial Service*

Associate Editor, *SIAM Journal on Applied Dynamical Systems,* 2012-present
Contributing Editor, *Nonlinear Dynamics*, Springer, 1990-present
Associate Technical Editor, *Journal of Vibration and Acoustics*, 2008-2014
Editorial Board, *Communications in Nonlinear Science and Numerical Simulation*, Elsevier Science, 2001-2009
Editorial Board, *Journal of Sound and Vibration*, Academic Press, 1995-2007
Editorial Board, *Archive of Applied Mechanics*, Springer-Verlag, 1997-2003
Editorial Advisory Board, *Encyclopedia of Vibration*, Academic Press, appeared in 2001
Editorial Board, *Dynamics and Stability of Systems*, Carfax, 1995-2000
Editorial Board, *International Journal of Bifurcation and Chaos*, World Scientific, 1992-98
Associate Technical Editor, *Journal of Applied Mechanic*s, ASME, 1994-97

*Paper Refereeing*

*Journal of Applied Physics; IEEE Transactions on Mechatronics; SIAM Journal on Applied Dynamical Systems; Experimental Mechanics; Journal of Engineering Mathematics; Mechanics Research Communications; Sensors and Actuators A: Physical; Electron Device Letters; Journal of Physics A: Mathematical and Theoretical; Journal of Physics: Condensed Matter; Journal of Microelectromechanical Systems (JMEMS); Journal of Micromechanics and Microengineering (JMM)*; *ASME Journal of Vibration and Acoustics*; *ASME Journal of Computational and Nonlinear Dynamics*; *International Journal of Bifurcation and Chaos*; *Journal of Guidance, Control, and Dynamics*; *Journal of Nonlinear Science*; *Nonlinear Dynamics*; *Physica D*; *Journal of Sound and Vibration (JSV)*; *ASME Journal of Dynamic Systems, Measurement and Control*; *ASME Journal of Applied Mechanics*; *Physics of Fluids*; *International Journal of Solids and Structures*; *Journal of Fluids and Structures*; *Meccanica*; IEEE *Transactions on Circuits and Systems*; SIAM *Journal on Applied Mathematics*; *Dynamics and Stability of Systems*; *International Journal of Mechanical Sciences*; *Journal of Vibration and Control*; *Proceedings of the Royal Society; Mechanism and Machine Theory; ASME Journal of Engineering for Gas Turbines and Power; Journal of Ship Research;* several ASME Conferences.

*Proposal Reviewing*

National Science Foundation (regularly), Army Research Office, Michigan Sea Grant Program, Science and Engineering Research Council-UK, US National Research Council, AFOSR, Australian Research Council, Ohio Board of Regents

*Outreach*

High School Engineering Institute, Organizer/ Lecturer, Mechanical Engineering Section, 2005, 2007-09, 2012-15
Spartan Engineering Teens, Organizer/Lecturer, Mechanical Engineering Section, 2011, 2016
High School Engineering Exploration, Organizer/Lecturer, Mechanical Engineering Section, 2010

*University Service*

Chairperson's Advisory Committee, MSU, 1988-91, 1994-97, 2003-07, 2010-15
Departmental/College Rating Committees, MSU, 1989-91, 1994-2002, 2004-15
College Rating Committee (for P&T), Chair, 2014
Departmental Chairperson Search Committee, Chair, 2009-10
Undergraduate Curriculum Committee, MSU, 1986-87, 1989, 1999-2001, 2008-09 (Chair)
Faculty Search Committees, MSU, chair of successful search for 4 new faculty members, 2007
Graduate Studies Committee, MSU, 1985-1991, 1996-98; chair, 1987-88, 1998-2002
Chair, Individual Reappointment/Promotion Committees; UM, 1991-93; MSU, 1994-2005
Co-Organizer, Mechanical Engineering Seminar Series, MSU, 1985-86, 1999-2002
Departmental Graduate Advisor, MSU, 1996-98
Chairperson's Advisory Committee, UM, 1993
Search Committee for Vice President of Research and Graduate Studies, MSU, 1987-90
Graduate Council, Oakland University, 1983-84

*Professional Service*

Co-organizer, with L. Rensen, Minisymposium, "Nonlinear Modes and Modal Interactions," IMAC XXXIV A Conference and Exposition on Structural Dynamics, Orlando, 2016
Scientific Committee Member, Sixth International Conference on Nonlinear Vibrations, Localization and Energy Transfer. Liège, Belgium, 2016
Panel Member, "Present and Future Challenges in Nonlinear Dynamics and Vibrations: From Theory to Design," IDETC, Boston, 2015
Member, NSF Committee on *Research Needs & Open Questions in Vibration Energy Transport & Dissipation*, A. Akay, Chair, 2015-16
Co-organizer, with K. Spak, Minisymposium, "Nonlinear Modal Interactions," IMAC XXXIII A Conference and Exposition on Structural Dynamics, Orlando, 2015
Co-organizer, with Jeff Rhoads, Minisymposium, "Applications of Resonance," USNCTAM, East Lansing, MI, 2014
Co-organizer, with Jeff Rhoads and Mohammad Younis, Minisymposium on "Micro- and Nano-Electro-Mechanical Systems," European Conference on Nonlinear Oscillations, Vienna, 2014
Co-Organizer, with J. Moehlis and W. Lacarbona, Symposium on Design of Dynamic Structures, Devices, and Systems, 1st ASME Dynamics for Design Conference (DFD), 2012
Organizing Committee, SIAM Conference on Applications of Dynamical Systems, 2011
Co-Organizer and Co-Chair, Funding Panel Session, SIAM Conference on Applications of Dynamical Systems, 2011
Program Committee, ASME Dynamic Systems and Control Conference, 2008, 2009
Scientific Committee, Symposium on Mechanics of Slender Structures (MoSS), University of Maryland, Baltimore County 2008
Co-Organizer, with O. Gottlieb, Min-symposium on "Nonlinear dynamics in nano- and micro-electromechanical systems," Sixth Euromech Conference on Nonlinear Vibrations, St. Petersburg, Russia, 2008
Organizing Committee, ASME International Conference on Micro and Nanosystems, 2007 ASME IDETC, September, Las Vegas, NV
Scientific Committee, The 2nd International Conference on Nonlinear Dynamics: KhPI 2007*,* in

honor of Alexander Lyapunov 150th Anniversary. National Technical University, Polytechnical Institute, Kharkov, Ukraine, 2007

Scientific Committee, International Conference on Material Theory and Nonlinear Dynamics, Hanoi, Vietnam, 2007

Organizing Committee, International Workshop on Applied Dynamical Systems – Mechanics, Turbulence, Knots, Cockroaches, and Chaos, Montreal, 2005

Co-Organizer, with O. Gottlieb, Min-symposium on "Nonlinear dynamics in nano- and micro-electromechanical systems," Fifth Euromech Conference on Nonlinear Vibrations, Eindhoven, 2005

Co-Organizer, with K. Turner and J. Moehlis, Mini-Symposium on "Nonlinear Dynamics of MEMS," SIAM Conference on Dynamical Systems, Snowbird, UT, 2005

Co-Organizer, with O. Gottlieb and K. Turner, Symposium on "Nonlinear dynamics, bifurcations and chaos in nano- and micro-electromechanical systems," 19th Biennial ASME Conference on Mechanical Vibration and Noise, Chicago, 2003

Co-Organizer, with C. Pierre, Symposium on "Nonlinear Normal Modes and Localization," 18th Biennial ASME Conference on Mechanical Vibration and Noise, Pittsburgh, 2001

Co-Organizer, with C. Pierre, Symposium on "Nonlinear Normal Modes and Localization," 17th Biennial ASME Conference on Mechanical Vibration and Noise, Las Vegas, 1999

Scientific Organizing Committee, IUTAM Symposium on Unilateral Multi-body Dynamics, Munich, August, 1998

Co-Organizer, with C. Pierre, Symposium on "Mode Localization and Nonlinear Normal Modes," 16th biennial ASME Conference on Mechanical Vibration and Noise, Sacramento, CA, 1997

Organizing Committee, Asia-Pacific Vibration Conference, held in Kitakyushu, Japan, November 14-18, 1993

Scientific Organizing Committee, IUTAM Symposium on Nonlinearity and Chaos in Engineering Dynamics, London, July 19-23, 1993

Co-Organizer and Chair, Invited Symposium on Nonlinear Dynamics, ASME Summer Meeting, Columbus, OH 1991

Session Chair, International Conference on Bifurcation and Chaos, Wurzburg, Germany, 1990

Organizer and Chair, Invited Mini-symposium on Nonlinear Mechanical Systems, SIAM Conference on Dynamical Systems, Orlando, FL 1990

Session Chair, Dynamics, Society of Engineering Science Meeting, Ann Arbor, MI, 1989.

Session Co-Chair, Chaotic Dynamics, IUTAM Symposium on Nonlinear Dynamics in Engineering Systems, Stuttgart, West Germany, 1989

Organizer, with F. Moon (Cornell) and R. Miller (USC), Symposium on Nonlinear Dynamics and Chaos, ASME/ASCE Mechanics Conference, San Diego, CA, 1989

Session Chair, Nonlinear Dynamics and Chaos, ASME/ASCE Mechanics Conference, San Diego, CA, 1989

Session Organizer and Chair, Modern Methods in Nonlinear Dynamics, Society of Engineering Science Meeting, Buffalo, NY, 1986

## INTELLECTUAL PROPERTY

US Patent 20150357992, *Frequency Divider Apparatus*, B. S. Strachan, K. Qalandar, S. Shaw, K. Turner, issued December 10, 2015.

US Patent 7584649, *Sensor with Microelectromechanical Oscillators*, S. W. Shaw, J. F. Rhoads, B. E. DeMartini, K. L. Turner, issued September 8, 2009

**JOURNAL PUBLICATIONS**

**Under review**

C. Chen, D. H. Zanette, D. Czaplewski, S. W. Shaw, and D. López, "Direct observation of coherent energy transfer in nonlinear micro-mechanical oscillators," submitted to *Nature*.

C. Cassella, S. Strachan, S. W. Shaw, and G. Piazza, "Phase Noise Suppression through Parametric Filtering," submitted to *Applied Physics Letters*.

