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- (54) **Title:** METHODS OF FRICTION TESTING LUBRICANTS

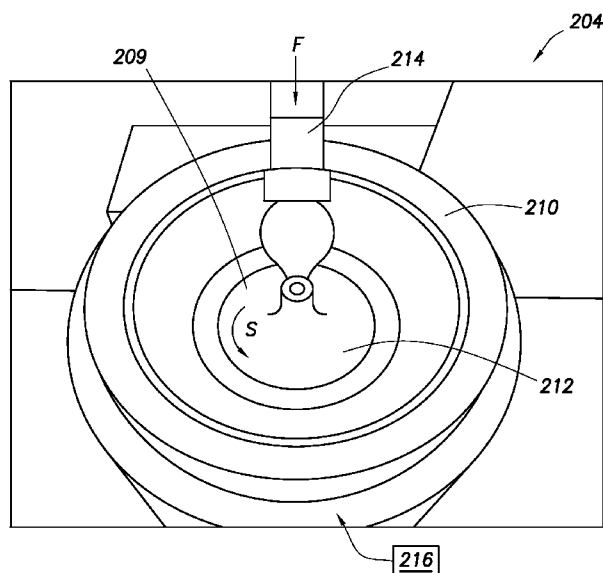


FIG.2

(57) **Abstract:** Methods of friction testing a lubricant in a test assembly are provided. The test assembly comprises a lubricant bath with a lubricant therein, a friction plate and a friction arm. The method involves applying a load to the friction plate with the friction arm, selectively moving the friction plate according to a test operation, and measuring at least one test parameter, such as coefficient of friction, during the test operation. The test operation includes at least one dynamic friction test having a dynamic speed and at least one static friction test having a static speed. The dynamic speed includes increasing from the static speed to a maximum speed and then decreasing from the maximum speed to the static speed. The method may also involve determining a static and a dynamic friction index from the measured test parameter, and identifying the lubricant from the static dynamic friction indices.



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METHODS OF FRICTION TESTING LUBRICANTS

Cross-Reference to Related Applications

[0001] This application claims the benefit of U.S. Provisional Application No. 61/819,186, filed on 3 May 2013, which is incorporated herein by reference.

5 Field of the Invention

[0002] The present disclosure relates generally to methods of determining performance properties of a lubricant. More specifically, the present disclosure relates to methods of determining performance properties of a lubricant used in vehicles (e.g., motorcycles).

Background of the Invention

10 [0003] Lubricants may be used in machinery, for example, to provide satisfied friction between moving parts, such as in wet clutches of motorcycles. In some cases, slippage may occur in wet clutches that may hinder the movement of the parts and, therefore, impact the performance of the wet clutches. Lubricants may be configured to prevent the likelihood of slippage and/or affect the performance of wet clutches.

15 [0004] Lubricants may include a mix of oils and other additives. The composition of the lubricant may be selected to define properties which can be used to enhance performance of the machinery. For example, various wet clutches may specify the use of a certain viscosity of lubricant under certain conditions, such as outdoor temperature. In another example, the composition of the lubricant (and/or its additives) may be selected to control
20 friction of the wet clutch.

[0005] Designed experiments may be performed to compare lubricants having various compositions. The experiments may involve performing tests of various lubricants to determine how each lubricant will perform in operation. In some cases, experiments may be conducted to determine properties of different lubricants that may affect the
25 performance of the machinery. For example, tests may be performed to determine the effect of lubricants on friction and wear of wet clutches. The experiments may be performed using apparatuses that simulate the wet clutch and provide controlled conditions for testing. For example, wet friction clutch testing of a lubricant may be performed using

a SAE No. 2 clutch friction test machine. Other examples of friction or wet clutch tests are provided in M. Ingram et al., *Frictional Properties of Automatic Transmission Fluids: Part I-Measurement of Friction-Sliding Behavior*, Tribology Transactions, vol. 54, pp. 145-153 (2011) and M. Ingram et al., *Frictional Properties of Automatic Transmission Fluids: Part II-Origins of Friction-Sliding Speed Behavior*, Tribology Transactions, vol. 54, pp. 154-167 (2011).

[0006] Testing of lubricants is often performed to determine if the lubricant satisfies certain performance and/or quality requirements set forth by a standard setting organization. For example, the Japanese Automotive Standards Organization (JASO) has created a set of performance and quality standards relating to motorcycle engine oils. Specifically, the JASO T903:2011 Standard sets forth a friction test designed to determine the suitability of lubricants for wet clutch usage.

[0007] Currently, the most common method used to determine whether a lubricant satisfies the requirements of the JASO T903:2011 Standard is to perform a friction test using a SAE No. 2 clutch friction test machine. However, this method suffers from certain disadvantages, including a lack of repeatability, the requirement for a large sample of the lubricant to be tested (40L per test), and the relatively high expense of performing the test. Accordingly, any method providing for an improvement in lubricant testing, and in particular the testing of frictional and/or wear properties of a lubricant, would be desirable.

