UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

BORGWARNER ITHACA LLC ,
Petitioners

v.

SCHAEFFLER GROUP USA INC.,
Patent Owner

Case IPR2022-00321
U.S. Patent No. 7,389,756

DECLARATION OF CHRISTOPHER M. WHITE, PH.D. IN SUPPORT OF PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 7,389,756

`

TABLE OF CONTENTS

I, Christopher M. White, declare as follows:

I. Introduction

1. I have been retained on behalf of BorgWarner Ithaca LLC ("BorgWarner") for the above-captioned *inter partes* review (IPR) proceeding. I am being compensated for my time in connection with this IPR at my standard hourly consulting rate. I understand that this proceeding involves U.S. Patent No. 7,389,756 ("the '756 patent") titled "Control valve for an apparatus for variable setting of the control times of gas exchange valves of an internal combustion engine" by Jens Hoppe and Ali Bayrakdar, and that the '756 patent is currently assigned to Schaeffler Group USA Inc. ("Patent Owner").

2. I have reviewed and am familiar with the specification of the '756 patent filed on November 2, 2006. I understand that the '756 patent has been provided as Ex. 1001. I will cite to the specification using the following format: '756 patent, 1:1-10. This example citation points to the '756 patent specification at column 1, lines 1-10.

3. I have reviewed and am familiar with the file history of the '756 patent. I understand that the file history has been provided as Ex. 1002.

4. I understand that the '756 patent has a filing date of November 2, 2006. For purposes of preparing this declaration, I have been asked to assume a priority date of November 3, 2005 (the filing date of German Application No.

10 2005 052 481). I have not been asked to opine, and do not provide any opinion, on whether the claims of the ’756 patent are entitled to this date.

5. In preparing this Declaration, I have also reviewed and am familiar with the following prior art used in my declaration below:

> **German Patent Application Publication No. 10346448** to Lehmann et al., entitled “Camshaft regulator for an internal combustion engine,” Published June 9, 2005, Filed October 7, 2003, Provided as Ex. 1004, Certified Translation Provided as Ex. 1005.
>
> **German Patent Application Publication No. 10340932** to Schafer et al., entitled “Slide valve and Method of manufacturing a slide valve,” Published March 31, 2005, Filed September 5, 2003, Provided as Ex. 1008, Certified Translation Provided as Ex. 1009.
>
> **U.S. Patent No. 5,325,762** to Walsh et al., entitled “Fluid pressure operated piston engine assembly,” Issued July 5, 1994, Filed July 26, 1993, Provided as Ex. 1010.
>
> **U.S. Patent No. 6,523,513** to Speier, entitled “Camshaft timing device for internal combustion engines,” Issued February 25, 2003, Filed March 16, 2002, Provided as Ex. 1012.
>
> **U.S. Patent No. 6,526,868** to Winkelmann et al., entitled “Master cylinder for use in power trains of motor vehicles,” Issued March 4, 2003, Filed April 8, 2002, Provided as Ex. 1013.
>
> **U.S. Patent Application Publication No. 2005/0109298** to Bolz et al., entitled “Camshaft adjuster for an internal combustion engine having hydraulic medium guides,” Published May 26, 2005, Filed October 7, 2004, Provided as Ex. 1014.

6. The ’756 patent describes a “control valve” to direct a hydraulic fluid or “pressure medium” to adjust the phase of a camshaft and thereby adjust valve timing in an internal combustion engine. ’756 patent, 1:8-59, 2:6-19.

7. I have been asked to provide my technical review, analysis, insights, and opinions regarding claims 1, 3-5, and 7-20 (“Challenged Claims”) of the ’756 patent and the above-noted references.

II. Qualifications

8. A copy of my current *curriculum vitae* is provided as Appendix B to this Declaration, and it provides a comprehensive description of my academic and employment history over the last twenty-plus years. In reaching the conclusions described in this declaration, I have relied on the documents and materials cited herein as well as those identified in Appendix A attached to this declaration. These materials comprise patents, related documents, and printed publications. Each of these materials is a type of document that experts in my field would have reasonably relied upon when forming their opinions and would have had access to either through the applicable patent offices and/or well-known libraries, conferences, publications, organizations, and websites in the field as further discussed herein. My opinions are also based upon my education, training, research, knowledge, and personal and professional experience.

9. I have over 20 years of experience in internal combustion engines, including experience as Senior Member of the Technical Staff, Combustion Research Facility, Engines Group, Sandia National Laboratories (2003-2006), Visiting Scientist, Combustion Research Facility, Engines Group, Sandia National Laboratories (2007), Consultant, Combustion Research Facility, Engines Group, Sandia National Laboratories (2007-2009), Invited Plenary Speaker 9th International Conference on Engines and Vehicles, Capri, Italy (2009), Principal

Investigator, National Science Foundation / Department of Energy, Advanced Combustion Engines: Collaborative Research: A Comprehensive Investigation of Unsteady Reciprocating Effects on Near-Wall Heat Transfer in Engines (2013-2017), and consultant services related to automotive mechanical engineering systems (2014-present).

10. I am currently Professor and Chair of the Department of Mechanical Engineering at the University of New Hampshire in Durham, New Hampshire. My research focuses on fluid mechanics, combustion, heat transfer, and energy conversion technologies. I have taught undergraduate and graduate courses in Fluid Mechanics, Thermodynamics, Experimental Measurements and Data Analysis, Experimental Fluid Dynamics, Renewable Energy Technologies, and Fluid Turbulence. In my research and in my academic instruction, I have used fluid control valves and provided instruction on the fundamental principles that underlie the kinematics and dynamics of fluid control valves.

11. I have expertise in mechanics, fluid dynamics, thermodynamics, combustion, and internal combustion engines.

12. Over the last 20 years, I have authored or co-authored a wide range of book chapters, journal articles, conference papers, and technical reports in the thermal-fluid sciences, including on various aspects of internal combustion engines. Among these works, I have had two papers designated by the Thomson Reuters

Essential Science Indicators (ESI) as a Highly Cited Paper. Highly Cited Papers are those that rank among the top 1% of most cited papers in their subject field. One Highly Cited Paper (White C.M., Steeper R.R. & Lutz A. E., *The hydrogen-fueled internal combustion engine: a technical review*, Int. J. Hydrogen Energy. 2006. 31:1292-1305. DOI:10.1016/j.ijhydene.2005.12.00) is on aspects of the internal combustion engine. As part of my research at Sandia National Laboratories in the Engines Group, I conducted internal combustion engine dynamometer tests. In addition, I performed optical/laser-based measurements within the combustion chamber of a direct-injection fueled internal combustion engine to study and quantify fuel-air mixing (White C.M., *OH chemiluminescence measurements in a direct-injection hydrogen-fuelled internal combustion engine*, Int. J. Engine Research. 2007. 8:185-204. DOI: 10.124314680874JER02206; Kaiser S. & White C.M. PIV and PLIF to Evaluate Mixture Formation in a Direct-Injection Hydrogen-Fuelled Engine. SAE Int. J. Engines 2009. 1:657-668. DOI:10.4271/2008-01-1034). For my research projects, I have designed and/or tested fluid control systems that included fluid control valves to regulate mass flow, pressure, temperature, and mixing rates. I have published invited research papers in the Department of Energy Progress Report for Advanced Combustion Engine Research and Development, Energy Efficiency and Renewable Energy Vehicle Technologies Office (2015, 2016, 2017). For my consultant work, I have disassembled internal combustion engines and analyzed engine timing systems. A detailed record of my professional qualifications, including a list of publications, awards, and professional activities, is set forth in my curriculum vitae attached to this declaration as Appendix B.

13. I received B.S. and M.S. degrees in Mechanical Engineering from Stony Brook University in 1994 and 1996, respectively. I received M.S. and Ph.D. degrees in Mechanical Engineering from Yale University in 1999 and 2001, respectively.

14. My *curriculum vitae* contains further details on my education, experience, publications, and other qualifications to render an expert opinion. Appendix B. My work on this case is being billed at a flat rate of $500 per hour, with reimbursement for actual expenses. My compensation is not contingent upon the outcome of this *inter partes* review proceeding.

III. Legal Understanding

A. My Understanding of Claim Construction

15. I have been informed that patent claims are construed from the viewpoint of a person of ordinary skill in the art of the patent at the time of the invention. I have been informed that patent claims generally should be interpreted consistent with their plain and ordinary meaning as understood by a person of ordinary skill in the art in the relevant time period (*i.e.*, at the time of the purported invention, or the so called "effective filing date" of the patent application), after reviewing the patent claim language, the specification and the prosecution history (*i.e.*, the intrinsic record).

16. I have further been informed that a person of ordinary skill in the art must read the claim terms in the context of the claim itself, as well as in the context of the entire patent specification. I understand that in the specification and prosecution history, the patentee may specifically define a claim term in a way that differs from the plain and ordinary meaning. I understand that the prosecution history of the patent is a record of the proceedings before the U.S. Patent and Trademark Office, and may contain explicit representations or definitions made during prosecution that affect the scope of the patent claims. I understand that an applicant may, during the course of prosecuting the patent application, limit the scope of the claims to overcome prior art or to overcome an examiner's rejection, by

clearly and unambiguously arguing to overcome or distinguish a prior art reference, or to clearly and unambiguously disavow claim coverage.

17. In interpreting the meaning of the claim language, I understand that a person of ordinary skill in the art may also consider "extrinsic" evidence, including expert testimony, inventor testimony, dictionaries, technical treatises, other patents, and scholarly publications. I understand this evidence is considered to ensure that a claim is construed in a way that is consistent with the understanding of those of ordinary skill in the art at the time of the claimed invention. This can be useful for a technical term whose meaning may differ from its ordinary English meaning. I understand that extrinsic evidence may not be relied on if it contradicts or varies the meaning of claim language provided by the intrinsic evidence, particularly if the applicant has explicitly defined a term in the intrinsic record.

18. I understand that there is a "means-plus-function" type of claim interpretation that may be argued to apply to certain terms, pursuant to 35 U.S.C. §112(6). For these terms, if the term is determined to be a "means-plus-function" term under §112(6), I understand that there must be a corresponding structure disclosed in the specification in a way that a person of ordinary skill in the art would understand what structure would perform the claimed function. I understand the disclosure may be implicit in the specification if it would have been clear to a person of ordinary skill in the art what structure corresponds to the claimed function.

B. My Understanding of Anticipation

19. I have been informed that if each and every element or step of a claim is disclosed within the "four corners" of a prior art reference, that claim is said to be "anticipated" by that single prior art reference and is invalid under 35 U.S.C. § 102 because the claimed invention is not, in fact, new or novel. I have been informed that the standard for anticipation in an *inter partes* review proceeding is by a preponderance of the evidence.

20. I have also been informed that a prior art reference can disclose a claim feature if that feature is expressly described by that reference, or inherent from its disclosure. I have been informed that something is inherent from a prior art reference if the missing descriptive matter must necessarily be present and if it would be so recognized by a person of ordinary skill in the art ("POSA"). I also have been informed that inherency cannot be established by probabilities or possibilities, and that the mere fact that something may result from a given set of circumstances is not sufficient to show inherency.

21. I have further been informed that where a reference discloses multiple embodiments, the reference should not be limited to a preferred embodiment. Instead, each disclosed embodiment may anticipate.

22. Moreover, I have been informed that as part of an anticipation analysis, it is proper to take into account not only specific teachings of the reference, but also

the inferences that one skilled in the art would reasonably be expected to draw therefrom. A reference can anticipate a claim even if it does not expressly spell out all the limitations arranged or combined as in the claim, if a person of skill in the art, reading the reference, would at once envisage the claimed arrangement or combination.

23. I have been informed that a prior art document can disclose a claim feature, and anticipate a claimed invention, if that feature is described in another document that has been incorporated by reference. I have also been informed that, to incorporate by reference, the host document must identify with detailed particularity what specific material it incorporates, and clearly indicate where that material is found in the incorporated document. I have also been informed that, in making the determination of the extent to which material is incorporated into a host document, the standard of a POSA should be used to determine whether the host document describes the material to be incorporated by reference with sufficient particularity.

C. My Understanding of Obviousness

24. I understand that a claim may be invalid under 35 U.S.C. § 103(a) if the subject matter described by the claim as a whole would have been obvious to a hypothetical person of ordinary skill in the art in view of a prior art reference or in view of a combination of references at the time the claimed invention was made.

Therefore, I understand that obviousness is determined from the perspective of a hypothetical person of ordinary skill in the art and that the asserted claims of the patent should be read from the point of view of such a person at the time the claimed invention was made. I further understand that a hypothetical person of ordinary skill in the art is assumed to know and to have all relevant prior art in the field of endeavor covered by the patent in suit.

25. I have been informed that there are two criteria for determining whether prior art is analogous and thus can be considered prior art: (1) whether the art is from the same field of endeavor, regardless of the problem addressed, and (2) if the reference is not within the field of the patentee's endeavor, whether the reference still is reasonably pertinent to the particular problem with which the patentee is involved. I have also been informed that the field of endeavor of a patent is not limited to the specific point of novelty, the narrowest possible conception of the field, or the particular focus within a given field. I have also been informed that a reference is reasonably pertinent if, even though it may be in a different field from that of the patentee's endeavor, it is one which, because of the matter with which it deals, logically would have commended itself to a patentee's attention in considering his/her problem.

26. I have also been advised that an analysis of whether a claimed invention would have been obvious should be considered in light of the scope and

content of the prior art, the differences (if any) between the prior art and the claimed invention, and the level of ordinary skill in the pertinent art involved. I understand as well that a prior art reference should be viewed as a whole.

27. I have also been advised that in considering whether an invention for a claimed combination would have been obvious, I may assess whether there are apparent reasons to combine known elements in the prior art in the manner claimed in view of interrelated teachings of multiple prior art references, the effects of demands known to the design community or present in the market place, and/or the background knowledge possessed by a person having ordinary skill in the art. I understand that other principles may be relied on in evaluating whether a claimed invention would have been obvious, and that these principles include the following:

- A combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results;
- When a device or technology is available in one field of endeavor, design incentives and other market forces can prompt variations of it, either in the same field or in a different one, so that if a person of ordinary skill can implement a predictable variation, the variation is likely obvious;
- If a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar

devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill;

- An explicit or implicit teaching, suggestion, or motivation to combine two prior art references to form the claimed combination may demonstrate obviousness, but proof of obviousness does not depend on or require showing a teaching, suggestion, or motivation to combine;
- Market demand, rather than scientific literature, can drive design trends and may show obviousness;
- In determining whether the subject matter of a patent claim would have been obvious, neither the particular motivation nor the avowed purpose of the named inventor controls;
- One of the ways in which a patent's subject can be proved obvious is by noting that there existed at the time of invention a known problem for which there was an obvious solution encompassed by the patent's claims;
- Any need or problem known in the field of endeavor at the time of invention and addressed by the patent can provide a reason for combining the elements in the manner claimed;
- "Common sense" teaches that familiar items may have obvious uses beyond their primary purposes, and in many cases a person of ordinary

skill will be able to fit the teachings of multiple patents together like pieces of a puzzle;

- A person of ordinary skill in the art is also a person of ordinary creativity, and is not an automaton;
- A patent claim can be proved obvious by showing that the claimed combination of elements was "obvious to try," particularly when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions such that a person of ordinary skill in the art would have had good reason to pursue the known options within his or her technical grasp; and
- One should be cautious of using hindsight in evaluating whether a claimed invention would have been obvious.

28. I further understand that, in making a determination as to whether or not the claimed invention would have been obvious to a person of ordinary skill, the Board may consider certain objective factors if they are present, such as: commercial success of products practicing the claimed invention; long-felt but unsolved need; teaching away; unexpected results; copying; and praise by others in the field. These factors are generally referred to as "secondary considerations" or "objective indicia" of nonobviousness. I understand, however, that for such objective evidence to be relevant to the obviousness of a claim, there must be a

causal relationship (called a "nexus") between the claim and the evidence and that this nexus must be based on a novel element of the claim rather than something in the prior art. I also understand that even when they are present, secondary considerations may be unable to overcome primary evidence of obviousness (such as motivation to combine with predictable results) that is sufficiently strong.

29. I have been asked to consider the validity of the Challenged Claims. I understand that for *inter partes* reviews, invalidity must be shown under a preponderance of the evidence standard. I have concluded that each of the Challenged Claims is invalid over the prior art based on the references described below and as explained herein.

D. Level of Ordinary Skill in the Art

30. In rendering the opinions set forth in this declaration, I was asked to consider the patent claims and the prior art through the eyes of a person of ordinary skill in the art at the time of the alleged invention. I understand that the factors considered in determining the ordinary level of skill in a field of art include the level of education and experience of persons working in the field; the types of problems encountered in the field, the teachings of the prior art, and the sophistication of the technology at the time of the alleged invention. I understand that a person of ordinary skill in the art is not a specific real individual, but rather is a hypothetical individual having the qualities reflected by the factors above. I understand that a person of

ordinary skill in the art would also have knowledge from the teachings of the prior art, including the art cited below.

31. Taking these factors into consideration, in my opinion, on or before November 3, 2005, a POSA relating to the technology of the ’756 patent would have had a minimum of: a Bachelor of Science degree in Mechanical Engineering or an equivalent field, with approximately two to three years of academic or industry experience in automotive systems, thermal fluids, or control engineering. This description is approximate, and a higher level of education or skill may make up for less experience, and vice-versa.

32. Well before November 3, 2005, my level of skill in the art was at least that of a person of ordinary skill. I am qualified to provide opinions concerning what a person of ordinary skill would have known and understood at that time, and my analysis and conclusions herein are from the perspective of a person of ordinary skill in the art as of November 3, 2005.

IV. Background of the Technology

33. As discussed in Section V, the ’756 patent is generally directed to a control valve for varying the timing of “gas exchange valves” (i.e., intake and exhaust valves) of internal combustion engines. ’756 patent, Abstract. The control valve directs hydraulic pressure into selected chambers to adjust the phase of the camshaft and thereby vary the timing of the gas exchange valves relative to the crankshaft. ’756 patent, 2:30-3:6, 9:6-30, 10:39-42, 12:5-32.

34. But, as discussed in the subsequent sections, each of the components of the Challenged Claims was well-known in the prior art, and the claims of the ’756 patent are, at most, simple combinations of these prior art elements.

35. Prior to the November 3, 2005 priority date of the ’756 patent, all the technology at issue in the ’756 patent was broadly applied and well known by developers in the automotive industry, including in the field of valves for camshaft timing. No individual elements of the ’756 patent claims were novel at the time of the alleged invention, and there was nothing novel about the manner in which those elements were combined in the claims. Indeed, as discussed more fully below, the claims are fully anticipated by the prior art. Further, there were no technological barriers to combining these elements to form the claimed invention and combining these elements would have yielded predictable results.

36. For example, Lehmann discloses a camshaft regulator with a guide sleeve, control piston, non-return valve, connections for flow of pressure medium, an oil-guide module, a pressure medium channel, and connections to working chambers which move the camshaft. Lehmann, [0019]-[0034], Figs, 1, 2, 4. And Bolz discloses a sleeve-shaped valve insert that can be manufactured from multiple parts and connected together. Bolz, [0034], [0052]-[0053]. Schafer discloses a hydraulic control valve with a one-piece metallic cylindrical insert. Schafer, [0009], [0028], [0032], Fig. 2. Walsh discloses that components of hydraulic control valves such as spools and sleeves can be made from stainless steel. Walsh, 4:51-65, 6:29-44. And Speier discloses a one-piece cylindrical housing that includes a threaded central neck that is screwed into a threaded bush of a camshaft. Speier, Abstract, 1:60-2:7, 3:5-40.

V. The ’756 Patent

A. Overview of the ’756 Patent

37. The ’756 patent is entitled “Control valve for an apparatus for variable setting of the control times of gas exchange valves of an internal combustion engine,” and describes valves which use a control plunger with a channel to direct flow of “pressure medium” (i.e., hydraulic fluid such as engine oil) between inflow, outflow, and working connections in order to vary the engine valve timing. ’756 patent, Abstract. Fig. 1 below shows an internal combustion engine 100 including a

"plunger" (i.e., a piston) 102 seated on a crankshaft 101. '756 patent, 8:41-54. An "apparatus" or "camshaft adjuster" 1, is attached to each of the camshafts 106 and 107 and advances or retards the opening and closing times of gas exchange valves 110 and 111 (i.e., intake and exhaust valves). '756 patent, 8:50-57.

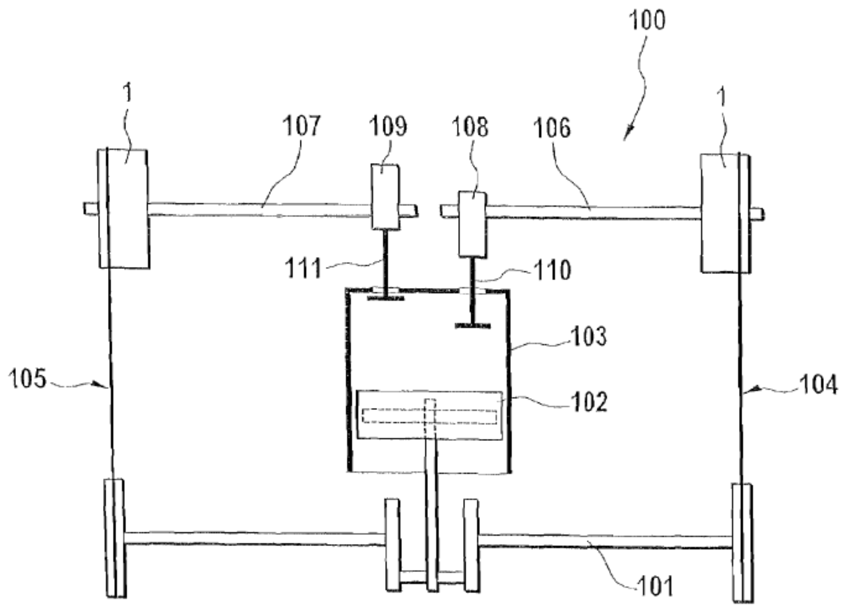
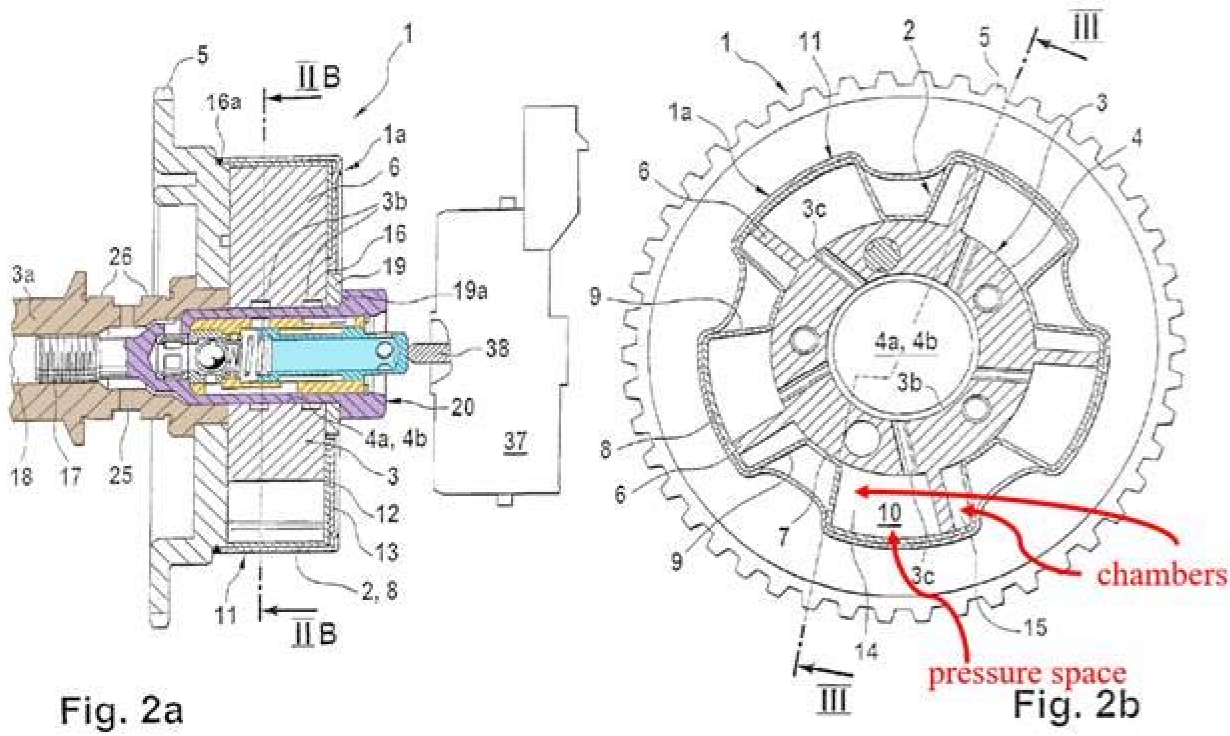


Fig. 1

38. As shown in Figs. 2a and 2b below, the adjusting apparatus 1a includes a drive wheel 5, stator 2, and an "output element" 3 comprising a wheel hub 4 and five vanes 6 that extend outward from the hub. '756 patent, 8:55-9:5. The output element 3 is attached to **camshaft 3a** by a central screw 17. '756 patent, 8:55-9:5. The stator 2 includes five pressure spaces 10 occupied by vanes 6 that divide each pressure space 10 into two pressure chambers 14 and 15. '756 patent, 9:6-30. During

operation, pressure medium (i.e., hydraulic fluid) passes into pressure medium chambers 14 and 15. ’756 patent, 10:39-42, 12:5-32. The ’756 patent explains that by controlling the flow of pressure medium into these individual chambers, the rotational camshaft adjuster adjusts the phase of the camshaft. ’756 patent, 2:30-3:6.



’756 patent, Figures 2a-b.

39. Fig. 3 below shows some details of the central screw 17 / control valve 20, as connected to **camshaft 3a**. The control valve 20 includes, for example, a **valve housing 22**, a **pressure medium guide insert 27**, and a **control plunger 35**. ’756 patent, 10:10-38, 11:37-12:4.

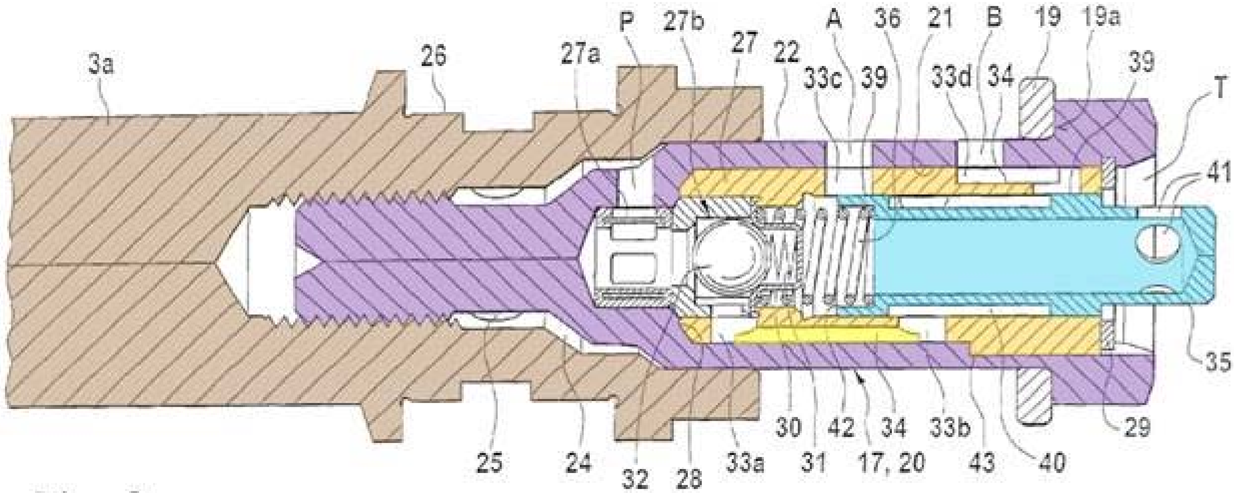


Fig. 3

’756 patent, Figure 3.

40. In operation, pressure medium (i.e., hydraulic fluid or engine oil) is caused to flow by a pressure medium pump (not shown) (i.e., hydraulic pump or oil pump) from a pressure medium reservoir (not shown) to the pressure chambers 14, 15 through various holes, channels, and connections, including: radial holes 25, annular channel 24, inflow connection P, working connections A, B, annular groove 40, radial openings 33a, 33b, 33c, 33d, and **pressure medium channel 34**. ’756 patent, 10:3-12:32. The position of the control plunger 35, *e.g.*, relative to the pressure medium guide insert, determines which openings and connections, and thus which chambers, receive/discharge the pressure medium at any given time. ’756 patent, 11:51-12:32.

B. Prosecution History of the ’756 Patent

41. I understand that the ’756 patent matured from U.S. Patent Application 11/555,751, filed on November 2, 2006. ’756 File History (Ex. 1002), 1-63. The

’756 patent claims received only one office action, which issued on December 11, 2007 and rejected a subset of the claims as being anticipated by U.S. 6,026,772 (“Shirabe”) or rendered obvious by Shirabe in view of U.S. 5,325,762 (“Walsh”), U.S. 4,439,984 (“Martin”), U.S. 5,289,805 (“Quinn”), or U.S. 2004/0055551 (“Maeyama”). Shirabe, Martin, Quinn, and Maeyama are not at issue here. I understand that Walsh was applied as a secondary reference by the Examiner, but was not considered in view of Lehmann or any teachings of the prior art identified below. Several dependent claims were indicated as reciting allowable subject matter. ’756 File History (Ex. 1002), 117-125.

42. The applicant responded to the examiner on February 29, 2008 with claim amendments that incorporated the allowable subject matter of original claim 2 into independent claim 1 and incorporated the allowable subject matter of original claim 3 into a new independent claim 22. ’756 File History (Ex. 1002), 131-139.

43. The examiner issued a Notice of Allowance on April 14, 2008 but did not indicate any reasons for allowance. ’756 File History (Ex. 1002), 145-153. Thus, the claims of the ’756 patent were apparently allowed because the Examiner believed that certain limitations of original claims 2 and 3 were missing from the prior art before the Examiner: “the external dimensions of the pressure medium guide insert are adapted to the internal dimensions of the valve housing” (original claim 2), “the pressure medium channel is formed at the interface between the valve housing and

the pressure medium guide insert" (original claim 2), and/or "the apparatus is fastened to a camshaft by means of a central screw and the valve housing is configured in one piece with the central screw" (original claim 3). '756 File History (Ex. 1002), 49-50, 125.

VI. Claim Construction

44. I understand that for purposes of this *Inter Partes* Review, the standard for claim construction is the same as the standard used in federal district court litigation: claim terms should generally be given their ordinary and customary meaning as understood by one of ordinary skill in the art at the time of the invention in light of the specification and the prosecution history pertaining to the patent. I have followed these principles in my analysis set forth in this document.

45. I understand that Patent Owner has not identified any terms as being subject to "means-plus function" terms in district court. I have been asked to apply Patent Owner's apparent constructions and the plain and ordinary meaning of the terms consistent with the specification. I have been instructed to not consider the issue of indefiniteness, but, where a term may be indefinite, to instead apply all reasonable interpretations of the term. With respect to the term listed below, to the extent that this term is interpreted under 35 U.S.C. §112(6), I have been asked to apply the following construction:

"form-fitting means" (Claim 19)

46. To the extent it is found that §112(6) applies to the term above, I have been asked to apply the following construction. The function is "to fix the pressure medium guide insert axially with respect to the valve housing and/or to fix it in a stationary manner in the circumferential direction," and the structure of the '756 specification linked to this function is "a tongue/groove connection." *See, e.g.,*'756 patent, 7:65-8:11 ("form-fitting elements on the pressure medium guide insert and the valve housing in the manner of ***a tongue/groove connection***"), 12:51-60 (As neither the pressure medium guide insert 27 nor the valve housing 22 are of rotationally symmetrical configuration with regard to a longitudinal axis of the control valve 20, antirotation safeguard means for the two components with respect to one another are advantageously provided. This can be realized, for example, by means of a ***tongue/groove connection 43.*** At the same time, the ***tongue/groove connection 43*** serves as mounting aid and ensures that the pressure medium guide insert 27 can be mounted within the valve housing 22 only in one orientation, the correct orientation."), Fig. 3 (depicting tongue/groove connection 43). Thus, to the extent it is found §112(6) applies, I construe the term "form-fitting means" to mean "a tongue/groove connection" and equivalents thereof.

VII. The ’756 Priority Date

47. The ’756 patent matured from U.S. Application 11/555,751, filed on November 2, 2006. The ’756 patent claims priority to German Application No. 10 2005 052 481 (filed November 3, 2005).

48. I have not formed an opinion on whether or not the priority claim is proper. Instead, I have been instructed to consider the patent and the prior art from the perspective of a POSA as of November 3, 2005.

VIII. Grounds of Unpatentability

49. In this section, I will explain why claims 1, 3, 9-11, 13-15, and 18 of the ’756 patent are anticipated by the disclosures of Lehmann (Exs. 1004, 1005). I will also explain how Lehmann’s disclosures at least render obvious claims 1, 3, and 9-18. I also will explain how Lehmann’s disclosures render obvious claims 4 and 7 in view of the teachings of Bolz (Ex. 1014), and render obvious claim 5 in view of the teachings of Schafer (Exs. 1008, 1009) and Walsh (Ex. 1010), and render obvious claim 8 in view of the teachings of Bolz and Schafer, and render obvious claim 19 in view of the teachings of Winkelmann (Ex. 1013), and render obvious claim 20 in view of the teachings of Speier (Ex. 1012). I note that in this discussion, I may focus on the particular language in specific claims, but it should be understood that my analysis applies to the corresponding limitations of all claims containing identical or substantially identical language.