L. L. Li, P. M. Polunin, S. Dou, O. Shoshani, B. S. Strachan, J. S. Jensen, S. W. Shaw, and K. L. Turner, "Tailoring the Nonlinear Response of MEMS Resonators Using Shape Optimization," submitted to *Applied Physics Letters*

**To appear**

P. Polunin and S. W. Shaw, "Self-Induced Parametric Amplification in Ring Resonating Gyroscopes," submitted to the *International Journal of Non-Linear Mechanics*

**2016**

C. Shi, S. W. Shaw, and R. G. Parker, "Vibration Reduction in a Tilting Rotor Using Centrifugal Pendulum Vibration Absorbers," *Journal of Sound and Vibration* **385**, pp. 55-68

O. Shoshani, D. Heywood, Y. Yang, T.W. Kenny, and S.W. Shaw, "Phase noise reduction in a MEMS oscillator using a nonlinearly enhanced synchronization domain," *Journal of Microelectromechanical Systems* **25**(5), pp. 870-876

Y. Yang, E. J. Ng, P. M. Polunin, Y. Chen, I. B. Flader, S. W. Shaw, M. I. Dykman, and T. W. Kenny, "Nonlinearity of Degenerately-Doped Bulk-mode Silicon MEMS Resonators," *Journal of Microelectromechanical Systems* **25**(2), pp. 859-869

O. Shoshani and S. W. Shaw, "Generalized Parametric Resonance," *SIAM Journal on Applied Dynamical Systems* **15**(2), pp. 767–788

P. M. Polunin, Y. Yang, M. I. Dykman, T. W. Kenny, and S. W. Shaw, "Characterization of MEMS Resonator Nonlinearities Using the Ringdown Response," *Journal of Microelectromechanical Systems* **25**(2), pp. 297-30

**2015**

O. Shoshani and S. W. Shaw, "Phase Noise Reduction and Optimal Operating Conditions for Synchronized Oscillators," *IEEE Transactions on Circuits and Systems* **63**(1), 1-11

S. Dou, B. S. Strachan, S. W. Shaw, J. S. Jensen, "Structural Optimization for Nonlinear Dynamic Response," invited paper for a theme issue of *Philosophical Transactions of the Royal Society* ***A*****373** no. 2051, 20140408

J. Issa and S. W. Shaw, "Synchronous and Non-synchronous Responses of Systems with Multiple Identical Nonlinear Vibration Absorbers," *Journal of Sound and Vibration* **348**, 105–125

**2014**

A. S. Alsuwaiyan and S. W. Shaw, "Non-synchronous and Localized Responses of Systems of Identical Centrifugal Pendulum Vibration Absorbers," *Arabian Journal for Science and Engineering* **39** (12), 9205-9217

K. Qalandar, B. S. Strachan, B. Gibson, M. Sharma, A. Ma, S. W. Shaw, and K. L. Turner, **"**Frequency Division Using a Micromechanical Resonance Cascade," *Applied Physics Letters* **105** 020451

B. J. Olson, S. W. Shaw, C. Pierre, C. Shi, and R. Parker, "Circulant Matrices and Their Application in Vibration Analysis," *Applied Mechanics Reviews* **66** 040803

**2013**

B. J. Vidmar, S. W. Shaw, B. F. Feeny, and B. K. Geist, "Nonlinear Interactions in Systems of Multiple Order Centrifugal Pendulum Vibration Absorbers," *Journal of Vibration and Acoustics* **135** 061012

B. S. Strachan, S. W. Shaw, and O. Kogan, "Subharmonic Resonance Cascades in a Class of Coupled Oscillators" *Journal of Computational and Nonlinear Dynamics* **8** 041015

K. Moran, C. Burgner, K. Turner, and S. W. Shaw, "A Review of Parametric Resonance in Microelectromechanical Systems," *Nonlinear Theory and Its Applications* **4**, 198-224

J. F. Rhoads, V. Kumara, S. W. Shaw, and K. L. Turner, "The Nonlinear Dynamics of Electromagnetically-Actuated Microbeam Resonators With Purely-Parametric Excitations," *International Journal of Nonlinear Mechanics* **55**, 70-89

C. Shi, R. G. Parker, and S. W. Shaw, "Tuning of Centrifugal Pendulum Vibration Absorbers for Translational and Rotational Vibration Reduction," *Mechanism and Machine Theory* **66**, 56-65

R. Monroe and S. W. Shaw, "Transient Dynamics of Centrifugal Pendulum Vibration Absorbers, Part I: Theory," *Journal of Vibration and Acoustics* **135** 011017

R. Monroe and S. W. Shaw, "Transient Dynamics of Centrifugal Pendulum Vibration Absorbers, Part II: Experimental Results," *Journal of Vibration and Acoustics* **135** 011018

**2012**

S. Gozen, B. J. Olson, S. W. Shaw, and C. Pierre, “Resonance Suppression in Multi-Degree-of-Freedom Rotating Flexible Structures Using Order-Tuned Absorbers,” *Journal of Vibration and Acoustics* **134** 061016

N. J. Miller and S. W. Shaw, “Escape Statistics for Parameter Sweeps Through Bifurcations,” *Physical Review E* **85** 046202

Z. Yie, N. J. Miller, S. W. Shaw, and K. L. Turner, “Parametric Amplification in a Resonant Sensing Array,” *Journal of Micromechanics and Microengineering* **22**, 035004

R. Monroe and S. W. Shaw, “Transient Dynamics of Nonlinear Oscillators,” *Nonlinear Dynamics* **67**, 2609-2619

B. Vidmar, B. F. Feeny, S. W. Shaw, A. G. Haddow, B. Geist, and N. J. Verhanovitz, “Effects of Coulomb Friction on Centrifugal Pendulum Vibration Absorbers,” *Nonlinear Dynamics* **69**, 589-600

N. J. Miller and S. W. Shaw, “Frequency Sweeping with Concurrent Parametric Amplification,” Journal *of Dynamic Systems, Measurement and Control* **134**, 021007

**2011**

R. Monroe, S. W. Shaw, B. Geist, and A. G. Haddow, “Accounting for Roller Dynamics in the Design of Bifilar Torsional Vibration Absorbers,” *Journal of Vibration and Acoustics* **133***,* 061002

**2010**

M. Dykman, J. Portman, M. Khasin, S. W. Shaw, “Spectrum of an Oscillator with Jumping Frequency and the Interference of Partial Susceptibilities,” *Physical Review Letters* **105**, 230601

J. F. Rhoads and S. W. Shaw, “Effects of Nonlinearity on Parametric Amplification,” *Applied Physics Letters* **96**, 234101

S. W. Shaw and B. Geist, “Tuning for Stability and Performance in Nearly-Tautochronic Torsional Vibration Absorbers,” *Journal of Vibration and Acoustics* **132**, 041005

J. Issa, R. Mukherjee, and S. W. Shaw, “Vibration Suppression in Structures Using Cable Actuators,” *Journal of Vibration and Acoustics* **132**, 031006

B. J. Olson and S. W. Shaw, “Nonlinear Behavior of Order-Tuned Absorbers for Cyclic Vibratory Systems,” *Nonlinear Dynamics* **60**, 149-182

J. F. Rhoads, S. W. Shaw, and K. L. Turner, “Nonlinear Dynamics and its Applications in Micro- and Nano-resonators,” invited review paper for the *Journal of Dynamic Systems, Measurement and Control* **132**, 034001

G. Bachar, E. Segev, O. Shtempluck, S. W. Shaw, and E. Buks, “Noise-Induced Intermittency in a

Superconducting Stripline Resonator," *European Physics Letters* **89** 17003

M. R. Jeffrey, M. diBernardo, A. R. Champneys, and S. W. Shaw, "Catastrophic Sliding Bifurcations: The Case of Superconducting Stripline Resonators," *Physical Review E* **81**, 016213; also selected for the February 1, 2010 issue of *Virtual Journal of Applications of Superconductivity*

**2008**

J. Issa, R. Mukherjee, A. Diaz, and S. W. Shaw, "Modal Disparity and Its Experimental Verification," *Journal of Sound and Vibration* **311**, 1465-1475

J. F. Rhoads, N. J. Miller, S. W. Shaw, and B. F. Feeny, "Mechanical Domain Parametric Amplification," *Journal of Vibration and Acoustics* **130**, 061006

B. E. DeMartini, J. F. Rhoads, M. A. Zielke, K. G. Owen, S. W. Shaw, and K. L. Turner, "A Single Input-Single Output Microresonator Array for the Detection and Identification of Multiple Analytes," *Applied Physics Letters* **93**, 054102:1-3; also selected for the August 18, 2008 issue of *Virtual Journal of Nanoscale Science & Technology*

S. W. Shaw and B. Balachandran, "A Review of Nonlinear Dynamics of Mechanical Systems in Year 2008," *JSME Journal of System Design and Dynamics* **2**, 611-640. Invited Review Paper for the Special Issue on Nonlinear Dynamics in Mechanical Systems

**2007**

G. Csernak, G. Stépán, and S. W. Shaw, "Sub-harmonic Resonant Solutions of a Harmonically Excited Dry-Friction Oscillator," *Nonlinear Dynamics* **50**, 93-109

B. E. DeMartini, J. F. Rhoads, S. W. Shaw, and K. L. Turner, "A Single Input – Single Output Mass Sensor Based on a Coupled Array of Microresonators," *Sensors and Actuators A: Physical* **13**, 147-156

B. E. DeMartini, J. F. Rhoads, K. L. Turner, J. Moehlis, S. W. Shaw, "Linear and Nonlinear Tuning of Parametrically Excited MEM Oscillators," *Journal of Microelectromechanical Systems* **16**, 310-318

**2006**

D. Jiang, C. Pierre, S. W. Shaw, "Nonlinear normal modes and their application in structural dynamics," *Mathematical Problems in Engineering,* **2006**, Article 10847.

S. W. Shaw, P. Schmitz, and A. G. Haddow, "Dynamics of Tautochronic Pendulum Vibration Absorbers," *Journal of Computational and Nonlinear Dynamics* **1**, 283-293.

J. Rhoads, S. W. Shaw, K. Turner, B. DeMartini, J. Moehlis, and W. Zhuang, "Generalized Parametric Resonance in Electrostatically Actuated Micromechanical Systems," *Journal of Sound and Vibration* **296**, 797-829.

S. Nudehi, R. Mukherjee, and S. W. Shaw, “Active Vibration Control of a Flexible Beam Using a Buckling-Type End Force,” *Journal of Dynamic Systems, Measurement and Control* **128**, 278-286.

J. Rhoads, S. W. Shaw, and K. Turner, “The Nonlinear Response of Resonant Microbeam Systems with Purely Parametric Electrostatic Actuation,” *Journal of Micromechanics and Microengineering* **16**, 890-899.

S. W. Shaw and C. Pierre, “The Dynamic Response of Tuned Impact Absorbers for Rotating Flexible Structures,” *Journal of Computational and Nonlinear Dynamics* **1**, 13-24.

**2005**

D. Jiang, C. Pierre, and S. W. Shaw, “Nonlinear Normal Modes for Vibratory Systems Under Periodic Excitation,” *Journal of Sound and Vibration* **288**, 791-812.

J. Rhoads, S. Shaw, K. Turner, and R. Baskaran, “Tunable MEMS Filters that Exploit Parametric Resonance,” *Journal of Vibration and Acoustics* **127**, 423-430.

P. Apiwattanalunggarn, S. W. Shaw, and C. Pierre. “Component Mode Synthesis Using Nonlinear Normal Modes,” *Nonlinear Dynamics* **41**, 17-46.

A. Singh, R. Mukherjee, K. Turner, and S. W. Shaw, “MEMS Implementation of Axial and Follower End Forces,” *Journal of Sound and Vibration* **286**, 637–644.

B. J. Olson, S. W. Shaw and G. Stépán, “Stability and Bifurcations of Longitudinal Vehicle Traction,” *Nonlinear Dynamics* **40**, 339–365.

D. Jiang, C. Pierre, and S. W. Shaw, “The Construction of Nonlinear Normal Modes for Systems with Internal Resonance,” *International Journal of Nonlinear Mechanics* **40**, 729-746.

**2004**

M. Legrand, D. Jiang, C. Pierre, and S. W. Shaw, “Nonlinear Normal Modes of a Rotating Shaft Based on the Invariant Manifold Method,” *International Journal of Rotating Machinery* **10**, 319-335.

D. Jiang, C. Pierre, and S. W. Shaw, “Large-Amplitude Nonlinear Normal Modes of Piecewise Linear Systems,” *Journal of Sound and Vibration* **272**, 869-891.