Summary

[0008] In at least one aspect, the disclosure relates to a method of friction testing a lubricant in a test assembly comprising a lubricant bath with a lubricant therein, a friction plate and a friction arm. The method comprises applying a load to the friction plate with the friction arm, selectively moving the friction plate according to a test operation, and measuring at least one test parameter (e.g., coefficient of friction) during the test operation. The test operation comprises at least one dynamic friction test having a dynamic speed and at least one static friction test having a static speed. The dynamic speed includes increasing from the static speed to a maximum speed and then decreasing from the maximum speed to the static speed.

[0009] In another aspect, the disclosure relates to a method of friction testing a lubricant.

The method involves providing a test assembly comprising a lubricant bath with a lubricant therein, a friction plate and a friction arm. The method also involves applying a load to the friction plate with the friction arm, selectively moving the friction plate according to a test operation, and measuring at least one test parameter (e.g., coefficient of friction) during the
5 test operation. The test operation includes at least one dynamic friction test having a dynamic speed and at least one static friction test having a static speed. The dynamic speed includes increasing from the static speed to a maximum speed and then decreasing from the maximum speed to the static speed.

[0010] Finally, in another aspect, the disclosure relates to a method of friction testing a
10 lubricant. The method involves providing a test assembly including a lubricant bath with a lubricant therein, a friction plate and a friction arm. The method also involves applying a load to the friction plate with the friction arm, selectively moving the friction plate according to a test operation, and measuring at least one test parameter (e.g., coefficient of friction) during the test operation. The test operation includes at least one dynamic friction
15 test having a dynamic speed and at least one static friction test having a static speed. The dynamic speed includes increasing from the static speed to a maximum speed and then decreasing from the maximum speed to the static speed. The method also involves determining a static friction index and a dynamic friction index from the measured test parameter(s), and identifying the lubricant from the static friction index and the dynamic
20 friction index.

Brief Description of the Drawings

[0011] So that the above recited features and advantages of the disclosure may be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to the embodiments thereof that are illustrated in the
25 appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this disclosure and are, therefore, not to be considered limiting of its scope. The figures are not necessarily to scale, and certain features and certain views of the figures may be shown exaggerated in scale or in schematic in the interest of clarity and conciseness.

30 [0012] Figure 1 is a schematic diagram depicting a test assembly for friction testing lubricants in accordance with the present disclosure;

[0013] Figure 2 is a detailed view of a friction assembly comprising a lubricant bath, a friction plate, and a friction arm for friction testing lubricants in accordance with the present disclosure;

[0014] Figure 3 is a schematic diagram depicting a friction plate with a test pad for friction testing lubricants in accordance with the present disclosure;

[0015] Figures 4A-4B are schematic diagrams depicting a test pad before and after friction testing lubricants, respectively, in accordance with the present disclosure;

[0016] Figure 5A-5E are graphs depicting various friction tests in accordance with the present disclosure;

[0017] Figure 6 is a graph depicting an example test cycle of a friction test in accordance with the present disclosure;

[0018] Figure 7 is a graph depicting a friction coefficient for various lubricants in accordance with the present disclosure;

[0019] Figure 8 is a graph depicting fluid mapping in accordance with the present disclosure; and

[0020] Figure 9 is a flow chart depicting a method of friction testing lubricants in accordance with the present disclosure.

Detailed Description

[0021] The description that follows includes exemplary apparatuses, methods, techniques, and instruction sequences that embody techniques of the inventive subject matter. However, it is understood that the described embodiments may be practiced without these specific details.

[0022] The disclosure relates to methods for determining a property of a lubricant, such as a frictional property of a lubricant. These methods may involve the use of a test assembly to friction test lubricants. The test assembly may apply friction and heat to the test lubricant in one or more test cycles of a friction test, such as a wet clutch friction test. Each test cycle may involve one or more test parameters, such as constant or variable

speed, lubricant temperature, lubricant viscosity, lubricant composition, load, and the like. Each test cycle may also involve a static friction test and a dynamic friction test. The static friction test may be performed by moving the friction plate at a constant static speed. The dynamic friction test may be performed by increasing the speed and then decreasing the speed of the friction plate. Additives may optionally be added during one or more test cycles of the friction test. The test cycles may be analyzed and test strips examined to evaluate the lubricant. The analysis may be used, for example, to identify the lubricant, evaluate lubricant properties (e.g., viscosity, composition, friction coefficient, etc.), determine other test parameters and/or fluid properties, and determine if a lubricant satisfies certain performance and quality standards set forth by a standard setting organization, such as JASO.

[0023] Further, the methods of the present disclosure may involve the use of a test assembly as described herein to perform a friction test, such as a dynamic friction test or static friction test, on a lubricant in accordance with the testing procedures set forth in an applicable JASO standard, such as JASO T903:2011.