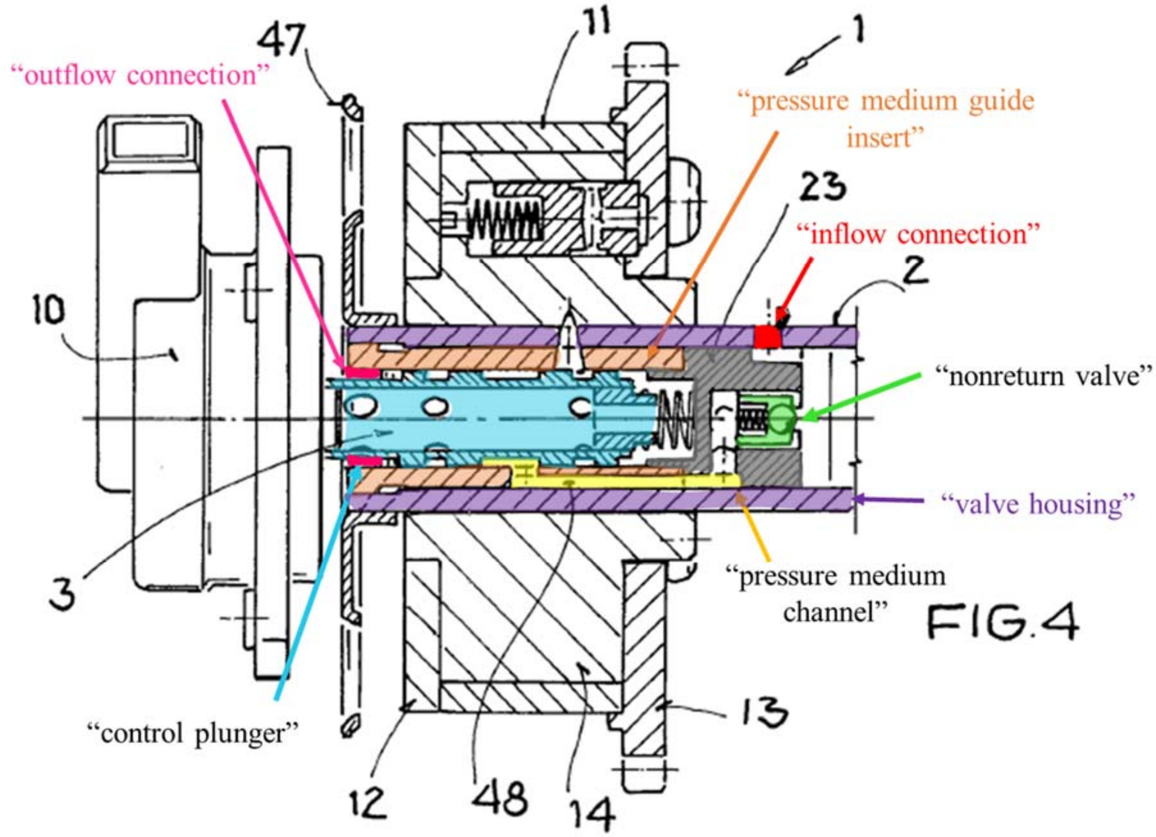
50. It is my opinion that the Challenged Claims of the ’756 patent are unpatentable as explained below:

Ground	References	Basis	Claims
1	Lehmann	Anticipation	1, 3, 9-11, 13-15, 18
2	Lehmann	Obviousness	1, 3, 9-18
3	Lehmann in view of Bolz	Obviousness	4, 7
4	Lehmann in view of Schafer and Walsh	Obviousness	5
5	Lehmann in view of Bolz and Schafer	Obviousness	8
6	Lehmann in view of Winkelmann	Obviousness	19
7	Lehmann in view of Speier	Obviousness	20

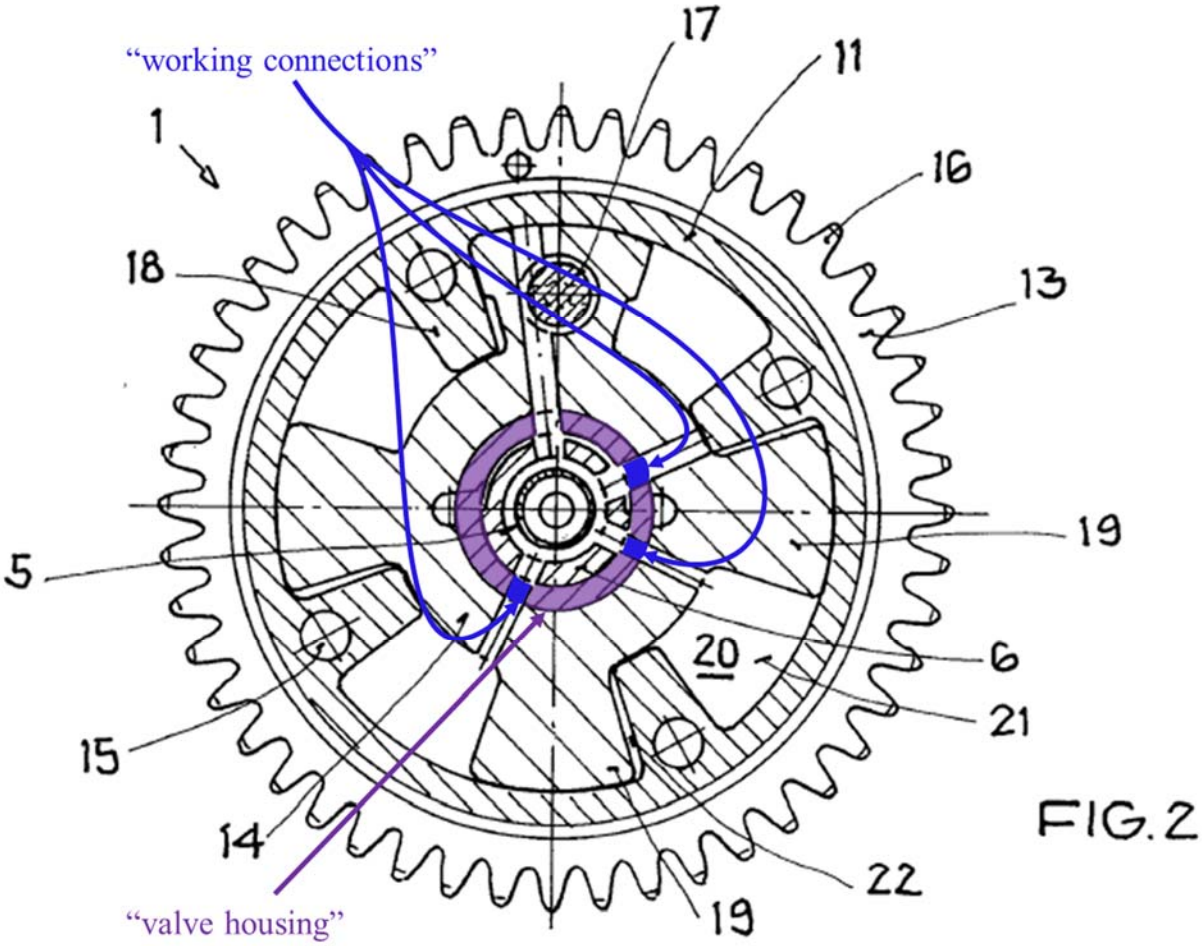
A. Overview of the Prior Art

1. Overview of Lehmann

51. Similar to the ’756 patent, Lehmann discloses a camshaft displacement device for internal combustion engines. Lehmann, Abstract (“The invention relates to a camshaft regulator for an internal combustion engine with a control valve (3) inserted into a camshaft (2) which has a hydraulic control piston (5) guided in a guide sleeve (6) ….”). The device allows for changing the phase position of the camshaft in order to reduce fuel consumption and emissions, and to increase power and torque. Lehmann, [0001]-[0005]. An example camshaft regulator 1 is shown in Fig. 4, annotated below.

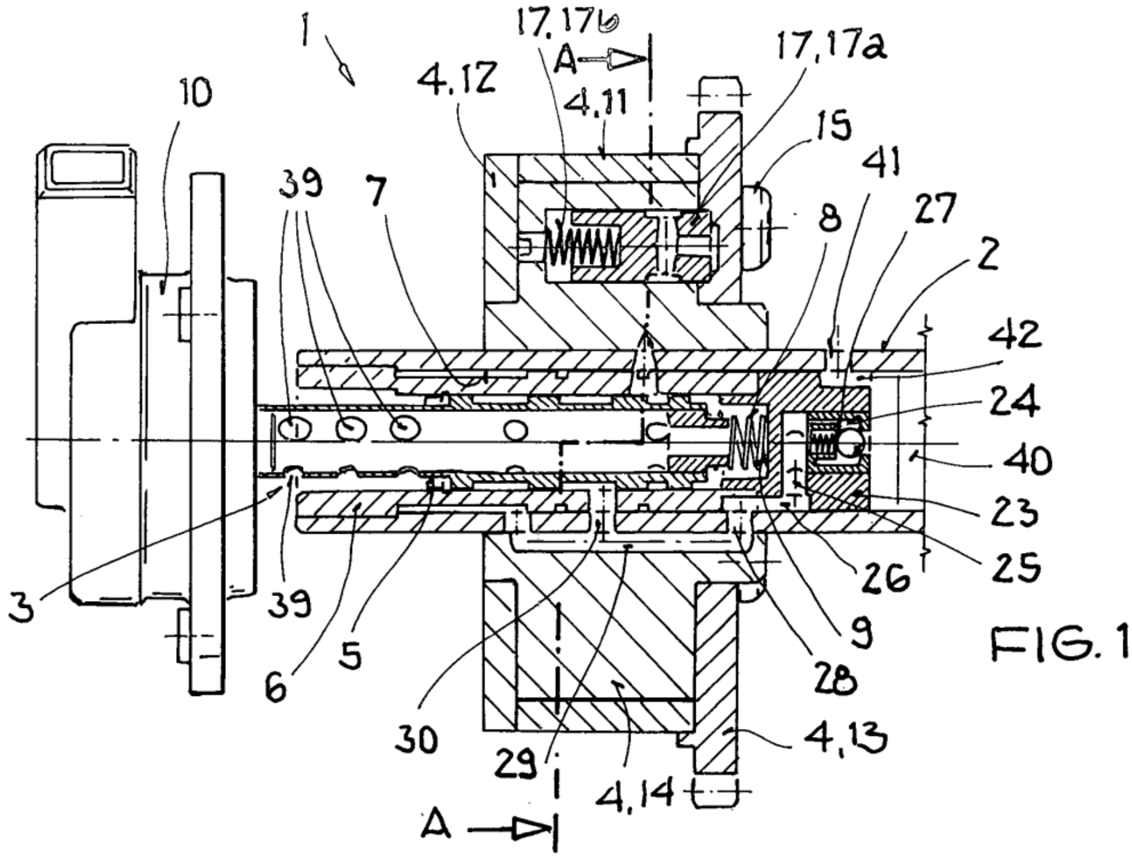


Lehmann, Figure 4.

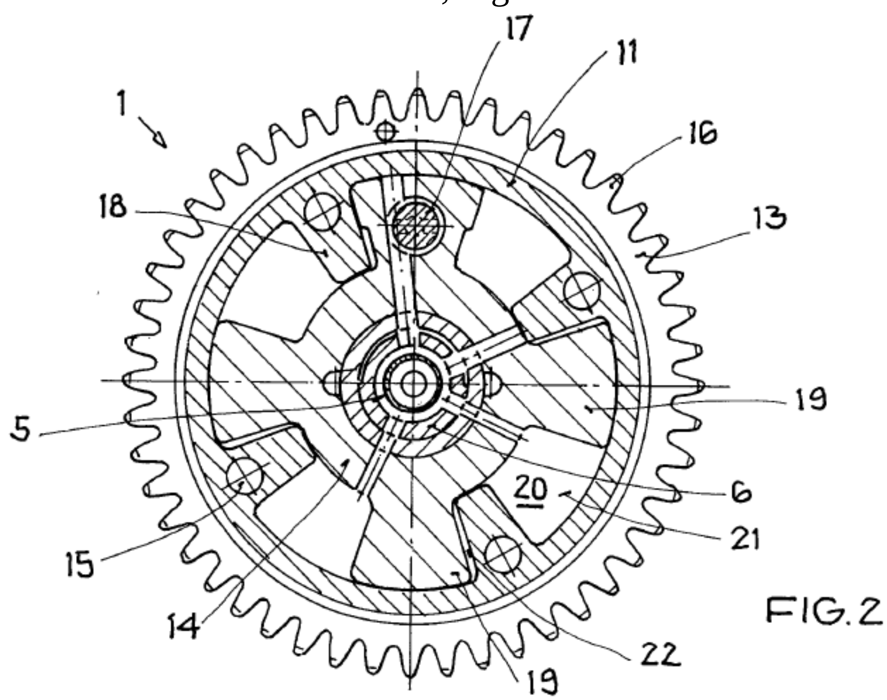


Lehmann, Figure 2

52. The device includes, *e.g.*, **camshaft 2** (a valve housing), **guide sleeve 6** (a pressure medium guide insert), **control piston 5** (a control plunger), **non-return valve 27** (a nonreturn valve), and various connections and channels for the flow of pressure medium, including **radial bore 41** (an inflow connection), **oil guide module 23**, **groove 48** (a pressure medium channel), **connections to chambers 21 and 22** (working connections), **bore 39** (outflow connection). *See also* Fig. 1 (labeling like components in an embodiment of camshaft regulator 1) and Fig. 2 (showing working connections and chambers 21 and 22). Lehmann, [0019]-[0034].



Lehmann, Figure 1.



Lehmann, Figure 2.

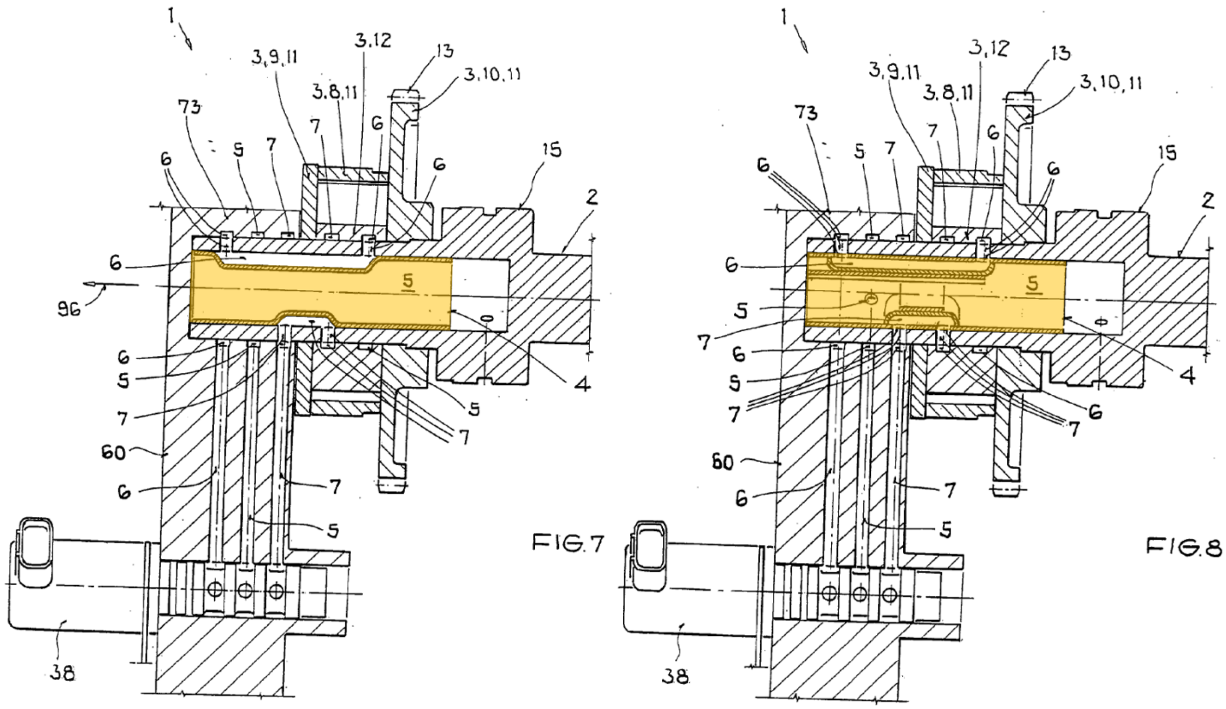
53. Inner body 14 of camshaft regulator 1 is non-rotatably connected to the camshaft 2 and transmits applied drive torque to the camshaft 2. Lehmann, [0028]. In practice, working chambers 21 and 22 are operated hydraulically by varying the pressure medium filling each of the working chambers, thereby altering the relative phase position of piston vanes 18 and opposing vanes 19. Lehmann, [0026], [0027], [0030].

54. The pressure medium is supplied to the working chambers from radial bore 41, through oil-guide module 23, through groove 48 (as in Fig. 4), other grooves and passages (*e.g.*, groove 29 in Fig. 1), to control piston 5, and on to working chambers 21 and 22. Lehmann, [0029]-[0030]. The position of control piston 5 within guide sleeve 6, and thus the supply of pressure medium to/from working chambers 21 and 22, is controlled via electromagnetic device 10 according to control requirements. Lehmann, [0027]-[0030].

2. Overview of Bolz

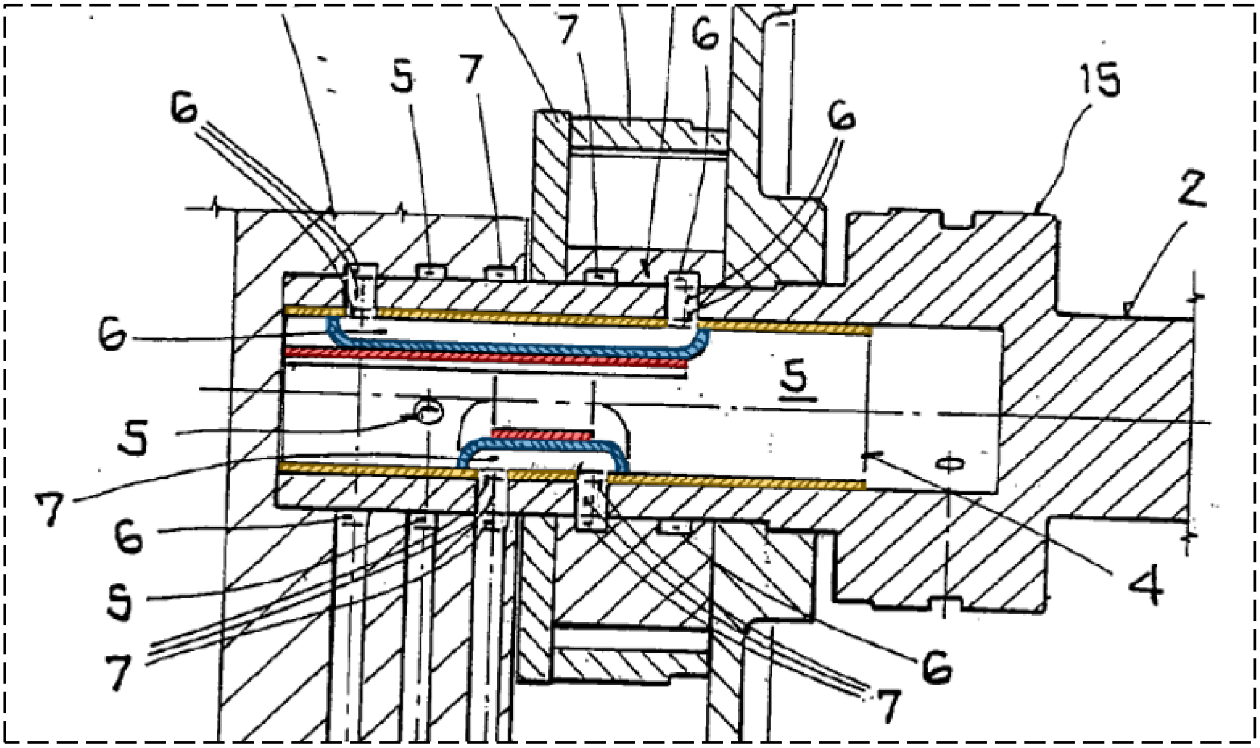
55. Bolz is directed to a camshaft adjuster for an internal combustion engine that adjusts the angle of a camshaft using a hydraulic medium. Bolz, Abstract. Bolz discloses a camshaft adjuster including a control unit 38, which supplies hydraulic medium to a setting unit to adjust the angle of camshaft 2. Bolz, [0031]. An **insert part 4** forms hydraulic medium guides or circuits 5, 6, and 7 (*e.g.*, channels) to supply the hydraulic medium to various parts of the camshaft adjuster.

Bolz, [0032]-[0033]. The insert part 4 may be structured in one piece (as in Fig. 7 annotated below) or in multiple pieces (as in Fig. 8 annotated below). Bolz, [0034], [0052]-[0053].



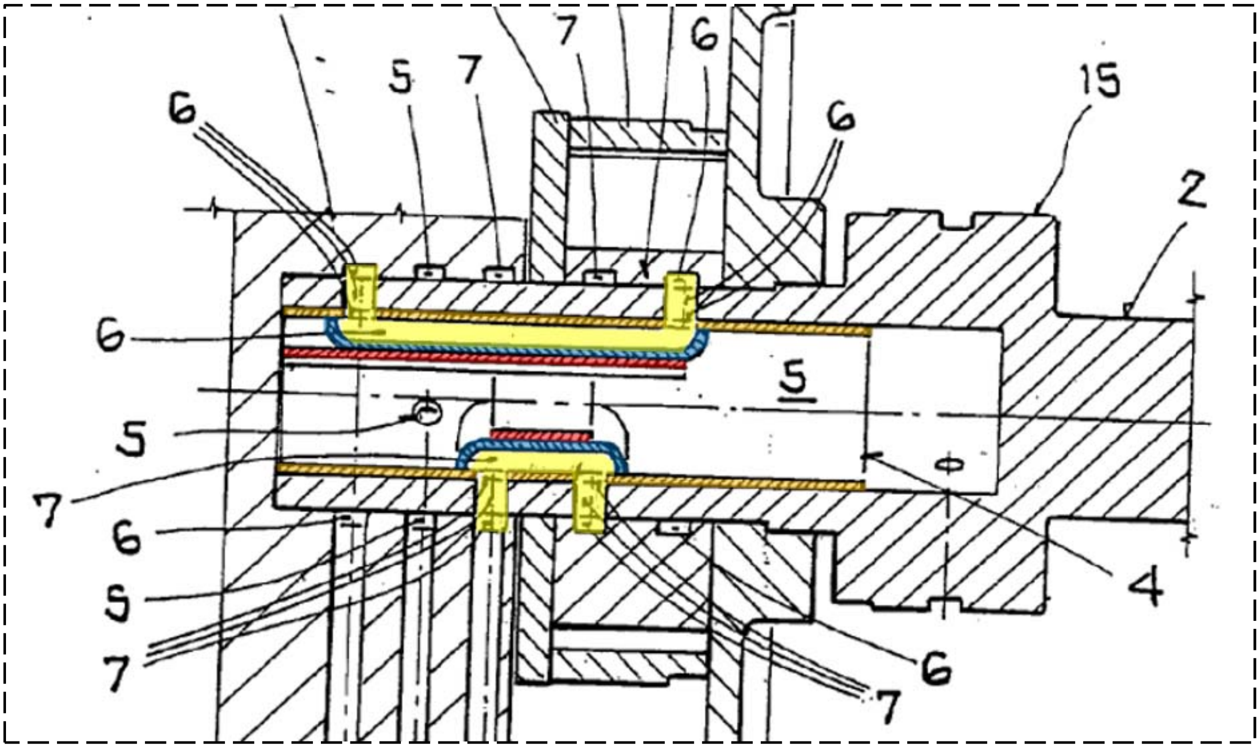
Bolz, Figures 7 and 8.

56. Insert part 4 of Fig. 8 is enlarged below, annotated to show the multiple pieces of the insert (in **orange**, **red**, and **blue**). Bolz discloses that the multiple pieces can be produced from pipes that are manufactured separately and then connected, *e.g.*, via gluing and other methods. Bolz, [0034].

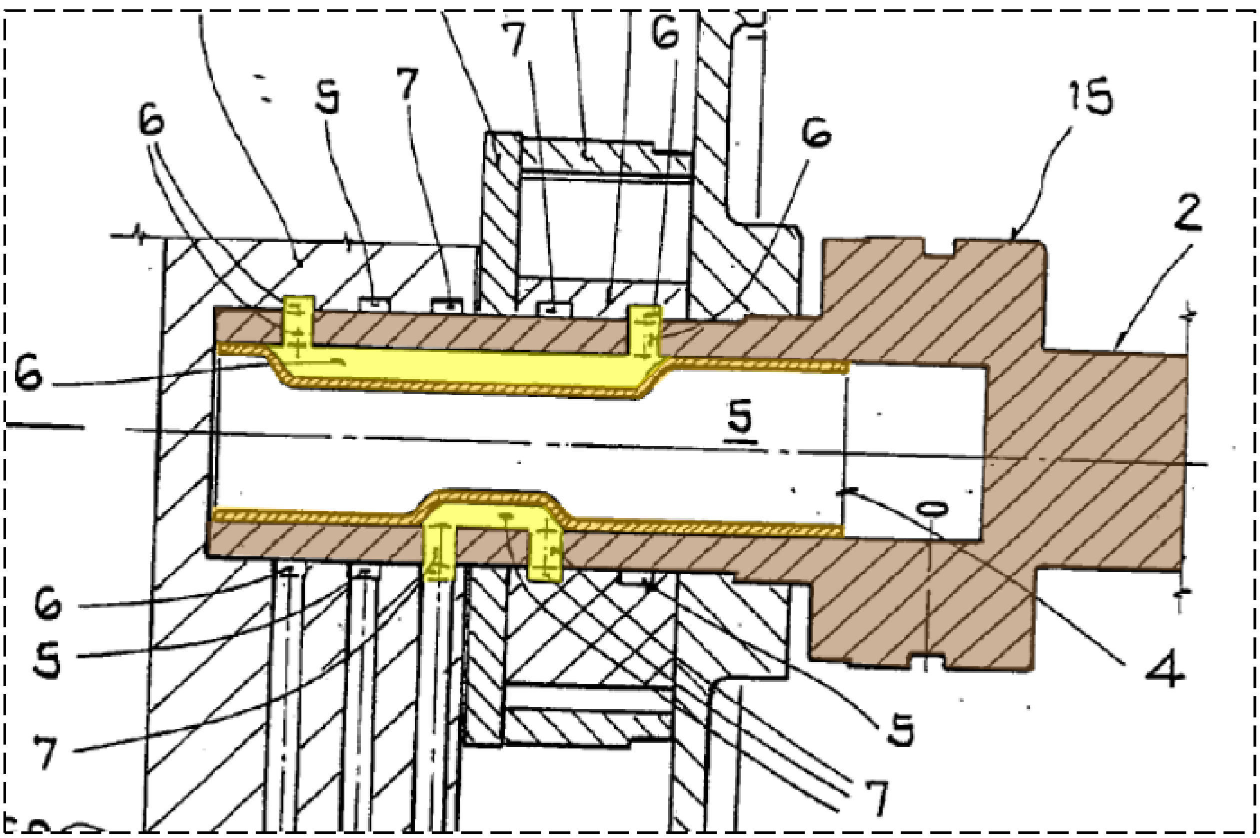


Bolz, Figure 8 (excerpt)

57. As shown, the **orange**, **blue**, and **red** sleeve-shaped components are layered as inner- and outer-parts of multi-part insert part 4. The hydraulic medium flows through the insert part between these sleeve-shaped components, and the medium channel may be delimited radially inward by a **blue** inner sleeve-shaped component (as in Fig. 8 below; flow shown in yellow). In other embodiments, Bolz discloses that the insert part need not delimit the medium channel radially outward—a channel may be formed outside the insert, and delimiting may be accomplished by the next outer component (*e.g.*, **camshaft 2**) (as in Fig. 7 below; flow shown in yellow).

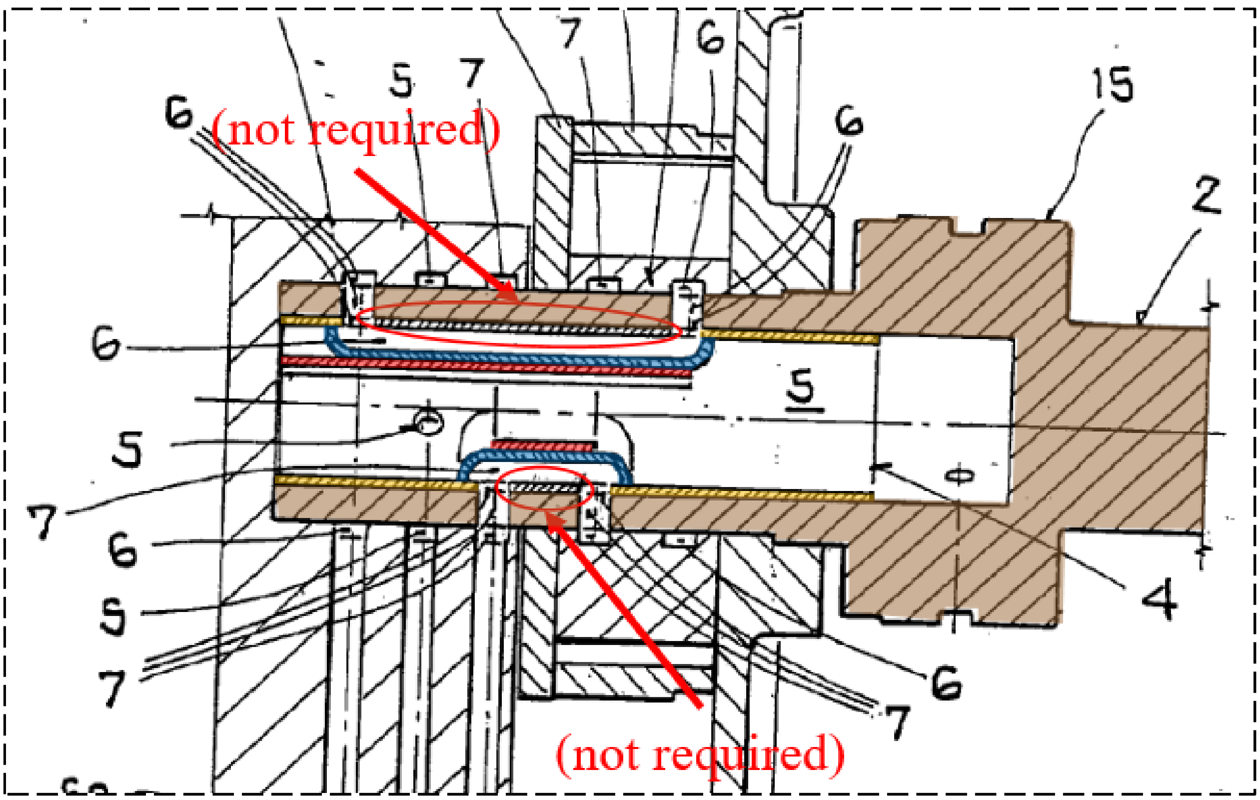


Bolz, Figure 8 (excerpt)



Bolz, Figure 7 (excerpt)

58. Bolz's teachings in Figs. 7 and 8 together show that a medium channel may be delimited radially inward by an inner sleeve-shaped component of an insert (**blue** as in Fig. 8 above) but that the insert need not have a component continuously adjacent to the next outer component to delimit the medium channel radially outward (as in Fig. 7 above). In such a configuration, the next outer component (*e.g.*, **camshaft 2**; a valve housing as in Lehmann) delimits the medium channel radially outward. *See* modified Fig. 8 below, indicating a section where the **orange** sleeve-shaped component is not required (as shown in Fig. 7 above), resulting in radially outward delimiting by **camshaft 2**.



Bolz, Figure 8 (excerpt, modified)

3. Motivation to Apply Bolz's Teachings in Implementing Lehmann

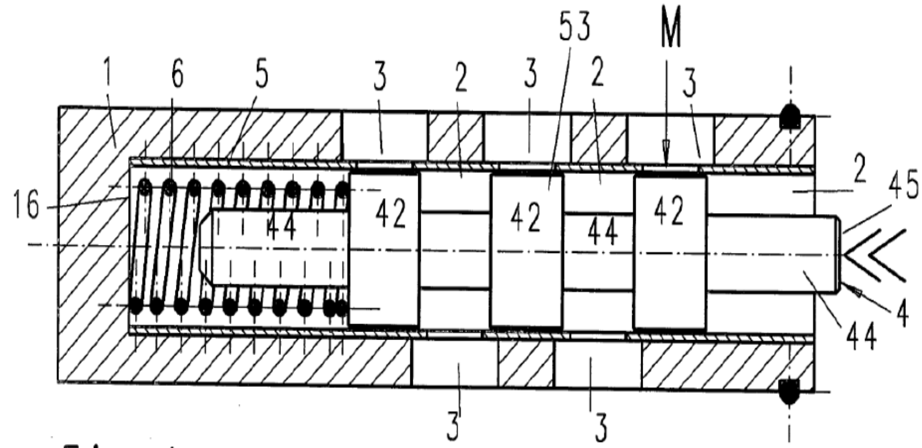
59. To the extent Patent Owner may argue that Lehmann does not explicitly disclose that "the pressure medium guide insert comprises at least one inner and one outer sleeve-shaped component, and in that the at least one pressure medium channel is configured as a slot in a wall of the outer sleeve-shaped component of the pressure medium guide insert, an inner circumferential surface of the valve housing delimiting the pressure medium channel radially outward and the inner sleeve-shaped component of the pressure medium guide insert delimiting the pressure medium channel radially inward, and the pressure medium channel communicating with the interior of the pressure medium guide insert via a radial opening which is formed on the inner sleeve-shaped component" (as in '756 patent claim 4), a POSA would have been motivated to modify Lehmann to fabricate the pressure medium guide insert in multiple inner and outer sleeve-shaped components (*e.g.*, pipes), wherein one or more pressure medium channels are delineated by those sleeve-shaped components and/or a camshaft (i.e., a valve housing), as taught by Bolz in order to provide interchangeability, ease of manufacture, and mechanical robustness. A two-piece sleeve provides interchangeability because the design of one component can be changed to allow use across different systems without affecting the other, thereby allowing easier design changes and reuse of common components. A two-piece sleeve provides ease of manufacture because it can be simpler, cheaper, and

more material-efficient to make two separate parts of simple design instead of one single part of complex design. Furthermore, to machine a blind depression channel in a one-piece sleeve requires an increased level of precision and cost that is not required using a two-piece sleeve with a through channel in one component and a channel base in the other component. A two-piece sleeve is mechanically robust because it includes fewer stress concentrations of the type formed by machining a depression channel in a one-piece sleeve. A POSA would have reasonable expectation of success in fabricating such a two-piece sleeve as claimed, as the modular design of parts and associated advantages were well-known in the art. Bolz teaches, through its plurality of embodiments, that the manufacture of components such as sleeves and inserts may be accomplished using one-piece or multi-part constructions. Bolz, Figs. 7-8, [0034], [0052]-[0053]. The multi-part constructions may be constructed using sheets or pipes that form inner and outer components of the pressure medium guide insert, as shown in Fig. 8 above (i.e., sleeve-shaped components). Bolz, [0034]. Additionally, Bolz teaches that a variety of configurations may be used for the channels that guide hydraulic/pressure medium through the device. An obvious variation of Lehmann as taught by Bolz would have thus included outward delimiting by the valve housing and inward delimiting by an inner sleeve-shaped component of the pressure medium guide insert. The application of known techniques (*e.g.*, one-piece or multi-piece construction; delimiting via a camshaft, valve housing, and/or inner sleeve-shaped component) to similar devices (*e.g.*, the camshaft adjusters of Lehmann and Bolz) to obtain predictable results (*e.g.*, providing an insert and channels to guide pressure medium through the camshaft adjuster), would have been obvious to a POSA.