**2003**

A. Haddow and S. W. Shaw, “Centrifugal Pendulum Vibration Absorbers: An Experimental and Theoretical Investigation,” *Nonlinear Dynamics* **34**, 293-307.

B. J. Olson, S. W. Shaw and G. Stépán, “Nonlinear Dynamics of Ground Vehicle Traction,” *Vehicle System Dynamics* **40**, 377-399.

P. Apiwattanalunggarn, S. W. Shaw, C. Pierre, and D. Jiang, “Finite-Element-Based Nonlinear Modal

Reduction of a Rotating Beam with Large-Amplitude Motion," *Journal of Vibration and Control* **9**, 235-263.

A. Alsuwaiyan and S. W. Shaw, "Steady-State Responses of Systems of Nearly-Identical Torsional Vibration Absorbers," *Journal of Vibration and Acoustics* **125**, 80-87.

**2002**

E. Pesheck, C. Pierre, and S. W. Shaw, "Model Reduction of a Nonlinear Rotating Beam Through Nonlinear Normal Modes," *Journal of Vibrations and Acoustics* **124**, 229-236.

E. Pesheck, C. Pierre, and S. W. Shaw, "A New Galerkin-Based Approach for Accurate Nonlinear Normal Modes Through Invariant Manifolds," *Journal of Sound and Vibration* **249**, 971-993.

A. Alsuwaiyan and S. W. Shaw, "Performance and Dynamic Stability of General-Path Centrifugal Pendulum Vibration Absorbers," *Journal of Sound and Vibration* **252**, 791-815.

**2001**

E. Pesheck, N. Boivin, C. Pierre, and S. W. Shaw, "Non-Linear Modal Analysis of Structural Systems Using Multi-Mode Invariant Manifolds," *Nonlinear Dynamics* **25**, 183-205.

E. Pesheck, C. Pierre, and S. W. Shaw, "Accurate Reduced-Order Models for a Simple Rotor Blade Model Using Nonlinear Normal Modes," *Mathematical and Computer Modelling* **33** (special issue on applications to rotorcraft), 1085-1097.

**2000**

C. Jiang, A. W. Troesch, and S. W. Shaw, "Capsize Criteria for Ship Models with Memory-Dependent Hydrodynamics and Random Excitation," *Philosophical Transactions of the Royal Society* **358**, 1761-1791, invited paper.

S.-L. Chen, S. W. Shaw, H. K. Khalil and A. W. Troesch, "Robust Stabilization of Large Amplitude Motions of Vessels in Beam Seas," *Journal of Dynamic Systems, Measurement and Control* **122**, 108-113.

C.-P. Chao and S. W. Shaw, "The Dynamic Response of Multiple Pairs of Subharmonic Pendulum Vibration Absorbers," *Journal of Sound and Vibration* **231**, 411-431.

**1999**

A. Alsuwaiyan and S. W. Shaw, "Localization of Free Vibration Modes in Systems of Nearly-Identical Vibration Absorbers," *Journal of Sound and Vibration* **228**, 703-711.

S.-L Chen, S. W. Shaw and A. W. Troesch, "A Systematic Approach to Modeling Nonlinear Multi-DOF Ship Motions in Regular Seas," *Journal of Ship Research*, **43**, 25-37.

S. W. Shaw, C. Pierre, E. Pesheck, "Modal Analysis-Based Reduced-Order Models for Nonlinear Structures

- An Invariant Manifold Approach," *Shock and Vibration Digest* **31**,3-16, invited paper.

**1998**

C.-P. Chao and S. W. Shaw, "The Effects of Imperfections on the Performance of the Subharmonic Vibration Absorber System," *Journal of Sound and Vibration* **215**, 1065-1099.

**1997**

C.-P. Chao, S. W. Shaw and C.-T. Lee, "Non-Unison Dynamics of Multiple Centrifugal Pendulum Vibration Absorbers," *Journal of Sound and Vibration* **204**, 769-794.

C.-P. Chao, C.-T. Lee and S. W. Shaw, "Stability of the Unison Response for a Rotating System with Multiple Centrifugal Pendulum Vibration Absorbers," *ASME Journal of Applied Mechanics* **64**, 149-156.

C.-T. Lee and S. W. Shaw, "Nonlinear Dynamic Response of Paired Centrifugal Pendulum Vibration Absorbers," *Journal of Sound and Vibration* **203**, 731-743.

C.-T. Lee, S. W. Shaw and V. T. Coppola, "A Subharmonic Vibration Absorber for Rotating Machinery," *ASME Journal of Vibration and Acoustics* **119**, 590-595.

**1996**

C. Jiang, A. W. Troesch and S. W. Shaw, "Highly Nonlinear Rolling Motion of Biased Ships in Random Beam Seas," *Journal of Ship Research* **40**, 125-135.

S.-L. Chen and S. W. Shaw, "A Fast-Manifold Approach to Melnikov Functions for Slowly Varying Oscillators," *International Journal of Bifurcation and Chaos* **6**, 1575-1578.

S.-L. Chen and S. W. Shaw, "Normal Modes for Piecewise-Linear Vibratory Systems," *Nonlinear Dynamics* **10**, 135-164.

C.-T. Lee and S. W. Shaw, "On the Counteraction of Periodic Torques in Rotating Systems Using Centrifugally Driven Vibration Absorbers," *Journal of Sound and Vibration* **191**, 695-719.

**1995**

N. Boivin, C. Pierre and S. W. Shaw, "Non-linear Modal Analysis of Structural Systems Featuring Internal Resonances," *Journal of Sound and Vibration* **182**, 336-341.

N. Boivin, C. Pierre and S. W. Shaw, "Non-Linear Normal Modes, Invariance, and Modal Dynamics Approximations of Non-Linear Systems," *Nonlinear Dynamics* **8**, 315-345, 1995.

**1994**

F. Farahanchi and S. W. Shaw, "Periodic and Chaotic Dynamics of a Slider-Crank Mechanism with Slider

Clearance," *Journal of Sound and Vibration* **177**, 307-324.

S.-R. Hsieh, A. W. Troesch and S. W. Shaw, "A Nonlinear Probabilistic Method for Predicting Vessel Capsizing in Random Beam Seas," *Proceedings of the Royal Society London* **446**, 195-211.

S. W. Shaw, A. G. Haddow and S.-R. Hsieh, "Properties of Cross-Well Chaos in an Impacting System," *Philosophical Transactions of the Royal Society of London* **A 347**, 391-410.

S.-R. Hsieh, S. W. Shaw and C. Pierre, "Normal Modes for Large Amplitude Motions of a Cantilever Beam," *International Journal of Solids and Structure*s **31**, 1981-2014.

S. W. Shaw, "An Invariant Manifold Approach to Nonlinear Normal Modes of Oscillation," *Journal of Nonlinear Science* **4**, 419-448.

S.-R. Hsieh and S. W. Shaw, "Dynamic Stability and Nonlinear Resonances of a Flexible Connecting Rod: Single Mode Model," *Journal of Sound and Vibration* **170**, 25-49.

S. W. Shaw and C. Pierre, "Normal Modes of Vibration for Nonlinear Continuous Systems," *Journal of Sound and Vibratio*n **169**, 319-347.

**1993**

S.-R. Hsieh and S. W. Shaw, "Dynamic Stability and Nonlinear Resonance of a Flexible Connecting Rod: Continuous Parameter Model," *Nonlinear Dynamics* **4**, 573-603.

S. W. Shaw and C. Pierre, "Normal Modes for Nonlinear Vibratory Systems," *Journal of Sound and Vibration* **164**, 85-124.

**1992**

J. Falzarano, S. W. Shaw and A. Troesch, "Applications of Modern Geometric Methods for Dynamical Systems to the Problem of Vessel Capsizing with Water-on-Deck," *International Journal of Bifurcation and Chaos* **2**, 101-115.

S. W. Shaw and A. G. Haddow, "On Rollercoaster Experiments for Nonlinear Oscillators," *Nonlinear Dynamics* **3**, 375-384.

M. Sharif-Bakhtiar and S. W. Shaw, "Effects of Nonlinearities and Damping on the Dynamic Response of a Centrifugal Pendulum Vibration Absorber," ASME *Journal of Vibration and Acoustics* **114**, 305-311.

**1991**

C. Pierre and S. W. Shaw, "Mode Localization Due to Symmetry-Breaking Nonlinearities," *International Journal of Bifurcation and Chaos* **1**, 471-475.

S. W. Shaw and C. Pierre, "Nonlinear Normal Modes and Invariant Manifolds," *Journal of Sound and*

*Vibration* **150**, 170-173.

J. Shaw and S. W. Shaw, "The Effect of Unbalance on Oil Whirl," *Nonlinear Dynamics* **1**, 293-311.

J. Shaw and S. W. Shaw, "Nonlinear Resonance of an Unbalanced Rotating Shaft with Internal Damping," *Journal of Sound and Vibration* **147**, 435-451.

**1990**

S. R. Hsieh and S. W. Shaw, "The Stability of Modes at Rest in a Chaotic System," *Journal of Sound and Vibration* **138**, 421-431.

D. Moore and S. W. Shaw, "Experimental Response of an Impacting Pendulum System," *International Journal of Nonlinear Mechanics* **25**, 1-16.

**1989**

J. Shaw and S. W. Shaw, "Instabilities and Bifurcations in a Rotating Shaft," *Journal of Sound and Vibration* **132**, 227-244.

J. Shaw and S. W. Shaw, "The Onset of Chaos in a Two Degree of Freedom Impacting System," ASME *Journal of Applied Mechanics* **56**, 168-174.

J. Shaw, S. W. Shaw and A. Haddow, "On the Dynamic Response of the Nonlinear Vibration Absorber," *International Journal of Nonlinear Mechanics* **24**, 281-293.

S. W. Shaw and R. H. Rand, "The Transition to Chaos in a Simple Mechanical System," *International Journal of Nonlinear Mechanics* **24**, 41-56.

**1988**

M. Sharif-Bakhtiar and S. W. Shaw, "The Dynamic Response of the Centrifugal Pendulum Vibration Absorber with Motion-Limiting Stops," *Journal of Sound and Vibration* **124**, 221-235.

S. W. Shaw, "Chaotic Dynamics of a Slender Beam Rotating About Its Longitudinal Axis," *Journal of Sound and Vibration* **124**, 329-343.

P.-C. Tung and S. W. Shaw, "A Method for the Improvement of Impact Printer Performance," ASME *Journal of Vibration, Acoustics, Stress and Reliability in Design* **110**, 528-532.

S. W. Shaw and S. Wiggins, "Chaotic Dynamics of a Whirling Pendulum," *Physica* **31D**, 190-211.

P.-C. Tung and S. W. Shaw, "The Dynamics of an Impact Print Hammer," ASME *Journal of Vibration, Acoustics, Stress and Reliability in Design* **110**, 193-200.

S. W. Shaw and S. Wiggins, "Chaotic Motions of a Torsional Vibration Absorber," ASME *Journal of Applied*

*Mechanics* **55**, 952-958.

S. Wiggins and S. W. Shaw, “Chaos and Three Dimensional Horseshoes in Slowly Varying Oscillators,” ASME *Journal of Applied Mechanics* **55**, 959-967.