[0024] Figure 1 illustrates a test assembly 100 usable for simulating a clutch and evaluating a lubricant in accordance with the methods disclosed herein. The test assembly 100 comprises a base 102, a friction assembly 104 and a processing unit 106. The friction assembly 104 is supported on the base 102. The base 102 has mechanisms, such as gears or motors, to selectively operate the friction assembly 104 for friction testing the lubricant in a desired test operation. For example, the base 102 may have mechanisms for applying force (or load), torque (e.g., rotation), power, heat and/or other means to operate the friction assembly 104.

[0025] The processing unit 106 is operatively coupled to the friction assembly 104 to receive data therefrom, and to generate outputs as desired. An example output 108 generated by the processing unit 106 is depicted as a friction graph. An average friction may be measured at various static and/or dynamic test conditions under various forces, speeds, lubricant temperatures, lubricant compositions and other test parameters. The friction graph may be generated by performing one or more cycles in a desired configuration of a test operation and analyzed in accordance with embodiments of the disclosure as will be described more fully herein.

[0026] The test assembly 100 is an example configuration intended to provide a simulated environment similar to that of a clutch in which the lubricant may be used. An example of a suitable test assembly capable of performing the methods disclosed herein is a mini-traction machine (MTM) with a low-load beam attachment, which is commercially
5 available from PCS INSTRUMENTS™ (see: www.pcs-instruments.com).

[0027] Figure 2 shows a detailed view of an example configuration of a friction assembly 204 which may be the same as the friction assembly 104 of Figure 1. The friction assembly 204 comprises a lubricant bath 210, a friction plate 212, and a friction arm 214. The lubricant bath 210 is configured to receive a lubricant 209 for testing. The lubricant
10 bath 210 may receive a desired amount of lubricant 209. For example, 30 mL of lubricant 209 may be tested in a given test operation. Lubricant 209 may be any suitable lubricant, including a lubricant intended for use in a four-stroke cycle motorcycle gasoline engine.

[0028] The friction plate 212 is positionable in the lubricant bath 210. Figure 3 shows the friction plate 212 in greater detail. As shown in this view, the friction plate 212 is an
15 elliptical plate having a flat testing surface 311 with a test strip 315 along a periphery thereof. Friction plates suitable for use in the test assembly include any friction plate capable of performing a friction test, such as a dynamic friction test or static friction test, on a lubricant in accordance with the desired testing operation. For example, a suitable friction plate may include any friction plate satisfying the specifications set forth in the
20 applicable JASO standard, such as a friction plate having part number 141-D1G26-00, which is commercially available from Chuoseiko Co., Ltd. (in accordance with JASO T903:2011). The test strip 315 may be, for example, any paper or carbon fiber-based friction material that may absorb a portion of the lubricant 209 and may receive a load. The paper may be, for example, a friction material commercially available from FCC™
25 (see: <http://www.fcc-net.co.jp/en/technical/friction.html>)

[0029] Figures 4A and 4B depict an example test strip 315 before and after testing, respectively. As shown in Figure 4B, the test strip 315 has a detectable change thereto as a result of testing. Microscopic techniques may be used to examine visual changes in the test strip. A visual examination using, for example, a surface profilometer may be
30 performed on the test plate, the test arm, and/or the test strip to detect, for example, wear, surface roughness, tribofilm formation, etc.

[0030] Referring to Figures 2-4, a friction arm 214 is disposable into the lubricant bath 210. A force F may be applied to the friction arm 214 to press the friction arm 214 against the friction plate 212 and test strip 315. The force may be, for example, about 0.5-8 MPa (7N) contact pressure. The friction plate 212 may be rotated at a speed S as the force is applied to the friction arm 214. The speed may be varied, for example, from about 0.0010 m/s to about 3.6 m/s, and/or from about 3.6 m/s to about 0.0010 m/s. The friction assembly 204 may also be provided with a heat source 216 to apply heat to the lubricant during testing.

[0031] While Figures 2 and 3 depict the friction assembly 204 as including a circular lubricant bath 210 with a friction arm 214 applying a force to a circular test strip 315 positioned on the friction plate 212, the friction assembly 204 may be any device capable of applying heat at a given temperature, movement of the friction plate 212 at a given speed S , and a force F at a given load on friction arm 214. The friction arm 214 is depicted as having a ball (e.g., a steel ball) at an end thereof positionable in frictional engagement with the friction plate 212 and test strip 315, but any shaped friction arm may be provided to establish the desired frictional contact. The friction plate 212 may be rotated as shown, or moved in a desired path (e.g., back and forth) to achieve the desired speed.