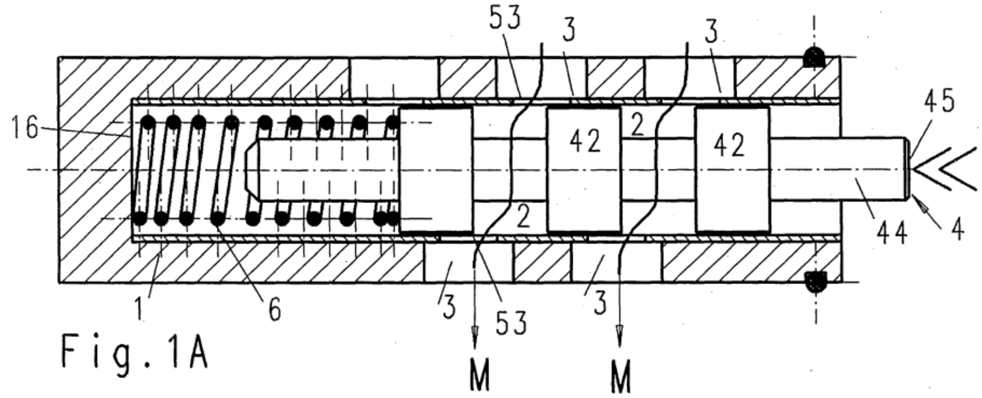
60. A POSA would have had a reasonable expectation of success including a multi-piece pressure medium guide insert and configuring a pressure medium channel in the manner claimed, as the manufacture and configuration of such components, which are substantially the same as other components in Lehmann (i.e. shaped and molded materials), would have involved mechanical components and techniques old and well-known in the art, and would have been well within the skill of a POSA. *See*, *e.g.*, Bolz, [0034] (produced from sheet-metal or pipes, connected by gluing). Accordingly, claim 4 would have been obvious to a POSA.

4. Overview of Schafer

61. Schafer is directed to a valve for the control of a fluid. Schafer, Abstract, [0001]-[0003]. Schafer discloses an example of a valve including a housing 1 and a closing element 4 accommodated in a cylindrical insert 5 (i.e., a pressure medium guide insert). Schafer, [0026]-[0028]. *See* Figs. 1 and 1A below.



Schafer, Figure. 1.



Schafer, Figure 1A.

62. The cylindrical insert 5 includes passage openings 53 through which medium M passes. Schafer, [0028]-[0029]. Fig. 2 below shows insert 5 formed from one metal bend 51 (i.e., a patterned sheet that is to be bent into a final shape). Schafer, [0009], [0028], [0032].

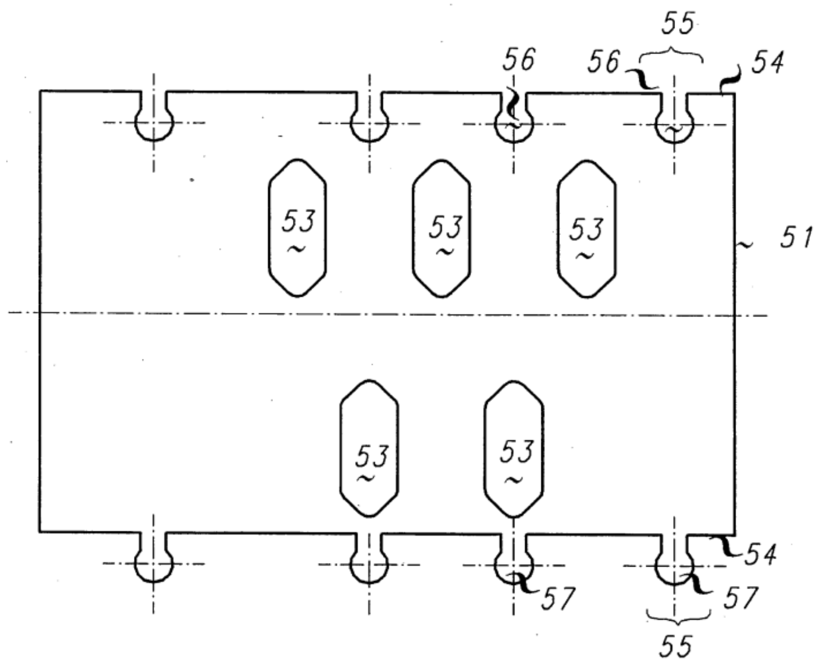


Fig.2

Schafer, Figure 2.

5. Overview of Walsh

63. Walsh is directed to a fluid pressure operated piston engine assembly valve for the control of a fluid. Walsh, Abstract. *See* Fig. 2.

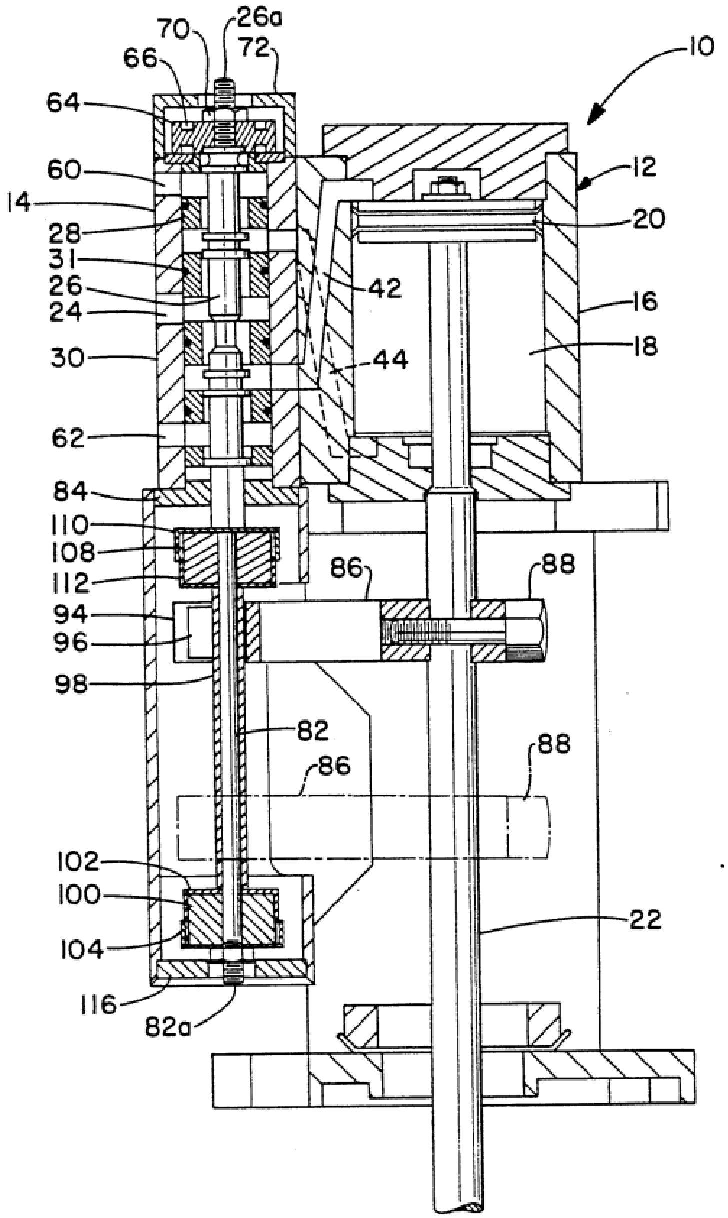


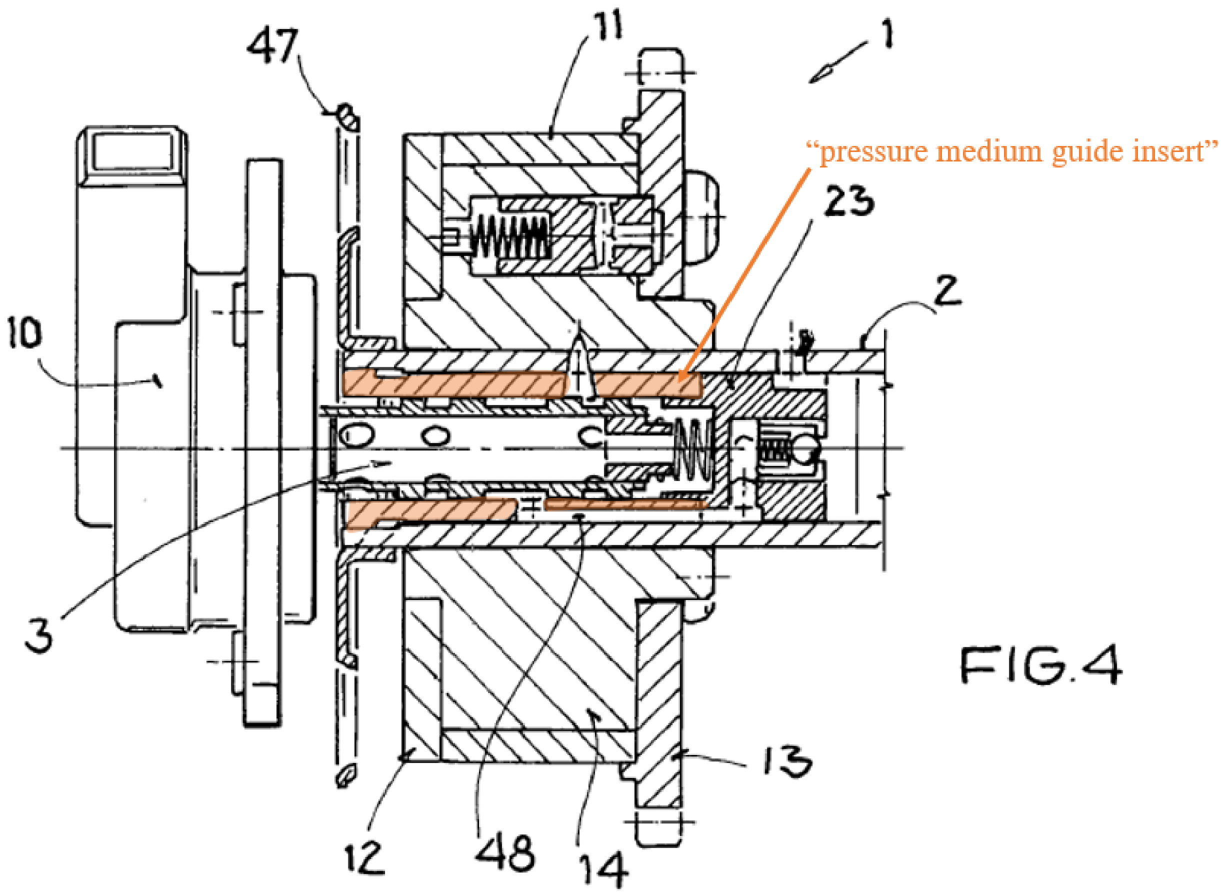
FIG.-2

Walsh, Figure 2.

64. Walsh discloses that spools and sleeves, such as spool 26 and sleeve 28, may be manufactured from stainless steel. Walsh, 4:51-65, 6:29-44.

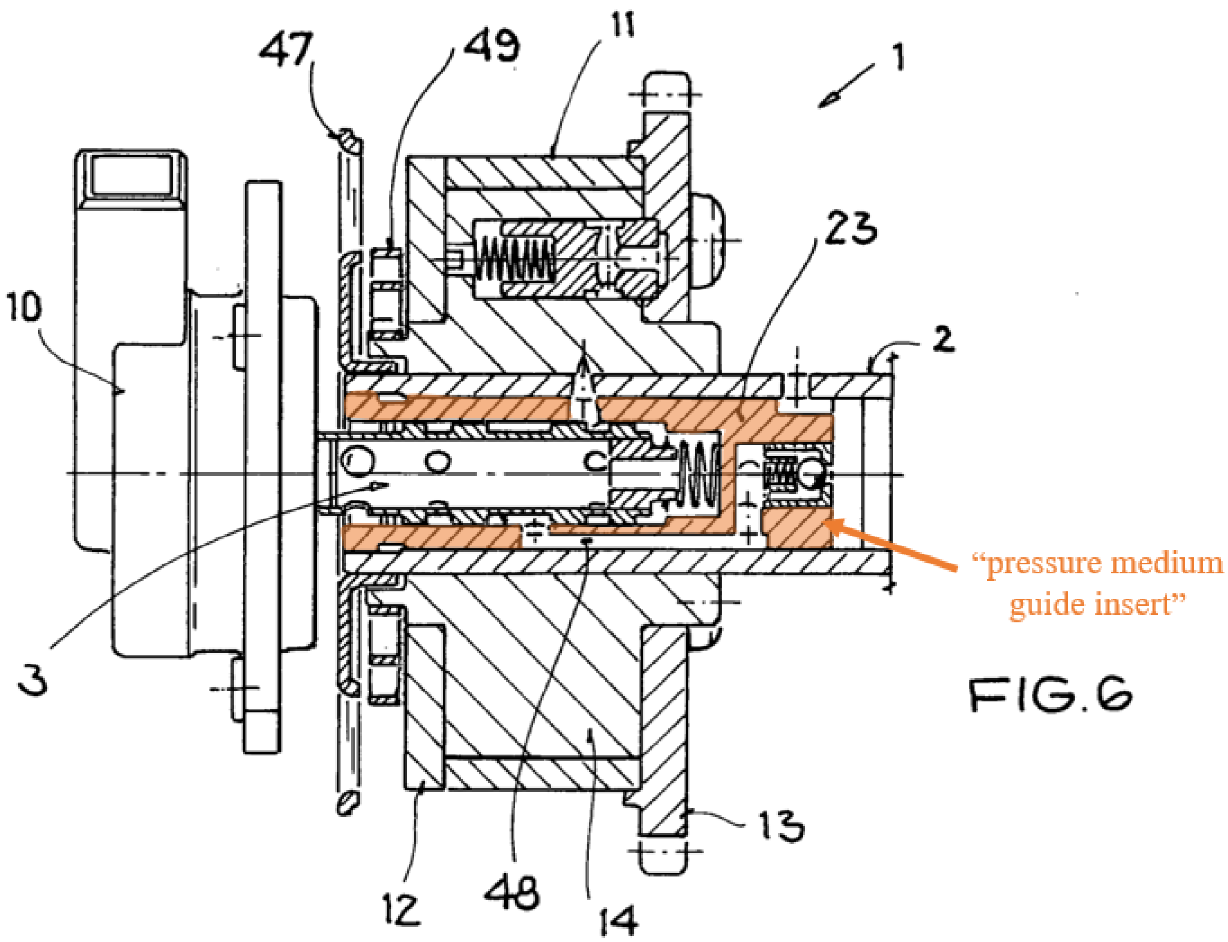
6. Motivation to Apply Schafer's and Walsh's Teachings in Implementing Lehmann

65. Lehmann discloses that the pressure medium guide insert is configured in one piece. *See* guide sleeve 6 in Fig. 4, annotated below, which is shown in one piece with the same cross-section shading pattern. *See also* Lehmann, [0034] (describing same shading pattern pieces as "a single-piece component").



Lehmann, Figure 4.

66. Lehmann, Fig. 6 is similar, where guide sleeve 6 and oil-guide module 23 are designed as a "single-piece component" having the same cross-section shading pattern. Lehmann, [0034].



Lehmann, Figure 6.

67. To the extent Patent Owner may argue that Lehmann does not explicitly disclose that "the pressure medium guide insert is configured in one piece and from steel" (as in '756 patent claim 5), a POSA would have been motivated to modify Lehmann to fabricate the pressure medium guide insert in one piece from steel, as taught by Schafer and Walsh. Schafer explains that manufacturing components using metal sheets provides low prices, long life, favorable leakage characteristics, a reliable process, ease of assembly, and good automation capability. Schafer, [0031], [0032]. Walsh further explains that using stainless steel for the manufacture of

components such as spools and sleeves provides for high tolerances in a material that is not magnetic or has low magnetic properties and therefore does not interact with other present magnetic fields. Walsh, 4:51-65, 6:29-44. Accordingly, it would have been obvious to a POSA to manufacture Lehmann's pressure medium guide insert from a sheet of stainless steel, as taught by Schafer and Walsh. The use of a single stainless steel sheet to manufacture a pressure medium guide insert would have been the application of known techniques (*e.g.*, manufacturing using the techniques and materials taught by Schafer and Walsh) to a known device (*e.g.*, the pressure medium guide insert of Lehmann) to yield a predictable result (*e.g.*, producing the pressure medium guide insert from a sheet of stainless steel), and therefore obvious to a POSA. Indeed, producing valve parts from magnetic and non-magnetic steel was a well-known technique, as demonstrated by Lei (Ex. 1016), which discloses a hydraulic control device including valve housings, spool valves, and pistons made of magnetic and non-magnetic steel. Lei (Ex. 1016), 7:8-20; *see also* Quinto (Ex. 1011), 2:1-6, 3:5-7.

68. A POSA would have had a reasonable expectation of success using a sheet of stainless steel to manufacture the pressure medium guide insert because it would have involved mechanical techniques old and well-known in the art, such as rolling, stamping, and laser machining, using a well-known material such as stainless

steel, and would have been well within the skill of a POSA. Accordingly, claim 5 would have been obvious to a POSA.

7. Motivation to Apply Schafer's Teachings in Implementing Lehmann in view of Bolz

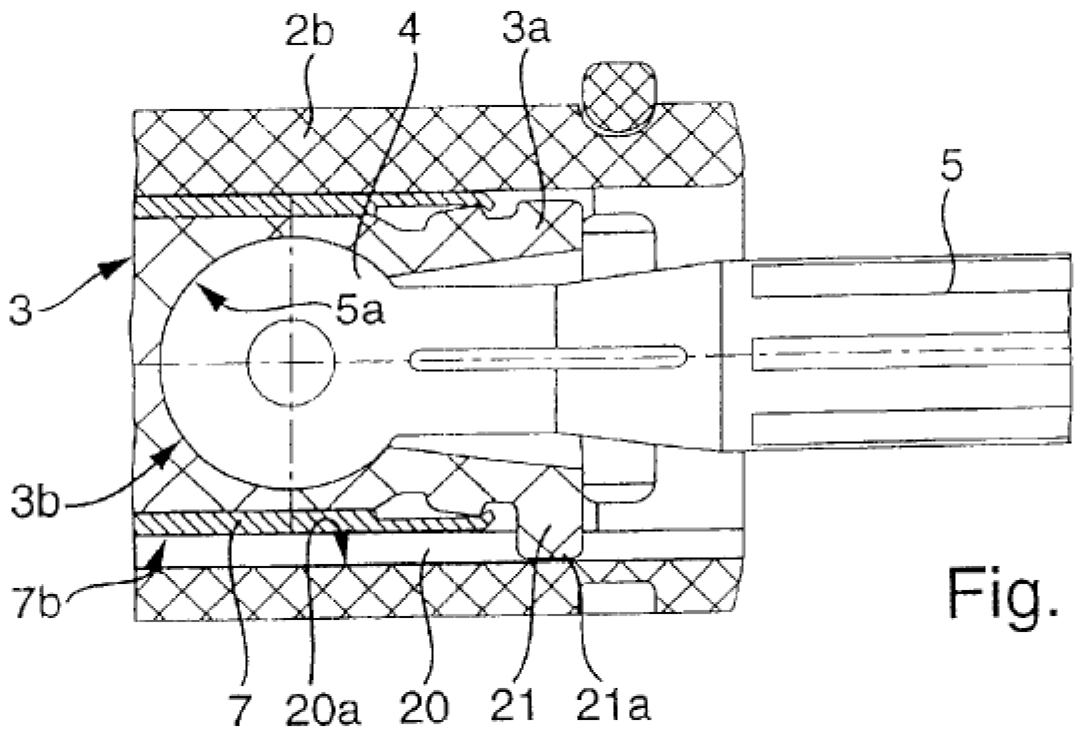
69. To the extent Patent Owner may argue that Lehmann and Bolz do not explicitly disclose that "the outer sleeve-shaped component is manufactured as an injection molded part and the inner sleeve-shaped component is configured as an insert component which is encapsulated by the outer sleeve-shaped component during the injection molding process of the latter" (as in '756 patent claim 8), a POSA would have been motivated to use an injection molding technique to manufacture the inner and outer sleeve-shaped components of Lehmann in view of Bolz, as taught by Schafer. Bolz explains that a variety of techniques may be used to manufacture its multi-part insert, including welding, soldering, gluing, crimping, riveting, pressing, shrinking in place, and pass-through joining. Bolz, [0034]. Schafer further explains that using a combination of manufacturing processes enables production in a cost-effective manner and that rolling and overmolding processes provide high degrees of automation. Schafer, [0031]. The use of an injection molding process for the outer sleeve-shaped component to encapsulate the inner sleeve-shaped component would have been the application of known techniques (*e.g.*, injection molding) to similar devices and methods (*e.g.*, the manufacturing of concentric cylinder components) to yield predictable results (*e.g.*,

producing the combined components in a cost-effective manner), and therefore obvious to a POSA.

70. A POSA would have had a reasonable expectation of success using an injection molding process because injection molding is old and well-known in the art, and would have been well within the skill of a POSA. Accordingly, claim 8 would have been obvious to a POSA.

8. Overview of Winkelmann

71. Winkelmann is directed to a master cylinder for use in power trains of motor vehicles. Winkelmann, Abstract. Winkelmann discloses that two components may be joined together with long-lasting sealing connections via different methods, such as by welding, using adhesives, or using mechanical connections like tongue and groove joints. Winkelmann, 7:47-54. For example, angular movements of a jacket and a core relative to each other can be prevented with axially parallel tongue-and-groove connections or with complementary profiles of adjacent faces. Winkelmann, 8:32-39. See Fig. 2 below (angular movements of jacket 7 and core 3a are prevented; tongue-and-groove connections not shown).



Winkelmann, Figure 2.

9. Motivation to Apply Winkelmann's Teachings in Implementing Lehmann

72. Lehmann discloses notches that are form-fitting means that axially fix guide sleeve 6 (a pressure medium guide insert) and camshaft 2 (a valve housing). Additionally, guide sleeve 6 and camshaft 2 are joined thermally, adhesively, mechanically, by welding, or using any other method. Lehmann, [0021], Figs. 1, 4. These joining methods serve to fix the two components axially and in a circumferential direction with respect to each other.

73. To the extent Patent Owner may argue that the "form-fitting means" must include a tongue-and-groove connection (*see* §VI above) and that Lehmann does not explicitly disclose a tongue-and-groove connection, a POSA would have

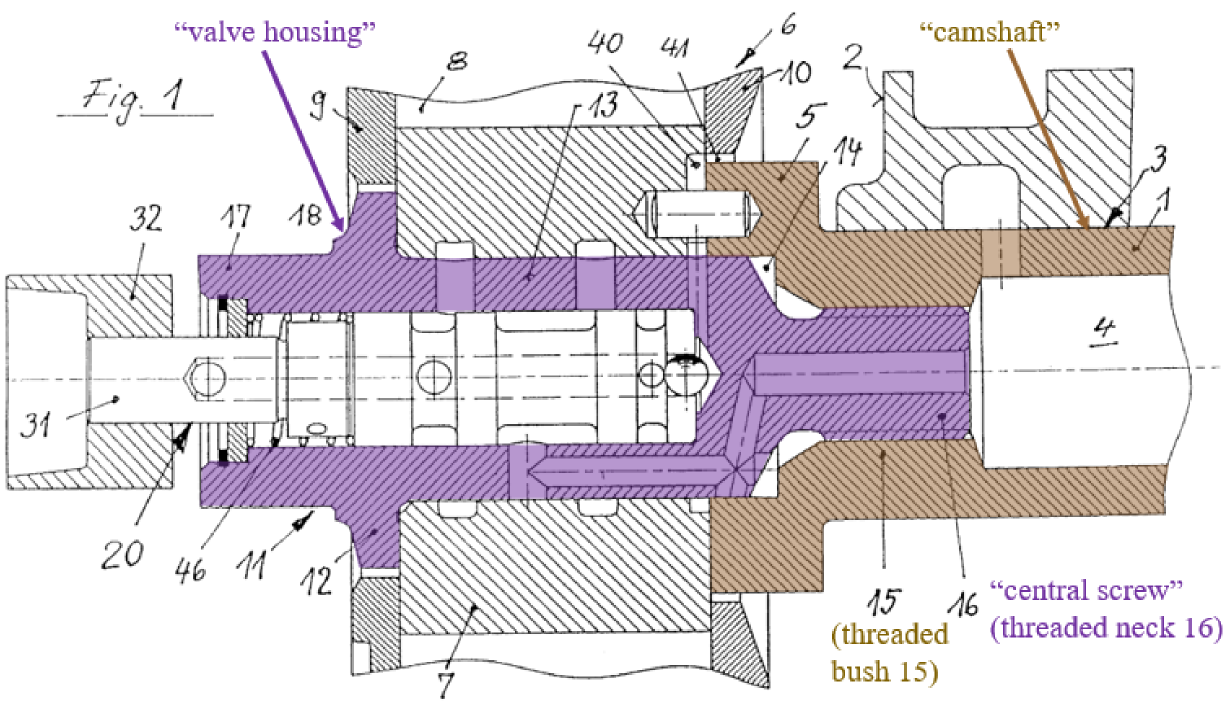
been motivated to modify Lehmann to use tongue-and-groove connection for mechanically joining the components, as taught by Winkelmann. As Lehmann acknowledges, the joining of components may be accomplished by any number of ways, including mechanically. Lehmann, [0021]. Winkelmann teaches that tongue-and-groove connections were a specific known mechanical joining method in automotive systems that, in one exemplary application, served to fix and prevent angular movements between two components (i.e., fixed in the circumferential direction). Winkelmann, 7:47-54, 8:32-39. The use of a tongue-and-groove connection to fix Lehmann's guide sleeve 6 and camshaft 2 (a valve housing), as taught by Winkelmann, would have been the application of a known technique (*e.g.*, tongue-and-groove) to similar devices (*e.g.*, components to be joined together) to yield a predictable result (*e.g.*, fixing the components in a circumferential manner), and therefore obvious to a POSA.

74. A POSA would have had a reasonable expectation of success implementing a tongue-and-groove connection, because the tongue-and-groove technique is a mechanical interfacing technique old and well-known in the art. The use of tongues and grooves in the guides and housings of Lehmann would have been well within the skill of a POSA. Accordingly, claim 19 would have been obvious to a POSA.

10. Overview of Speier

75. Speier is directed to a camshaft timing device for internal combustion engines. Speier, Abstract. The camshaft timing device includes, *e.g.*, cylindrical housing 18 (a valve housing) and control spool 20, which is movable to control the admission of hydraulic fluid. Speier, Abstract, 1:60-2:7, 3:5-40.

76. Speier discloses that cylindrical housing 18 includes a threaded neck 16 that is screwed into threaded bush 15 of camshaft 1. Speier, 3:14-25.



Speier, Figure 1.

11. Motivation to Apply Speier's Teachings in Implementing Lehmann

77. To the extent Patent Owner may argue that Lehmann does not explicitly disclose that "the apparatus is fastened to a camshaft by means of a central screw, and the valve housing is configured in one piece with the central screw" (as in '756

patent claim 20), a POSA would have been motivated to modify Lehmann's camshaft displacement device, which as discussed in §VIII.B.2 would have been obvious to provide in a dedicated separate valve housing, to include a threaded neck on the valve housing for fastening the camshaft adjuster to the camshaft in a secure manner. As Lehmann acknowledges, the fastening of components may be accomplished in many ways known in the art, such as in a material-fitting, force-fitting, and form-fitting manners and "other joining processes." Lehmann, [0024]. The use of an "other joining process[]" to secure the camshaft adjuster to the camshaft, such as by including a threaded neck configured in one piece with a valve housing, as taught by Speier, would have been the application of a known technique (*e.g.*, fastening via the threaded neck taught by Speier) to a known device (*e.g.*, the valve housing of Lehmann) to yield a predictable result (*e.g.*, securely fastening the camshaft adjuster to the camshaft), and therefore obvious to a POSA. The design of such components so that they are integral (*e.g.*, as in Speier) or separable would have been obvious to a POSA.

78. A POSA would have had a reasonable expectation of success implementing a central screw, configured in one piece with the valve housing, to fasten the camshaft adjuster to the camshaft, because the use of threaded interfaces to mechanically join components is a technique old and well-known in the art. The addition of a threaded interface to the valve housing of Lehmann would have been

well within the skill of a POSA. Accordingly, claim 20 would have been obvious to a POSA.

B. Ground 1: Lehmann anticipates claims 1, 3, 9-11, 13-15, and 18

79. As explained further below, Lehmann anticipates claims 1, 3, 9-11, 13-15, and 18 of the ’756 patent.

1. Overview

80. As discussed in Section V, the ’756 patent is generally directed to a control valve which uses a control plunger with a channel to direct flow of a pressure medium such as hydraulic fluid between inflow, outflow, and working connections to vary engine valve timing. At their core, the claims recite (1) a hollow valve housing with inflow, outflow, and working connections; (2) a control plunger within a pressure medium guide insert, which is in turn arranged within the valve housing; and (3) a channel that allows pressure medium to flow between at least one of the connections and the interior of the pressure medium guide insert. Every element of claims 1, 3, 9-11, 13-15, and 18 was well known prior to the priority date of the ’756 patent, and the claims are anticipated by Lehmann as explained below.

81. Similar to the ’756 patent, Lehmann discloses a camshaft adjuster for internal combustion engines. As explained below, Lehmann discloses a hollow valve housing (a hollow camshaft) with inflow, outflow, and working connections, a pressure medium guide insert, a pressure medium channel between the valve housing

and pressure medium guide insert that connects the interior of the pressure medium guide insert to at least one of the connections, and a control plunger within the pressure medium guide insert. Lehmann also describes the same additional limitations in the dependent claims of the ’756 patent including the pressure medium channel configured as a depression on the outer surface of the pressure medium guide insert, a nonreturn valve upstream of the pressure medium channel, and a filter element, for example. As I will explain in further detail below, Claims 1, 3, 9-11, 13-15, and 18 are anticipated by Lehmann.

2. Invalidity of Claims 1, 3, 9-11, 13-15, and 18 Over Lehmann (Ground 1)

(a) Element [1pre]

82. **Element [1pre] recites “A control valve for an apparatus for the variable setting of the control times of gas exchange valves of an internal combustion engine.”** Lehmann discloses a control valve (*e.g.*, “hydraulic control valve 3” and “oil guide module 23” housed by camshaft 2) for an apparatus (*e.g.*, for “camshaft regulator 1”) for the variable setting of the control times of gas exchange valves of an internal combustion engine. *See* Lehmann, ¶¶1, 5, 20, 29.

83. Lehmann discloses a “hydraulic control valve” for a “camshaft regulator” which adjusts “the phase position of the camshaft,” thereby adjusting the timing of intake and exhaust valve opening and closing. Lehmann, [0001], [0005], [0020]. For example, Lehmann discloses, “The invention relates to a camshaft

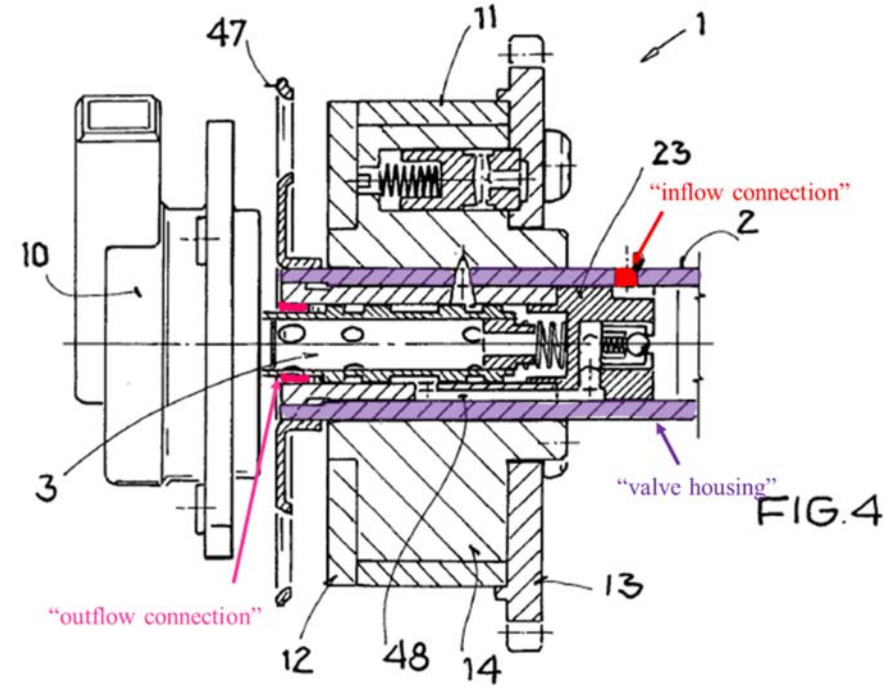
regulator for an internal combustion engine according to the preamble of claim 1." Lehmann, [0001]. Lehmann also discloses, "The invention is based on the problem of creating a camshaft regulator for an internal combustion engine which permits high adjustment speeds for changing the phase position of the camshaft while being easy and inexpensive to manufacture and while saving time and costs in assembling the camshaft regulator." Lehmann, [0005]. Lehmann further discloses, "The camshaft regulator according to Fig. 1 to Fig. 6 is designated as a whole by 1 and is shown in association with a camshaft 2 of an internal combustion engine. The camshaft regulator 1 has a hydraulic control valve 3, which can be used to control an actuating unit 4 for adjusting the angle of the camshaft 2." Lehmann, [0020]. Lehmann further discloses that oil guide module 23 works with hydraulic control valve 3 to supply the hydraulic medium: "an oil guide module 23 … is connected upstream of the control valve 3 and serves to guide the hydraulic medium from the camshaft 2 into the control valve 3." Lehmann, [0029]. Together, hydraulic control valve 3 and oil guide module 23 function as a "control valve." *See also* Lehmann, [0034] (describing oil guide module 23 and guide sleeve 6 in one piece).

(b) Element [1a]

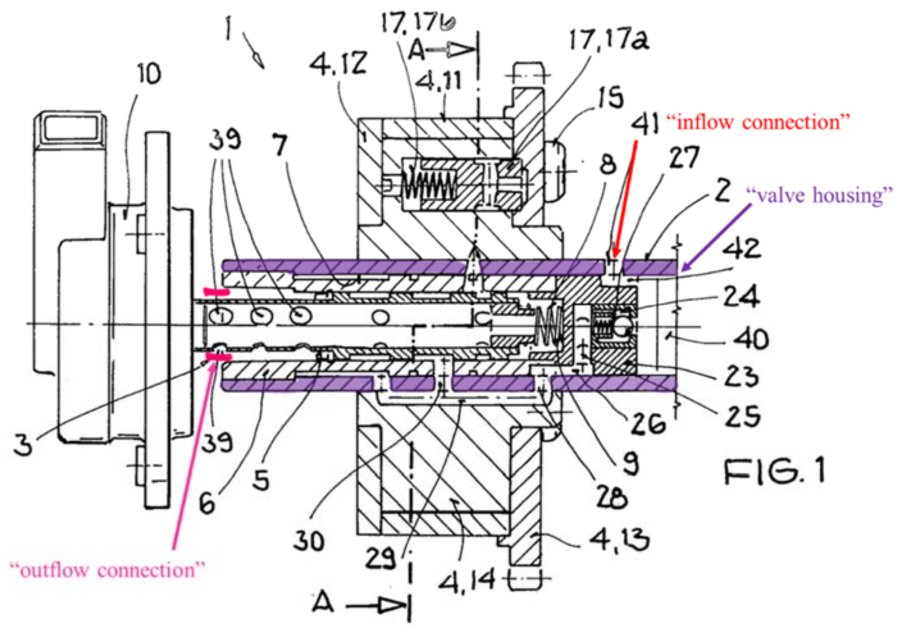
84. **Element [1a] recites "a valve housing of hollow configuration, which has at least one inflow connection, at least one outflow connection and at least two working connection."** Lehmann discloses a valve housing of hollow

configuration (*e.g.*, section of "camshaft 2," shown in purple in annotated Figs. 1 and 4 below), which has at least one inflow connection (*e.g.*, "radial bore 41," shown in red in annotated Figs. 1 and 4 below), at least one outflow connection (*e.g.*, "bores 39," shown in magenta in annotated Figs. 1 and 4 below) and at least two working connection (*e.g.*, connections to at least "chambers 21, 22," shown in blue in annotated Fig. 2 below). *See* Lehmann, [0028], [0029], Figs. 1, 2, 4.