S. W. Shaw and P.-C. Tung, “The Dynamic Response of a System with Pre-Loaded Compliance,” ASME *Journal of Dynamic Systems, Measurement, and Control* **110**, 278-283.

**1987**

P. R. Sethna and S. W. Shaw, “On Codimension Three Bifurcations in the Motion of Articulated Tubes Conveying a Fluid,” *Physica* **24D**, 305-327.

**1986**

S. N. Chow and S. W. Shaw, “Bifurcations of Subharmonics,” *Journal of Differential Equations* **65**, 304-320.

S. W. Shaw, “On the Dynamic Response of a System with Dry Friction,” *Journal of Sound and Vibration* **108**, 305-325.

**1985**

*S. W. Shaw, “The Dynamics of a Harmonically Excited System Having Rigid Amplitude Constraints, Part I: Subharmonic Motions and Local Bifurcations,” ASME *Journal of Applied Mechanics* **52**, 453-458.

*S. W. Shaw, “The Dynamics of a Harmonically Excited System Having Rigid Amplitude Constraints, Part II: Chaotic Motions and Global Bifurcations,” ASME *Journal of Applied Mechanics* **52**, 459-464.

S. W. Shaw, “Forced Vibrations of a Beam with One-Sided Amplitude Constraint: Theory and Experiments,” *Journal of Sound and Vibration* **99**, 199-212.

**1983**

S. W. Shaw and P.J. Holmes, “Periodically Forced Linear Oscillator with Impacts: Chaos and Long Period Motions,” *Physical Review Letters* **51**, 623-626.

S. W. Shaw and P.J. Holmes, “A Periodically Forced Impact Oscillator with Large Dissipation,” ASME *Journal of Applied Mechanics* **50**, 849-857.

S. W. Shaw and P.J. Holmes, “A Periodically Forced Piecewise Linear Oscillator,” *Journal of Sound and Vibration* **90**, 129-155.

F.C. Moon and S. W. Shaw, “Chaotic Vibrations of a Beam with Nonlinear Boundary Conditions,” *International Journal of Nonlinear Mechanics* **18**, 465-477.

**OTHER PUBLICATIONS**

Steven W. Shaw, Oriel Shoshani, and Pavel M. Polunin, "Modeling for Non-linear Vibrational Response of Mechanical Systems," chapter to appear in *The Art of Modeling Mechanical Systems,* Springer volume based on a 2015 CISM course.

P. M. Polunin, P. Zhou, J. J. Miller, S. W. Shaw, H. B. Chan, M. I. Dykman, "Revealing non-Gaussian noise through noise-induced switching in a parametric oscillator," Abstract, APS March Meeting, 2015

B. S. Strachan, D. A. Czaplewski, C. Chen, M. I. Dykman, D. Lopez, and S. W Shaw, "Fluctuation reduction in a Si micromechanical resonator tuned to nonlinear internal resonance," Abstract, APS March Meeting, 2015

P. Polunin, Y. Yang, J. Atalaya, E. Ng, S. Strachan, O. Shoshani, M. Dykman, S. Shaw, and T. Kenny, "CHARACTERIZING MEMS NONLINEARITIES DIRECTLY: THE RING-DOWN MEASUREMENTS," The 18th International Conference on Solid State Sensors, Actuators and Microsystems (Transducers), 2015

Yushi Yang, Eldwin Ng, Pavel Polunin, Yunhan Chen, Scott Strachan, Vu Hong, Chae Hyuck Ahn, Ori Shoshani, Steven Shaw, Mark Dykman, and Thomas Kenny, "EXPERIMENTAL INVESTIGATION ON MODE COUPLING OF BULK MODE SILICON MEMS RESONATORS," *Micro Electro Mechanical Systems (MEMS), 2015 28th IEEE International Conference on*. IEEE, pp. 1008-1011, 2015

N. J. Miller, B. S. Strachan, P. Polunin, S. W. Shaw, and M. I. Dykman, "Phase Noise in MEMS Oscillators Based on Nonlinear Resonances," extended abstract, European Conference on Nonlinear Oscillations, Vienna, 2014

B. S. Strachan, K. R. Qalandar, B. Gibson, M. Sharma, P. Polunin, S. W. Shaw, and K. L. Turner, "A Passive Micromechanical Frequency Divider," Hilton Head Workshop 2014: A Solid-State Sensors, Actuators and Microsystems Workshop, Hilton Head, SC, 2014

D. A. Czaplewski, B. S. Strachan, S. W Shaw, M. I. Dykman, and D. Lopez, "Phase Noise Reduction in an Oscillator Through Coupling to an Internal Resonance Mode," Hilton Head Workshop 2014: A Solid-State Sensors, Actuators and Microsystems Workshop, Hilton Head, SC, 2014

S. W. Shaw, M. A. Acar, B. F. Feeny, B. K. Geist, "Vibration Modes and Resonances for Flexible Rotating Shafts with Centrifugal Pendulum Vibration Absorbers," 15th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery, ISROMAC-15, Honolulu, 2014

C. Shi, R. G. Parker, S. W. Shaw, "Vibration Response of Rotor Systems with Centrifugal Pendulum Vibration Absorbers Under Gravitational Loading," extended abstract, 15th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery, ISROMAC-15, Honolulu, 2014

S. W. Shaw, M. A. Acar, B. F. Feeny, B. K. Geist, "Vibration Modes and Resonances for Flexible Rotating Shafts with Centrifugal Pendulum Vibration Absorbers," extended abstract, IMAC XXXII A Conference & Exposition On Structural Dynamics, Orlando, FL, 2014

B. Vidmar, S. Shaw, and B. Feeny, “Experimental Investigation of Multiple Order Centrifugal Pendulum Vibration Absorbers,” paper DETC2013-12688, *Proceedings of the ASME 2013 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference,* Portland, OR, 2013

C. Shi, R. Parker, and S. Shaw, “Optimal Tuning of Centrifugal Pendulum Vibration Absorbers,” paper DETC2013-12449, *Proceedings of the ASME 2013 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference,* Portland, OR, 2013

S. W. Shaw and B. S. Strachan*, “*Exploiting Nonlinear Modal Interactions in MEMS,” paper #359, extended abstract, International Modal Analysis Conference, Garden Grove, CA, 2013

S. W. Shaw, “Designing Nonlinear Torsional Vibration Absorbers,” Chapter 4 in *Exploiting Nonlinear Behavior in Structural Dynamics,* pages 135-169, CISM International Centre for Mechanical Sciences, Vol. 536, D. Wagg and L. Virgin (Eds.), 2012

N. J. Miller, P. Polunin, M. I. Dykman, and S. W. Shaw, “The Balanced Dynamical Bridge: Detection and Sensitivity to Parameter Shifts and Non-Gaussian Noise,” paper DETC2012-70318, *Proceedings of the ASME 2012 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference,* Chicago, IL, 2012

B. J. Vidmar, S. W. Shaw, B. F. Feeny, and B. K. Geist, “Analysis and Design of Multiple Order Centrifugal Pendulum Vibration Absorbers,” paper DETC2012-71074, *Proceedings of the ASME 2012 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference,* Chicago, IL, 2012

B. J. Vidmar, S. W. Shaw and B. F. Feeny, “Nonlinear Interactions in Systems of Multi-Order Torsional Vibration Absorbers,” *Proceedings of the 14th International Symposium on Transport and Dynamics of Rotating Machinery*, Honolulu, HA, 2012

S. W. Shaw, N. J. Miller, M. I. Dykman, C. Burgner and K. L Turner, “Dynamic Bifurcations with Loss of Local Stability in the Presence of Noise,” Abstract, SIAM Conference on Applications of Dynamical Systems, Snowbird, UT, 2011

B. S. Strachan and S. W. Shaw, “Subharmonic Resonance Cascades in a Class of Coupled Resonators,” paper DETC2011-48599, *Proceedings of the ASME 2011 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference,* Washington, DC, 2011

R. J. Monroe and S. W. Shaw, “Nonlinear Transient Dynamics of Pendulum Torsional Vibration Absorbers,” paper DETC2011-48353, *Proceedings of the ASME 2011 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference,* Washington, DC, 2011

C. Burgner, K. Turner, N. Miller and Steven Shaw, “Noise Squeezing Control for Bifurcation Detection Sensing in MEMS,” paper DETC2011/MNS-47461, *Proceedings of the ASME 2011 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference*, Washington, DC, 2011

K. L. Turner, C. Burgner, Z. Yie, S. W. Shaw, N. J. Miller, “Nonlinear dynamics of MEMS systems,” proceedings of the INTERNATIONAL CONFERENCE ON APPLICATIONS IN NONLINEAR DYNAMICS (ICAND 2010); doi:10.1063/1.3574849, American Institute of Physics Conference Series, Volume 1339, pp.111-113, 2011

C. Burgner, K. Turner, N. Miller, Steven Shaw, and M. Dykman, “Parameter Sweep Strategies for Sensing Using Bifurcations in MEMS,” Paper 201, *Hilton Head, 2010: A Solid State Sensor, Actuator, and Microsystems Workshop*; Hilton Head, SC, 2010

Z. Yie, K.L. Turner, N.J. Miller, and S. W. Shaw, “Sensitivity Enhancement Using Parametric Amplification in Resonant Sensing Array,” Paper 95, *Hilton Head, 2010: A Solid State Sensor, Actuator, and Microsystems Workshop*; Hilton Head, SC, 2010

N. Miller, C. Burgner, M. Dykman, S. Shaw, and K. Turner, “Fast estimation of Bifurcation Conditions using Noisy Response Data,” Proceedings of *the SPIE*, Vol. 7647, 7647-23, 2010

J. Portman, M. Khasin, S. W. Shaw, M. I. Dykman, "The spectrum of an oscillator with fluctuating mass and nanomechanical mass sensing," Abstract: V14.00010, APS March Meeting, 2010

S. Gozin, B. J. Olson, C. Pierre, and S. W. Shaw, “Resonance Suppression in Multi-DOF Cyclic Systems Using Order-Tuned Absorbers,” *The 2009 ASME International Design Engineering Technical Conferences,* DETC2009-86287, *22nd Biennial Conference on Mechanical Vibration and Noise*, San Diego, CA, 2009

R. Monroe, S. W. Shaw, B. Geist, and A. G. Haddow, “Accounting for Roller Dynamics in the Design of Bifilar Torsional Vibration Absorbers” *The 2009 ASME International Design Engineering Technical Conferences,* Paper DETC2009-87431*, 22nd Biennial Conference on Mechanical Vibration and Noise*, San Diego, CA, 2009.

J. F. Rhoads, S. W. Shaw, and K. L. Turner, “Nonlinear Dynamics and its Applications in Micro- and Nano-resonators,” invited keynote paper, Paper DSC2008-254, *Proceedings of the ASME Dynamic Systems and Controls Conference*, Ann Arbor, 2008.

J. Issa, R. Mukherjee, and S. W. Shaw, “Control of Space Structures Using Cable Actuators,” Paper DSC2008-009, *Proceedings of the ASME Dynamic Systems and Controls Conference*, Ann Arbor, 2008.

N. J. Miller and S. W. Shaw, “Frequency Sweeping with Concurrent Parametric Amplification,” Paper DSC2008-118, *Proceedings of the ASME Dynamic Systems and Controls Conference*, Ann Arbor, 2008.