[0032] Figures 5A-5E show various graphs 500A-E depicting test operations that may be performed using the test assembly 100 and/or friction assembly 104, 204. As shown by the graphs 500A-E, one or more test cycles may be performed during a test operation. The graphs 500A-E depict co-efficient of friction (y-axis) versus time (x-axis) for C1-CN number of test cycles performed on a lubricant in a test operation. The test operation may be performed, for example, by measuring a coefficient of friction (COF) generated as an output 108 using the test assembly 100 and friction assembly 104, 204 of Figures 1 and 2. One or more variables, such as speed, duration, load, lubricant composition, lubricant viscosity, lubricant temperature and/or other test parameters of the test operation, may be selectively varied as desired.

[0033] As shown in Figure 5A, a series of test cycles C1-CN are performed at times t_1 - t_N . Each test cycle C1-CN for a lubricant includes a dynamic friction test D1-N and a static friction test St_1 -N performed at the same dynamic and static speeds S , force F , and lubricant temperature T . A dynamic friction curve 520 and a static friction curve 522 are

generated at each cycle.

[0034] As shown in Figure 5B, a series of test cycles C1-CN are performed at times t1-tN. Each test cycle C1-CN for a lubricant includes a dynamic friction test D1-DN and a static friction test St1-StN performed at the same dynamic and static speeds S and force F, but at
5 a varied lubricant temperature ΔT .

[0035] As shown in Figure 5C, a series of test cycles C1-CN are performed at times t1-tN. Each test cycle C1-CN for a lubricant includes a dynamic friction test D1-DN and a static friction test St1-StN performed at the same dynamic and static speeds S and lubricant temperature T, but at a varied force ΔF .

10 [0036] As shown in Figure 5D, a series of test cycles C1-CN are performed at times t1-tN. Each test cycle C1-CN for a lubricant includes a dynamic friction test D1-DN and a static friction test St1-StN performed at the same dynamic and static speeds S, force F, and lubricant temperature T, but with an additive A added during the test operation. In some cases, the lubricant can be varied by providing a lubricant with different additives.

15 [0037] As shown in Figure 5E, a series of test cycles C1-CN are performed at times t1-tN. Each test cycle C1-CN for a lubricant includes a dynamic friction test D1-DN and a static friction test St1-StN performed at varied dynamic and static speeds ΔS , varied lubricant temperature ΔT , and varied force ΔF , and with an additive A added during the test operation. In some cases, the lubricant can be varied by providing a lubricant with
20 different additives.

[0038] As demonstrated by Figures 5A-5E, various operating parameters, such as lubricant temperature, viscosity, speed, composition of the lubricant, and/or force, may be kept constant or varied as desired. Variations may be used to alter the curves generated during the test cycle. Desired combinations of curves may be used to simulate various conditions
25 and/or to evaluate the lubricant. The speed may be selectively varied in one or more cycles by selectively stepping up and down the speed. In another example, a series of about 300 repeat cycles may be performed in 30 steps at a first speed and 30 steps at a second speed.

[0039] The test operation may be performed, for example, at a lubricant temperature T of about 100° C with an applied pressure (or force F) of about 0.785 MPa on a friction plate

with a radius of about 57.4 mm at a max speed (S) of about 1800 rpms for a duration of 1000 cycles. Furthermore, the test operation may be performed, for example, to satisfy the applicable friction testing procedures set forth by JASO with respect to motorcycle engine oils. Specifically, the test operation may be performed to satisfy the friction testing
 5 procedures set forth in the JASO T903:2011 Standard.

[0040] Figure 6 is a graph 600 depicting cycle C1 of Figures 5A-5E in greater detail. Cycle C1 has the dynamic friction test D1 starting at time t1 and static friction test St1 starting at time tSt. The dynamic friction curve 520 is generated by moving the friction plate 212 (Figure 2) at a dynamic speed as indicated by speed curve 624. The dynamic
 10 speed of rotation increases from about zero (or the static speed) at a time t1 to a maximum speed Smax at time tmax, and then decreases back to about zero at a time tSt. As shown, the dynamic speed increases and decreases at a constant rate. The dynamic speed may be, for example, increasing to a maximum speed Smax of about 4 m/s. As shown by the static friction curve 522, the static friction test St1 starts at time tSt and is performed at a static
 15 speed near zero (e.g., at about 0.004 m/s) until time tf.

[0041] Figure 7 is graph 700 depicting static friction curves 726A-E for identifying various lubricants, namely Oil A-E. The graph 700 plots coefficient of friction (COF) (y-axis) versus cycle (C1-CN) (x-axis) for each static friction test performed during a test operation. As shown by this graph, various lubricants have various static friction curves 726A-E.
 20 This graph demonstrates that lubricants may be identifiable by their static friction curves. This graph also demonstrates that about 300 test cycles may be performed using the test operation.

[0042] Figure 8 is a graph 800 depicting a friction map for identifying various lubricants according to JASO T903:2011 specifications. The friction map 828A, B plots a known
 25 static friction index SI (y-axis) versus a known dynamic friction index DI (x-axis) for given lubricants. Lubricants can be plotted by their static and dynamic indices for identification. Lubricants that fall within friction map 828A may be identified as a given lubricant X; lubricants that fall within friction map 828B may be identified as a given lubricant Y.