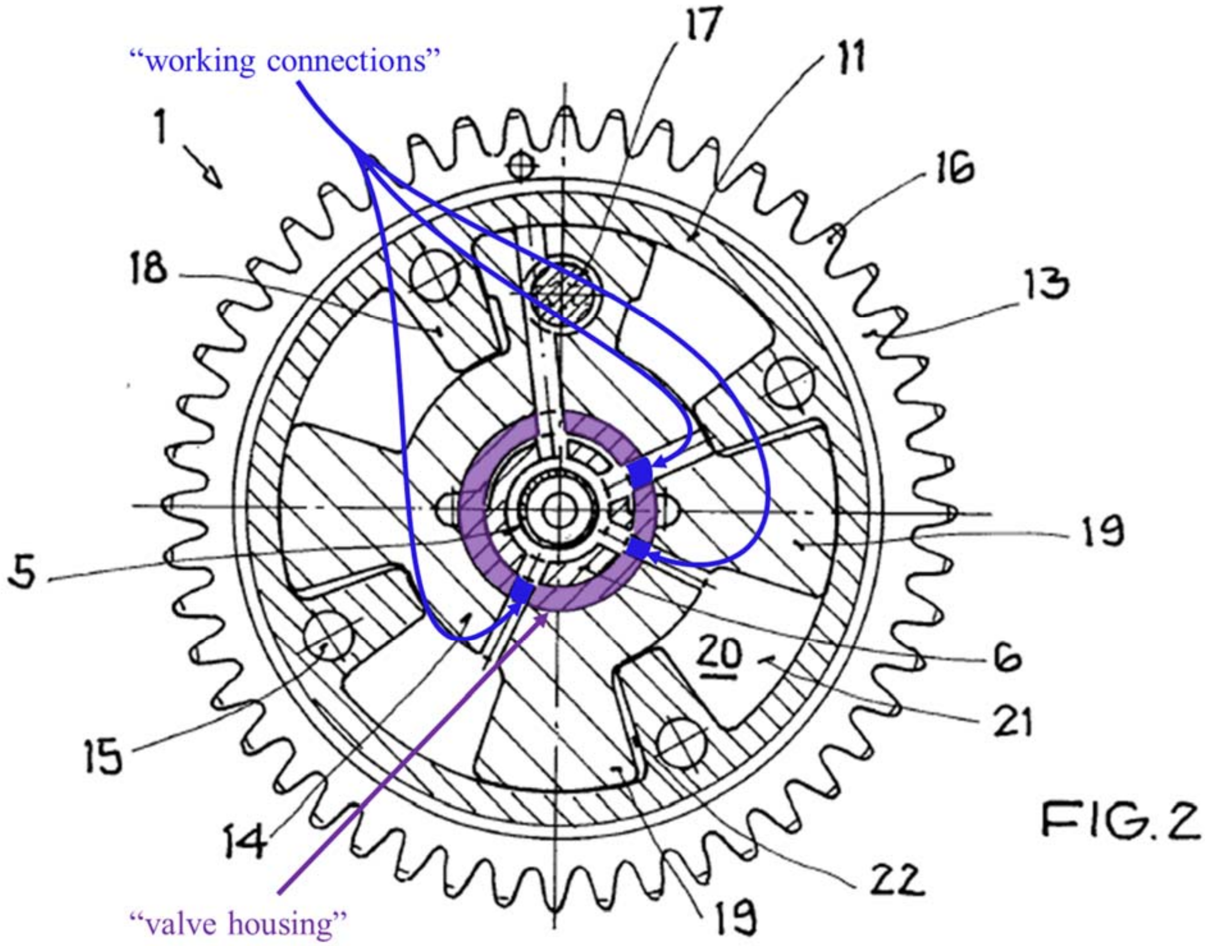
85. Lehmann discloses a hollow "camshaft 2" which houses the "hydraulic control valve 3" and has inflow, outflow, and multiple working connections. For example, Lehmann discloses, "The interior 40 of the camshaft 2 is supplied with pressure medium via a radial bore 41 in the camshaft 2 from a pressure medium supply point not shown, which is arranged in a camshaft bearing." Lehmann, [0029]. Lehmann also discloses, "The supply of pressure medium to the respective working chamber 21, 22 is effected from the camshaft 2 via the control valve 3." Lehmann, [0028]. Lehmann further discloses, "From the radial bore 28, the hydraulic medium passes via a groove 29 into a radial guide 30 in the camshaft 2. From the radial guide 30, the hydraulic medium enters the control valve 3 to supply the respective working chambers 21, 22 of the camshaft regulator 1 as required in accordance with the control requirements. The hydraulic medium is then discharged to the outside within the control valve 3 via bores 39 arranged in the control piston 5." Lehmann, [0029].



Lehmann, Fig. 4 (annotated)



Lehmann, Fig. 1 (annotated)



Lehmann, Fig. 2 (offset section view along A-A of Fig. 1, showing chambers 21, 22 and four working connections)

86. Figure 1 of Lehmann is a full section view of the camshaft regulator 1, which shows the valve housing (annotated in purple), the inflow connection (annotated by red arrow), and the outflow connection (annotated in magenta). The working connections connect the control valve 3 to the four sets of working chambers 21, 22 and to the locking mechanism 17. The working chambers 21, 22 are arrayed in a circle as depicted in Figure 2.

87. Figure 2 of Lehmann depicts an offset section view of the camshaft regulator 1 along the offset section line A-A of Figure 1. Three working connections are visible in this section view, annotated in blue. The connection in the top left quadrant (not annotated) is to/from the locking mechanism 17. The working connection in the top right quadrant is to/from one of the chambers 22. The two working connections visible in the two bottom quadrants of Fig. 2 are to/from two respective chambers 21. Because Figure 2 is an offset section view corresponding to the offset section line A-A in Figure 1, the two top quadrants in Figure 2 are located in a different axial position than the two bottom quadrants in Figure 2.

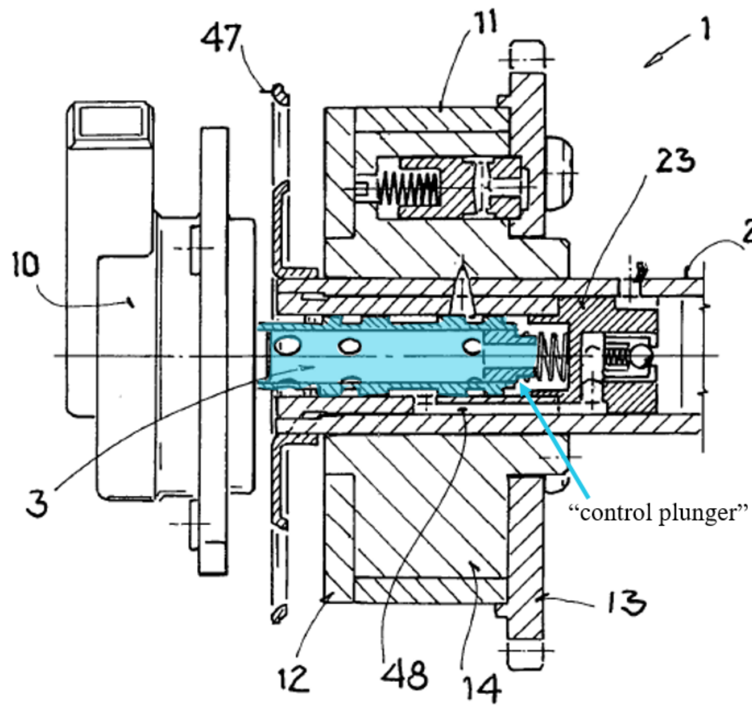
88. Lehmann's "camshaft 2" provides a valve housing of hollow configuration as claimed because it includes a hollow cylinder that encloses the "hydraulic control valve 3." *See* '756 patent, 3:21-22 ("the valve housing which is of substantially hollow-cylindrical configuration"); McGraw-Hill Dictionary of Scientific and Engineering Terms (Ex. 1015), at 1015 (defining "housing" as "A case or enclosure to cover and protect a structure or a mechanical device").

(c) Element [1b]

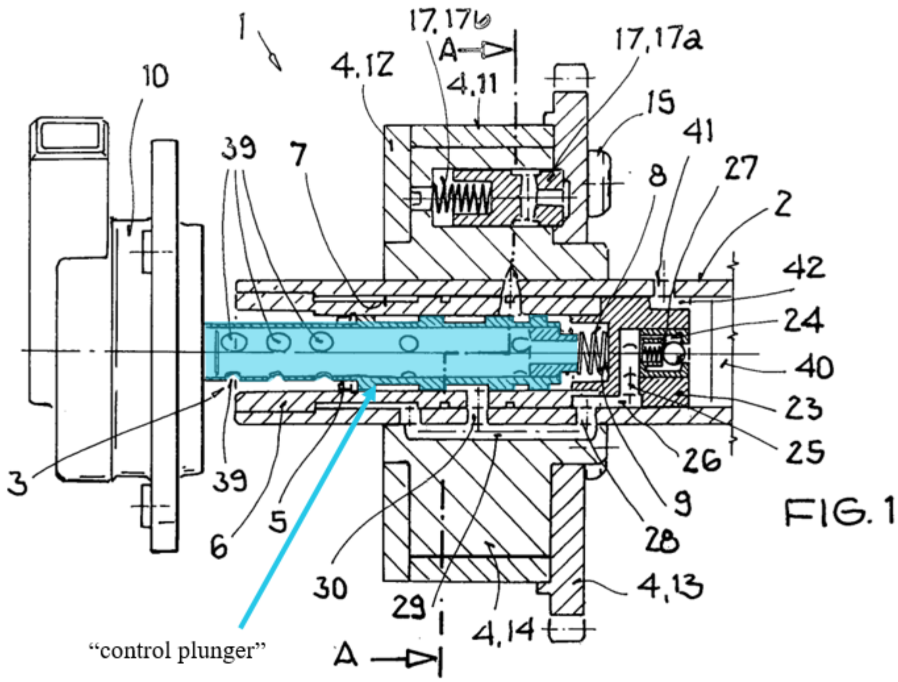
89. **Element [1b] recites "a control plunger."** Lehmann discloses a control plunger (*e.g.*, "control piston 5"). *See* Lehmann, [0021], Figs. 1, 4.

90. Lehmann discloses a control piston 5. For example, Lehmann discloses, "The hydraulic control valve 3 has a control piston 5 which is guided in a guide

sleeve 6, the guide sleeve 6 being inserted in a concentric bore 7 of the camshaft 2 extending from one end of the camshaft 2 in the axial direction. The joining may be performed thermally. Furthermore, the joint can be glued, mechanically joined or welded. Likewise, other joining methods are possible." Lehmann, [0021].



Lehmann, Fig. 4 (annotated)

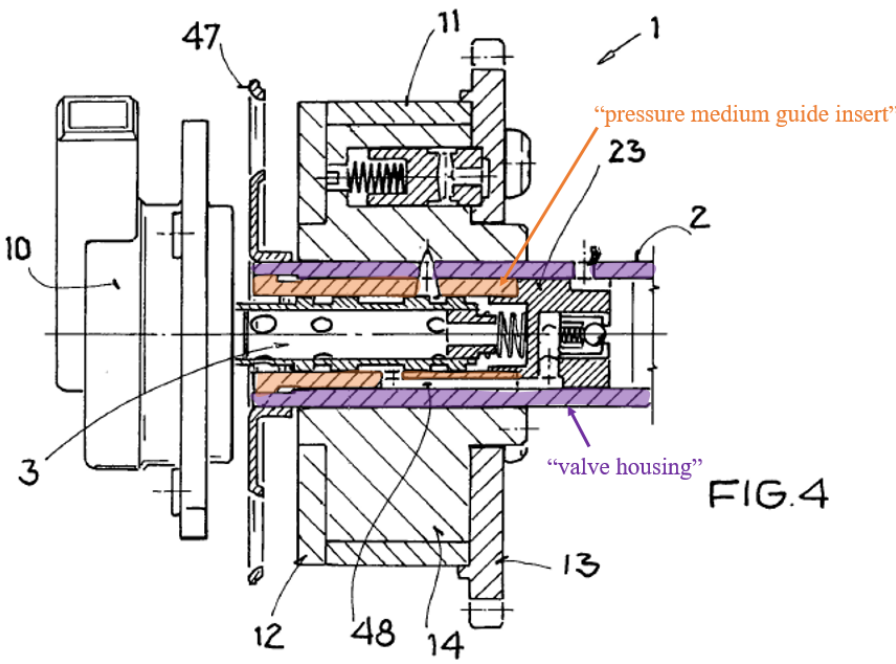


Lehmann, Fig. 1 (annotated)

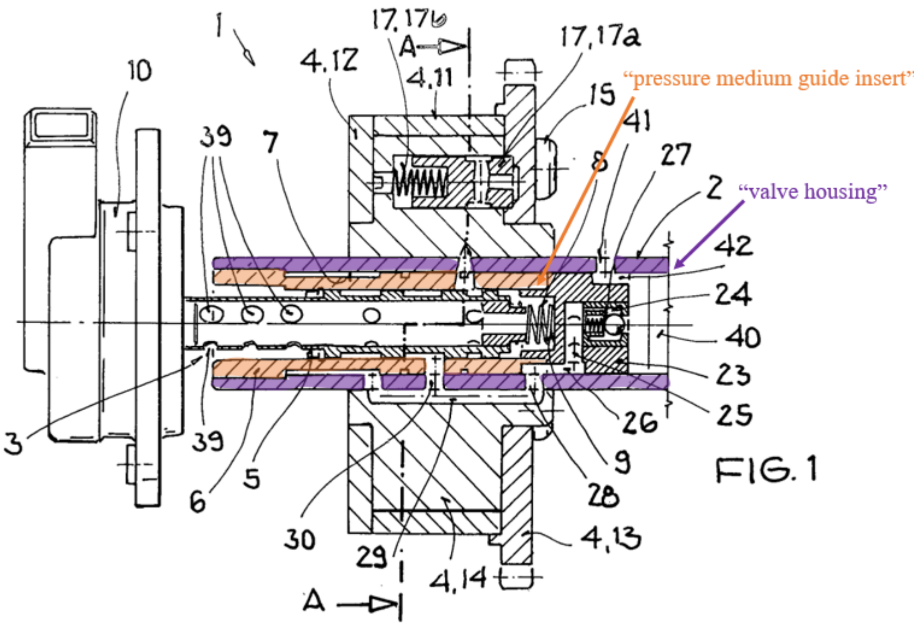
(d) Element [1c]

91. **Element [1c] recites "a pressure medium guide insert of hollow configuration arranged within the valve housing, the external dimensions of the pressure medium guide insert being adapted to the internal dimensions of the valve housing."** Lehmann discloses a pressure medium guide insert of hollow configuration (*e.g.*, "guide sleeve 6") arranged within the valve housing (*e.g.*, arranged within "camshaft 2," the valve housing), the external dimensions of the pressure medium guide insert being adapted to the internal dimensions of the valve housing (*e.g.*, "guide sleeve 6" is inserted in the bore of "camshaft 2"). *See* Lehmann, [0021], Figs. 1, 4.

92. Lehmann discloses guide sleeve 6 that is arranged within camshaft 2 and has external dimensions that match the internal dimensions of camshaft 2. Specifically, Lehmann discloses, "The hydraulic control valve 3 has a control piston 5 which is guided in a guide sleeve 6, the guide sleeve 6 being inserted in a concentric bore 7 of the camshaft 2 extending from one end of the camshaft 2 in the axial direction. The joining may be performed thermally. Furthermore, the joint can be glued, mechanically joined or welded. Likewise, other joining methods are possible." Lehmann, [0021].



Lehmann, Fig. 4 (annotated)



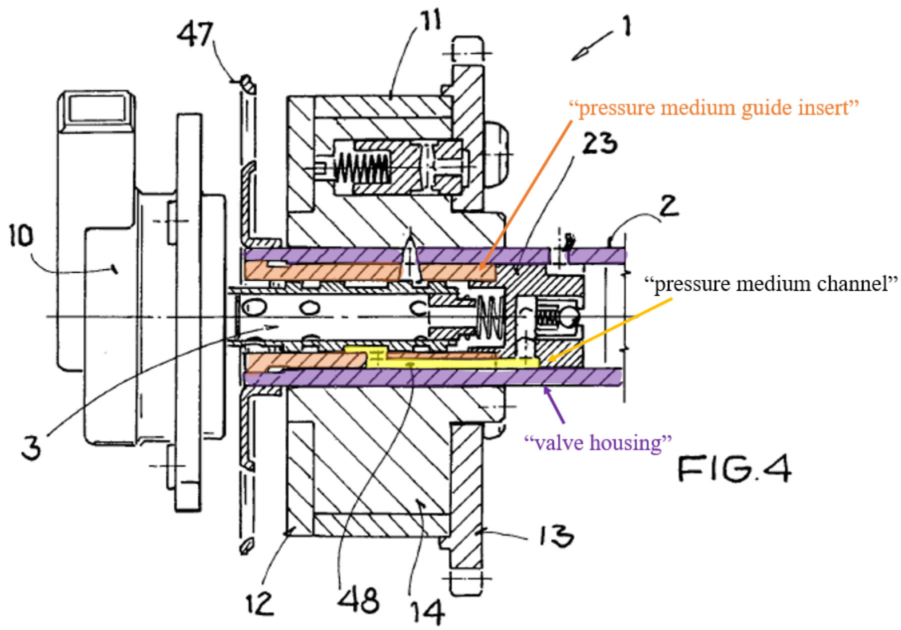
Lehmann, Fig. 1 (annotated)

(e) Element [1d]

93. **Element [1d] recites "at least one pressure medium channel formed at the interface between the valve housing and the pressure medium guide insert and which extends substantially in the axial direction."** Lehmann discloses at least one pressure medium channel formed at the interface between the valve housing and the pressure medium guide insert and which extends substantially in the axial direction (*e.g.*, "groove 48" in Fig. 4 annotated below; "groove 26" in Fig. 1 annotated below). *See* Lehmann, [0029], [0031], [0032], Figs. 1, 4.

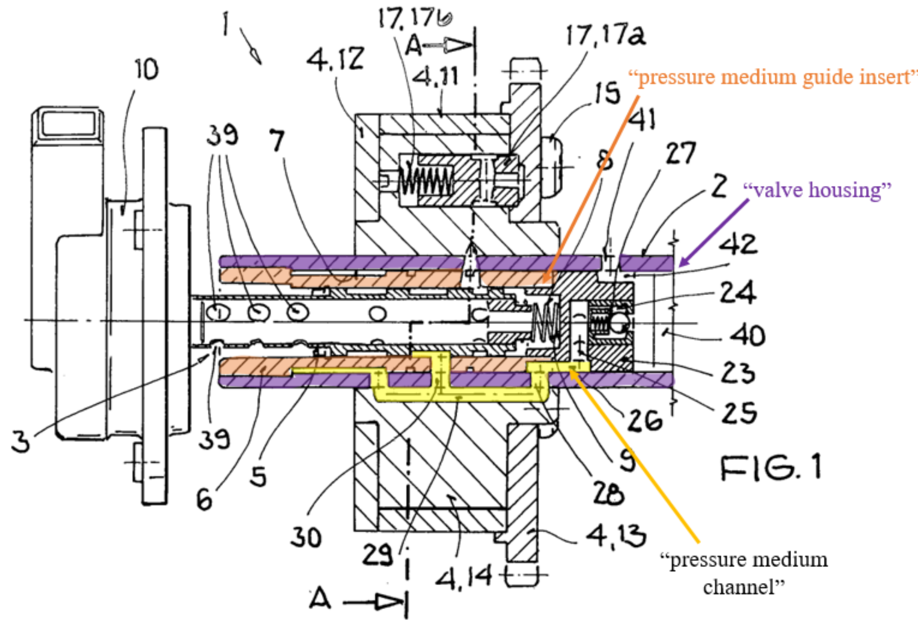
94. Lehmann discloses a groove 48 and a groove 26 that are at the interface between the camshaft 2 and the guide sleeve 6. Specifically, Lehmann discloses, "In a further embodiment of the invention according to Fig. 4 to Fig. 6, the groove 29 in the inner body 14 can also be dispensed with, in that the pressure medium from the

oil guide module 23 reaches the control valve 3 via a groove 48 in the guide sleeve 6." Lehmann, [0032].



Lehmann, Fig. 4 (annotated)

95. Lehmann further discloses, "Starting from the interior 40 of the camshaft 2, an axial channel 24 arranged in the oil guide module 23 leads to a radial bore 25, which terminates in an annular space or groove 26 located between the oil guide module 23 and the camshaft 2 and between the guide sleeve 6 and the camshaft 2." Lehmann, [0029].



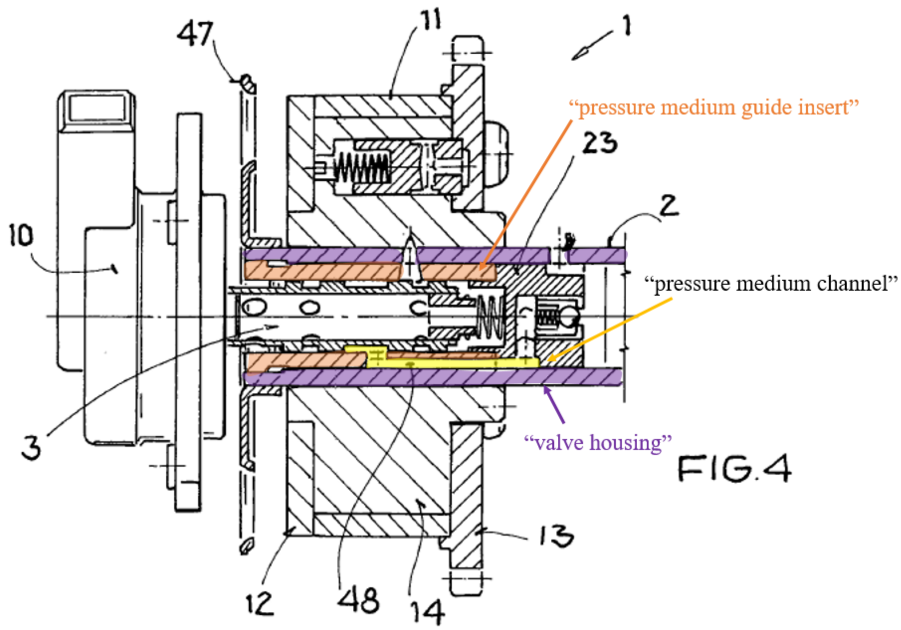
Lehmann, Fig. 1 (annotated)

(f) Element [1e]

96. **Element [1e] recites "the pressure medium guide insert engaging around the pressure medium channel at least partially."** Lehmann discloses the pressure medium guide insert engaging around the pressure medium channel at least partially (as shown in Figs. 1 and 4, the groove 26 and groove 48 are formed at least partially by an inset feature in the outer surface of guide sleeve 6. As the groove 26 and groove 48 are not fully annular, their lateral extents are defined in part by the guide sleeve 6, and the guide sleeve 6 thereby engages around the groove 26 and groove 48 laterally and radially). *See* Lehmann, Figs. 1, 4, *see also* Lehmann, [0029], [0032].

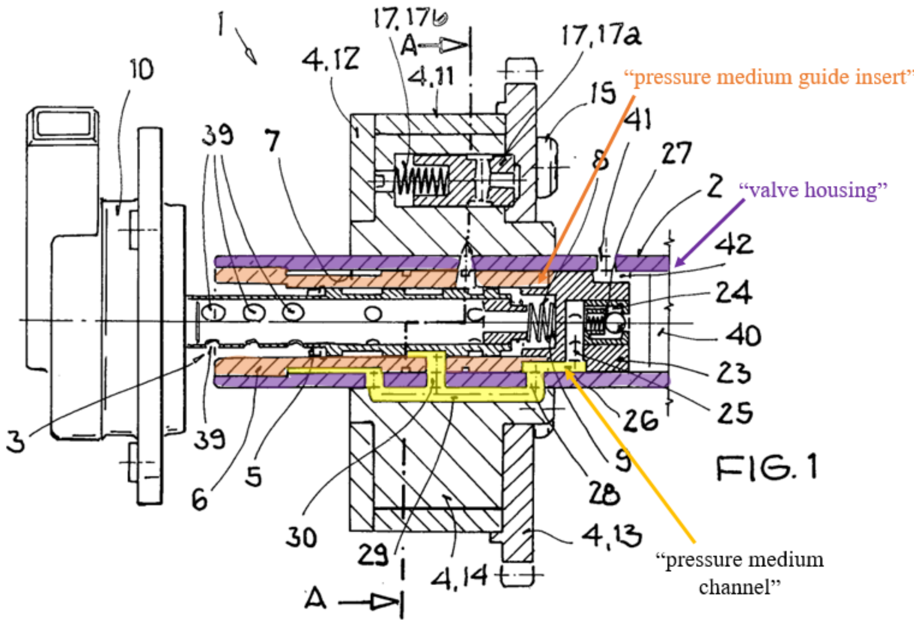
97. Lehmann discloses that the guide sleeve 6 is engaged around the groove 48 and groove 26. For example, in Figure 4, the groove 48 is formed at least partially

by an inset feature in the outer surface of guide sleeve 6. As the groove 48 is not fully annular, its lateral extents are defined in part by the guide sleeve 6, and the guide sleeve 6 thereby engages around the groove 48 laterally and radially.



Lehmann, Fig. 4 (annotated)

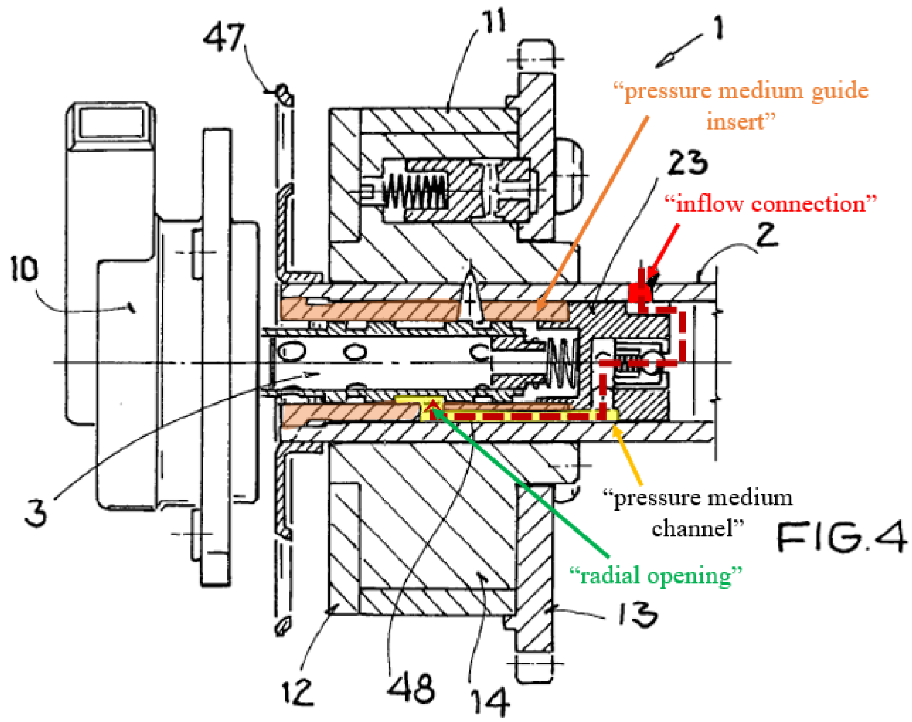
98. As another example, in Figure 1, the groove 26 is formed at least partially by an inset feature in the outer surface of guide sleeve 6. As the groove 26 is not fully annular, its lateral extents are defined in part by the guide sleeve 6, and the guide sleeve 6 thereby engages around the groove 26 laterally and radially.



Lehmann, Fig. 1 (annotated)

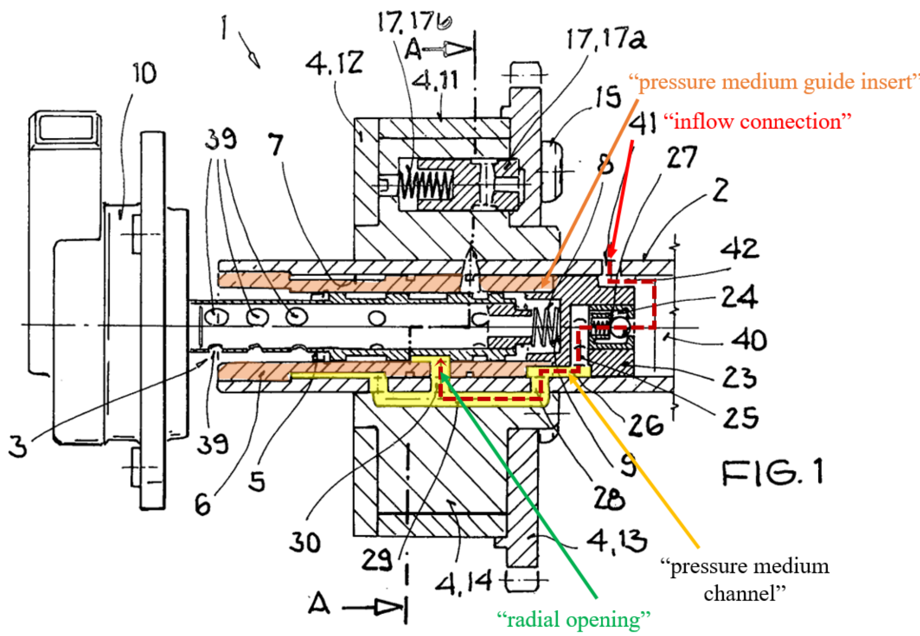
(g) Element [1f]

99. **Element [1f] recites "the pressure medium channel communicating with at least one of the connections and, via a radial opening, with the interior of the pressure medium guide insert."** Lehmann discloses the pressure medium channel communicating with at least one of the connections and, via a radial opening, with the interior of the pressure medium guide insert (*e.g.*, pressure medium is guided from the inflow connection, through "groove 48" of Fig. 4 or "groove 26" of Fig. 1, to "control valve 3," which is in the interior of the pressure medium guide insert, through a radial opening; see dashed red flow in Figs. 1 and 4 annotated below). *See* Lehmann, [0029], [0031], [0032], Figs. 1, 4.



Lehmann, Fig. 4 (annotated)

100. Lehmann discloses that the pressure medium enters at the port indicated by a red arrow in Fig. 4 above and then can flow into the groove 48 of Fig. 4. From the groove 48, the pressure medium can flow into the control valve 3 via the radial bore 41. For example, Lehmann discloses, "The interior 40 of the camshaft 2 is supplied with pressure medium via a radial bore 41 in the camshaft 2 from a pressure medium supply point not shown, which is arranged in a camshaft bearing." Lehmann, [0029]. Lehmann further discloses, "In a further embodiment of the invention according to Fig. 4 to Fig. 6, the groove 29 in the inner body 14 can also be dispensed with, in that the pressure medium from the oil guide module 23 reaches the control valve 3 via a groove 48 in the guide sleeve 6." Lehmann, [0032].



Lehmann, Fig. 1 (annotated)

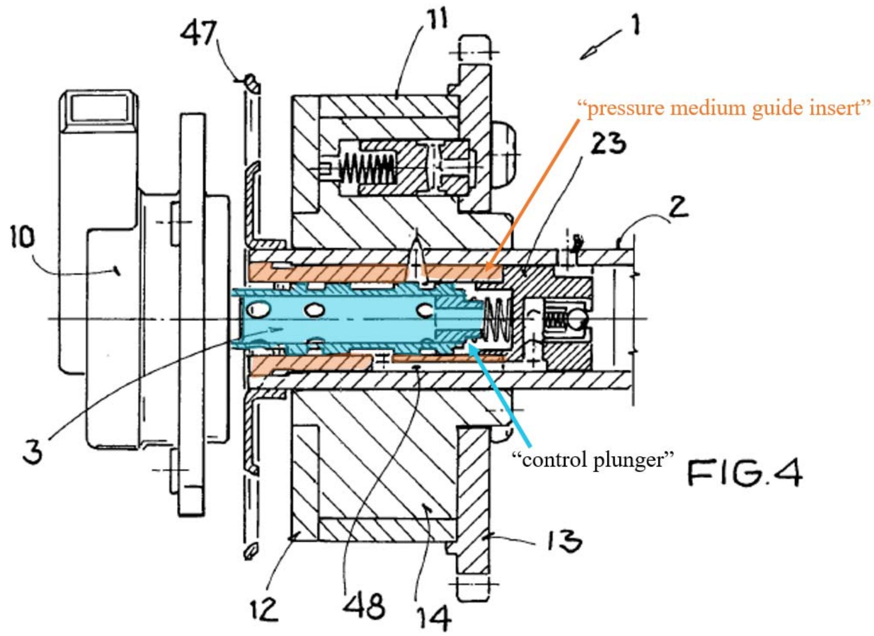
101. Lehmann further discloses, "Via the annular space or groove 26, the hydraulic medium enters a radial bore 28 formed in the camshaft 2. From the radial bore 28, the hydraulic medium passes via a groove 29 into a radial guide 30 in the camshaft 2. From the radial guide 30, the hydraulic medium enters the control valve 3 to supply the respective working chambers 21, 22 of the camshaft regulator 1 as required in accordance with the control requirements. The hydraulic medium is then discharged to the outside within the control valve 3 via bores 39 arranged in the control piston 5." Lehmann, [0029].