B. E. DeMartini, M. A. Zielke, K. G. Owen, K. L. Turner, J. F. Rhoads, and S. W. Shaw, “Detection and Identification of Multiple Chemicals Using a Single Input-Single Output Coupled Microresonator Array,” Extended Abstract, *International Workshop on Nanomechanical Cantilever Sensors*, Max Planck Institute for Polymer Research, Mainz, Germany, 2008.

J. F. Rhoads and S. W. Shaw, “Effects of Nonlinearity on Parametric Amplifiers,” *Proceedings of the 2008 ASME IDETC*, Paper DETC2008-49594, Brooklyn, NY, 2008.

B. J. Olson and S. W. Shaw, “Vibration Absorbers for Cyclic Rotating Flexible Structures: Linear and Nonlinear Tuning,” Paper SMASIS08-632, *Proceedings of the ASME 2008 Conference on Smart Materials, Adaptive Structures, and Intelligent Systems*, Baltimore, 2008.

N. J. Miller, S. W. Shaw, L. A. Oropeza-Ramos, and K. L. Turner, “Analysis of a Novel MEMS Gyroscope Actuated by Parametric Resonance,” *Proceedings of the Sixth EUROMECH Nonlinear Dynamics Conference* (ENOC 2008), St. Petersburg, Russia, 2008.

N. Miller, S. Shaw, L. Oropeza-Ramos, and K. Turner, “A MEMS-Based Rate Gyroscope Based on Parametric Resonance,” Paper ESDA08-59567, *Proceedings of the 9th Biennial ASME Conference on Design and Analysis*, Haifa, Israel, 2008.

S. W. Shaw, M. Orlowski, A. Haddow, and B. Geist “Transient Dynamics of Centrifugal Pendulum Vibration Absorbers,” Paper 2008-20119, *Twelfth International Symposium on Transport Phenomena and Dynamics of Rotating Machinery* (ISROMAC-12), Honolulu, Hawaii, February, 2008.

J. F. Rhoads, N. J. Miller, S. W. Shaw, and B. F. Feeny. “Mechanical Domain Parametric Amplification,” Paper DETC2007-35426, *IDETC/CIE 2007: The 2007 ASME International Design Engineering Technical Conferences, 6th International Conference on Multibody Systems, Nonlinear Dynamics, and Control*. Las Vegas, Nevada, 2007.

B. DeMartini, J. Rhoads, S. Shaw, K. Turner, “A Resonant SISO Sensor Based on a Coupled Array of Micromechanical Oscillators,” *Hilton Head, 2006: A Solid State Sensor, Actuator, and Microsystems Workshop*; Hilton Head, SC, 2006.

J. Rhoads, B. DeMartini, S. Shaw, K. Turner, “A SISO, Multi-Analyte Sensor Based on a Coupled Micromechanical Array,” *Proceedings of the 2006 ASME IMECE*, Chicago, 2006.

S. W. Shaw, B.J. Olson, and C. Pierre, “Order-Tuned and Impact Vibration Absorbers for Rotating Flexible Structures,” *Eleventh International Symposium on Transport Phenomena and Dynamics of Rotating Machinery* (ISROMAC-11), Honolulu, Hawaii, March, 2006.

B. E. DeMartini, J. Moehlis, K. L. Turner, J. F. Rhoads, S. W. Shaw, and W. Zhang, “Modeling of Parametrically Excited Microelectromechanical Oscillator Dynamics with Application to Filtering,” Paper PID134530, IEEE Sensors 2005, 4th IEEE Conference on Sensors, Irvine, CA, 2005.

B. J. Olson, S. W. Shaw, and C. Pierre, “Order-Tuned Vibration Absorbers for Cyclic Rotating Flexible Structures,” Paper DETC2005-84641, *Proceedings of the 20th Biennial Conference on Mechanical Vibration and Noise*, Long Beach, California, 2005.

J. F. Rhoads, S. W. Shaw, K. L. Turner, J. Moehlis, B. E. DeMartini, and W. Zhang. “Nonlinear Response of Parametrically-Excited MEMS,” Paper DETC2005-84603, *Proceedings of the 20th Biennial Conference on Mechanical Vibration and Noise*. Long Beach, California, 2005.

S. S. Nudehi, R. Mukherjee, and S. W. Shaw, “Vibration Control in a Flexible Beam Using a Conservative Force,” Paper IMECE2004-60783, *Proceedings of the 2004 ASME International Mechanical Engineering Conference*. Anaheim, California, 2004

B. J. Olson, S. W. Shaw, and G. Stépán, “Nonlinear Dynamics of Longitudinal Vehicle Traction,” *Proceedings of the 9th Mini-Conference on Vehicle System Dynamics, Identifications and Anomalies* (Budapest, Hungary), 2004.

S. W. Shaw, T. Nester, A. Haddow, and P. Schmitz, “Experimental Observations of Centrifugal Pendulum Vibration Absorbers,” *Tenth International Symposium on Transport Phenomena and Dynamics of Rotating Machinery* (ISROMAC-10), Honolulu, Hawaii, March, 2004.

S. W. Shaw, K. L. Turner, J. F. Rhoads, and R. Baskaran, “Parametrically Excited MEMS-Based Filters,” *Proceedings of the IUTAM Symposium on Chaotic Dynamics and Control of Systems and Processes in Mechanics*, 137-146. Rome, Italy: Springer. 2003.

T.M. Nester, A. G. Haddow, and S. W. Shaw. “Experimental Investigation of a System of Nearly-Identical Centrifugal Pendulum Vibration Absorbers,” *Proceedings of the 19th Biennial Conference on Mechanical Vibration and Noise,* Paper DETC/2003-48410, Chicago, September 2003.

D. Jiang, C. Pierre, and S. W. Shaw. “Nonlinear Normal Modes for Vibratory Systems Under Periodic Excitation,” *Proceedings of the 19th Biennial Conference on Mechanical Vibration and Noise,* Paper DETC/2003-48443, Chicago, September 2003.

P. Apiwattanalunggarn, S. W. Shaw, and C. Pierre. “Component Mode Synthesis Using Nonlinear Normal Modes,” *Proceedings of the 19th Biennial Conference on Mechanical Vibration and Noise,* Paper DETC/2003-48441, Chicago, September 2003.

T.M. Nester, A. G. Haddow, S. W. Shaw, J.E. Brevick, and V.J. Borowski. “Vibration Reduction in Variable Displacement Engines Using Pendulum Absorbers,” Paper 2003-01-1484 *Proceedings of the SAE Noise and Vibration Conference and Exhibition*, Traverse City, MI, 2003.

T.M. Nester, S. W. Shaw, A. G. Haddow, and J.E. Brevick. “Centrifugal Pendulum Vibration Absorbers in Variable Displacement Engines.*”* Abstract, *Ninth Conference on Nonlinear Vibrations, Stability, and Dynamics of Structures*. Blacksburg, VA, July 28-August 1, 2002.

D. Jiang, C. Pierre, and S. W. Shaw, “The Construction of Nonlinear Normal Modes for Systems with Internal Resonance: Application to Rotating Beams,” Abstract, *Ninth Conference on Nonlinear Vibrations, Stability, and Dynamics of Structures*. Blacksburg, VA, July 28-August 1, 2002.

M. Legrand, D. Jiang, C. Pierre, and S. W. Shaw, “Nonlinear Normal Modes of a Rotating Shaft Based on the Invariant Manifold Method,” *Ninth International Symposium on Transport Phenomena and Dynamics of Rotating Machinery* (ISROMAC-9), Honolulu, Hawaii, February 10-14, 2002.

A. Haddow and S. W. Shaw, “An Experimental Study of Torsional Vibration Absorbers,” *Proceedings of the 18th Biennial Conference on Mechanical Vibration and Noise*, ASME Paper DETC2001/VIB-21754, Pittsburgh, Pennsylvania, September 9-12, 2001.

D. Jiang, V. Soumier, C. Pierre, and S. W. Shaw. "Large amplitude nonlinear normal modes of piecewise linear systems," *Proceedings of the 18th Biennial Conference on Mechanical Vibration and Noise*, ASME Paper DETC2001/VIB-21734, Pittsburgh, Pennsylvania, September 9-12, 2001.

A. Haddow and S. W. Shaw, "Torsional Vibration Absorbers: A Testing and Evaluation Apparatus," *Proceedings of SAE Noise and Vibration Conference*, SAE Paper 2001-01-1577, 2001.

S. W. Shaw, "Perturbation Techniques for Nonlinear Systems," *Encyclopedia of Vibration*, Academic Press, pp. 1009-1011, 2001.

S. W. Shaw, Questions for Structural Dynamics 2000, *Structural Dynamics 2000: current status and future directions*, pp. 469-470, D.J. Ewins and D.J. Inman, eds., Research Studies Press, Ltd., 2001.

B. J. Olson, S. W. Shaw, and G. Stépán, "A Nonlinear Model for Vehicle Braking," in the *Eighth Conference on Nonlinear Vibrations, Stability, and Dynamics of Structures*, (Blacksburg, VA), Jul 23-27, 2000.

S. W. Shaw and A. Alsuwaiyan, "Torsional Vibration Reduction Using Passive Nonlinear Absorbers," *Proceedings of the SPIE Conference on Smart Structures*, Newport Beach, CA, March, 2000.

F. Salam, H. Khalil, C. Radcliffe, and S. Shaw, "Development of a Course Sequence in Sensing and Control for Automotive Systems," *Proceedings of the Conference on Decision and Control*, 1999.

H. Khalil and S. W. Shaw, "Classical Stability Theory: Nonlinear," *Wiley Encyclopedia of Electrical and Electronics Engineering*, Volume 20, 390-398, 1999.

S. W. Shaw and C. Pierre, "Invariant Manifolds and Model Reduction in Nonlinear Systems," *Applied Mechanics in the Americas*, Volume 8, Dynamics, 1597-1600, 1999.

E. Pesheck, C. Pierre and S. W. Shaw, "Model Reduction of a Nonlinear Rotating Beam Through Nonlinear Normal Modes," paper DETC99/VIB-8074, Proceedings 1999 ASME Design Engineering Technical Conferences (to appear on CD-ROM).

C. P. Chao and S. W. Shaw, "Dynamically Stable Non-Linear Modes of Multiple Subharmonic Torsional Vibration Absorbers," paper DETC99/VIB-8073, Proceedings 1999 ASME Design Engineering Technical Conferences (to appear on CD-ROM).

A. Alsuwaiyan and S. W. Shaw, "Steady-State Synchronous and Localized Responses of Tuned Pendulum Vibration Absorbers," paper DETC99/VIB-8014, Proceedings 1999 ASME Design Engineering Technical Conferences.

A. Alsuwaiyan and S. W. Shaw, "Stability Limitations for Multiple Centrifugal Pendulum Vibration Absorbers," paper DETC99/VIB-8055, Proceedings 1999 ASME Design Engineering Technical Conferences.

S. W. Shaw, C.P. Chao and C.T. Lee, "Nonlinear Dynamics and the Design of Tuned Pendulum Vibration

Absorbers," *Proceedings of the IUTAM Symposium on Applications of Nonlinear and Chaotic Dynamics in Mechanics*, 223-234, edited by F. C. Moon. Kluwer, 1998.