[0043] Static friction index (SFI) may be calculated according to the JASO industry specification (JASO T903:2011) as follows:

$$SFI = 1 + \frac{\mu_s(S) - \mu_s(B)}{\mu_s(A) - \mu_s(B)} \quad \text{Eq. (1)}$$

where, $\mu_s(S)$ is the average static friction coefficient of test oil, $\mu_s(A)$ is the average static friction coefficient of high friction reference oil (JAFRE-A11), $\mu_s(B)$ is the average static friction coefficient of low friction reference oil (JAFRE-B11).

[0044] The dynamic friction index (DFI) may be calculated according to the JASO industry specification (JASO T903:2011) as follows:

$$DFI = 1 + \frac{\mu_d(S) - \mu_d(B)}{\mu_d(A) - \mu_d(B)} \quad \text{Eq. (2)}$$

where, $\mu_d(S)$ is the average dynamic friction coefficient of test oil, $\mu_d(A)$ is the average dynamic friction coefficient of high friction reference oil (JAFRE-A11), $\mu_d(B)$ is the average dynamic friction coefficient of low friction reference oil (JAFRE-B11).

[0045] Figure 9 depicts a method 900 of testing a lubricant. The method involves providing a test assembly comprising a lubricant bath with a lubricant therein, a friction plate and a friction arm, and applying a load to the friction plate with the friction arm and selectively moving the friction plate according to a test operation. The test operation includes at least one dynamic friction test having a dynamic speed and at least one static friction test having a static speed. The dynamic speed includes increasing from the static speed to a maximum speed and then decreasing from the maximum speed to the static speed. The method also involves measuring at least one test parameter during the test operation. The test parameter comprises a coefficient of friction.

[0046] The method may also involve determining a static friction index and a dynamic friction index from the measured at least one test parameter, identifying the lubricant from the static friction index and the dynamic friction index, and/or examining a test strip positioned on the friction plate during the test operation. An additive may optionally be provided either by adding an additive, or providing a lubricant with a different additive. The method may be performed in any order, and repeated as desired.

[0047] While the embodiments are described with reference to various implementations and exploitations, it will be understood that these embodiments are illustrative and that the scope of the inventive subject matter is not limited to them. Many variations, modifications, additions and improvements are possible. For example, one or more test
5 cycles with various combinations of constant and/or variable test parameters (e.g., temperature, load, speed, composition, etc.) may be provided.

[0048] Plural instances may be provided for components, operations or structures described herein as a single instance. In general, structures and functionality presented as separate components in the exemplary configurations may be implemented as a combined
10 structure or component. Similarly, structures and functionality presented as a single component may be implemented as separate components. These and other variations, modifications, additions, and improvements may fall within the scope of the inventive subject matter.