(h) Element [1g]

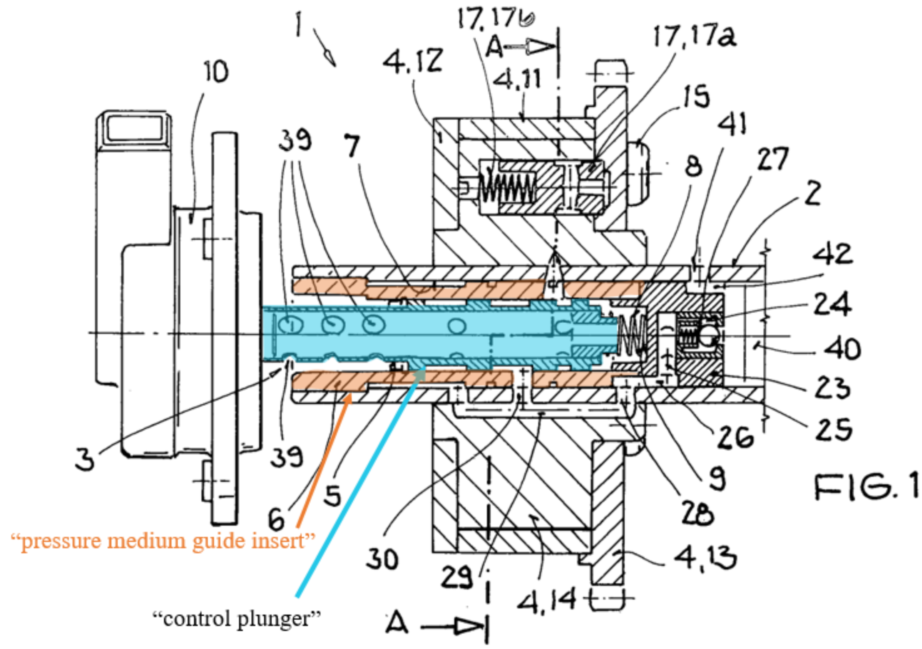
102. **Element [1g] recites "the control plunger being arranged within the pressure medium guide insert."** Lehmann discloses the control plunger (*e.g.*, "hydraulic control valve 3" including "control piston 5") being arranged within (*e.g.*,

"guided" within) the pressure medium guide insert (*e.g.*, "guide sleeve 6"). *See* Lehmann, [0021], Figs. 1, 4.

103. Lehmann discloses that the control piston 5 is located within the guide sleeve 6. For example, Lehmann discloses, "The hydraulic control valve 3 has a control piston 5 which is guided in a guide sleeve 6, the guide sleeve 6 being inserted in a concentric bore 7 of the camshaft 2 extending from one end of the camshaft 2 in the axial direction. The joining may be performed thermally. Furthermore, the joint can be glued, mechanically joined or welded. Likewise, other joining methods are possible." Lehmann, [0021].



Lehmann, Fig. 4 (annotated)



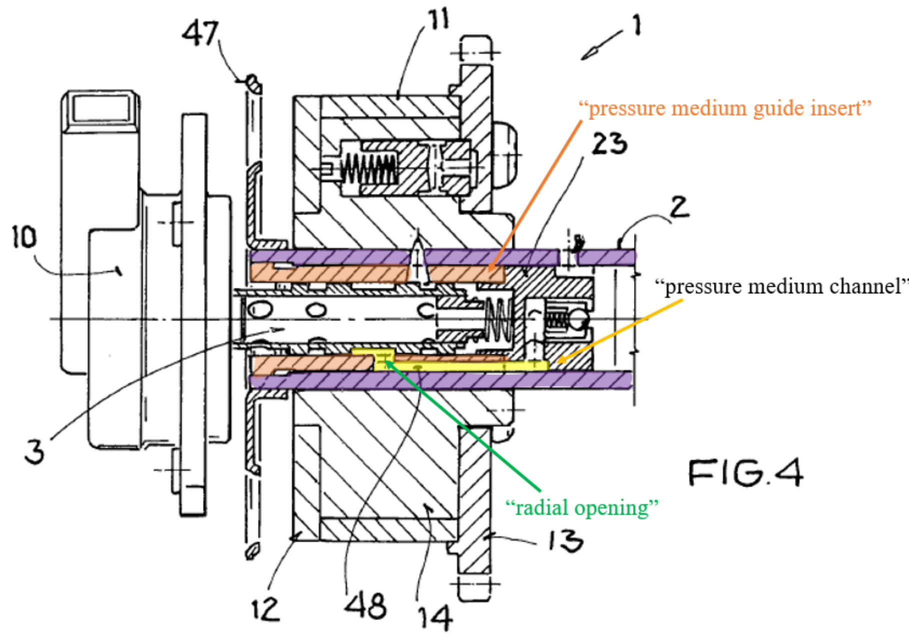
Lehmann, Fig. 1 (annotated)

(i) Claim [3]

104. **Claim [3] recites "The control valve of claim 1, wherein the at least one pressure medium channel is configured as a depression on an outer circumferential surface of the pressure medium guide insert, an inner circumferential surface of the valve housing delimiting the pressure medium channel radially outward, and the pressure medium channel communicating with the interior of the pressure medium guide insert via a radial opening which is formed on said pressure medium guide insert."** Lehmann discloses the at least one pressure medium channel (*e.g.*, "groove 48" of Fig. 4; "groove 26" of Fig. 1) is configured as a depression on an outer circumferential surface of the pressure medium guide insert (*e.g.*, a depression on the outer circumferential surface of

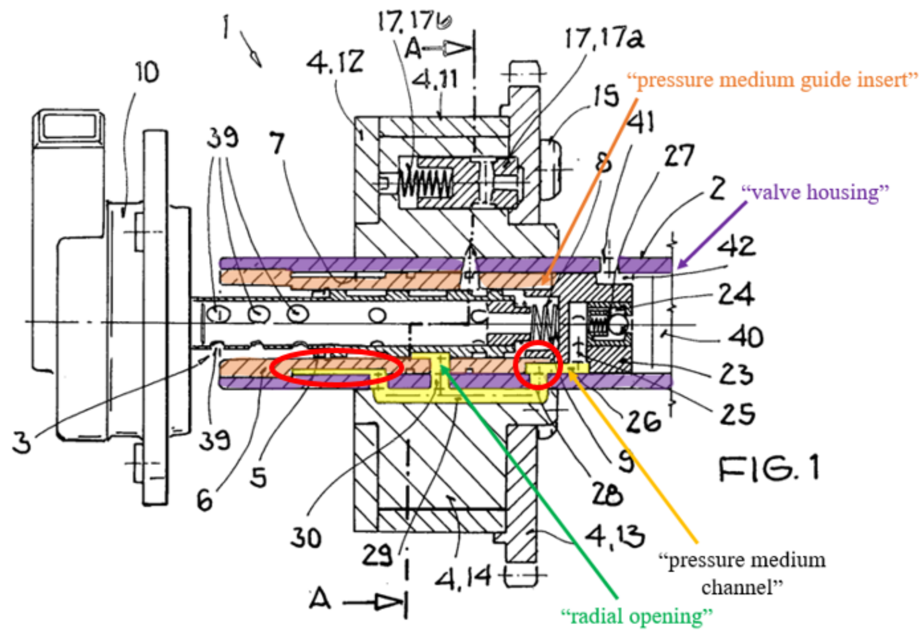
"guide sleeve 6"), an inner circumferential surface of the valve housing delimiting the pressure medium channel radially outward (*e.g.*, inner circumferential surface of "camshaft 2," a valve housing, delimiting the pressure medium channel radially outward), and the pressure medium channel communicating with the interior of the pressure medium guide insert via a radial opening which is formed on said pressure medium guide insert (see the radial opening in Figs. 1 and 4 annotated below; *e.g.*, "radial guide 30"). *See* Lehmann [0029], Figs. 1, 4.

105. Lehmann discloses that the groove 48 of Fig. 4 is inset into the outer surface of the guide sleeve 6, and that the inner surface of the camshaft 2 forms the opposing boundary. Lehmann also discloses that pressure medium in the groove 48 can flow into the interior of the guide sleeve 6 via a radial opening (annotated in green in Fig. 4 below). Lehmann discloses, "In a further embodiment of the invention according to Fig. 4 to Fig. 6, the groove 29 in the inner body 14 can also be dispensed with, in that the pressure medium from the oil guide module 23 reaches the control valve 3 via a groove 48 in the guide sleeve 6." Lehmann, [0032].



Lehmann, Fig. 4 (annotated)

106. Lehmann also discloses, "Via the annular space or groove 26, the hydraulic medium enters a radial bore 28 formed in the camshaft 2. From the radial bore 28, the hydraulic medium passes via a groove 29 into a radial guide 30 in the camshaft 2. From the radial guide 30, the hydraulic medium enters the control valve 3 to supply the respective working chambers 21, 22 of the camshaft regulator 1 as required in accordance with the control requirements. The hydraulic medium is then discharged to the outside within the control valve 3 via bores 39 arranged in the control piston 5." Lehmann, [0029].



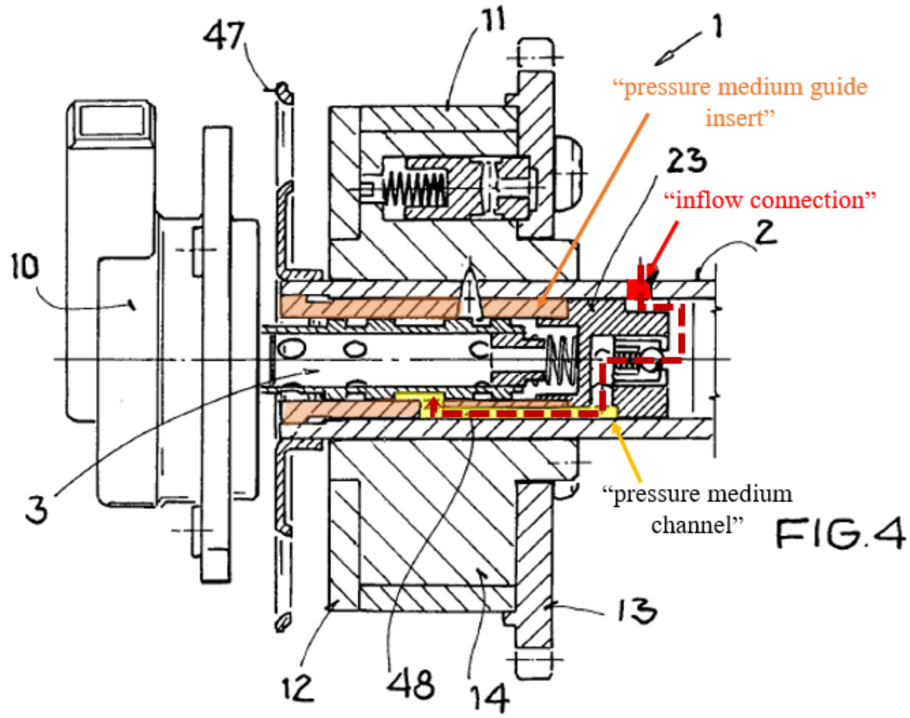
Lehmann, Fig. 1 (annotated; depressions circled)

(j) Claim [9]

107. **Claim [9] recites "The control valve of claim 1, wherein the pressure medium channel connects the inflow connection to the interior of the pressure medium guide insert."** Lehmann discloses the pressure medium channel connects the inflow connection (*e.g.*, "radial bore 41") to the interior of the pressure medium guide insert (see example flow of pressure medium, dashed red lines in Figs. 1 and 4 annotated below). *See* Lehmann, [0029], [0032].

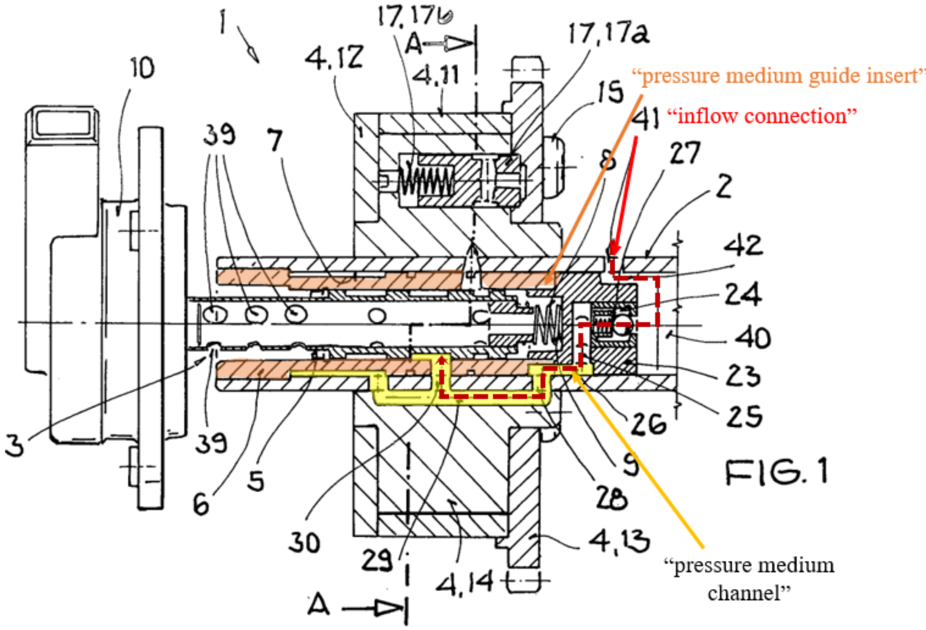
108. Lehmann discloses that the groove 48 connects radial bore 41 to the interior of the guide sleeve 6. For example, Lehmann discloses, "In order to improve the function of the camshaft regulator 1 and to enable higher turnout speeds, according to the invention, in addition to the control valve 3, an oil guide module 23 is inserted into the camshaft 2, which is connected upstream of the control valve 3

and serves to guide the hydraulic medium from the camshaft 2 into the control valve 3. The interior 40 of the camshaft 2 is supplied with pressure medium via a radial bore 41 in the camshaft 2 from a pressure medium supply point not shown, which is arranged in a camshaft bearing. The pressure medium can enter the camshaft 2 directly or, as shown in Fig. 1, be passed through axial channels 42 or annular channels to the interior 40 of the camshaft 2. Starting from the interior 40 of the camshaft 2, an axial channel 24 arranged in the oil guide module 23 leads to a radial bore 25, which terminates in an annular space or groove 26 located between the oil guide module 23 and the camshaft 2 and between the guide sleeve 6 and the camshaft 2." Lehmann, [0029]. Lehmann also discloses, "In a further embodiment of the invention according to Fig. 4 to Fig. 6, the groove 29 in the inner body 14 can also be dispensed with, in that the pressure medium from the oil guide module 23 reaches the control valve 3 via a groove 48 in the guide sleeve 6." Lehmann, [0032].



Lehmann, Fig. 4 (annotated)

109. Lehmann further discloses, "Via the annular space or groove 26, the hydraulic medium enters a radial bore 28 formed in the camshaft 2. From the radial bore 28, the hydraulic medium passes via a groove 29 into a radial guide 30 in the camshaft 2. From the radial guide 30, the hydraulic medium enters the control valve 3 to supply the respective working chambers 21, 22 of the camshaft regulator 1 as required in accordance with the control requirements. The hydraulic medium is then discharged to the outside within the control valve 3 via bores 39 arranged in the control piston 5." Lehmann, [0029].



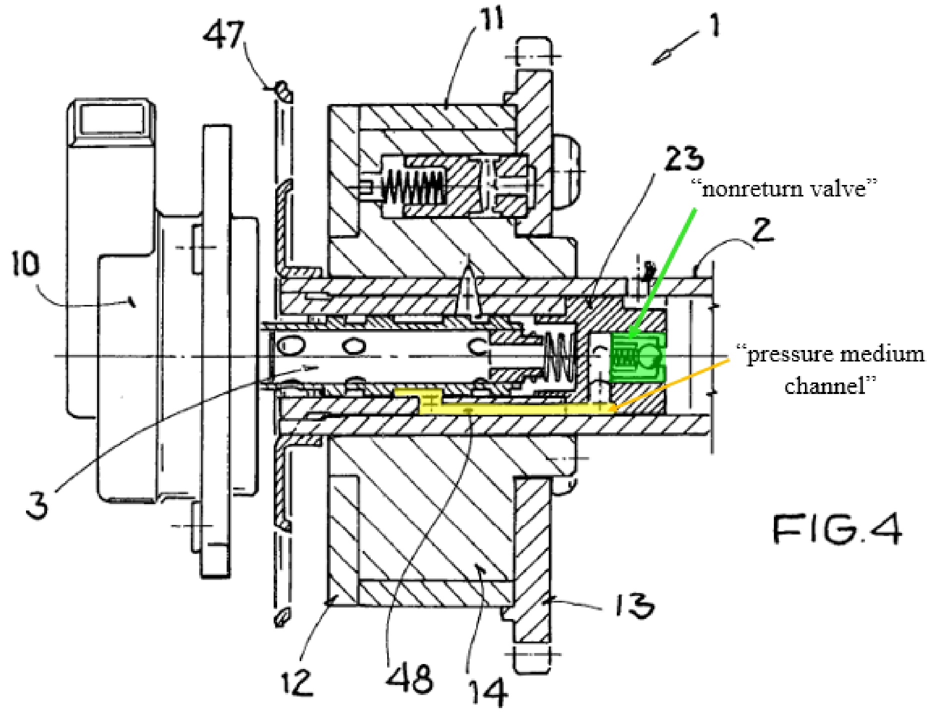
Lehmann, Fig. 1 (annotated)

(k) Claim [10]

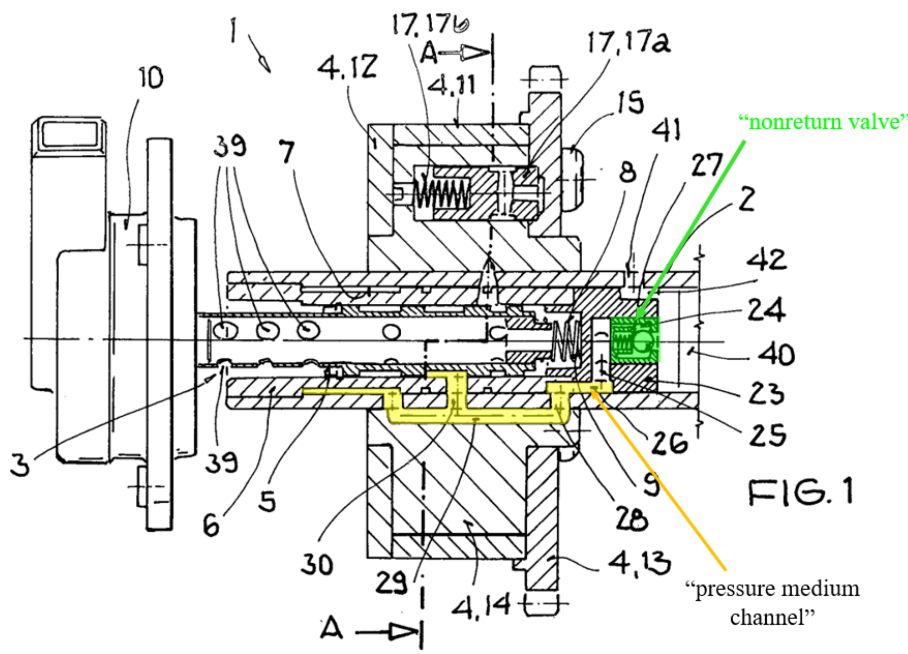
110. **Claim [10] recites "The control valve of claim 9, wherein a nonreturn valve is arranged within the control valve upstream of the pressure medium channel."** Lehmann discloses a nonreturn valve is arranged within the control valve upstream of the pressure medium channel (*e.g.*, "non-return valve 27" upstream of "groove 48" in Fig. 4 and "groove 26" in Fig. 1). *See* Lehmann, [0029], Figs. 1, 4.

111. Lehmann discloses the non-return valve 27 is located within the hydraulic control valve 3 upstream of the groove 48 in Fig. 4 and the groove 26 in Fig. 1. For example, Lehmann discloses, that "oil guide module 23 … is connected upstream of the control valve 3 and serves to guide the hydraulic medium from the camshaft 2 into the control valve 3," and "[i]n the axial channel 24 of the oil guide

module 23, a non-return valve 27 is provided to prevent backflow of pressurized fluid into the camshaft 2." Lehmann, [0029].



Lehmann, Fig. 4 (annotated)



Lehmann, Fig. 1 (annotated)

(l) Claim [11]

112. **Claim [11] recites "The control valve of claim 9, wherein a filter element is arranged within the control valve upstream of the pressure medium channel."** Lehmann discloses a filter element (*e.g.*, "oil filter") is arranged within the control valve upstream of the pressure medium channel. *See* Lehmann, [0029].

113. Lehmann discloses that an oil filter can be located within the oil guide module 23, which is upstream of the groove 26 and the groove 48. For example, Lehmann discloses that "oil guide module 23 … is connected upstream of the control valve 3 and serves to guide the hydraulic medium from the camshaft 2 into the control valve 3," and "[i]n the axial channel 24 of the oil guide module 23, a non-return valve 27 is provided to prevent backflow of pressurized fluid into the camshaft 2. Furthermore, the oil guide module 23 can accommodate an oil filter, not shown here, to filter the pressure medium before it is fed into the valve 3." Lehmann, [0029].

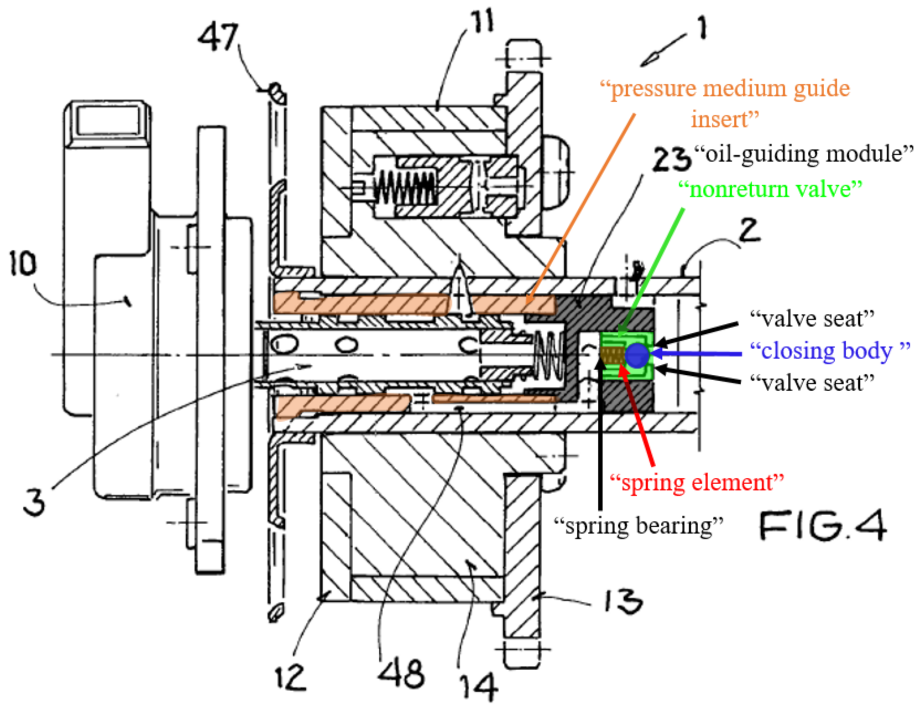
(m) Claim [13]

114. **Claim [13] recites "The control valve of claim 10, wherein the nonreturn valve has a closing body which is loaded with a force by a spring element, a spring bearing and a valve seat, at least the spring bearing or the valve seat being configured as a component which is separate from the pressure medium guide insert."** Lehmann discloses the nonreturn valve (*e.g.*, "non-return

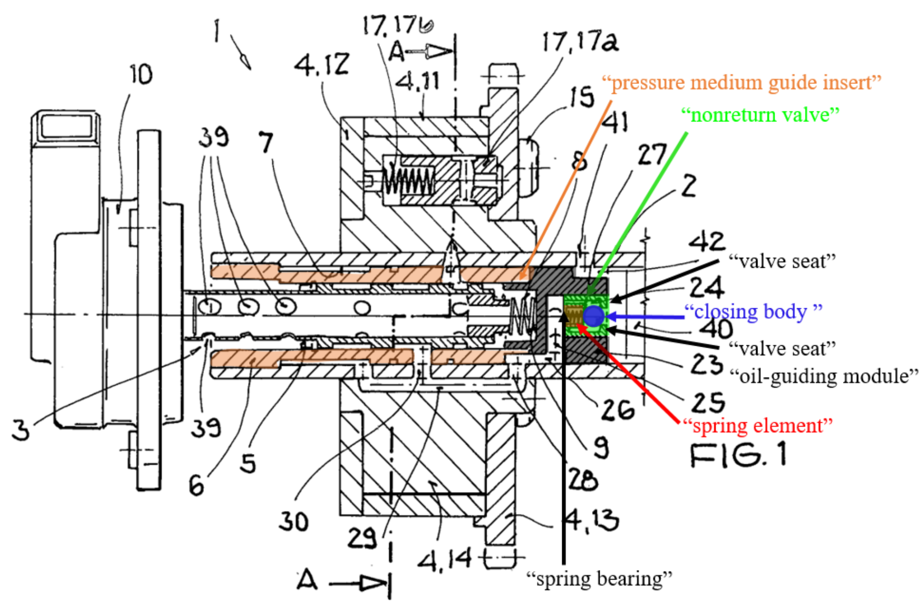
valve 27”) has a closing body (*e.g.*, sphere shaded blue in annotated Figs. 1 and 4) which is loaded with a force by a spring element (*e.g.*, spring shaded red in annotated Figs. 1 and 4), a spring bearing (*e.g.*, the spring element, which pushes the closing body rightward in Figs. 1 and 4, acts on a spring bearing that is the left side of the nonreturn valve) and a valve seat (*e.g.*, *right* side of the nonreturn valve that the closing body rests against, as indicated in annotated Figs. 1 and 4), at least the spring bearing or the valve seat being configured as a component which is separate from the pressure medium guide insert (*e.g.*, “oil guide module 23,” in which “non-return valve 27” and its spring bearing and valve seat are located, is a component separate from “guide sleeve 6”). *See* Lehmann, [0029], Figs. 1, 4.

115. Lehmann discloses that the sphere of the non-return valve 27 is pressed by a spring onto the right side of the non-return valve 27, which acts as a valve seat and is a separate component from the guide sleeve 6. The left-hand end of the spring bears against the left side of non-return valve 27, which in Figures 1 and 4 is part of the oil guide module 23, a separate component from the guide sleeve 6.

116. For example, Lehmann discloses, “In the axial channel 24 of the oil guide module 23, a non-return valve 27 is provided to prevent backflow of pressurized fluid into the camshaft 2.” Lehmann, [0029].



Lehmann, Fig. 4 (annotated)



Lehmann, Fig. 1 (annotated)

I note that Lehmann discloses that Figure 6 depicts the guide sleeve 6 and the oil guide module 23 as a one-piece component. Lehmann, [0034] ("In a further embodiment according to Fig. 6, the guide sleeve 6 of the control valve 3 and the oil guide module 23 are formed into a single-piece component.”). This is different than Figures 1 and 4 which depict the guide sleeve 6 and oil guide module 23 as separate components.

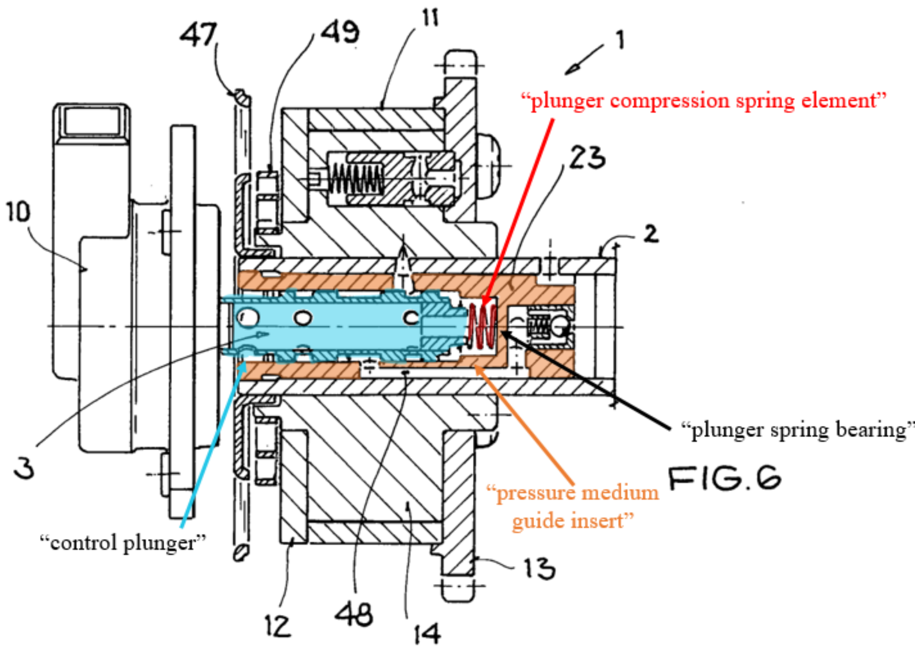
(n) Claim [14]

117. **Claim [14] recites “The control valve of claim 1, wherein a plunger compression spring element is provided which loads the control plunger with a force in an axial direction, [s]aid plunger compression spring element being supported on a plunger spring bearing which is configured in one piece with the pressure medium guide insert.”** Lehmann discloses a plunger compression spring element is provided which loads the control plunger with a force in an axial direction (*e.g.*, “pressure spring 8” acting on “control piston 5” in an axial direction), said plunger compression spring element being supported on a plunger spring bearing which is configured in one piece with the pressure medium guide insert (*e.g.*, “oil-guide module 23,” which supports “pressure spring 8,” is configured in one piece with “guide sleeve 6”). *See* Lehmann, [0022], [0023], [0030], [0034], Figs. 1, 6.

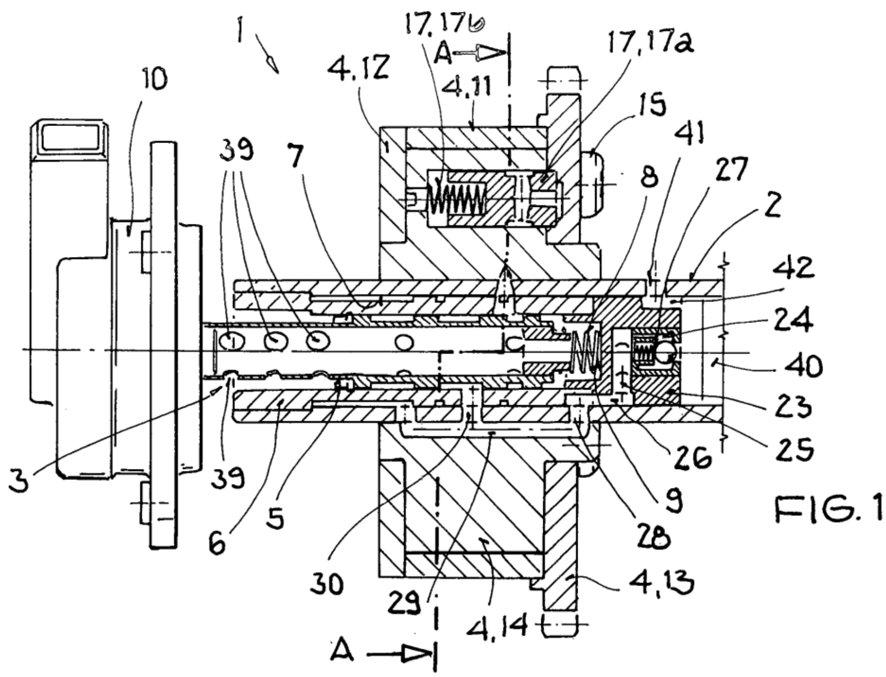
118. Lehmann discloses a pressure spring 8 that loads control piston 5 in an axial direction. The right-hand end of pressure spring 8 bears against oil-guide module 23, which in Figure 6 is part of the same component as guide sleeve 6. For

example, Lehmann discloses, "The control piston 5 is positioned by the balance between the force of the pressure spring 8 and the opposing magnetic force of the electromagnetic device 10." Lehmann, [0030]. Lehmann also discloses, "On a side of the control piston 5 facing the camshaft 2, a pressure spring 8 acting on the control piston 5 is arranged, which is supported with its end facing away from the control piston 5 on a base 9 of the guide sleeve 6 closed to the side of the camshaft 2 and acts on the control piston 5 with its end facing the control piston 5." Lehmann, [0022]. Lehmann further discloses, "On the side of the control piston 5 facing away from the camshaft 2, an electromagnetic device 10 formed by a pressure magnet and mounted fixed to the engine is arranged, via which the control piston 5 can be adjusted against the spring force of the pressure spring 8. For this purpose, on an end of the control piston 5 facing away from the pressure spring 8, there is a contact point, not shown in more detail, between a plunger of the pressure magnet and the control piston 5, which transmits the actuating forces of the pressure magnet to the control piston 5 in a known manner. For better power transmission between the electromagnetic device 10 and the control piston 5, a starting piece, not visible here, can be used in the control piston 5, which reduces friction and wear caused by the fact that the electromagnetic device 10 is fixed to the engine and the control piston 5 rotates with the camshaft 2." Lehmann, [0023]. In addition, Lehmann discloses, "In a further embodiment according to Fig. 6, the guide sleeve 6 of the control valve

3 and the oil guide module 23 are formed into a single-piece component." Lehmann, [0034].



Lehmann, Fig. 6 (annotated)



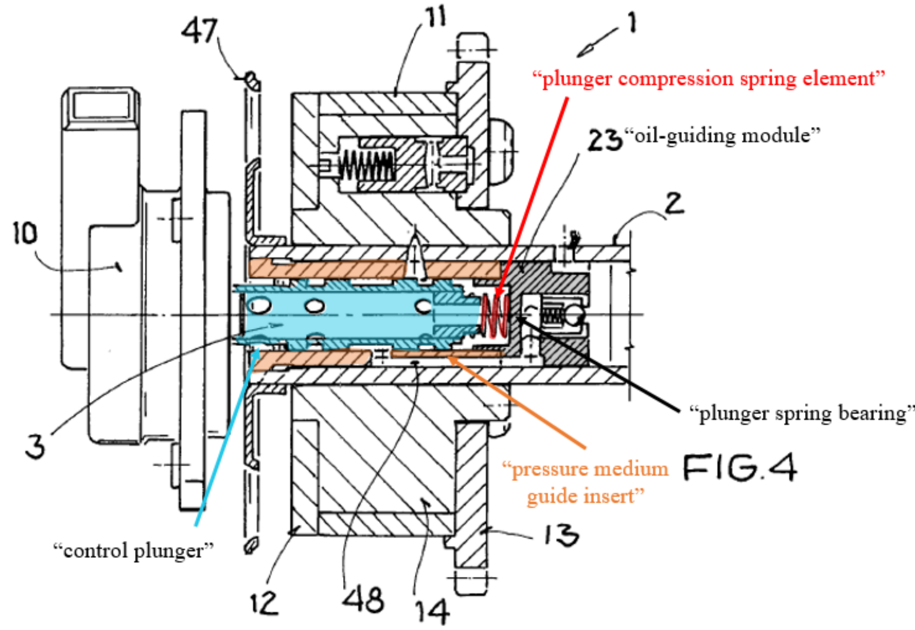
Lehmann, Fig. 1 (depicting location of components not labeled in Fig. 6)

(o) Claim [15]

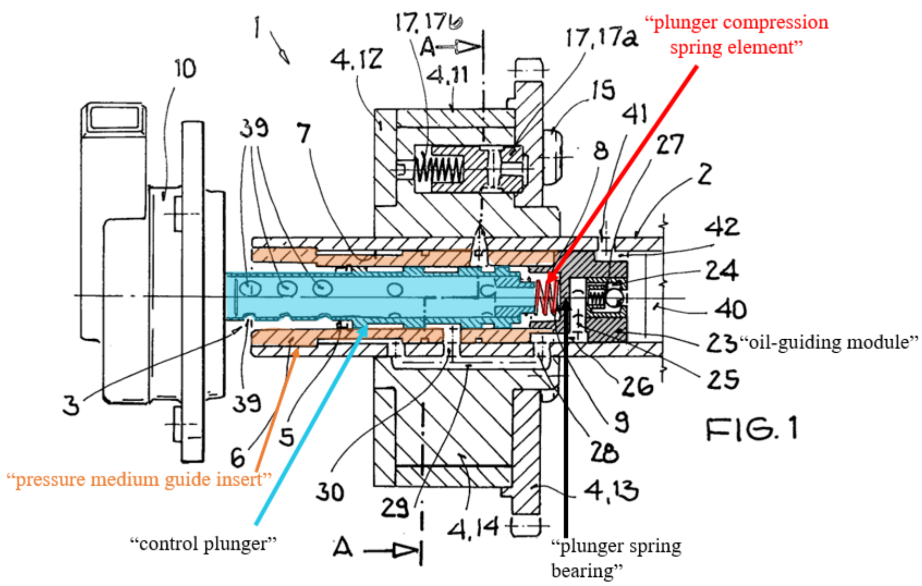
119. **Claim [15] recites "The control valve of claim 1, wherein a plunger compression spring element is provided which loads the control plunger with a force in an axial direction, [s]aid plunger compression spring element being supported on a plunger spring bearing which is configured separately from the pressure medium guide insert."** Lehmann discloses a plunger compression spring element is provided which loads the control plunger with a force in an axial direction (*e.g.*, "pressure spring 8" acting on "control piston 5" in an axial direction), said plunger compression spring element being supported on a plunger spring bearing which is configured separately from the pressure medium guide insert (*e.g.*, "oil-guide module 23," which supports "pressure spring 8," is configured separately from "guide sleeve 6"). *See* Lehmann, [0022], [0023], [0030], [0034], Figs. 1, 4.