S. W. Shaw and B. F. Feeny, "Nonlinear Dynamics with Impacts and Friction," *Dynamics and Chaos in Manufacturing Processes,* Chapter 9, 241-264, edited by F.C. Moon. Wiley Interscience, 1998,

Y. Wang, C.P. Chao, and S. W. Shaw, "Design of Pendulum Vibration Absorbers for the Attenuation of Transverse Vibrations in Rotating Beams," with, paper DETC97/VIB-4182, Proceedings 1997 ASME Design Engineering Technical Conferences, 1997.

S. R. Hsieh, S. W. Shaw, J. Her and V. Borowski "Rattle Reduction of Automotive Components - An FEM Approach," paper DETC97/VIB-3928, Proceedings 1997 ASME Design Engineering Technical Conferences 1997.

C. P. Chao and S. W. Shaw, "On the Effects of Imperfections and Mistuning on the Performance of Subharmonic Vibration Absorbers," with C.P. Chao, paper DETC97/VIB-4104, Proceedings 1997 ASME Design Engineering Technical Conferences, 1997.

C.P. Chao and S. W. Shaw, "Nonlinear Localization in Systems of Tautochronic Pendulum Vibration Absorbers," paper DETC97/VIB-3956, Proceedings 1997 ASME Design Engineering Technical Conferences, 1997.

S. L. Chen and S. W. Shaw, "Phase Space Transport in a Class of Multi-Degree of Freedom Systems," paper DETC97/VIB-4105, Proceedings 1997 ASME Design Engineering Technical Conferences, 1997.

+ "Attenuation of Engine Torsional Vibrations Using Tuned Pendulum Absorbers," with V. Garg and C.P. Chao, Paper 971961, Proceedings of the 1997 *SAE Noise and Vibration Conference and Exposition*, 1997.

"A CAE Methodology for Reducing Rattle in Structural Components," S. R. Hsieh, V. J. Borowski, J. Y. Her, S. W. Shaw, Paper 972057, Proceedings of the 1997 *SAE Noise and Vibration Conference and Exposition*, 1997.

"On the dynamics of systems with multiple centrifugal pendulum vibration absorbers - stability and bifurcation of the unison response," invited paper, with C.P. Chao, 2nd European Nonlinear Oscillations Conference, Prague, September, 1996.

"Robust Stabilization of Large Amplitude Ship Rolling in Regular Beam Seas," with S.L. Chen, H. K. Khalil and A. W. Troesch. Symposium Volume on *Nonlinear Dynamics and Control*, 1996 International Mechanical Engineering Conference and Exposition, Atlanta.

"Nonlinear Modal Analysis of the Forced Response of Structural Systems," Paper 96-1250, with N. Boivin and C. Pierre, *Proceedings of the AIAA Dynamics Specialists Conference*, Salt Lake City, UT, April 1996.

"Torsional Vibration Reduction in Internal Combustion Engines Using Centrifugal Pendulums," ASME Design Engineering Technical Conference, Volume DE-84-1, 487-492, with C.T. Lee, 1995.

“A Comparative Study of Nonlinear Centrifugal Pendulum Vibration Absorbers,” *Nonlinear and Stochastic Dynamics*, ASME Volume AMD-Vol.192/DE-Vol. 78,91-98, with C.T. Lee, 1994.

“Nonlinear Dynamics and Capsizing of Small Fishing Vessels,” *Proceedings of the Fifth International Conference on Stability of Ships and Ocean Vehicles,* Volume 3, with C. Jiang and A. W. Troesch, 1994.

“On the Nonlinear Dynamics of Centrifugal Pendulum Vibration Absorbers,” *Proceedings of the Conference on Asymptotics in Mechanics*, with C.T. Lee, St. Petersburg, Russia, 1994.

“On the Nonlinear Dynamics of Centrifugal Pendulum Vibration Absorbers,” *Smart Structures, Nonlinear Vibration and Control*, Volume 1, 247-309, A. Guran and D. J. Inman, eds., Prentice Hall, with C.T. Lee, 1995.

“Non-Linear Modal Analysis of Structural Systems Using Multi-Mode Invariant Manifolds,” Paper 94-1672, with N. Boivin and C. Pierre, *Proceedings of the AIAA Dynamics Specialists Conference*, Hilton Head, SC, April 1994.

“A Predictive Method for Vessel Capsize in Random Seas,” *Nonlinear Dynamics of Marine Vehicles*, ASME Volume, with S. R. Hsieh and A. W. Troesch, 1993.

Forward for Volume **4** (6) of *Nonlinear Dynamics*, pp. 527-530, in honor of the 70th birthday of Professor P. R. Sethna, with A.K. Bajaj, 1993.

“Normal Modes and Modal Analysis Techniques for Nonlinear Structural Systems,” with C. Pierre, to appear in the volume, *Stochastic Modelling and Nonlinear Dynamics: Applications to Mechanical Systems,* CRC Press, N. Sri Namachchivaya and W. Klieman, eds., 1992.

“On Nonlinear Normal Modes,” *Nonlinear Vibrations*, ASME Volume DE-50 (and AMD-144), pp. 1-5, R.A. Ibrahim, N.S. Namachchivaya and A.K. Bajaj (eds.), with C. Pierre, 1992, invited.

“Reducing Vibration of Reciprocating Engines with Crankshaft Pendulum Absorbers,” 1991 SAE Technical Paper 911876, V. J. Borowski, H.H. Denman, D. L. Cronin, J. P. Hanisko, L. T. Brooks, D.A. Mikulec, W. B. Crum, and M.P. Anderson, 1991. Also appeared in the SAE Transactions.

“The Local Stability of Inactive Modes in Chaotic Multi-Degree-of-Freedom Systems,” *International Series of Numerical Mathematics* 97, 333-342, (from the Proceedings of the Conference: Bifurcation and Chaos: Analysis, Algorithms, and Applications, Wurzburg, 1990), with S. R. Hsieh, 1991, invited.

“On Domains of Convergence in Eigenvalue Optimization Problems,” *Proceedings of the Third Air Force/NASA Symposium on Recent Advances in Multidisciplinary Analysis and Optimization*, 198-203, with A. Diaz and J. Pan, 1990.

“On Domains of Convergence in Eigenvalue Optimization Problems,” *Proceedings of the Second World Congress on Computational Mechanics*, Extended Abstract, International Association of Computational Mechanics, with A. Diaz, 1990.

“The Stability of Modes at Rest in a Chaotic System,” Abstract, Third Conference on Nonlinear Vibrations, Stability, and Dynamics of Structures and Mechanisms, Blacksburg, VA, 1990.

“Nonlinear Interactions in Rotordynamics,” Abstract, Third Conference on Nonlinear Vibrations, Stability, and Dynamics of Structures and Mechanisms, Blacksburg, VA, 1990.

“Nonlinear Interactions Between Resonance and Instability in a Symmetric Rotor,” *Proceedings of the Third International Symposium on Transport Phenomena and Dynamics of Rotating Machinery*, Volume 2, 198-212, with J. Shaw, 1990, invited.

“The Suppression of Chaos in Periodically Forced Oscillators,” *Nonlinear Dynamics in Engineering Systems*, W. Schielen (Ed.), 289-296 (from the IUTAM Symposium, Stuttgart), 1990, invited.

“Nonlinear Dynamics of a Rotating Shaft,” *Trends in the Applications of Mathematics to Mechanics*, W. Schneider, H. Troger, and F. Ziegler (eds.), 62-70, with J. Shaw, 1991, invited.

“Nonlinear Interactions in Rotordynamics,” Abstract, 26th Meeting of the Society of Engineering Science, 1989, invited.

“Chaotic Dynamics in a Class of Multi-Degree of Freedom Systems,” Abstract, Applied Mechanics and Engineering Sciences Conference, 89, 1988.

“Extensions and New Applications of Melnikov's Method for Predicting the Onset of Chaos,” Abstract, Second Workshop on Non-linear Vibrations, Stability and Dynamics of Structures and Mechanisms, 1988.

“The Performance of an Impact Print Hammer,” *Developments in Mechanics* 14b, 826-831, with P.C. Tung, 1987.

“Experimental Response of a Single Degree of Freedom Impacting System,” *Developments in Mechanics* 14b, 839-844, with D. Moore, 1987.

“The Dynamic Analysis of the Centrifugal Pendulum Vibration Absorber with Motion Limiting Stops,” *Developments in Mechanics* 14b, 845-850, with M. Sharif-Bakhtiar, 1987.

“On the Effects of Asymmetries on a System Near a Codimension Two Point,” *Dynamical Systems Approaches to Nonlinear Problems in Circuits and Systems*, 317-332, SIAM Publication, F. Salam and M. Levi (eds.), with P. R. Sethna.

“Chaotic Dynamics of a Rotating Beam,” Abstract, AFOSR/ARO Workshop on Nonlinear Dynamics, Stability, and Dynamics at Structures and Mechanisms, 1987.

“Chaotic Motions of a Torsional Vibration Absorber,” Abstract, 23rd Annual Meeting of the Society of Engineering Science, S-16 #2, 1986, invited.

S. W. Shaw, “Arnold Tongues and Subharmonics in the Forced Oscillations of a Mechanical Clock,” *Proceedings 1985 IEEE Conference on Decision and Control*, 976-981, 1985, invited.

S. W. Shaw, “Forced Oscillations of the Inverted Pendulum with Constraints,” Abstract, 22nd Annual Meeting of the Society of Engineering Science, 321, 1985, invited.

P. R. Sethna and S. W. Shaw, “Bifurcations of Articulated Tubes Conveying a Fluid,” Abstract, 1985 Summer Conference on Multiparameter Bifurcation Theory, American Mathematical Society, 1985.

S. W. Shaw, “The Dynamic Response of a Single Degree of Freedom System with Dry Friction,” *Developments in Mechanics* 13, 434-435, 1985.

S. W. Shaw and P. J. Holmes, “Piecewise Linear Forced Oscillations,” Abstract, Ninth U.S. National Congress of Applied Mechanics, 149, 1982.