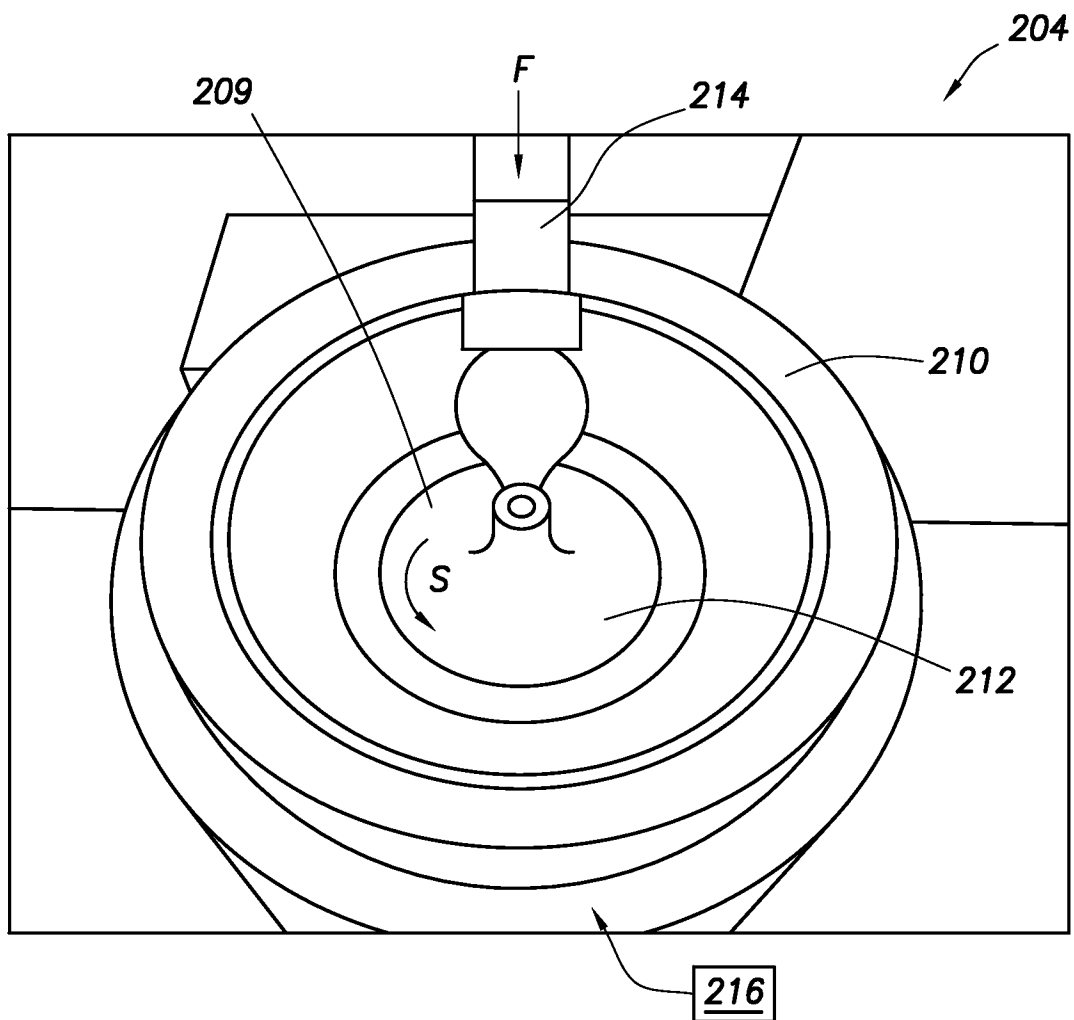
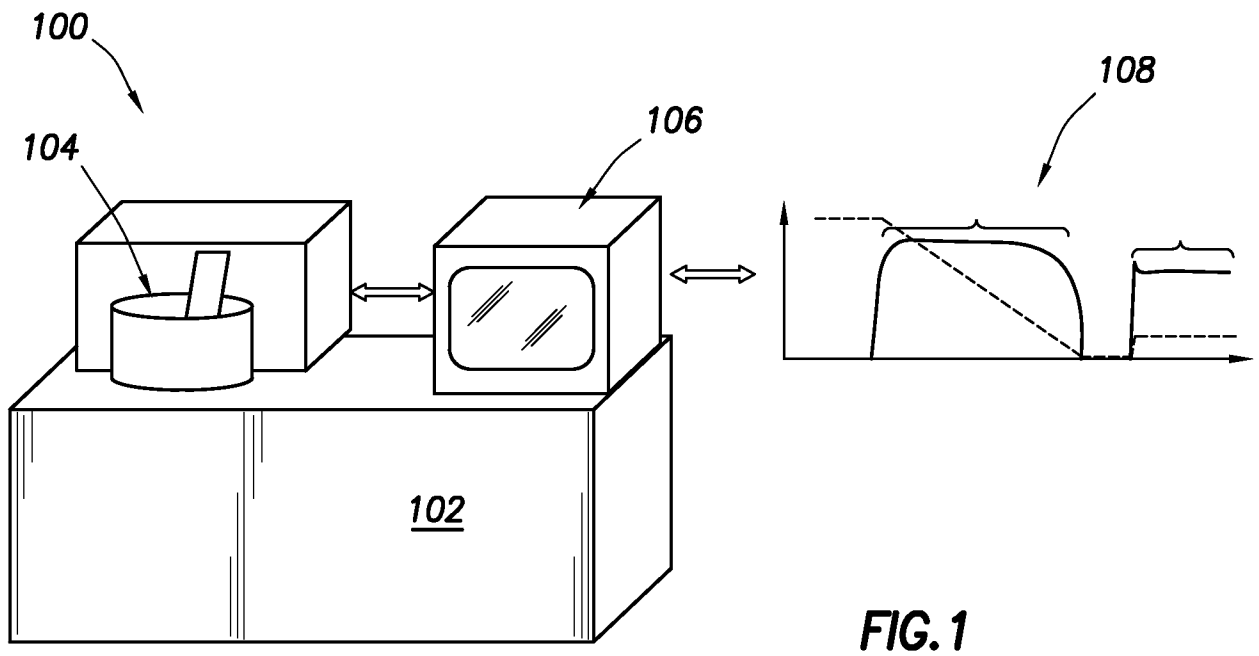
WHAT IS CLAIMED IS:

1. A method of friction testing a lubricant in a test assembly comprising a lubricant bath with a lubricant therein, a friction plate and a friction arm, the method comprising:
applying a load to the friction plate with the friction arm and selectively moving the
5 friction plate according to a test operation, the test operation comprising at least one dynamic friction test having a dynamic speed and at least one static friction test having a static speed, the dynamic speed comprising increasing from the static speed to a maximum speed and then decreasing from the maximum speed to the static speed; and
10 measuring at least one test parameter during the test operation, the at least one test parameter comprising a coefficient of friction.
2. The method of Claim 1, further comprising examining a test strip positioned on the friction plate during the test operation.
3. The method according to any one of Claims 1-2, wherein the applying further
15 comprises adding an additive to the lubricant.
4. The method according to any one of Claims 1-3, wherein the applying further comprises applying heat to the lubricant.
5. The method according to any one of Claims 1-4, wherein applying further comprises varying the load during the test operation.
- 20 6. The method according to any one of Claims 1-5, wherein the dynamic friction test comprises increasing and decreasing at a constant rate.
7. The method according to any one of Claims 1-6, further comprising analyzing the measured test parameters.
8. The method of Claim 7, further comprising plotting the coefficient of friction
25 measured during the at least one static friction test.
9. The method of Claim 7, wherein the analyzing comprises calculating one of static friction index, dynamic friction index, and combinations thereof.
10. The method of Claim 8, further comprising identifying the lubricant by mapping the static friction index and the dynamic friction index.
- 30 11. The method according to any one of Claims 1-10, wherein the at least one test cycle comprises a plurality of test cycles, the plurality of test cycles being one of identical or different.

12. The method according to any one of Claims 1-11, wherein the at least one test parameter further comprises at least one of temperature, viscosity, speed, composition of the lubricant, and force.