120. Lehmann discloses a pressure spring 8 that loads control piston 5 in an axial direction. The right-hand end of pressure spring 8 bears against oil-guide module 23, which in Figures 1 and 4 is a different component from guide sleeve 6. For example, Lehmann discloses, "The control piston 5 is positioned by the balance between the force of the pressure spring 8 and the opposing magnetic force of the electromagnetic device 10." Lehmann, [0030]. Lehmann also discloses, "On a side of the control piston 5 facing the camshaft 2, a pressure spring 8 acting on the control piston 5 is arranged, which is supported with its end facing away from the control

piston 5 on a base 9 of the guide sleeve 6 closed to the side of the camshaft 2 and acts on the control piston 5 with its end facing the control piston 5." Lehmann, [0022]. Lehmann further discloses, "On the side of the control piston 5 facing away from the camshaft 2, an electromagnetic device 10 formed by a pressure magnet and mounted fixed to the engine is arranged, via which the control piston 5 can be adjusted against the spring force of the pressure spring 8. For this purpose, on an end of the control piston 5 facing away from the pressure spring 8, there is a contact point, not shown in more detail, between a plunger of the pressure magnet and the control piston 5, which transmits the actuating forces of the pressure magnet to the control piston 5 in a known manner. For better power transmission between the electromagnetic device 10 and the control piston 5, a starting piece, not visible here, can be used in the control piston 5, which reduces friction and wear caused by the fact that the electromagnetic device 10 is fixed to the engine and the control piston 5 rotates with the camshaft 2." Lehmann, [0023]. *See also* Lehmann, [0034] (describing Fig. 6 with guide sleeve 6 and oil-guide module 23 as one-piece; contrasting with Figs. 1 and 4, which do not include the guide sleeve 6 and oil-guide module 23 as one-piece).



Lehmann, Fig. 4 (annotated)



Lehmann, Fig. 1 (annotated)

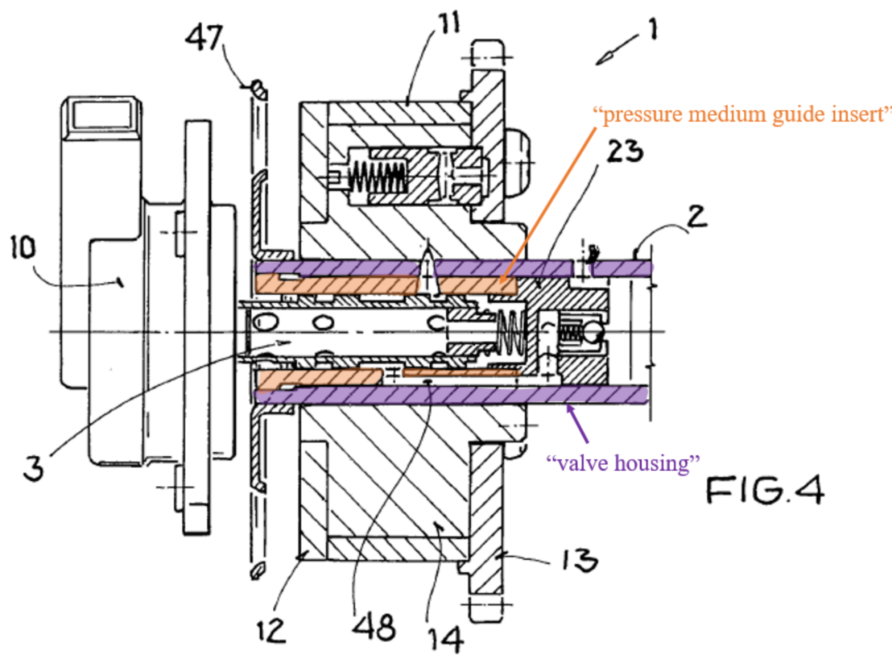
(p) Claim [18]

121. **Claim [18] recites "The control valve claim of 1, wherein the pressure medium guide insert is arranged within the valve housing in a stationary manner with respect to the valve housing."** Lehmann discloses the

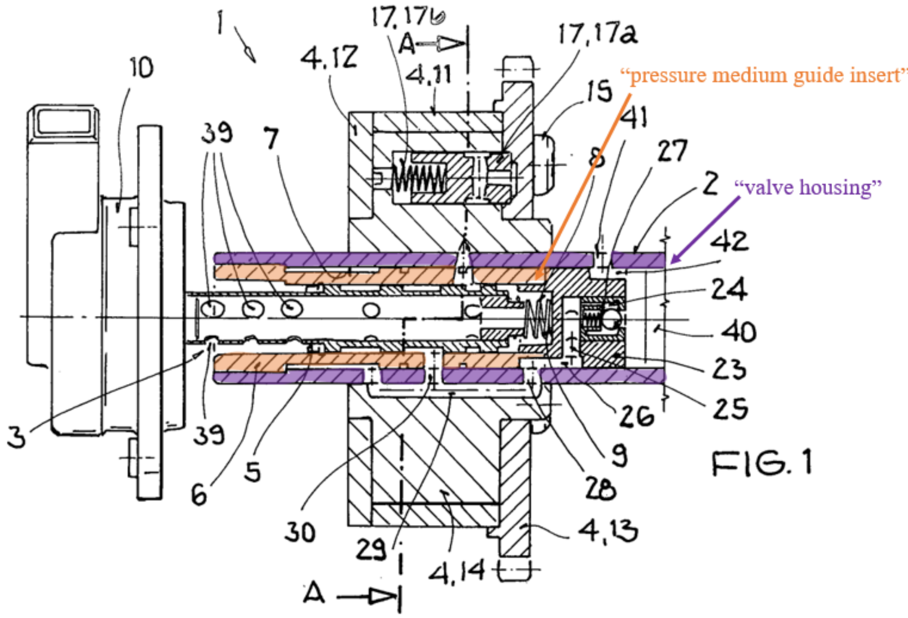
pressure medium guide insert (*e.g.*, “guide sleeve 6”) is arranged within the valve housing in a stationary manner with respect to the valve housing (joined, *e.g.*, thermally or via gluing, to “camshaft 2,” a valve housing). *See* Lehmann, [0021], [0024], Figs. 1, 4.

122. Lehmann discloses that the guide sleeve 6 is joined thermally, glued, mechanically joined, or welded to the concentric bore 7 of the camshaft 2, which are all joining methods that result in a stationary, non-rotatable joint between the parts. For example, Lehmann discloses, “The hydraulic control valve 3 has a control piston 5 which is guided in a guide sleeve 6, the guide sleeve 6 being inserted in a concentric bore 7 of the camshaft 2 extending from one end of the camshaft 2 in the axial direction. The joining may be performed thermally. Furthermore, the joint can be glued, mechanically joined or welded. Likewise, other joining methods are possible.” Lehmann, [0021]. A POSA would have understood that thermal joining is a class of processes that includes welding, brazing, and soldering, and that these processes, like gluing, result in a joint that does not allow any motion between the parts. Manufacturing Processes Reference Guide (Ex. 1017), at vi (teaching that “Thermal Joining” methods include “Electron Beam Welding,” “Furnace Brazing,” “Gas Metal Arc Welding (MIG),” “Gas Torch Braze Welding,” “Gas Tungsten Arc Welding (TIG),” “Laser Beam Welding,” “Metal Bath Dip Soldering,” “Plasma Arc Welding,” “Projection Welding,” “Shielded Metal Arc Welding (SMAW),” “Spot

Welding," "Submerged Arc Welding (SAW)," and "Wave Soldering."). Lehmann also discloses, "The cover 12, the housing 11 and the outer body 13 enclose an annular space in which an inner body 14 in the form of an impeller is arranged. The inner body 14 is rotationally fixed on the camshaft 2. The fixing can be achieved by material, force and/or form-fitting, for example by thermal joining, press-fitting, internal high pressure forming or by means of other joining processes." Lehmann, [0024].



Lehmann, Fig. 4 (annotated)



Lehmann, Fig. 1 (annotated)

C. Ground 2: Lehmann renders obvious claims 1, 3, and 9-18

1. Overview

123. While Lehmann anticipates 1, 3, 9-11, 13-15, and 18 as explained in §VIII.B above, Lehmann also at minimum renders these claims obvious. In addition, Lehmann renders claims 12, 16, and 17 obvious. As I will explain in further detail below, Claims 1, 3, and 9-18 are rendered obvious by Lehmann.

2. Invalidity of Claims 1, 3, and 9-18 (Ground 2)

124. As explained in §VIII.B above, Lehmann discloses each element of the control valve of claims 1, 3, 9-11, 13-15, and 18. However, to the extent Patent Owner argues that Lehmann does not expressly disclose in a single "embodiment" all elements of the Challenged Claims, for example because Lehmann describes that Figs. 1-6 represent "5 embodiments" of the invention (I generally rely on the

embodiments shown in Figs. 1, 2, 4, and 6 above), that is incorrect because Lehmann's "embodiments" are not wholly separate devices to be considered in isolation. For example, the detailed operation of the camshaft regulator of Figs. 1 and 2 is described in [0020]-[0030]. Fig. 6 provides, in one aspect, that "[i]n a further embodiment…, the guide sleeve 6 of the control valve 3 and the oil guide module 23 are formed into a single-piece component." Lehmann, [0034]. A POSA would have recognized that this feature "according to Fig. 6" would have been applicable to the same guide sleeve 6 and oil guide module 23 of Fig. 1, which shares the same reference numerals. *See also* Lehmann, [0013]-[0018] ("Fig. 1 a longitudinal section through **a camshaft regulator**," "Fig. 3 **the camshaft regulator, wherein** a camshaft bearing is arranged…," "Fig. 4 **the camshaft regulator with** an impulse wheel," "Fig. 5 **the camshaft regulator with** a return spring," "Fig. 6 **the camshaft regulator in which** the guide sleeve of the control valve and the oil guide module are made in one piece") (emphasis added).Thus, Lehmann's "embodiments" further build on the more detailed disclosure of Figs. 1 and 2.

125. Nevertheless, the claims are obvious over Lehmann. It would have been obvious to combine the cited teachings because Lehmann teaches, at the very least, that they are all directed to closely related variations of the same control valves. Lehmann, [0013]-[0018].

126. With further respect to claim 1, to the extent Patent Owner may argue that Lehmann does not explicitly disclose a separate, dedicated valve housing (which is not required by claim 1) because, *e.g.*, the element that houses the pressure medium guide insert in Lehmann is labeled as "camshaft," the design of separate components so that they are integral (*e.g.*, Lehmann's camshaft regulator is integral with camshaft 2) or separable (*e.g.*, Lehmann's camshaft regulator is separate from camshaft 2) would have been obvious to a POSA. *See also* '756 patent, 2:30-48 (prior art plunger adjusters known to connect to camshafts in a variety of ways: *e.g.*, pressing, screwing, welding). Moreover, a POSA would have been motivated to provide the camshaft regulator with a valve housing separate from a camshaft to provide obvious benefits to portability, for example by permitting use of the camshaft adjuster as a retrofit for existing motor vehicle camshafts. Palesch (Ex. 1006), 1:23-42, 4:13-19. A separate valve housing facilitates shipping a camshaft adjuster as an assembly to an engine plant for connection to a camshaft.

127. With further respect to claims 12, 16, and 17, which claim certain components "in one piece" or connected with a "material-to-material fit," such design variations would have also been obvious to a POSA for the reasons discussed in §§VIII.C(a)-(c) below.

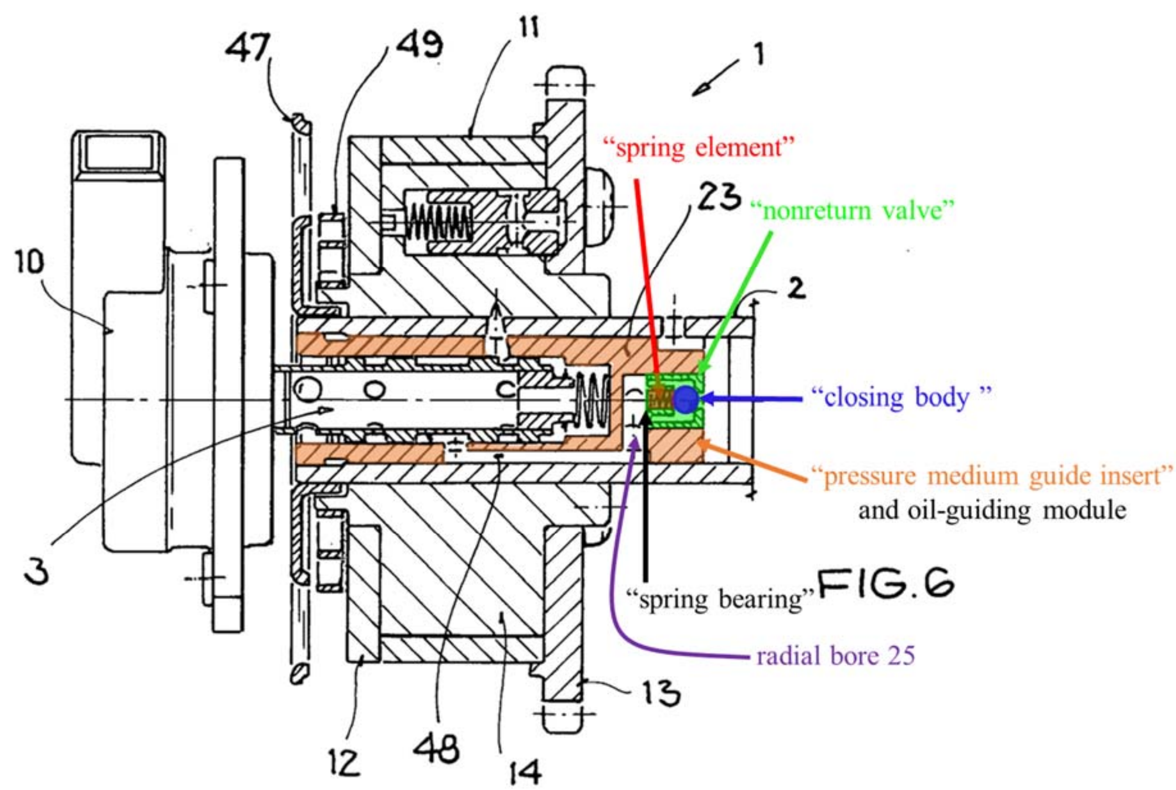
128. A POSA would have had a reasonable expectation of success implementing Lehmann's camshaft displacement device with a separate valve

housing, with components in one piece, and/or with material-to-material fits. One-piece constructions, multi-piece constructions, material-to-material fits (*e.g.*, pressing, welding), etc., were all general design techniques known and used in Lehmann, the myriad prior art cited herein, and by a POSA for both automotive and non-automotive applications. *See also* ’756 patent, 2:33-38 (describing *known* connections), 3:62-67 (describing components in one-piece). Accordingly, claims 1, 3, and 9-18 would have been obvious to a POSA.

(a) Claim [12]

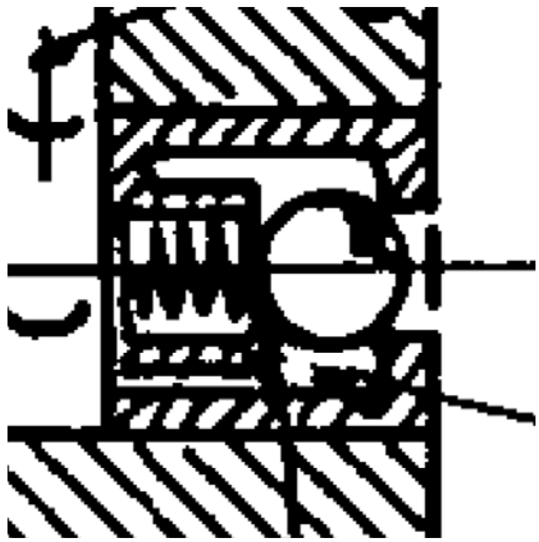
129. **Claim [12] recites “The control valve or claim 10, wherein the nonreturn valve has a closing body which is loaded with a force by a spring element, the spring element being supported on a spring bearing which is configured in one piece with the pressure medium guide insert.”** Lehmann discloses the nonreturn valve (*e.g.*, “non-return valve 27”) has a closing body (*e.g.*, sphere shaded blue in annotated Fig. 6) which is loaded with a force by a spring element (*e.g.*, spring shaded red in annotated Fig. 6), the spring element being supported on a spring bearing (*e.g.*, left side of the nonreturn valve 27, which the spring element must compress against in order to apply force to the closing body) which is configured in one piece with the pressure medium guide insert (*e.g.*, “oil guide module 23,” in which “non-return valve 27” is located, is in one piece with “guide sleeve 6”). *See* Lehmann, [0029], [0034], Figs. 4, 6.

130. Lehmann discloses that the non-return valve 27 has a sphere which is held in place by a spring. Lehmann discloses that the spring is supported at the opposite end from the sphere by the left side of non-return valve 27, as shown in Figure 6. For example, Lehmann discloses, "In the axial channel 24 of the oil guide module 23, a non-return valve 27 is provided to prevent backflow of pressurized fluid into the camshaft 2." Lehmann, [0029]. Lehmann also discloses, "In a further embodiment according to Fig. 6, the guide sleeve 6 of the control valve 3 and the oil guide module 23 are formed into a single-piece component." Lehmann, [0034].



Lehmann, Fig. 6 (annotated)

131. Figure 1 (below) of the original German publication of Lehmann (Ex. 1004) makes clear that the spring is supported at the opposite end from the sphere by the left side of non-return valve 27.



Ex. 1004 (Original German Publication of Lehmann), Figure 1 (excerpt)

132. To the extent Patent Owner argues that the bearing surface for the spring is not configured in the same piece as the guide sleeve 6, a POSA would have recognized that whether any two functional components in a device are comprised of one piece or two pieces is an obvious design choice. For example, as Lehmann shows in Figs. 4 and 6, guide sleeve 6 and oil-guide module 23 may be designed as separate components or a one-piece component. Accordingly, where Lehmann discloses that non-return valve 27 (the left side of which acts as the spring bearing) is introduced in a passage of the oil-supply module 23 (which is in one piece with the pressure medium guide insert in Fig. 6), but does not explain whether non-return valve 27 is in one piece with the oil-supply module 23, it would have been obvious

to a POSA to manufacture the non-return valve 27 and oil-guide module 23 in one piece. Especially where Lehmann does not disclose that the nonreturn valve and oil guide module and/or the pressure medium guide insert must be configured separately or loosely, manufacturing may be simplified by configuring multiple components as one piece. *See, e.g.*, Knecht (Ex. 1007) [0018] ("To simplify the manufacture, the support elements 50 and the insert sleeve 51 or the jacket sleeve 52 are made as one piece and of suitable plastic"), Bolz, [0034] (insert structured in one or multiple pieces).

(b) Claim [16]

133. **Claim [16] recites "The control valve of claim 1, wherein both a plunger spring bearing and a spring bearing which is configured in one piece with the former are provided."** Lehmann discloses both a plunger spring bearing (*e.g.*, surface of "oil guide module 23" on which plunger compression spring element ("pressure spring 8") acts) and a spring bearing which is configured in one piece with the former are provided (*e.g.*, surface of "non-return valve 27" on which the spring element acts opposing the closing body). *See* Lehmann, [0022], [0023], [0030], Fig. 4.

134. Lehmann discloses a plunger spring bearing, as described above with respect to claim 15. Lehmann discloses a pressure spring 8 that loads control piston 5 in an axial direction. The right-hand end of pressure spring 8 bears against a surface

of the oil-guide module 23, which is the plunger spring bearing. Lehmann also discloses a spring bearing, as described above with respect to claim 12. *See also* Lehmann, [0030], [0022], and [0023], describing pressure spring 8. As discussed above with respect to claim 12, the left-hand end of the spring of the non-return valve 27 bears against the left side of non-return valve 27.

135. To the extent Patent Owner argues the spring bearing for the non-return valve 27 is not part of the oil guide module 23, as explained in the discussion of claim 12 above, a POSA would have been motivated to manufacture non-return valve 27 (containing the spring element's bearing) and oil-guide module 23 (containing the plunger spring element's bearing) in one piece. In that configuration "both a plunger spring bearing and a spring bearing which is configured in one piece with the former are provided," as recited in claim 16.

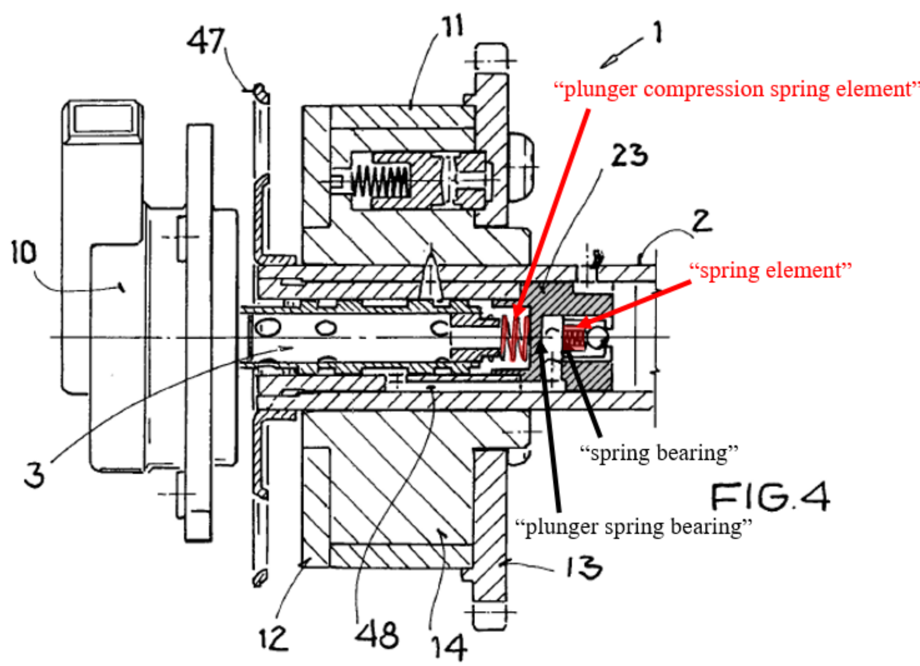


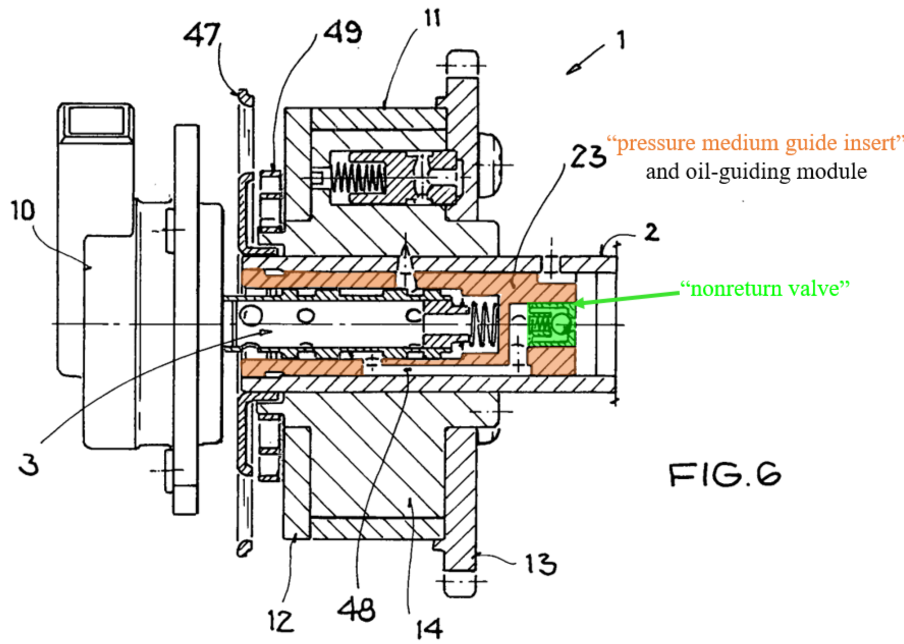
FIG.4

Fig. 4 (annotated)

(c) Claim [17]

136. **Claim [17] recites "The control valve of claim 12 wherein the filter element and/or parts of the nonreturn valve are/is connected to the pressure medium guide insert with a material-to-material fit."** Lehmann discloses the filter element and/or parts of the nonreturn valve are/is connected to the pressure medium guide insert (*e.g.*, "oil-guide module 23," which includes "non return valve 27" and an "oil filter," is in one piece with "guide sleeve 6" (the pressure medium guide insert)). *See* Lehmann, [0003], [0007], [0021], [0029], Fig. 6.

137. Lehmann discloses the non-return valve 27 is connected to the oil guide module 23 with a material-to-material fit. For example, Lehmann discloses, "In the axial channel 24 of the oil guide module 23, a non-return valve 27 is provided to prevent backflow of pressurized fluid into the camshaft 2. Furthermore, the oil guide module 23 can accommodate an oil filter, not shown here, to filter the pressure medium before it is fed into the valve 3." Lehmann, [0029]. As can be seen in Figure 6 below, the non-return valve 27 is pressed into the oil-guide module 23, which is of one piece with the guide sleeve 6. The '756 patent describes pressing as an example of a material-to-material fit. '756 patent, 2:33-38.



Lehmann, Fig. 6 (annotated)

138. To the extent Patent Owner argues that Lehmann does not explicitly disclose the manner of connecting non-return valve 27 to oil-guide module 23 or guide sleeve 6, a POSA would have been motivated, in light of Lehmann's disclosure, to use a material-to-material fit (*e.g.*, pressing, screwing, or welding) to connect components. Indeed, the '756 patent includes examples of material-to-material fits, including pressing, screwing, and welding. '756 patent, 2:33-38, 12:61-67. Lehmann teaches various material-to-material fits for connecting components. The use of well-known techniques to connect components would have been obvious and well within the skill of a POSA.

139. Lehmann discloses that material-to-material fits (pressing, screwing, welding, and other joining processes) were well known methods of connecting the

components that a POSA would be motivated to use for improved reliability; smaller, lighter, and less expensive connections; and reduced space requirements. For example, Lehmann discloses, "The control piston is guided in a separate guide sleeve which is pressed into the camshaft." Lehmann, [0003]. Lehmann also discloses, "A significant advantage of the invention lies in the method of connecting the oil guide module to the camshaft. The use of an oil guide module results in a camshaft regulator with significantly improved functional characteristics, particularly with respect to adjustment speeds. The fact that the oil guide module is pressed into the camshaft means that there is no need for screwed connections, which increases operational reliability. As a result, the camshaft regulator can not only be smaller, but also lighter and less expensive. A further advantage is that the oil guide module can also be used to accommodate other components, such as a non-return valve and/or a filter. This reduces the space required to accommodate further components." Lehmann, [0007]. Lehmann further discloses, "The hydraulic control valve 3 has a control piston 5 which is guided in a guide sleeve 6, the guide sleeve 6 being inserted in a concentric bore 7 of the camshaft 2 extending from one end of the camshaft 2 in the axial direction. The joining may be performed thermally. Furthermore, the joint can be glued, mechanically joined or welded. Likewise, other joining methods are possible." Lehmann, [0021].

140. A POSA would have been motivated to connect the non-return valve 27 to the guide sleeve 6 with a material-to-material fit such as pressing to improve operational reliability, to make the connection smaller, lighter, and less expensive, and to allow more room for other components, as disclosed by Lehmann. Lehmann, [0007], *see also* [0003], [0021].

D. Ground 3: Lehmann in view of Bolz renders obvious claims 4 and 7

1. Overview

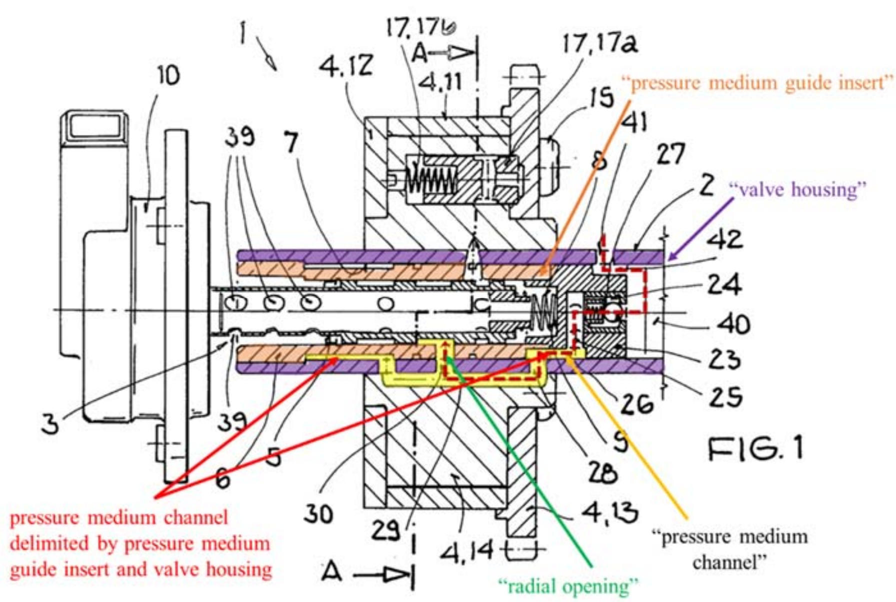
141. Similar to the ’756 patent, Bolz expressly discloses a valve insert that can be structured in one piece or in multiple pieces connected together. Bolz, [0031]-[0034], [0052]-[0053], Fig. 7. A POSA would have been motivated to apply these teachings in implementing Lehmann as discussed further in Section VIII.A.3 and in the sections below.

2. Invalidity of Claims 4 and 7 (Ground 3)

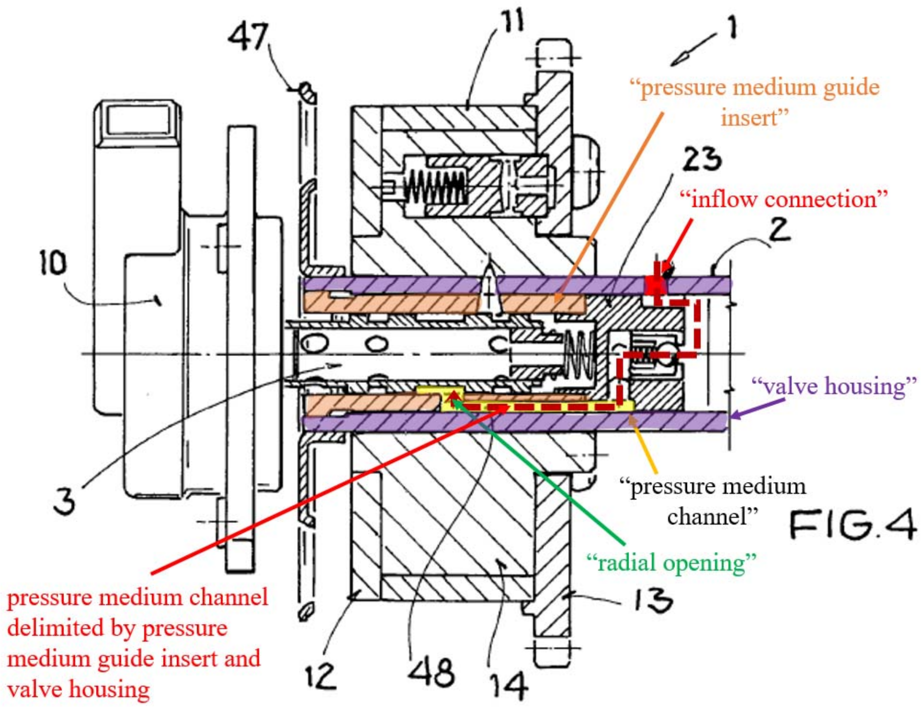
(a) Claim [4]

142. **Claim [4] recites “The control valve of claim 1, wherein the pressure medium guide insert comprises at least one inner and one outer sleeve-shaped component, and in that the at least one pressure medium channel is configured as a slot in a wall of the outer sleeve-shaped component of the pressure medium guide insert, an inner circumferential surface of the valve housing delimiting the pressure medium channel radially outward and the**

inner sleeve-shaped component of the pressure medium guide insert delimiting the pressure medium channel radially inward, and the pressure medium channel communicating with the interior of the pressure medium guide insert via a radial opening which is formed on the inner sleeve-shaped component." Lehmann discloses an inner circumferential surface of the valve housing delimiting the pressure medium channel radially outward and the pressure medium guide insert delimiting the pressure medium channel radially inward, and the pressure medium channel communicating with the interior of the pressure medium guide insert via a radial opening which is formed on the inner component of the pressure medium guide insert (see annotated Figs. 1 and 4 below). *See* Lehmann, Figs. 1, 4.



Lehmann, Figure 1.



Lehmann, Figure 4.