## PRESENTATIONS

*Invited External Seminars*

Department of Mechanical Engineering, University of Washington, Seattle, WA, 2016
Valeo Research and Development Center, Amiens, France, 2015
Center for Applied Mathematics, Cornell University, Ithaca, NY, 2014
Department of Mechanical and Aerospace Engineering, Florida Institute of Technology,
    Melbourne, FL, 2014
Ocean and Mechanical Engineering Department, Florida Atlantic University, Boca Raton, FL, 2013
Department of Power Engineering, National Tsing Hua University, Hsinchu, Taiwan, 2012
Mechanical Engineering Department, McGill University, Montreal, 2005, 2011
Dynamics Interest Group, UIUC, 2010
Department of Mechanical Engineering, Purdue University, 1985, 1992, 2010
Dynamics and Controls Group, Department of Mechanical Engineering, TU/Eindhoven, 2009
Research and Innovation Center, Ford Motor Company, Dearborn, MI, 2009
Department of Mechanical Engineering, Rice University, Houston, TX, 2009
Department of Mechanical Engineering, University of Maryland-Baltimore County, 2008
Department of Mechanical Engineering, University of Rhode Island, 2008
Department of Mechanical Engineering, Tel Aviv University, 2008
Department of Mechanical Engineering, Southern Methodist University, Dallas, 2008
Department of Mechanical Engineering, Duke University, 1992, 2008
Control Engineering Seminar, University of Michigan, 2004, 2007
Department of Engineering Mathematics, University of Bristol, Bristol, UK, 2007
Boeing Integrated Defense Systems, El Segundo, CA, 2007
Department of Mechanical Engineering, UCLA, 2007
Department of Mechanical Engineering, Technion, Haifa, Israel, 2006.
Center for Control Engineering and Computing, UC-Santa Barbara, 2000, 2004.
Mechanical Engineering Seminar, Oakland University, March, 2002.
Mathematics Department Seminar, Calvin College, April, 2001.
Mechanical Engineering Department Seminar, University of Akron, April, 2001.
Department of Dynamical Systems and Control, Caltech, 2000.
NASA Langley, Structural Dynamics Branch, Hampton, VA, (with C. Pierre), 1999
Department of Aeronautical and Astronautical Engineering, University of Illinois, Urbana,

1992, 1995
Department of Aerospace Engineering and Mechanics, University of Minnesota, 1994.
Center for Nonlinear and Complex Systems, Duke University, 1992
Department of Mechanical Engineering, Case Western Reserve University, 1992
Department of Mechanical and Aerospace Engineering, Arizona State University, 1990, 1992
Department of Mathematics, University of Missouri-Rolla, 1992
Department of Mechanical Engineering, University of Missouri-Rolla, 1992
Department of Theoretical and Applied Mechanics, Cornell University, 1991
Department of Mechanical Engineering, University of Washington, 1991
Department of Mechanical Engineering, Washington State University, 1991
Engineering Research, Ford Motor Company, Dearborn, 1984, 1988, 1991.
Power Systems Department, General Motors Research Laboratories, 1990
Department of Mechanical Engineering, University of Michigan, Ann Arbor, 1983, 1987
Scientific Laboratories, Ford Motor Company, Dearborn, 1990
Physics Department, Oberlin College, 1989
Applied Mechanics/Mechanical Engineering, Caltech, 1989
Applied Mathematics, University of Michigan, Ann Arbor, 1988
Physics Department, University of Michigan, Flint, 1988
Department of Mechanical Engineering, Wayne State University, 1987
Department of Mechanical Engineering, University of California, Berkeley, 1986
Physics Department, Wayne State University, 1984

*In-House Seminars*

ASME Student Chapter, Florida Tech, 2016
Mechanical and Aerospace Engineering Department, Florida Tech, 2016
Condensed Matter Group, Physics and Astronomy, MSU, 2012
Electrical and Computer Engineering Department, MSU, 2012
Mechanical Engineering Department, MSU, 1986, 1987 (fluids group), 1991, 1994, 2003, 2007
Applied Math Seminar, Department of Mathematics, MSU, 1984, 1987(2), 1991, 2006
School of Engineering, Oakland University, 1983
Department of Theoretical and Applied Mechanics, Cornell University, 1983

*Conferences* (presentations without associated papers; keynote and other special lectures listed above)

IDEAS (Investigating Dynamics in Engineering and Applied Science), A workshop celebrating Gábor Stépán's 60th birthday, 2014, Budapest, Hungary, invited
USNCTAM, minisymposium in honor of F. C. Moon, East Lansing, MI, 2014, invited
Symposium on Advances in Nonlinear Dynamics, in honor of A. K. Bajaj, West Lafayette, IN, 2012, invited
IUTAM Symposium on Nonlinear Dynamics in Advanced Technologies and Engineering Design, Aberdeen, Scotland, 2010
Nonlinear Vibrations Workshop, Duke University, Durham, NC, 2008, 2010
SPIE Smart Structures/NDE Conference, San Diego, CA, 2010
Non-linear Vibrations, Stability, and Dynamics of Structures and Mechanisms, Blacksburg, VA, 1988, 1990, 1992, 1994, 1996, 2000, 2010
22nd Biennial Conference on Mechanical Vibration and Noise, ASME International Design

Engineering Technical Conference, San Diego, CA, 2009
CMMI Grantees Conference, Honolulu, 2 posters, 2009
Ninth Biennial ASME Conference on Design and Analysis, Haifa, Israel, 2008
Sixth EUROMECH Conference on Nonlinear Dynamics, St. Petersburg, Russia, 2008
Twelfth International Symposium on Transport Phenomena and Dynamics of Rotating
Machinery (ISROMAC-12), Honolulu, Hawaii, 2008
2007 ASME Design Engineering Technical Conferences, Las Vegas
Applied Nonlinear Dynamics: Making it Real, University of Bristol, Bristol, UK, invited, 2007
Workshop on Coupled Oscillators and Applications to Nanosystems, Santa Barbara, CA, 2007
DARPA Workshop on Nonlinear Dynamics in Nano-mechanical Systems, San Francisco, CA,
invited, 2007
Eleventh International Symposium on Transport Phenomena and Dynamics of Rotating
Machinery (ISROMAC-11), Honolulu, Hawaii, March, 2006
2005 ASME Design Engineering Technical Conferences (2 papers), Long Beach
International Workshop on Applied Dynamical Systems – Mechanics, Turbulence, Knots,
Cockroaches, and Chaos, Montreal, October, 2005, invited
Fifth EUROMECH Conference on Nonlinear Dynamics, Eindhoven, 2005, two presentations,
including one invited sectional lecture
SIAM Conference on Dynamical Systems, Snowbird, UT, 2005, invited
IUTAM Symposium on Chaotic Dynamics and Control of Systems and Processes in Mechanics,
Rome, 2003
Tenth International Symposium on Transport Phenomena and Dynamics of Rotating
Machinery (ISROMAC-10), Honolulu, Hawaii, March, 2004
2003 ASME Design Engineering Technical Conferences (3 papers), Chicago
SAE Noise and Vibration Conference and Exhibition, Traverse City, MI, 2003
JSME Minisymposium on Nonlinear Dynamics and Chaos in Mechanical Systems, Tokyo, 2001
SPIE Conference on Smart Structures, Newport Beach, 2000
Symmetry and Stability in Nonlinear Mechanics, Budapest, 2000, invited
1999 ASME Design Engineering Technical Conferences (4 papers), Las Vegas
1999 ASME Mechanics and Materials Conference (2 papers), Blacksburg, VA
NASA Ames, Rotorcraft Dynamics Branch, Moffett Field, CA, 1998
1997 ASME Design Engineering Technical Conferences (5 papers), Sacramento, CA
IUTAM Symposium on Applications of Nonlinear and Chaotic Dynamics in Mechanics,
Ithaca, NY, invited keynote speaker, 1997
1997 SAE Noise and Vibration Conference and Exposition, Traverse City, MI
1996 Winter Annual Meeting, Atlanta, GA
Second European Non-Linear Oscillations Conference, Prague, 1996, invited sectional lecture
The Panther CAE Experience, Ford Motor Co., Dearborn, MI, 1995, invited
Advanced Research Workshop on Nonlinear Dynamics, Aberdeen, Scotland, 1995, invited
NSF Workshop on Nonlinear Dynamics in Manufacturing, La Jolla, CA, 1995, invited
1994 ASME Winter Annual Meeting, Chicago, invited
31st Annual Meeting of the Society of Engineering Science, College Station, TX, 1994
International Symposium on Asymptotics in Mechanics, St. Petersburg, Russia, 1994
Twelfth U.S. National Congress of Applied Mechanics, Seattle, 1994
1992 ASME Winter Annual Meeting, Anaheim, CA, invited
XVIIIth International Congress of Theoretical and Applied Mechanics, Haifa, Israel, 1992

ASME Summer Applied Mechanics Conference, Scottsdale, AZ, 1992
Fourth ARO Workshop on Rotorcraft Dynamics, College Park, MD, 1991, invited
Bifurcation and Chaos: Analysis, Algorithms, and Applications, Wurzburg, Germany, 1990, invited
26th Annual Meeting of the Society of Engineering Science, Ann Arbor, 1989, invited
IUTAM Symposium on Nonlinear Dynamics in Engineering Systems, Stuttgart, FRG, 1989, invited
8th Symposium on Trends in the Application of Mathematics to Mechanics, Hollabrunn, Austria, 1989, invited
ASME/ASCE Mechanics Conference, San Diego, 1989, invited
SIAM Conference on Control in the 90's, San Francisco, 1989, invited
Applied Mechanics and Engineering Sciences Conference, Berkeley, 1988
AFOSR/ARO Workshop on Nonlinear Vibrations, Stability, and Dynamics of Structures and Mechanisms, Blacksburg, VA, 1987
Engineering Foundation Workshop on Nonlinear Dynamics, Henniker, NH, 1986, invited
23rd Annual Meeting of the Society of Engineering Science, Buffalo, 1986, invited
IEEE Conference on Decision and Control, Ft. Lauderdale, 1985, invited
22nd Annual Meeting of the Society of Engineering Science, State College, PA, 1985, invited.
19th Midwest Mechanics Conference, Columbus, 1985
American Mathematical Society Summer Conference on Multiparameter Bifurcation Theory, Arcata, CA, 1985
ASME/ASCE Mechanics Conference, Albuquerque, 1985, 2 papers
XVIth International Congress of Theoretical and Applied Mechanics, Lyngby, Denmark, 1984
ASME Winter Annual Meeting, Boston, 1983

*Other Meetings Attended (without presentation):*

DARPA MTO MESO Program Review, Washington, DC, 2013
DARPA MTO MESO Program Review, Jykell Island, GA, 2011
Hilton Head: A Solid State Sensors, Actuator, and Microsystems Workshop; Hilton Head, SC, 2008, 2012, 2014, 2016
SIAM Conference on Dynamical Systems, Snowbird, UT, 2009
Structural Dynamics 2000, Workshop on the future of structural dynamics, invited participant, Los Alamos, 1999
SAE Noise and Vibration Conference and Exposition, Traverse City, MI, 1995
ASME Summer Conference, Columbus, OH, 1991
SIAM Conference on Dynamical Systems, Orlando, FL, 1990
Twentieth Midwestern Mechanics Conference, West Lafayette, IN, 1987
ASME Winter Annual Meeting, Anaheim, CA, 1986
NSF Workshop on Research Needs in Theoretical Dynamics, Buffalo, NY, 1986, invited participant
First IBM/University Symposium on Impact Printing, Yorktown Heights, NY, 1985 invited participant
Army Research Office Workshop on Chaos in Nonlinear Dynamical Systems, Research Triangle Park, NC, 1983
Chaos in Dynamical Systems, College Park, MD, 1983

**GRADUATE STUDENTS** (at MSU unless otherwise indicated)

*Current:*
Joey Fisher, M.S. (thesis), FIT
B. Scott Strachan, dual Ph.D. in ME and ECE, joint with P. Chahal, ECE
Pavel Polunin, dual Ph.D. in ME and Physics, joint with M. Dykman, Physics
Mustafa Acar, Ph.D., joint with B. Feeny

*Past:*
Ming Mu, M.S., 2015, joint with B. Feeny
S. Tran, M.S., 2014 (project), joint with B. Feeny
Abhisek Jain, M.S. 2013 (thesis), joint with B. Feeny
Pavel Polunin, M.S., 2013 (thesis)
Brendan Vidmar, Ph.D., 2012, joint with B. Feeny
Nicholas Miller, dual Ph.D. in ME and Physics, 2012, joint with M. Dykman, Physics
Thomas Theisen M.S., 2011 (thesis) joint with B. Feeny
Ryan Monroe, Ph.D., 2011
Brendan Vidmar, M.S., 2009 (thesis), joint with B. Feeny
Jeffrey Rhoads, Ph.D., 2007
Nicholas Miller, M.S., 2007 (thesis)
Mark Orlowski, M.S., 2007 (thesis)
Brian Olson, Ph.D., 2006
Jeffrey Rhoads, M.S. 2003 (thesis)
Dongying Jiang, Ph.D., UM, 2003, joint with C. Pierre
Polarit Apiwattanalunggarn, Ph.D., 2003, joint with C. Pierre
Tyler Nester, M.S. 2002 (thesis)
Brian Olson, M.S., 2001 (thesis)
Abdallah Alsuwaiyan, Ph.D., 1999
Eric Pesheck, Ph.D., UM, 1999, joint with C. Pierre
Chang-Po Chao, Ph.D., 1997
Vishal Garg, M.S., 1996 (thesis)
Shyh-Leh Chen, Ph.D., 1996
Cheng-Tang Lee, Ph.D., UM, 1994
Nicholas Boivin, Ph.D., UM, 1995, joint with C. Pierre
Changben Jiang, Ph.D., UM, 1995, joint with A. Troesch
L. Steven Gunsiore, M.S., 1995, (project)
Haider Arafat, M.S.E., UM, 1993 (project)
Anthony Boardman, M.S.E., UM, 1993 (project)
Rosamond Dolid, M.S.E., UM, 1993 (project)
Charisse Russell, M.S.E., UM, 1993 (project), joint with N. Perkins
John Miller, M.S.E., UM, 1992 (project), joint with C. Pierre
Faramarz Farahanchi, M.S., 1991 (thesis)
Shang-Rou Hsieh, Ph.D., 1991
Jinsiang Shaw, Ph.D., 1989
Mehrnam Sharif-Bakhtiar, Ph.D., 1989
Doug Moore, M.S., 1987 (thesis)
Pi-Cheng Tung, Ph.D., 1987

*Visiting*: Johannes Mayet, 2014, from TU-Munich, advisor: H. Ulbrich
Suguang Duo, 2014, from TU-Denmark, advisor: J. Jensen
Guangming Zhao, 2012, from Wuhan University of Technology, advisor: J. Zhengfeng
Hein van Beek, 2010, from TU-Eindhoven, advisor: H. Nijmeijer
Gábor Csernák, 1999, from TU-Budapest, advisor: G. Stépán

**UNDERGRADUATE STUDENT SUPERVISION** (since 2007)

Previous: Michael Thelen, Jessica O'Brien, James Miller, Cody Little, Bara Aldasouqi, Kyle Justus, Brian Rockwell, J. T. Whitman, Brian Wagonecht, Thomas Theisen, Ashley Kulczycki, Brian Rockwell, Jelena Paripovic

**EXTERNAL FUNDING** (* indicates active and approved projects)

* "Pendulum Vibration Absorbers," Achates Power Inc., through Florida Tech Consulting (FTC)

* "Collaborative Research: Tailoring the Nonlinear Response of MEMS," NSF. PIs: S. W. Shaw and K. L. Turner (UCSB), May 2016-May 2019. $600K total, FIT portion $300k.

* "GOALI: Vibration Absorbers for Multi-Frequency Excitation," NSF. PIs: S. W. Shaw, B. F. Feeny, and B. Geist, (FCA, Chrysler), June 2011-June 2017 (including two years no cost extension), $350k (plus a $6k RUE supplement in 2009).

"Pendulum Absorber Software," Valeo, through FTC, $45k, 2016.

"Nonlinear Elasticity of Doped Semiconductors," DARPA MTO, PIs: M. I. Dykman and S. W. Shaw, Nov. 2015-Nov. 2016, $134k.

"Collaborative Research: MEMS Frequency Converters Based on Nonlinear Resonances," NSF. PIs: S. W. Shaw, P. Chahal, and K. Turner (UCSB), Sept. 2012-Aug. 2016 (including two years no cost extension). $550K total, MSU portion $225k.

"Pendulum Absorber for Axle Whine," FCA (Chrysler), PIs: S. W. Shaw and B. F. Feeny, June 2015-July 2016, $50k.

"Studying Electron Transport in Nanowires Using Fluctuations of Nanomechanical Vibrations," ARO. PIs: M. I. Dykman and S. W. Shaw, July 2012-June 2016 (including one year no cost extension), $450k.

"DEFYS: Practical Nonlinearities," subcontract from Stanford, DARPA MTO prime, MSU PIs: M. I. Dykman, S. W. Shaw. T. Kenny (Stanford); Jan. 2014-Dec. 2015, MSU portion: $550k.

"Pendulum Vibration Absorber Analysis," Valeo, 10/1/2015-1/15/2016, $45k.

"Pendulum Absorber Simulation Software Integration," PIs: S. W. Shaw and B. Feeny, Ford Motor Company; 2014-15, $27k.

"DEFYS: Dynamics Enabled NEMS Oscillators," subcontract from Caltech, DARPA MTO prime, MSU PI: M. I. Dykman, co-PI: S. W. Shaw; Caltech PI: M. Roukes; Phase I: July 1, 2010-Dec 13, 2013; MSU portion: $490K.

"Collaborative Research: Noisy Nonlinear Microscale Oscillators for Novel Applications," NSF. PIs: S. W. Shaw, M. I. Dykman, and H. B. Chan (U. of Florida/Hong Kong U. of Science and Technology), July 1, 2009-June 30, 2013 (including a one-year no-cost extension), $424k total (MSU portion $295k, plus a $6k RUE supplement in 2009).

"Crankshaft Pendulum Absorber," Honda R & D Americas, Inc. PIs: S. W. Shaw and B. F. Feeny, Feb. 14 - Aug. 14, 2013. $30k.

"Development of CAE Tools for Pendulum Absorber Design," Ford Motor Co. PIs: S. W. Shaw and B. F. Feeny, Jan.-Dec., 2012, $55k.

"Collaborative Research: Novel Microscale Resonant Sensors for Chemical and Biological Detection," NSF PIs: S. W. Shaw and K. L. Turner (UCSB), Aug 16, 2008-Aug. 15, 2012 (including a one-year, no-cost extension), $436k (MSU portion $180k, plus a $6k RUE supplement in 2009).

"GOALI: Transient Dynamics of Torsional Vibration Absorbers," NSF. PIs: S. W. Shaw, A. G. Haddow, B. F. Feeny (MSU), and B. Geist, (Chrysler Group, LLC), Sept. 2007-Aug. 2011 (including a one-year, no-cost extension), $350k, plus a $6k RUE supplement in 2009, and a $3k travel supplement in 2009.

"Pendulum Vibration Absorber to Expand MDS Operating Range," Chrysler Challenge Fund. PIs: S. W. Shaw and B. F. Feeny, July 2010-June 2011, $50k.

"Pendulum Vibration Absorber to Expand MDS Operating Range," Chrysler Challenge Fund. PIs: A. G. Haddow and S. W. Shaw, July 2008-June 2009, $50k.

"Pendulum Vibration Absorber to Expand MDS Operating Range," Chrysler Challenge Fund. PIs: A. G. Haddow and S. W. Shaw, July 2007-June 2008, $50k.

"Vibration Absorbers for Systems with Cyclic Symmetry," NSF, Collaborative Grant. PIs: S. W. Shaw and A. G. Haddow (MSU), C. Pierre (McGill University), Aug. 2004-July 2008 (including a one-year, no-cost extension), $300k total (MSU portion $170k).

"Dynamics of Microbeam Sensor Arrays," NSF SST (Small Sensors Team). PIs: K. Turner (UCSB), S. W. Shaw, J. Moehlis (UCSB), Sept. 2004-Aug. 2007, $400k total (MSU portion $110k).

"Improved Control Authority in Flexible Structures Using Stiffness Variation," AFOSR, PIs: R. Mukherjee (MSU) and S. W. Shaw, Feb. 2004-Aug. 2007, $271k.

"Pendulum Vibration Absorber to Expand MDS Operating Range," Chrysler Challenge Fund. PIs: A. G. Haddow and S. W. Shaw, Jan. 2006-Jan. 2007, $50k.

“Improved Performance for MEMS-based Filters,” AFOSR, PIs: K. Turner (UCSB) and S. W. Shaw, Jan. 2002-June 2005, $289k.

“Model Reduction Techniques for Large-Amplitude Vibrations of Complex Nonlinear Structures,” ARO, PIs: S. W. Shaw and C. Pierre (U. of Michigan), May 2001-Dec. 2004, $210k.

“The Dynamic Performance of Nonlinear Vibration Absorbers,” NSF, Dynamic Systems and Control Program. PIs: S. W. Shaw and A. Haddow (MSU), Sept. 2000-Aug. 2004, $235k.

“Improved Control Authority Using Variable Stiffness,” AFOSR, PIs: R. Mukherjee and S. W. Shaw, March 2003-Feb. 2004, $47k.

“The Dynamics of Systems with Tuned Substructures,” NSF, with A. Haddow, Aug. 1997-Aug. 2001, $240k.

“Nonlinear Modal Analysis and Component-Mode Synthesis of Large-Scale Structural Systems,” Army Research Office, with C. Pierre, Jan. 1997-Dec. 2000, $257k.

“Real-Time Automotive Sensing and Control,” NSF, PI: F. Salam, Co-PIs: S. Shaw, H. Khalil, C. Radcliffe, L. Tummala, Aug. 1997-Aug. 2000, $420k.

“Risk Analysis of Commercial Fishing Vessels Operating in Extreme Seas,” Michigan Sea Grant College Program, with A. Troesch, Sept. 1997-Aug. 2000, $180k.

“A Nonlinear Probabilistic Approach to the Problem of Fishing Vessel Capsize,” Michigan Sea Grant Program, with A. Troesch, Sept. 1993-Aug. 1996, $180k.

“Modal Analysis Techniques for Nonlinear, Large-Scale Systems,” Army Research Office, with C. Pierre, Jan. 1993-Dec. 1996, $257k.

“An Invariant Manifold Approach to Modal Analysis of Nonlinear Structural Systems,” NSF, Grant MSS-9201815 (at UM) and MSS-9496271 (at MSU), with C. Pierre, Sept. 1992-Jan. 1997, $283k.

“A Nonlinear Probabilistic Approach to the Problem of Fishing Vessel Capsize,” Michigan Sea Grant Program, with A. Troesch, Sept. 1991-Aug. 1993, $120k.

“Nonlinear Dynamics of Mechanical Systems,” NSF, Grant MSS-8915453, Feb. 1990-July 1993, $181k.

“Dynamic Signal Analyzer,” NSF Engineering Research Equipment Grant, Co-PI, P.I.: A. G. Haddow, 1988, $40k (with $37k MSU matching funds).

“Nonlinear Dynamics,” DARPA, with S. N. Chow, A. Novick-Cohen, B. Drachman, S. Dragosh, L. Ni and K. Mischaikow. Jan. 1988-Dec. 1990, $1,306k. (moved to Georgia Tech with S. N. Chow in Sept., 1988).

“Dynamics of Nonlinear Mechanical Systems,” NSF, Grant MSM-8613294, Jan. 1987- Dec. 1989, $152k.

“National Intelligence Mathematics and Multiprocessing Project,” DARPA, 1985-87, with S. N. Chow, B. Drachman, T.Y. Li, L.M. Ni and L.S. Young, $741k.

“Forced Vibrations of Mechanical Systems Having Amplitude Constraints,” NSF Research Initiation Grant, MEA-8421248, 1984-86, $48k.