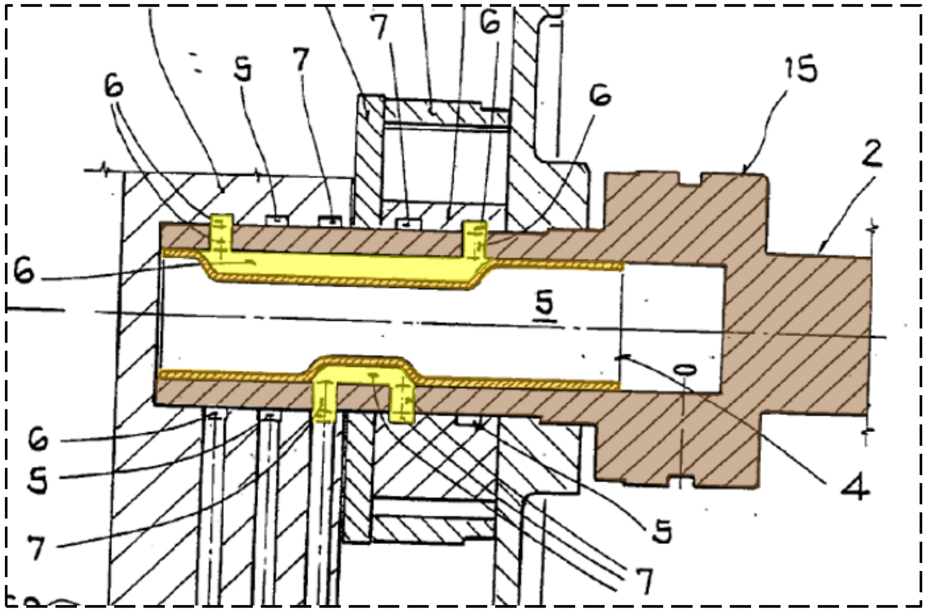
143. To the extent that Patent Owner may argue that Lehmann does not explicitly disclose inner and outer sleeve-shaped components and the pressure medium channel configured as in claim 4, a POSA would have been motivated to modify Lehmann, as taught by Bolz, as discussed in §VIII.A.3 above.

144. Bolz discloses the pressure medium guide insert comprises at least one inner and one outer sleeve-shaped component (*e.g.*, "insert part 4" produced in multiple pieces from pipes), and in that the at least one pressure medium channel is configured as a slot in a wall of the outer sleeve-shaped component of the pressure medium guide insert, an inner circumferential surface of the valve housing delimiting the pressure medium channel radially outward and the inner sleeve-shaped component of the pressure medium guide insert delimiting the pressure

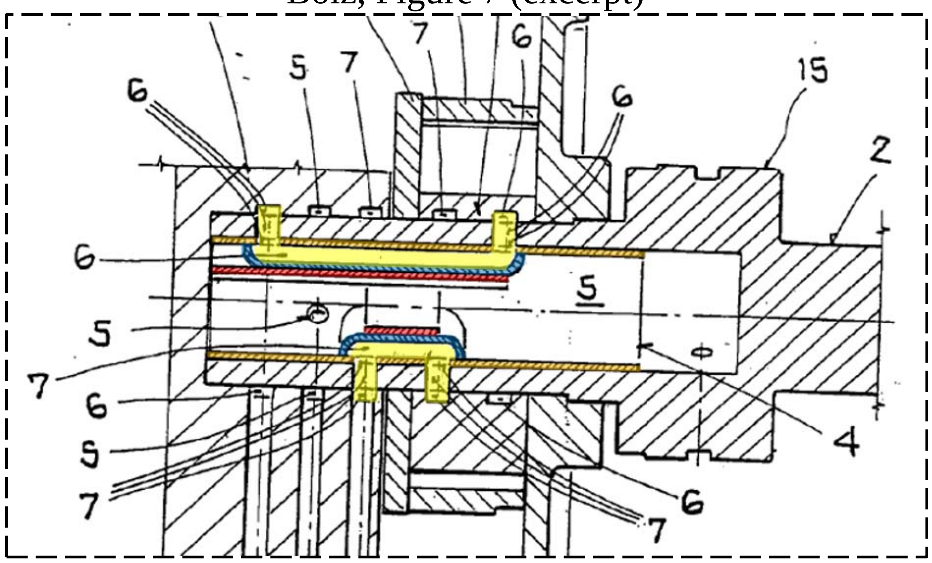
medium channel radially inward, and the pressure medium channel communicating with the interior of the pressure medium guide insert via a radial opening which is formed on the inner sleeve-shaped component. *See* Bolz, [0034], [0052], [0053], Figs. 7, 8.

145. Bolz discloses that a valve insert can be made of multiple pieces that are permanently connected together. For example, Bolz discloses, “Insert part 4 can be structured in one piece or, according to FIG. 8, in multiple pieces. Insert part 4 can be produced from sheet-metal formed parts and/or pipes. With a multi-part embodiment of the insert part 4, made of sheet-metal parts and/or pipes, the parts can be permanently connected with one another by welding, soldering, gluing, crimping, riveting, pressing, shrinking in place, or pass-through joining. Thermal joining, gluing, welding, internal high-pressure forming, etc. can be used as joining methods for the insertion of the insert part 4 into camshaft 2.” Bolz, [0034]. Bolz also discloses, “FIG. 7 shows a seventh embodiment of a camshaft adjuster 1 with a one-piece insert part 4 that has cross-sections that change in the axial longitudinal direction 96, and with the hydraulic medium circuits 5, 6 and 7. Alternatively, it would be possible that insert part 4 has non-coaxial channels, for example according to FIG. 6, and/or contours with uniform and/or variable cross-sections over axial length 96, for example as shown in FIG. 7, or forms them together with camshaft 2.” Bolz, [0052]. Bolz further discloses, “FIG. 8 shows an eighth embodiment of

camshaft adjuster 1 having a multi-part insert part 4 and hydraulic medium circuits 5, 6 and 7." Bolz, [0053].



Bolz, Figure 7 (excerpt)



Bolz, Figure 8 (excerpt)

(b) Claim [7]

146. **Claim [7] recites "The control valve of claim 4, wherein the inner sleeve-shaped component is manufactured separately with respect to the outer**

sleeve-shaped component and is connected to the latter by means of a force-transmitting or form-fitting connection or an adhesive bond." Lehmann, in view of Bolz, discloses the inner sleeve-shaped component is manufactured separately with respect to the outer sleeve-shaped component (*e.g.*, produced from "multiple pieces") and is connected to the latter by means of a force-transmitting or form-fitting connection or an adhesive bond (*e.g.*, connected by "gluing, crimping riveting").

147. Bolz discloses that the multiple parts of a valve insert can be permanently connected by methods such as "gluing, crimping, or riveting" that are form-fitting and force-transmitting (and for gluing, that use an adhesive bond). For example, Bolz discloses, "Insert part 4 can be structured in one piece or, according to FIG. 8, in multiple pieces. Insert part 4 can be produced from sheet-metal formed parts and/or pipes. With a multi-part embodiment of the insert part 4, made of sheet-metal parts and/or pipes, the parts can be permanently connected with one another by welding, soldering, gluing, crimping, riveting, pressing, shrinking in place, or pass-through joining." Bolz, [0034].

E. Ground 4: Lehmann in view of Schafer and Walsh renders obvious claim 5

1. Overview

148. Similar to the '756 patent, Schafer expressly discloses the implementation detail of a one-piece metal cylindrical insert (i.e., a pressure medium

guide insert). Schafer, [0026]-[0028], Fig. 1A. Walsh expressly discloses the implementation detail of manufacturing valve spools and sleeves from stainless steel. Walsh, 4:51-65, 6:29-44. A POSA would have been motivated to apply these teachings in implementing Lehmann as discussed further in Section VIII.A.6 and in the sections below.

2. Invalidity of Claim 5 Over Lehmann in view of Schafer and Walsh (Ground 4)

(a) Claim [5]

149. **Claim [5] recites "The control valve of claim 1, wherein the pressure medium guide insert is configured in one piece and from steel."** Lehmann discloses the pressure medium guide insert is configured in one piece (*e.g.*, in one piece with the same shading pattern, as in annotated Fig. 4). *See* Lehmann, Fig. 4.

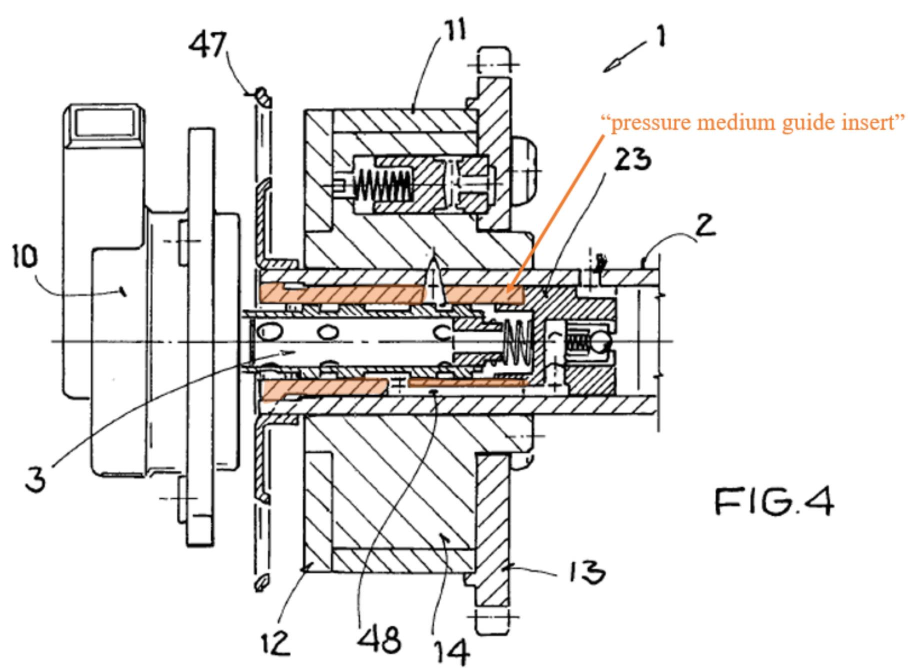


FIG.4

Lehmann, Fig. 4 (annotated)

150. To the extent Patent Owner may argue that Lehmann does not explicitly disclose the material of the pressure medium guide insert, a POSA would have been motivated to configure the pressure medium guide from steel, as taught by Schafer and Walsh. *See* §6 above.

151. Schafer discloses the pressure medium guide insert is configured in one piece and from metal (*e.g.*, "metal bend 51 for forming the insert 5"). *See* Schafer, [0008], [0028], [0033].

152. Schafer discloses a one-piece valve insert made of metal. For example, Schafer discloses, "The insert is preferably provided by forming a flat metal bend with through-openings for a medium and by forming the metal bend according to the outer circumference of a channel in the valve, whereby the inner circumference of the insert forms the actual channel through which the medium to be controlled or regulated flows." Schafer, [0008]. Schafer also discloses, "In the illustrated and particularly preferred embodiment, the outer circumference of the closing element 4 does not lie directly against the inner circumference of the valve housing 1, but against the inner circumference of an insert or insert part 5. ***The insert is made of an arcuate and preferably metallic material, which is suitably shaped according to the outer circumferential shape of the channel 2 or the inner circumferential shape of the valve housing 1.*** The insert 5 has corresponding passage openings 53,

which are arranged adjacent to the supply and/or discharge openings 3 of the valve housing 1. The use of an insert 5 made of a thin- walled metal results in sharp control edges for regulating the flow depending on the closed position of the closing element 4 sliding on the inside of the insert 5." Schafer, [0028]. Schafer further discloses, "Fig. 2 shows a preferred metal bend 51 for forming the insert 5. The metal bend 51 is preferably provided by manufacturing processes known per se and simple, and is provided with openings for forming the through-openings 53. Thereby, processes known per se such as stamping, laser machining, water jet machining and/or mechanical machining can be used. The two opposing edge regions 54, which rest against each other after the metal bend 51 has been shaped into the insert 5, have edge sections 55 which allow interlocking according to the tongue/groove principle. In the region of the edge section 55 of the first edge region 54, corresponding recesses 56 are formed into which, in the formed state, protrusions 57 of the corresponding edge sections 55 of the opposite edge region 54 engage. However, such interlocking is not absolutely necessary, but offers advantages in the subsequent injection molding process due to the meanwhile stable and closed cylindrical shape of the insert 5. A metal bend 51 prepared in this way can be shaped by simple rolling in the case of a cylindrical cross-section of the channel 2." Schafer, [0033].

153. Walsh discloses the pressure medium guide insert is configured in one piece and from steel (*e.g.*, "sleeve 28" made of "hardened stainless steel"). *See* Walsh, 4:59-65, 6:29-44.

154. Walsh discloses a one-piece valve sleeve made of stainless steel. For example, Walsh discloses, "Good results have been obtained however, for spools and sleeves manufactured of a hardened stainless steel and having a ±0.0005 tolerance. This is a larger clearance than is found with typical air valves. It has also been found for this particular combination that it is preferred that the air utilized by the air valve is non-lubricated air." Walsh, 4:59-65. Walsh also discloses, "Due to the presence of the magnetic fields, ***it is preferred that the valve spool 26 and the sleeve 28 of the fluid valve are also manufactured from a non-magnetic material or of a material which is only somewhat magnetic, such as a hardened stainless steel. For example, valve spools and sleeves of stainless steel having a 45-55 Rockwell 'C' rating work well for hot melt applications.*** This prevents the possibility that one or both of these parts could become magnetized, thereby preventing or hindering the sliding movement of the valve spool 26 within the sleeve 28, and thus interfering with the direction of the flow of air to and from the piston chamber 18. In such embodiment, the housing 30 was aluminum and there were a plurality of o-rings 31 to accommodate the expansion and contraction of the two dissimilar metals." Walsh, 6:29-44.

155. As explained in Section §VIII.A.6 above, it would have been obvious to a POSA to manufacture Lehmann's pressure medium guide insert from a sheet of stainless steel, as taught by Schafer and Walsh.

F. Ground 5: Lehmann in view of Bolz and Schafer renders obvious claim 8

1. Overview

156. Similar to the '756 patent, Schafer expressly discloses the implementation detail of an outer cylindrical component manufactured as an injection molded part encapsulating an inner cylindrical component. Schafer, [0031], Fig. 1. A POSA would have been motivated to apply these teachings in implementing Lehmann in view of Bolz as discussed further in Section VIII.A.7 and in the sections below.

2. Invalidity of Claim 8 Over Lehmann in view of Bolz and Schafer (Ground 5)

(a) Claim [8]

157. **Claim [8] recites "The control valve of claim 4, wherein the outer sleeve-shaped component is manufactured as an injection molded part and the inner sleeve-shaped component is configured as an insert component which is encapsulated by the outer sleeve-shaped component during the injection molding process of the latter."** Schafer discloses the outer sleeve-shaped component is manufactured as an injection molded part and the inner sleeve-shaped component is configured as an insert component which is encapsulated by the outer

sleeve-shaped component during the injection molding process of the latter (*e.g.*, "valve housing 1" created using injection molding process that encapsulates "insert 5."). *See* Schafer, [0031].

158. Schafer describes using an injection molding process to make an outer sleeve-shaped component that encapsulates an inner sleeve-shaped component. For example, Schafer discloses, "In this method, in a first step the insert 5 is formed as a flat and thin-walled metal bend 51 with the through-openings 53, in particular stamped, and in a second process step rolled into a cylinder. Subsequently, the insert 5 formed in this way is injection-molded with plastic using a plastic injection molding process, the plastic forming the valve housing 1. During the injection process, corresponding supply and/or discharge openings 3 are formed or subsequently machined out in the plastic corresponding to the positions of the through-openings 53 of the insert 5." Schafer, [0031].

159. As explained in Section §VIII.A.7 above, it would have been obvious to a POSA to manufacture Lehmann and Bolz's outer sleeve-shaped component by injection molding to encapsulate an inner sleeve-shaped component, as taught by Schafer.

G. Ground 6: Lehmann in view of Winkelmann renders obvious claim 19

1. Overview

160. Similar to the ’756 patent, Winkelmann expressly discloses the implementation detail of using tongue-and-groove connections in automotive systems to fix and prevent angular movements between two components (i.e., fixed in the circumferential direction). Winkelmann, 7:47-54, 8:32-39. A POSA would have been motivated to apply these teachings in implementing Lehmann as discussed further in Section VIII.A.9 and in the sections below.

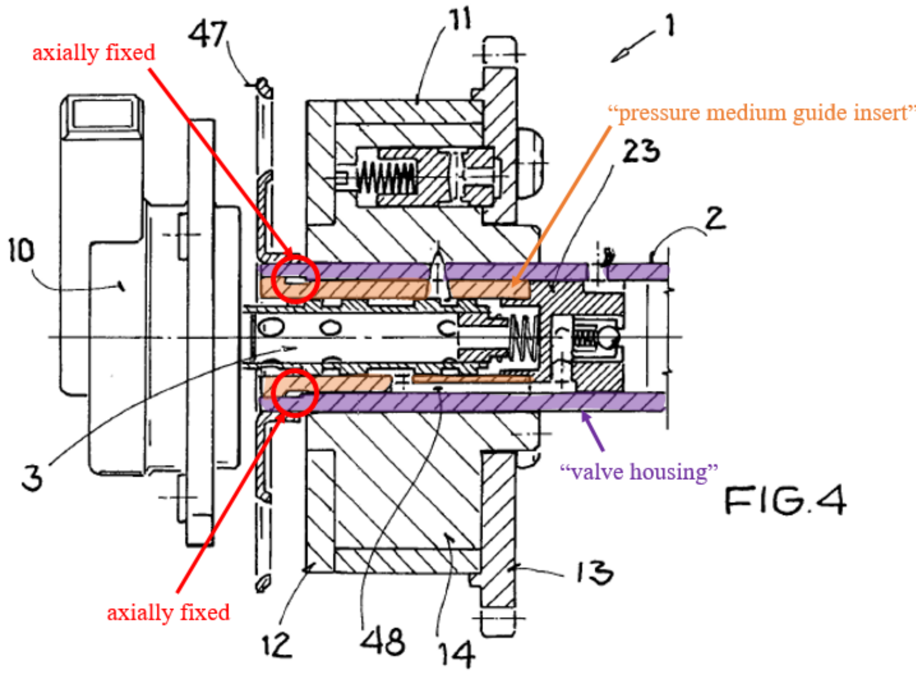
2. Invalidity of Claim 19 Over Lehmann in view of Winkelmann (Ground 6)

(a) Claim [19]

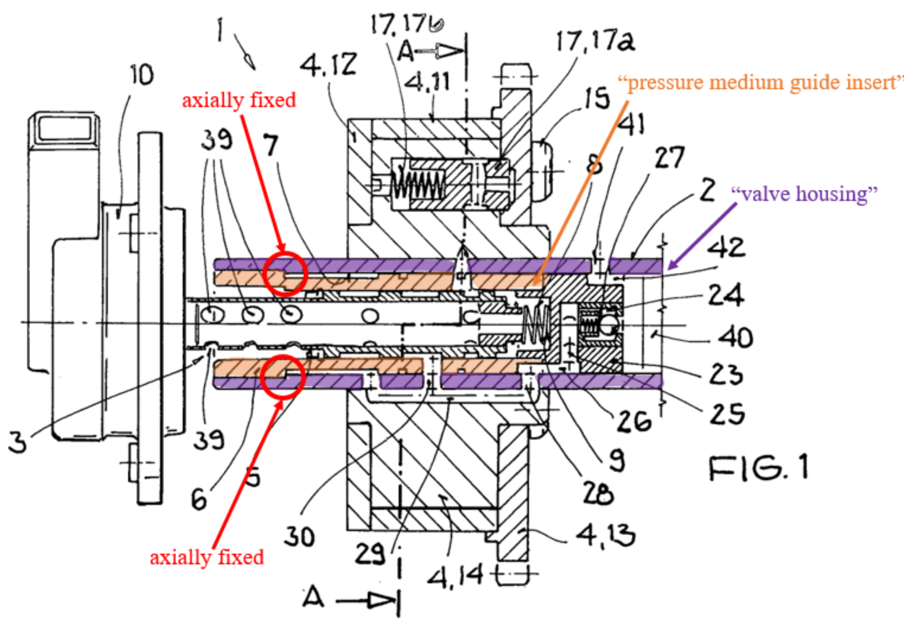
161. **Claim [19] recites “The control valve of claim 18, wherein form-fitting means are provided on the pressure medium guide insert and on the valve housing, which form-fitting means serve to fix the pressure medium guide insert axially with respect to the valve housing and/or to fix it in a stationary manner in the circumferential direction.”** Lehmann discloses form-fitting means are provided on the pressure medium guide insert and on the valve housing (*e.g.*, features annotated in red in Figs. 1 and 4 below), which form-fitting means serve to fix the pressure medium guide insert axially with respect to the valve housing and/or to fix it in a stationary manner in the circumferential direction (*e.g.*, features that are form-fitting means that axially fix “guide sleeve 6” and “camshaft 2”, and guide

sleeve 6 and camshaft 2 are joined thermally, adhesively, mechanically, by welding, or using any other method). *See* Lehmann, [0021], Figs. 1, 4.

162. Lehmann discloses that guide sleeve 6 is inserted in a bore of camshaft 2 (the valve housing) and that their "joining may be performed thermally…. glued, mechanically joined or welded" and that "other joining methods are possible." Lehmann, [0021]. Additionally, Lehmann discloses form-fitting means that axially fix guide sleeve 6 (a pressure medium guide insert) and camshaft 2 (a valve housing). Additionally, guide sleeve 6 and camshaft 2 are joined thermally, adhesively, mechanically, by welding, or using any other method. Lehmann, [0021]. These joining methods serve to fix the two components axially and in a circumferential direction with respect to each other. For example, Lehmann discloses, "The hydraulic control valve 3 has a control piston 5 which is guided in a guide sleeve 6, the guide sleeve 6 being inserted in a concentric bore 7 of the camshaft 2 extending from one end of the camshaft 2 in the axial direction. The joining may be performed thermally. Furthermore, the joint can be glued, mechanically joined or welded. Likewise, other joining methods are possible." Lehmann, [0021]. A POSA would have understood that a tongue-and-groove connection is a type of mechanical joining. Integral Mechanical Attachment (Ex. 1018), at 10, 15, 61 (teaching that "tongue-and-groove joints" are a type of "integral mechanical attachment," which is a "subclassification[] of mechanical joining").



Lehmann, Fig. 4 (annotated)



Lehmann, Fig. 1 (annotated)

163. The features annotated in red in Figures 1 and 4 of Lehmann above are comparable to the "tongue/groove connection 43" depicted in in Figure 3 of the '756 patent (annotated in red below). *See* '756 patent, 12:51-60.

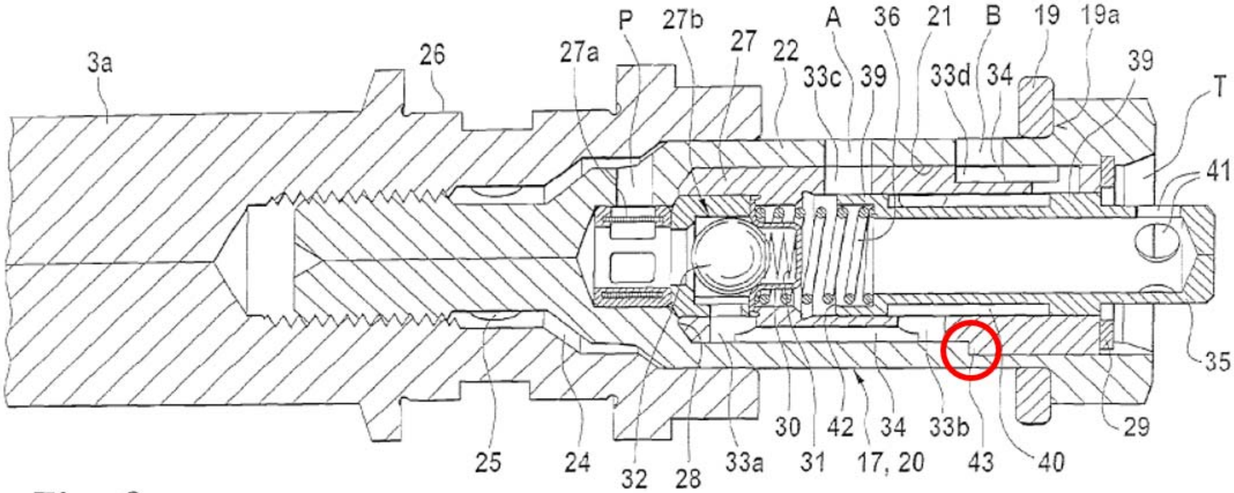


Fig. 3

’756 patent, Figure 3.

164. To the extent Patent Owner may argue that the “form-fitting means” must include a tongue-and-groove connection (*see* §VI above) and that Lehmann does not explicitly describe a tongue-and-groove connection, a POSA would have been motivated to modify Lehmann to use tongue-and-groove connection for mechanically joining the components, as taught by Winkelmann. *See* §VIII.A.9 above.

165. Winkelmann discloses that tongue-and-groove connections were a specific known mechanical joining method in automotive systems that, in one exemplary application, served to fix and prevent angular movements between two components (i.e., fixed in the circumferential direction). Winkelmann, 7:47-54, 8:32-39. For example, Winkelmann discloses, “If the sections 2a, 2b of the housing 2 are two separately produced parts, they are or they can be sealingly secured to each other by resorting to ultrasonic welding, by resorting to a suitable adhesive, by

resorting to a reliable mechanical connection (such as a tongue and groove joint) and/or in any other suitable manner which guarantees the establishment of a long-lasting sealing connection." Winkelmann, 7:47-54. Winkelmann further discloses, "Angular movements of the jacket 7 and the core 3a relative to each other can be prevented by resorting to one or more axially parallel tongue-and-groove connections and/ or by providing the left-hand end face of the core 3a and the adjacent end wall of the jacket 7 with interfitted complementary profiles. The just mentioned profiling or the establishment of one or more tongue-and-groove con[n]ections is optional if the jacket 7 is adequately bonded to the core 3a." Winkelmann, 8:32-39.

H. Ground 7: Lehmann in view of Speier renders obvious claim 20

(a) Overview

166. Similar to the ’756 patent, Speier discloses a cylindrical housing 18 that includes a threaded neck 16 that is screwed into threaded bush 15 of camshaft 1. Speier, 3:14-25. A POSA would have been motivated to apply these teachings in implementing Lehmann as discussed further in Section VIII.A.11 and in the sections below.

2. Invalidity of Claim 20 Over Lehmann in view of Speier (Ground 7)

(a) Element [20pre]

167. **Element [20pre] recites "A control valve for an apparatus for the variable setting of the control times of gas exchange valves of an internal combustion engine."** Lehmann discloses a control valve (*e.g.*, "hydraulic control valve 3" and "oil guide module 23" housed by camshaft 2) for an apparatus (*e.g.*, for "camshaft regulator 1") for the variable setting of the control times of gas exchange valves of an internal combustion engine.

168. My analysis of element [1pre] with respect to similar claim language is equally applicable to element [20pre]. *See* Section VIII.B.2(a).

(b) Element [20a]

169. **Element [20a] recites "a valve housing of hollow configuration, which has at least one inflow connection, at least one outflow connection and at least two working connection."** Lehmann discloses a valve housing of hollow configuration (*e.g.*, section of "camshaft 2") which has at least one inflow connection (*e.g.*, "radial bore 41"), at least one outflow connection (*e.g.*, "bore 39") and at least two working connection (*e.g.*, connections to at least "chambers 21, 22").

170. My analysis of element [1a] with respect to similar claim language is equally applicable to element [20a]. *See* Section VIII.B.2(b).

(c) Element [20b]

171. **Element [20b] recites "wherein the apparatus is fastened to a camshaft by means of a central screw, and the valve housing is configured in one piece with the central screw."** Lehmann discloses the apparatus is fastened to a camshaft (*e.g.*, "inner body 14" of camshaft adjuster is fastened to "camshaft 2" using a "material, force, and/or form fitting" manner). *See* Lehmann, [0024].

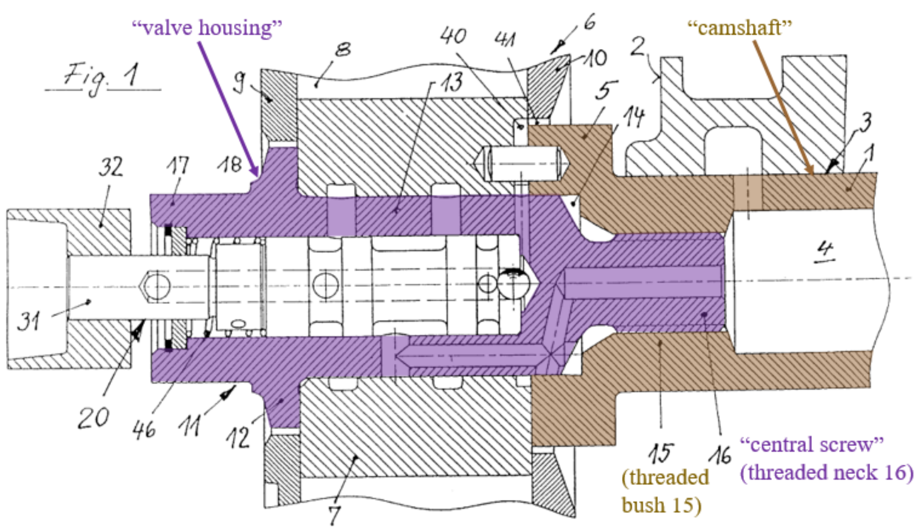
172. Lehmann discloses the camshaft regulator is attached to the camshaft 2 by material, force, and/or form fitting. For example, Lehmann discloses, "The cover 12, the housing 11 and the outer body 13 enclose an annular space in which an inner body 14 in the form of an impeller is arranged. The inner body 14 is rotationally fixed on the camshaft 2. The fixing can be achieved by material, force and/or form-fitting, for example by thermal joining, press-fitting, internal high pressure forming or by means of other joining processes. The cover 12, the housing 11 and the outer body 13 are clamped by axially extending clamping screws 15 and form a unit rotatably mounted on the inner body 14 or the camshaft 2." Lehmann, [0024].

173. To the extent Patent Owner may argue that Lehmann does not explicitly disclose fastening the apparatus to a camshaft with a central screw in one piece with the valve housing, a POSA would have been motivated to do so, as taught by Speier. *See* §VIII.A.11 above.

174. Speier discloses the apparatus (*e.g.*, "camshaft timing device 6) is fastened to a camshaft ("camshaft 1") by means of a central screw (*e.g.*, "threaded neck 16" fastened to "threaded bush 15"), and the valve housing is configured in one piece with the central screw (*e.g.*, "cylindrical housing 18" is configured in one piece with "threaded neck 16"). *See* Speier, 2:35-45, 3:5-31, Fig. 1.

175. Speier discloses the camshaft timing device 6 is fastened to camshaft 1 by threaded neck 16 and threaded bush 15. For example, Speier discloses, "The reference numeral 1 designates the camshaft which is mounted in the housing of an internal combustion engine, or in its cylinder head. In the figure the bearing assigned to one end wall 2 of the housing or of the cylinder head is illustrated partially and is designated by the reference numeral 3. The camshaft 1 is provided with a central oil bore 4. In its end region the camshaft 1 projects beyond the end wall 2. It carries a fastening flange 5, against which the camshaft timing device 6, illustrated here only partially, is braced and centered." Speier, 2:35-45. Speier also discloses, "The inner body 7 is centered and axially braced against the flange 5 of the camshaft via a clamping screw 11. For this purpose, the clamping screw 11 includes a clamping collar 12 which extends over, and engages, the inner body 7 in the radially inner region and which is radially surrounded by the side wall 9. The clamping screw 11 has a shank 12, which extends centrally through the inner body 7, so that the latter is centered via the shank 13. With its end region remote from the clamping collar

12, the shank 13 is fitted into a central opening 14 in the fastening flange 5. The damping screw 11 extends, in the direction of the oil bore 4 of the camshaft 1, into a portion of the camshaft 1, which is configured as a threaded bush 15 and into which the clamping screw 11 is screwed via its threaded neck 16. The neck 16 lies in the extension of the shank 13. Its outside diameter is reduced in relation to that of the shank 13. The threaded neck 16 which is screwed into that end region of the camshaft 1, which is configured as a threaded bush 15, forms an end-face plug of the oil bore 4 of the camshaft 1 and is likewise concentric to the camshaft 1. The clamping screw 11 is hollow over the length of its shank 13 and the head region 17 which extends from the tension collar 12. It forms a cylindrical housing 18 which is closed opposite the head region 17 by a bottom well 19 disposed at the transition from the shank 13 to the threaded neck 16." Speier, 3:5-31.



Speier, Fig. 1 (annotated)

(d) Element [20c]

176. **Element [20c] recites "a control plunger."** Lehmann discloses a control plunger (*e.g.*, "hydraulic control valve 3" including "control piston 5").

177. My analysis of element [1b] with respect to similar claim language is equally applicable to element [20c]. *See* Section VIII.B.2(c).

(e) Element [20d]

178. **Element [20d] recites "a pressure medium guide insert of hollow configuration arranged within the valve housing."** Lehmann discloses a pressure medium guide insert of hollow configuration (*e.g.*, "guide sleeve 6") arranged within the valve housing (*e.g.*, arranged within "camshaft 2," the valve housing).

179. My analysis of element [1c] with respect to similar claim language is equally applicable to element [20d]. *See* Section VIII.B.2(d).

(f) Element [20e]

180. **Element [20e] recites "at least one pressure medium channel which extends substantially in the axial direction; the pressure medium guide insert engaging around the pressure medium channel at least partially."** Lehmann discloses at least one pressure medium channel which extends substantially in the axial direction (*e.g.*, "groove 48" in Fig. 4 annotated below; "groove 26" in Fig. 1 annotated below); the pressure medium guide insert engaging around the pressure medium channel at least partially (*e.g.*, "guide sleeve 6" engages around "groove 48" and "groove 26" at least partially).

181. My analysis of element [1d] and [1e] with respect to similar claim language is equally applicable to element [20e]. *See* Sections VIII.B.2(e)-(f).

(g) Element [20f]

182. **Element [20f] recites "the pressure medium channel communicating with at least one of the connections and, via a radial opening, with the interior of the pressure medium guide insert."** Lehmann discloses the pressure medium channel communicating with at least one of the connections and, via a radial opening, with the interior of the pressure medium guide insert (*e.g.*, pressure medium is guided from the inflow connection, through "groove 48" of Fig. 4 or "groove 26" of Fig. 1, to "control valve 3," which is in the interior of the pressure medium guide insert, through a radial opening; see dashed red flow in Figs. 1 and 4 annotated in Element [1f]).

183. My analysis of element [1f] with respect to similar claim language is equally applicable to element [20f]. *See* Section VIII.2.B.2(g).

(h) Element [20g]

184. **Element [20g] recites "the control plunger being arranged within the pressure medium guide insert."** Lehmann discloses the control plunger (*e.g.*, "hydraulic control valve 3" including "control piston 5") being arranged within (*e.g.*, "guided" within) the pressure medium guide insert (*e.g.*, "guide sleeve 6").

185. My analysis of element [1g] with respect to similar claim language is equally applicable to element [20g]. *See* Section VIII.B.2(h).

IX. Secondary Considerations

186. As discussed above, claims 1, 3, 9-11, 13-15, and 18 are anticipated by Lehmann and secondary considerations do not need to be considered under this analysis. However, to the extent that it is argued that additional disclosure is required, I have addressed above why these claims would have also been obvious in view of Lehmann standing alone. Likewise, I have addressed above why all of the Challenged Claims (claims 1, 3-5, and 7-20) would have been obvious over Lehmann standing alone and/or over Lehmann in view of Bolz, Schafer, Walsh, Winkelmann, or Speier.

187. The Applicant did not present any other evidence of secondary considerations during prosecution and based on my analysis I have not observed and am not aware of any evidence of secondary considerations with a nexus to any of the Challenged Claims. The clear teachings of the prior art demonstrate that the claims are also obvious for the reasons set forth above. As demonstrated by the prior art discussed above, any purported problems, solutions or unexpected results in the ’756 patent were already well known. To the extent it is argued that any of the claims satisfy unmet needs, the prior art already met these alleged needs for the reasons discussed in §VIII. Indeed, as demonstrated by the prior art referenced herein, any

purported problems, solutions or unexpected results in the ’756 patent were already well known. Should Patent Owner or its experts present evidence of secondary considerations as part of this proceeding, I reserve the right to opine on that evidence.

X. Conclusion

188. I have concluded that claims 1, 3, 9-11, 13-15, and 18 are unpatentable as anticipated by Lehmann and, at least, rendered obvious in light of Lehmann and the knowledge of one of ordinary skill in the art, as discussed above.

189. I have also concluded that claims 12, 16, and 17 are rendered obvious in light of Lehmann and the knowledge of one of ordinary skill in the art, as discussed above.

190. I have also concluded that claims 4 and 7 are rendered obvious in light of Lehmann in view of Bolz, as discussed above.

191. I have also concluded that claim 5 is rendered obvious in light of Lehmann in view of Schafer and Walsh, as discussed above.

192. I have also concluded that claim 8 is rendered obvious in light of Lehmann in view of Bolz and Schafer, as discussed above.

193. I have also concluded that claim 19 is rendered obvious in light of Lehmann in view of Winkelmann, as discussed above.

194. I have also concluded that claim 20 is rendered obvious in light of Lehmann in view of Speier, as discussed above.

195. To the extent it is argued that any further disclosure is required for a limitation in claims 1, 3-5, and 7-20 that I have identified as being disclosed by Lehmann, Bolz, Schafer, Walsh, Winkelmann, or Speier, a POSA would certainly have found that limitation obvious to include based on the same explicit disclosure or inherent disclosures and analysis I have identified above.

196. I reserve the right to supplement my opinions in the future to respond to any arguments that Patent Owner or its expert(s) may raise and to take into account new information as it becomes available to me.

197. In signing this declaration, I recognize that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in the case 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.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Executed this 23rd day of December 2021, in Durham, New Hampshire.

Respectfully submitted,

Christopher M. White, Ph.D.

Appendix A – LIST OF MATERIALS CONSIDERED

Exhibit No.	Description
1001	U.S. Patent No. 7,389,756 ("'756")
1002	File History of U.S. Patent No. 7,389,756 ("'756 File History")
1004	German Patent Application Publication No. DE 103 46 448 A1 ("Lehmann")
1005	Certified English Translation of German Patent Application Publication No. DE 103 46 448 A1 ("Lehmann")
1006	U.S. Patent No. 6,871,621 ("Palesch")
1007	U.S. Patent Application Publication No. 2003/0015157 ("Knecht")
1008	German Patent Application Publication No. DE 103 40 932 A1 ("Schafer")
1009	Certified English Translation of German Patent Application Publication No. DE 103 40 932 A1 ("Schafer")
1010	U.S. Patent No. 5,325,762 ("Walsh")
1011	U.S. Patent No. 3,342,205 ("Quinto")
1012	U.S. Patent No. 6,523,513 ("Speier")
1013	U.S. Patent No. 6,526,868 ("Winkelmann")
1014	U.S. Patent Application Publication No. 2005/0109298 ("Bolz")
1015	McGraw-Hill Dictionary of Scientific and Technical Terms, excerpt
1016	International Patent Application Publication No. WO 00/70216 ("Lei")
1017	Todd, et. al, Manufacturing Processes Reference Guide, Chapter 6
1018	Messler, Integral Mechanical Attachment, Chapters 1 and 3

Appendix B – *CURRICULUM VITAE*

CHRISTOPHER M. WHITE

University of New Hampshire, Durham, NH 03824
W101 Kingsbury Hall, Mechanical Engineering Department
E-mail: chris.white@unh.edu, Phone: (603) 862-1495, Fax: (603) 862-1865

Education:

Yale University	Mechanical Engineering	Ph.D.	2001
Yale University	Mechanical Engineering	M.S.	1999
Stony Brook University	Mechanical Engineering	M.S.	1996
Stony Brook University	Mechanical Engineering	B.S.	1994

Area of Specialization:

Fluid dynamics, thermodynamics, automotive engineering, energy conversion technologies, turbulence and unsteady flows, complex fluids, drag reduction.

Employment History:

2019– **Department Chair**
University of New Hampshire, Mechanical Engineering Department

2019– **Professor**
University of New Hampshire, Mechanical Engineering Department

2012–2019 **Associate Professor**
University of New Hampshire, Mechanical Engineering Department

2006–2012 **Assistant Professor**
University of New Hampshire, Mechanical Engineering Department

2003–2006 **Senior Member of the Technical Staff**
Sandia National Laboratories, Combustion Research Facility

2001–2003 **Postdoctoral Research Associate**
Stanford University, Mechanical Engineering Department

Visiting Positions:

2018 **University Visitor**, University of Melbourne
2014 **University Visitor**, University of Melbourne
2007 **University Summer Faculty**, Sandia National Laboratories

Expert Witness:

2021–	**Patent Infringement: Open** Control Valve for Automotive System Work Performed: Expert Opinion on IPR Review
2021–	**Class Action: Open** Automotive Timing Chain System Work Performed: Expert Opinion on Requests for Production of Documents
2019–	**Class Action: Open** Automotive Timing Chain Driven Water Pump Work Performed: Part Dissection, Failure Analysis, Literature Research, Expert Declaration, Expert Affidavit.
2019–	**Class Action: Open** Automotive Timing Chain Driven Water Pump Work Performed: Engine Disassembly, Engine Assembly, Vehicle Inspection, Engine Part Removal, Part Dissection, Failure Analysis, Literature Research, Review Defendant Response, Review Protective Order, Keyword Search, Expert Declaration.
2019–	**Class Action: Open** Automotive Timing Chain Driven Water Pump Work Performed: Vehicle Inspection, Engine Part Removal,Part Dissection, Failure Analysis, Literature Research, Expert Declaration.
2014–2020	**Patent Infringement, 3 separate patents: Settled** (1) Fuel Injector, (2) Air Throttle Controller, (3) Emissions Control Work Performed: Patent Review, Claim Construction, IPR Review, Measurements & Data Analysis, Expert Declaration.

Awards and Honors:

1. NSF Early Career Development (CAREER) award (2009–2013)
2. Invited Plenary Speaker 9^{th} International Conference on Engines and Vehicles (2009)
3. Invited author Annual Review of Fluid Mechanics (2008)
4. Northrop Grumman Fellow (1999–2001)
5. Perkin-Elmer Corporate Fellowship (1998)
6. Peter Gagnebein Endowed Yale University Fellowship (1997)

Primary Courses Taught:

• Fluid Dynamics • Thermodynamics •Experimental Measurements and Data Analysis
• Experimental Fluid Dynamics • Turbulence • Renewable Energy Technologies

Professional Societies:

1. American Physical Society
2. American Society of Mechanical Engineers

Published Scholarly Work (ResearcherID E-1669-2011, Author ID: 7404152922):

ISI Web of Science: Over 1900 citations
Google Scholar: Over 3300 citations; https://scholar.google.com/citations?user=8WaCG5AAAAAJ

Book Chapters:

1. Elsnab J.R., White C.M. & Klewicki J.C. Turbulence Production in the Low Polymer Drag Reduction Regime. In Progress in Turbulence VIII iTi 2018. Springer Proceedings in Physics, vol 226, *ed. rl R., Talamelli A., Peinke J., Oberlack M.*, Springer, Cham. 2007. 105-110. ISBN 978-3-030-22195-9
2. Schefer R.W., White C.M. & Keller J. Lean Hydrogen Combustion. In Lean Combustion Technology and Control, *ed. D.Dunn*, Academic Press. 2007. 822-854. ISBN 012370619X

Archival Journal Publications:

1. Wengrove, M., Ebadi, A., White, C.M., Evaluation of the momentum integral method to determine the wall skin friction in separated flows. *Exp. Fluids.* 61:A250 (2020). DOI: 10.1007/s00348-020-03065-8
2. Montemuro, B., White, C.M., Klewicki, J.C., Chini G., A self-sustaining process theory for uniform momentum zones and internal shear layers in high Reynolds number shear flows. *J. Fluid Mech.* 901:A28 (2020). DOI: 10.1017/jfm.2020.517
3. Ebadi, A., Bautista, J.C.C., White, C.M., Chini, G.P. & Klewicki, J.C., A heat transfer model of fully developed turbulent channel flow. *J. Fluid Mech.* 884:R7 (2020). DOI: 10.1017/jfm.2019.1006
4. Ebadi, A., White, C. M., Pond I. & Dubief, Y. Mean dynamics and transition to turbulence in oscillatory channel flow. *J. Fluid Mech.* 880:864-889 (2020). DOI: 10.1017/jfm.2019.706
5. Biles, D., Ebadi, A., Allard, M. & White, C.M. (2018) The Design and Validation of a Thermal Boundary Layer Wall Plate. *ASME J. Fluids Eng.* 141:121403-1:10 (2019). DOI: 10.1115/1.4043773
6. Elsnab, J.R., Monty, J.P., White, C.M., Koochesfahani, M.M. & Klewicki, J.C. (2019) High-fidelity measurements in channel flow with polymer wall injection. *J. Fluid Mech.* 859:851-886 (2019) DOI:10.1017/jfm.2018.873
7. Bautista, J.C.C., Ebadi, A. White, C.M., Chini, G.P. & Klewicki, J.C., A uniform momentum zone-vortical fissure model of the turbulent boundary layer. *J. Fluid Mech.* 858:609-633 (2019). DOI:10.1017/jfm.2018.769
8. White, C.M., Dubief, Y. & Klewicki, J.C., Properties of the Mean Momentum Balance in Polymer Drag Reduced Channel Flow. *J. Fluid Mech.* 834:409-433 (2018). DOI 10.1007/jfm.2017.721
9. Elsnab, J.R., Monty, J.P., White, C.M., Koochesfahani, M.M. & Klewicki, J.C., Efficacy of single-component MTV to measure turbulent wall-flow velocity derivative profiles at high resolution. *Exp. Fluids* 58:128 (2017). DOI: 10.1007/s00348-017-2410-2

10. I. Pond, A. Ebadi, Y. Dubief & White C. M. An integral validation technique of RANS turbulence models. *Comp. & Fluids* 149:150-159 (2017). DOI: 0.1016/j.compfluid.2017.02.016

11. G. P. Chini, B. Montemuro, C.M. White & J. Klewicki A self-sustaining process model of inertial layer dynamics in high Reynolds number turbulent wall flows. *Phil. Trans. A.* 375:20160090 (2017). DOI: 10.1098/rsta.2016.0090

12. A. Ebadi, F. Mehdi & White C. M. On determination of wall heat flux in wall-bounded turbulent flows. *Int. J. Heat and Mass Flow* 84:856-861 (2015). DOI 10.1016/j.ijheatmasstransfer.2014.12.068

13. Mehdi, F., Johansson, T.G., White, C.M. & Naughton, J.W On determining wall shear stress in spatially developing two-dimensional wall bounded flows. *Exp. Fluids* 55:1656 (2014). DOI 10.1007/s00348-013-1656-6

14. P. Vincenti, J. Klewicki, C. Morrill-Winter, C.M. White & M. Wosnik Streamwise velocity statistics in turbulent boundary layers that spatially develop to high Reynolds Number. *Exp. Fluids* 54:1629 (2013). DOI 10.1007/s00348-013-1629-9

15. F. Mehdi, J.C. Klewicki & C.M. White Mean force structure and its scaling in rough-wall turbulent boundary layers. *J. Fluid Mech.* 731:682-712 (2013). DOI: 10.1017/jfm2013.385.

16. DeMarchi N. & White C.M. Echo Particle Image Velocimetry. *J. Vis. Exp.* 70:e4265 (2012). DOI:10.3791/4265.

17. White C.M., Dubief Y. & Klewicki J.C. Re-examing the logarithmic dependence of the mean velocity distribution in polymer drag reduced wall-bounded flow. *Phys. Fluids.* 24:021701 (2012). DOI: 10.1063/1.3681862.

18. Mehdi F. & White C.M. Integral form of the skin friction coefficient suitable for experimental data *Exp. Fluids.* 50:43-51 (2011). DOI: 10.1007/s00348-010-0893-1

19. Mehdi F., Klewicki J.C. & White C.M. Mean momentum balance analysis of rough-wall turbulent boundary layers. *Physica D.* 239:1329-1337 (2010). DOI: 10.1016 /j.physd.2009.06.008

20. Kaiser S. & White C.M. PIV and PLIF to Evaluate Mixture Formation in a Direct-Injection Hydrogen-Fuelled Engine. *SAE Int. J. Engines* 1:657-668 (2009). DOI: 10.4271/2008-01-1034

21. † White C.M. & Mungal M.G. Mechanics and prediction of turbulent drag reduction with polymer additives. *Ann. Rev. Fluid Mech.* 40:235-256 (2008). DOI: 10.1146/annurev.fluid.40.111406.102156

22. White C.M. OH chemiluminescence measurements in a direct-injection hydrogen-fuelled internal combustion engine. *Int. J. Engine Research.* 8:185-204 (2007). DOI: 10.1243/14680874JER02206

23. †White C.M., Steeper R.R. & Lutz A. E. The hydrogen-fueled internal combustion engine: a technical review. *Int. J. Hydrogen Energy.* 31:1292-1305 (2006). DOI: 10.1016/j.ijhydene.2005.12.001

---

†Officially designated by the Thompson Reuters Essential Science Indicators as a Highly Cited Paper (2017-2019) in Physics. Highly Cited Papers are those that rank among the top 1% most cited in their subject field.

†Officially designated by the Thompson Reuters Essential Science Indicators as a Highly Cited Paper (2011-2017) in Engineering. Highly Cited Papers are those that rank among the top 1% most cited in their subject field.

24. Dubief Y, Terrapon V.E., White C.M., Shaqfeh E.S.G., Moin P. & Lele S. K. New answers on the interaction between polymers and vortices in turbulent flows. *Flow Turbulence and Combustion.* 74:311-329 (2005). DOI: 10.1007/s10494-005-9002-6
25. Dubief Y, White C.M., Terrapon V.E., Shaqfeh E.S.G., Moin P. & Lele S.K. On the coherent drag-reducing and turbulence-enhancing behaviour of polymers in wall flows. *J. Fluid Mech.* 514:271-280 (2004). DOI: 10.1017/S0022112004000291
26. White C.M., Somandepalli V.S.R. & Mungal M.G. The turbulence structure of drag reduced boundary layer flow. *Exp. Fluids.* 36:62-69 (2004). DOI: 10.1007/s00348-003-0630-0
27. White C.M., Karpetis A.N. & Sreenivasan K.R. High Reynolds numbers in small apparatus: grid turbulence in cryogenic liquids. *J. Fluid Mech.* 452:189-197 (2002). DOI: 10.1017/S0022112001007194
28. Donnelly R.J., Karpetis A.N., Niemela, J.J., Sreenivasan K.R., Vinen W.F. & White C. M. The use of particle image velocimetry in the study of turbulence in liquid helium. *J. Low Temp. Phys.* 126:327-3302 (2002). DOI: 10.1023/A:1013745118386
29. Lyder C. H., Shannon R., Empleo-Frazier, O., McGeHee D. & White C.M. A comprehensive program to prevent pressure uclers in long-term care: exploring costs and outcomes. *Ostomy/Wound Management.* 48:52-62 (2002). PMID:11993061
30. Karpetis A.N., White C.M. & Sreenivasan K.R. Laser wipers. *Phys. Rev. E.* 62:4421-4423 (2000). DOI: 10.1103/PhysRevE.62.4421
31. Sreenivasan K.R. & White C.M. The onset of drag reduction and the maximum drag reduction asymptote. *J. Fluid Mech.* 409:149-164 (2000). DOI: 10.1017/S0022112099007818
32. Van Doorn E., White C.M. & Sreenivasan K.R. The decay of grid turbulence in polymer and surfactant solutions. *Phys. Fluids.* 11:2387-2393 (1999). DOI: 10.1063/1.870100
33. White C.M. & Sreenivasan K.R. Does molecular rotation affect the transitional Reynolds number? *Phys. Let. A.* 238:323-327 (1998). DOI: 10.1016/S0375-9601(97)00765-2

Conference Proceedings, Reports, Research Briefs:

1. C.M. White, M. Jansons & Y. Dubief A Comprehensive Investigation of Unsteady Reciprocating Effects on Near-Wall Heat Transfer in Engines, *U.S. DOE, EERE, Vehicle Technologies Office, Advanced Combustion Engines, Annual Report. 2016.*
2. D. Sahagian, A. A. Proussevitch, C.M. White & J. Klewicki Hazards posed by distal ash transport and sedimentation from extreme volcanic eruptions *American Geophysical Union, Fall Meeting, 2016.* NH44A-04
3. C.M. White, M. Jansons & Y. Dubief A Comprehensive Investigation of Unsteady Reciprocating Effects on Near-Wall Heat Transfer in Engines, *U.S. DOE, EERE, Vehicle Technologies Office, Advanced Combustion Engines, Annual Report. 2015.*
4. C.M. White, M. Jansons & Y. Dubief A Comprehensive Investigation of Unsteady Reciprocating Effects on Near-Wall Heat Transfer in Engines, *U.S. DOE, EERE, Vehicle Technologies Office, Advanced Combustion Engines, Annual Report. 2014.*
5. White C. M., Kaiser S. & Roux M. Fuel-Air Mixing in a Direct-Injection Hydrogen-Fueled Internal Combustion Engine. *14th Intl. Symp. Appl. Laser Tech. Fluid Mech.,* 2008.

6. Kaiser S. & White C. M. PIV and PLIF to Evaluate Mixture Formation in a Direct-Injection Hydrogen-Fueled Engine. Paper No. 2008-01-1034. *Society of Automotive Engineers, World Congress,* 2008.
7. White C. M. A qualitative evaluation of mixture formation in a direct-injection hydrogen-fuelled engine. Paper No. 2007-01-1467. *Society of Automotive Engineers, World Congress,* 2007.
8. White C. M. Final results of mixture formation and combustion in an optical engine. Project No. 506604 HYICE, Deliverable D4.3.F. 2007. *Optimization of a Hydrogen Powered Internal Combustion Engine, European Commission Research,* 2007.
9. White C. M. Evaluation of Mixture Formation and Combustion in an Optical Engine using OH* Chemiluminescence. Project No. 506604 HYICE, Deliverable D4.3.B. 2006. *Optimization of a Hydrogen Powered Internal Combustion Engine, European Commission Research,* 2006.
10. Somandepalli V. S. R., White C. M. & Mungal M. G. Boundary layer studies on polymer drag reduction using PIV and PLIF. Paper No. FEDSM2003-45659 pp. 763-771 doi:10.1115/FEDSM2003-45659. *Proc. 4th ASME/JSME Joint Fluids Eng. Conf.,* 2003.
11. Dubief Y, White C. M., Terrapon V. E., Shaqfeh E. S. G., Moin P. & Lele S. K. Numerical Simulation of High Drag Reduction Regime in Polymer Solutions. Keynote. Paper no. FEDSM2003-45652 pp. 713-720 doi:10.1115/FEDSM2003-45652. *Proc. 4th ASME/JSME Joint Fluids Eng. Conf.,* 2003.
12. White C. M., Somandepalli V. S. R. & Mungal M. G. PIV measurements of drag reducing boundary layer flows. *11^{th} Intl. Symp. Appl. Laser Tech. Fluid Mech.,* 2002.
13. White C. M., Raghu, S., Giannotti G. & Giannotti H. Power boost of gas turbines by inlet air cooling. Paper 2:725-729. DOI: 10.1109/IECEC.1996.553787 *Proc. 31st Energy Conversion Engineering Conf.,* 1996.

Invited Lectures:

1. White C.M. "Properties of the Mean Momentum Balance in Polymer Drag-Reduced Channel Flow", Fluid Mechanics Research Group Seminar Series, University of Melbourne (2019).
2. White C.M. "Properties of the Mean Momentum Balance in Polymer Drag-Reduced Channel Flow", Fluid Dynamics Seminar Series, Johns Hopkins University (2018).
3. White C.M. "Properties of the Mean Momentum Balance in Polymer Drag-Reduced Channel Flow", Frontiers in Turbulence–KRS70 at Denver (2017).
4. White C.M. "Transport of Heat and Momentum in Non-Equilibrium Wall-Bounded Flows", Mechanical Engineering Department Seminar Series, U. Connecticut (2016).
5. White C.M., Jansons M. and Dubief Y "Heat Transfer in Non-Equilibrium Boundary Layers and Piston Engines", Ford Research and Innovations, Dearborn, Michigan (2014).
6. White C.M. "Turbulent Ablation", 4^{th} AFOSR/NASA/SNL Ablation Modeling Workshop, New Mexico (2011).

7. WHITE C.M. "Hydrogen in Piston Engines: Potential and Challenges" **Invited Plenary Speaker**, 9^{th} International Conference on Engines and Vehicles, Capri, Italy (2009)
8. WHITE C.M. "Hydrogen in Piston Engines" Engineering Professional Development, University of Wisconsin Madison (2009)
9. WHITE C.M. "Hydrogen in Piston Engines" Engineering Professional Development, University of Wisconsin Madison (2008)
10. WHITE C.M. "Advanced Hydrogen-Fueled Engines: Potential and Challenges" Future Fuels for Internal Combustion Engines, University of Wisconsin Madison, (2007)
11. WHITE C.M. "H2ICE Emissions and Near-ZEV Performance" Hydrogen Internal Combustion Engines Symposium, WestStart-FTA (2007)
12. WHITE C.M. "Evaluation of Mixture Formation and Combustion in a Hydrogen Fuelled Engine using OH chemiluminescence" Mechanical Engineering Department, University of New Hampshire (2006)
13. WHITE C.M. "Sandia Hydrogen-Fueled Internal Combustion Engine Program" Workshop on Research Frontiers for Combustion in the Hydrogen Economy, National Science Foundation (2006),
14. WHITE C.M. "Technical Review of Hydrogen-fueled Internal Combustion Engines" ZEV Technology Symposium, California Air Resources Board (2006)
15. WHITE C.M. "Structure of Drag Reduced Turbulence", Combustion Research Facility, Sandia National Laboratories (2003)
16. WHITE C.M. "PIV Measurements of the Structure of Drag-Reduced Turbulence and the Mechanisms of Polymer Drag Reduction" Fluid Mechanics Seminar, California Institute of Technology (2002)
17. WHITE C.M. "Turbulence in Liquid Helium", Department of Mechanical Engineering Seminar, Columbia University (2001)
18. WHITE C.M. "High Reynolds Number Flows in Small Apparatus Using Liquid Helium", Combustion Research Facility, Sandia National Laboratories (1999)

Proposal Activity:

Funded Proposals (Total $5,559,875 CMW Total $2,077,299):

1. **Current**
   Dispersion of Methane Gas
   Source of Support: Schlumberger Technology Corporation
   Total Award Amount: $203,633
   Total Award Period: 9/01/2021 to 8/31/2021
   Location of Project: University of New Hampshire
   Person Months Per Year: 1
   Investigators: PI: C.M. White

2. **Current**
   Predicting Non-Equilibrium Wall-Flow Phenomena at High Reynolds Numbers
   Source of Support: Office of Naval Research

Total Award Amount: $1,200,000
Total Award Period: 12/01/2016 to 11/30/2021
Location of Project: University of New Hampshire
Person Months Per Year: 0.6
Investigators: PI: J. Klewicki, co-PIs: G.P. Chini, C.M. White

3. **Current**
   Innovative Packaging to Achieve Extremely Light Weight Sensor Pod Systems
   Source of Support: Naval Air Systems Command (NAVAIR)– Navy STTR PHASE 2
   Total Award Amount: $1,000,000 (UNH share $247,018)
   Total Award Period: 8/1/2018 to 1/21/2021
   Location of Project: Spectra Sciences Inc. & University of New Hampshire
   Person Months Per Year: 1
   Investigators: UNH PI: C.M. White

4. **Closed**
   Volumetric Atmospheric Modeling from Point Measurements or a Single Profile
   Source of Support: Naval Underwater Warfare Center (NUWC) – Navy STTR PHASE 2 Total Award Amount: $1,000,000 (UNH share $205,761)
   Total Award Period: 8/21/2018 to 8/20/2021
   Location of Project: Mentis Sciences Inc. & University of New Hampshire
   Person Months Per Year: 1
   Investigators: UNH PI: C.M. White

5. **Closed**
   Enhanced Aerodynamics Using Novel Surface Coatings
   Source of Support: NHRIC / US Nanosolutions
   Total Award Amount: $35,000
   Total Award Period: 01/01/2020 to 09/30/2020
   Location of Project: University of New Hampshire
   Person Months Per Year: 0.2
   Investigators: C.M. White

6. **Closed**
   Development of an Asymptotically-Reduced, Multiscale Model of Turbulent Boundary Layer Dynamics at Extreme Reynolds Numbers
   Source of Support: National Science Foundation
   Total Award Amount: $410,00 (original) + $65000 (supplement) = $475,000
   Total Award Period: 7/01/2015 to 6/30/2018
   Location of Project: University of New Hampshire
   Person Months Per Year: 0.6
   Investigators: PI: G. Chini, co-PIs: J. Klewicki, C.M. White

   (a) Supplemental Support: Development of an Asymptotically-Reduced, Multiscale Model of Turbulent Boundary Layer Dynamics at Extreme Reynolds Numbers
   Source of Support: National Science Foundation

Total Award Amount: \$60,000
Total Award Period: 7/01/2018 to 6/30/2019

(b) REU Supplement: Development of an Asymptotically-Reduced, Multiscale Model of Turbulent Boundary Layer Dynamics at Extreme Reynolds Numbers
Source of Support: National Science Foundation
Total Award Amount: \$5,000
Total Award Period: 6/01/2015 to 6/30/2017
Location of Project: University of New Hampshire
Investigators: PI: G. Chini, co-PIs: J. Klewicki, C.M. White

7. **Closed**
Cooling System for Laser Enclosure
Source of Support: Naval Air Systems Command (NAVAIR)–STTR PHASE 1
Total Award Amount:\$125,00 (UNH share \$35,000)
Total Award Period: 6/01/2017 to 12/08/2018
Location of Project: Mentis Sciences Inc. & University of New Hampshire
Person Months Per Year: 0.6
Investigators: UNH PI: C.M. White, co-PI G. Chini

8. **Closed**
Innovative Packaging to Achieve Extremely Light Weight Sensor Pod Systems
Source of Support: Naval Air Systems Command (NAVAIR)–STTR PHASE 1
Total Award Amount:\$250,00 (UNH share \$70,000)
Total Award Period: 8/01/2017 to 9/30/2018
Location of Project: Mentis Sciences Inc. & University of New Hampshire
Person Months Per Year: 1
Investigators: UNH PI: C.M. White

9. **Closed**
NSF/DOE Advanced Combustion Engines: Collaborative Research: A Comprehensive Investigation of Unsteady Reciprocating Effects on Near-Wall Heat Transfer in Engines
Source of Support: National Science Foundation
Total Award Amount: \$207,818 (original) + \$35,739 (supplement) = \$243,557
Total Award Period: 9/15/2013 to 8/31/2017
Investigators: PI: C.M. White

(a) Supplemental Support: NSF/DOE Advanced Combustion Engines: Collaborative Research: A Comprehensive Investigation of Unsteady Reciprocating Effects on Near-Wall Heat Transfer in Engines
Source of Support: National Science Foundation
Total Award Amount: \$30,739
Total Award Period: 8/31/2016 to 8/31/2017
Investigators: PI: C.M. White

(b) REU Supplement: NSF/DOE Advanced Combustion Engines: Collaborative Research: A Comprehensive Investigation of Unsteady Reciprocating Effects on Near-

Wall Heat Transfer in Engines
Source of Support: National Science Foundation
Total Award Amount: $5,000
Total Award Period: 6/01/2015 to 8/31/2016
Investigators: PI: C.M. White

10. **Closed**
Project Title: CAREER: Experimental studies of the rheology and flow properties of liquefied biomass in wall-bounded turbulent flows
Source of Support: National Science Foundation
Grant No. #0846359
Total Award Amount: $400,000
Total Award Period: 4/15/2009 to 3/31/2014
Location of Project: University of New Hampshire
Investigators: PI: C.M. White

11. **Closed**
Project Title: Collaborative research: Collaborative Research: Fundamental Investigation of Turbulent Ablation
Source of Support: National Science Foundation
Total Award Amount: UNH Effort $195,054;(Total Funding $400,000)
Total Award Period: 5/5/2010 to 4/30/2013
Location of Project: University of New Hampshire
Investigators: PI: C.M. White (UNH effort)

12. **Closed**
EAGER: Collaborative Research: Towards Elucidating the Transport Mechanisms of Fine Volcanic Ash
Source of Support: National Science Foundation
Total Award Amount: $66,289
Award No. 1160355
Total Award Period: 7/14/2012 to 7/13/2013
Investigators: PI: A. Proussevitch, co-PIs: J. Klewicki, G. Mulukutla, C.M. White, D.L. Sahagian, K. Genareau

13. **Closed**
Project Title: MRI: Acquisition of an Integrated High Frame-Rate Particle Image Velocimetry (HFR-PIV) System
Source of Support: National Science Foundation
Grant No. #0812608
Total Award Amount: $234,126
Total Award Period: 8/1/2008 to 7/31/2011
Location of Project: University of New Hampshire
Investigators: PI: M. Wosnik, co-PIs: J. Klewicki, C.M. White, K.Baldwin

14. **Closed**
Project Title: Compliant Surface Testing

Source of Support: National Science Foundation EPSCoR RII
Grant No. sub-awardee from #0701730
Total Award Amount: $24,996
Total Award Period: 3/1/2011 to 7/31/2011
Location of Project: University of New Hampshire
Investigators: PI: C.M. White, co-PI: J. Klewicki

15. **Closed**
Project Title: Foam Control
Source of Support: Chem Free DeFoam (subcontract from United States Department of Agriculture)
Total Award Amount: $10,198
Total Award Period: 6/1/2010 to 1/1/2011
Location of Project: University of New Hampshire
Investigators: PI: C.M. White (UNH effort)

Funded International Proposals (Total $380,000, CMW Total $15,000):

1. **Closed**
Project Title: Advancing a First-Principles Basis for the Prediction and Manipulation of Turbulent Wall-Flow Transport
Source of Support: Australian Research Council
Project ID: #DP120101467
Total Award Amount: $380,000
Total Award Period: 1/1/2012 to 12/31/2014
Location of Project: University of Melbourne
Investigators: PI: J. Klewicki, K. Chauhan, co-PI(s): K. Manoochehr, C.M. White

Service Activities:

Department Service:

1. Curriculum Committee, Department of Mechanical Engineering (2007–present)
2. Equipment Committee, Department of Mechanical Engineering (2010–present)
3. Advisory Committee, Department of Mechanical Engineering (2018–present)
4. Admitted Student Day, Yearly Participant
5. Industrial Advisory Board Meeting, Yearly Participant
6. Faculty Search Committee, Department of Mechanical Engineering (2017)
7. P & T Committee, Department of Mechanical Engineering(2016)
8. Lecturer Search Committee, Department of Mechanical Engineering (2015)
9. P & T Committee, Department of Mechanical Engineering (2014)
10. P & T Committee, Department of Mechanical Engineering (2013)
11. Faculty Search Committee, Department of Mechanical Engineering (2007)

University/College Service:

1. Radiation Safety Committee (2018–present)
2. CEPS Award Committee (2017)
3. CEPS Award Committee (2016)
4. Faculty Fellow, UNH CAREER Proposal Program (2015-2016)
5. Faculty Facilitator, Graduate Workshop on Responsible Conduct of Research and Scholarly Activity (2015)
6. Disclosure Review Committee (2012-2015)
7. Faculty Senate Representative (2013-2015)
8. CEPS Graduate Fellowship Committee (2015)
9. Kingsbury Hall Emergency Operations Committee (2014)
10. Academic Advisor, Research Experience and Apprenticeship Program (2014)
11. Search Committee, Associate Dean for Academic Affairs, College of Engineering and Applied Sciences (2013)
12. CEPS Curriculum and Academic Advising Committee (2011-2013)
13. Participant North East Alliance (NEA) Science Day (2013)
14. Academic Advisor, McNair Scholars Program (2013)
15. CEPS Industrial Scholarship, Panelist (2010)
16. University Strategic Planning Roundtables (2008)

Professional Service Since UNH Appointment:

1. Session Chair, American Physical Society, Division of Fluid Dynamics Meeting (2018)
2. Proposal Review External Panelist–National Science Foundation (2017)
3. Fellowship Review Panelist, National Science Foundation Graduate Research Fellowship (2016)
4. Proposal Review Panelist–National Science Foundation (2015)
5. Session Chair, American Physical Society, Division of Fluid Dynamics Meeting (2014)
6. Proposal Review Panelist–National Science Foundation (2014)
7. Co-Organizer of UNH High Reynolds Number Turbulence Workshop (2013)
8. Fellowship Review Panelist, National Science Foundation Graduate Research Fellowship (2013)
9. Proposal Review Panelist–National Science Foundation (2013)
10. Proposal Review Panelist–National Science Foundation (2012)
11. Scholarship Review Panelist, NASA Aeronautics Scholarship Program (2012)
12. Judge, Davidson Institute Fellowship (2011)
13. Review Panelist, U.S. Department of Energy Annual Merit Review & Peer Evaluation (2011)
14. Chair, Fellowship Review Panel, National Defense Science & Engineering Graduate (NDSEG) Fellowship (2011)

15. Scholarship Review Panelist, NASA Aeronautics Scholarship Program (2011)
16. Proposal Review Panelist–National Science Foundation (2011)
17. Proposal Reviewer–National Science Foundation (2011)
18. Fellowship Review Panelist, National Defense Science & Engineering Graduate (NDSEG) Fellowship (2010)
19. Scholarship Review Panelist, The Science, Mathematics And Research for Transformation (SMART) Scholarship (2010)
20. Proposal Review Panelist–National Science Foundation (2009)
21. Proposal Review External Panelist–Austria Science Fund (2009)
22. Journal Referee – Journal of Fluid Mechanics, Physical Review Fluids, Physics of Fluids, Experiments in Fluids, Journal of Turbulence, Journal of Rheology, Physics Review Letters, Physical Review E, Physica D, International Journal of Hydrogen Energy, Society of Automotive Engineering, International Journal of Engine Research, Combustion Institute, Chemical Engineering Science, International Journal of Heat and Fluid Flow, Experimental Thermal and Fluid Science, International Journal of Heat and Mass Transfer, Journal of Rheology, Flow Turbulence and Combustion, Rheology ACTA, Journal of Non-Newtonian Fluid Mechanics, Journal of Manufacturing Science and Engineering, Proceedings of the National Academy of Sciences.