13. The method of Claim 12, further comprising varying the at least one test parameter
5 during the test operation.

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2/11

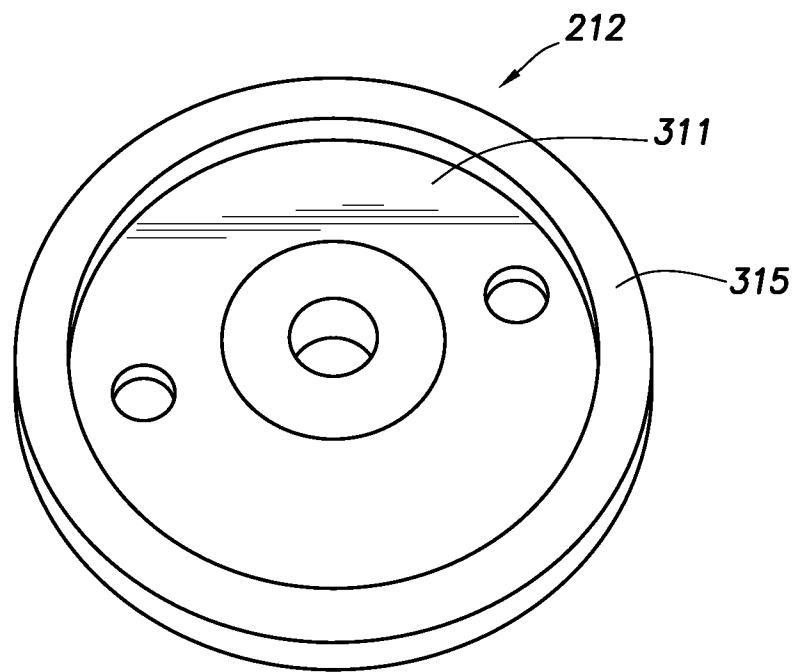


FIG. 3

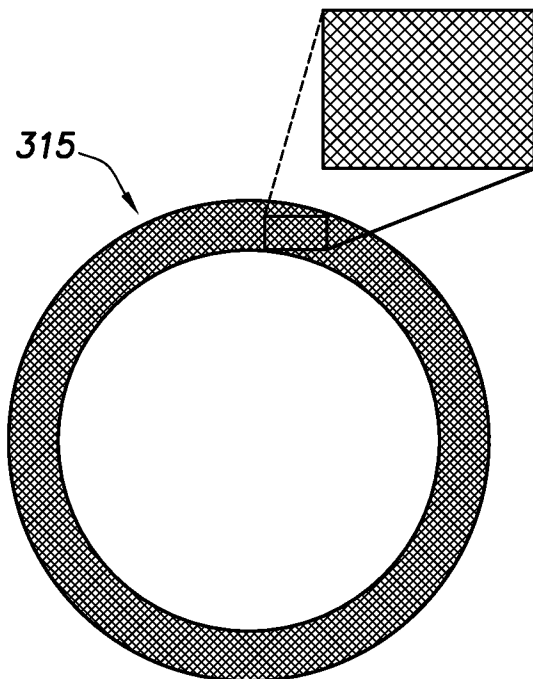


FIG. 4A

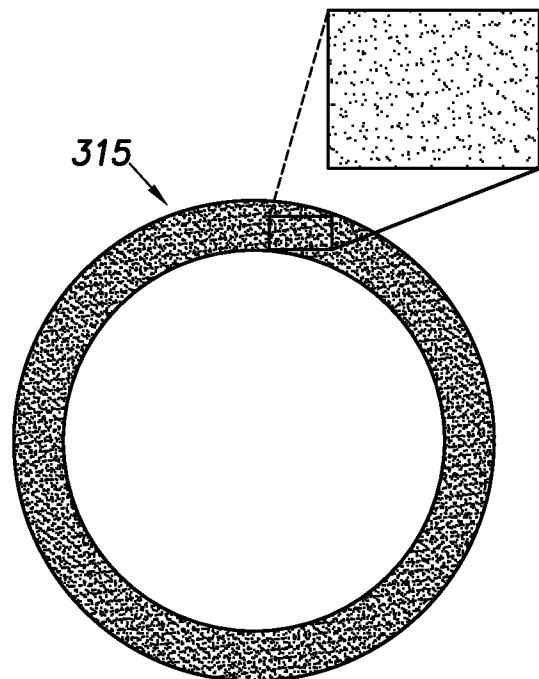


FIG. 4B

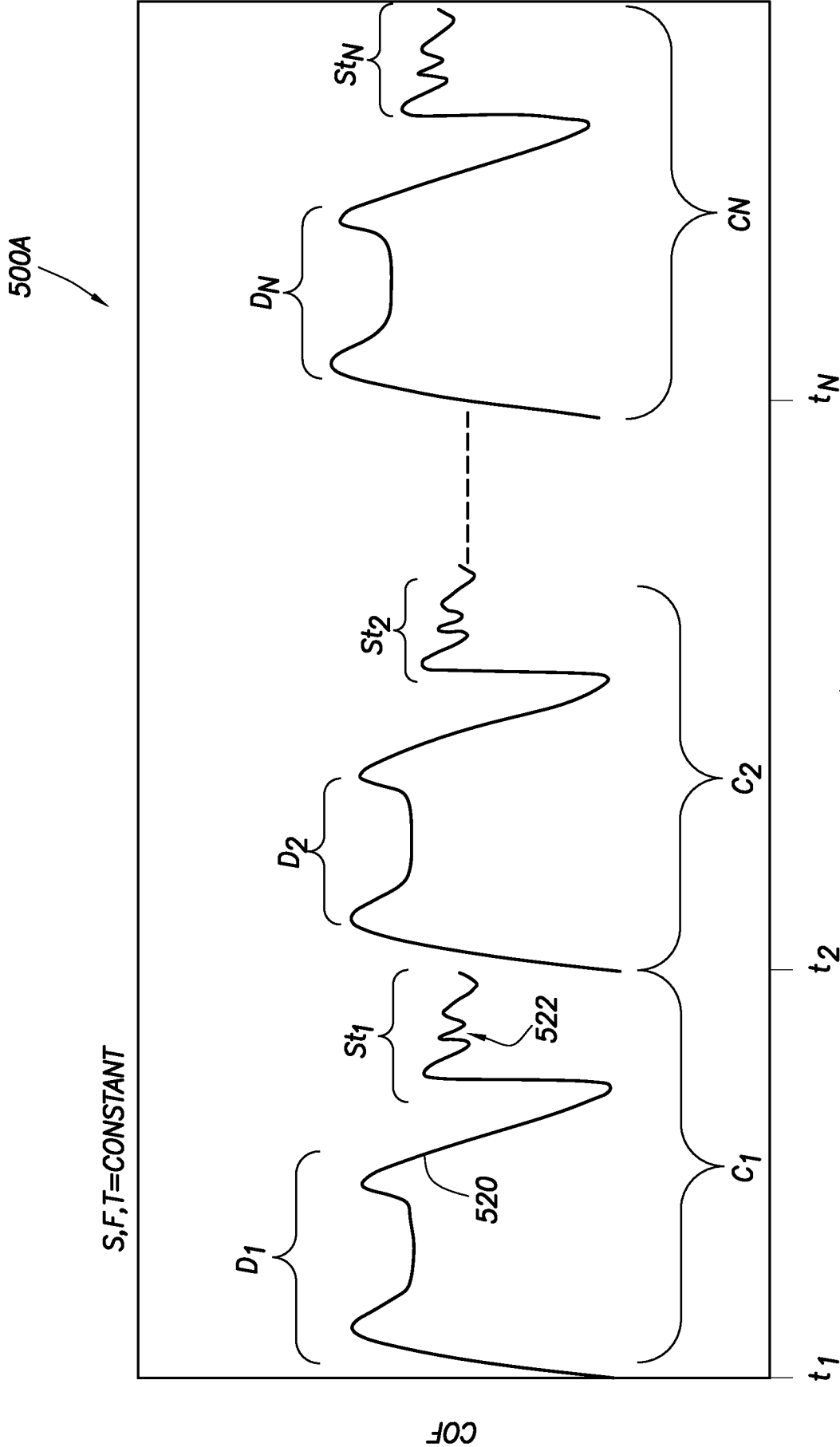


FIG.5A

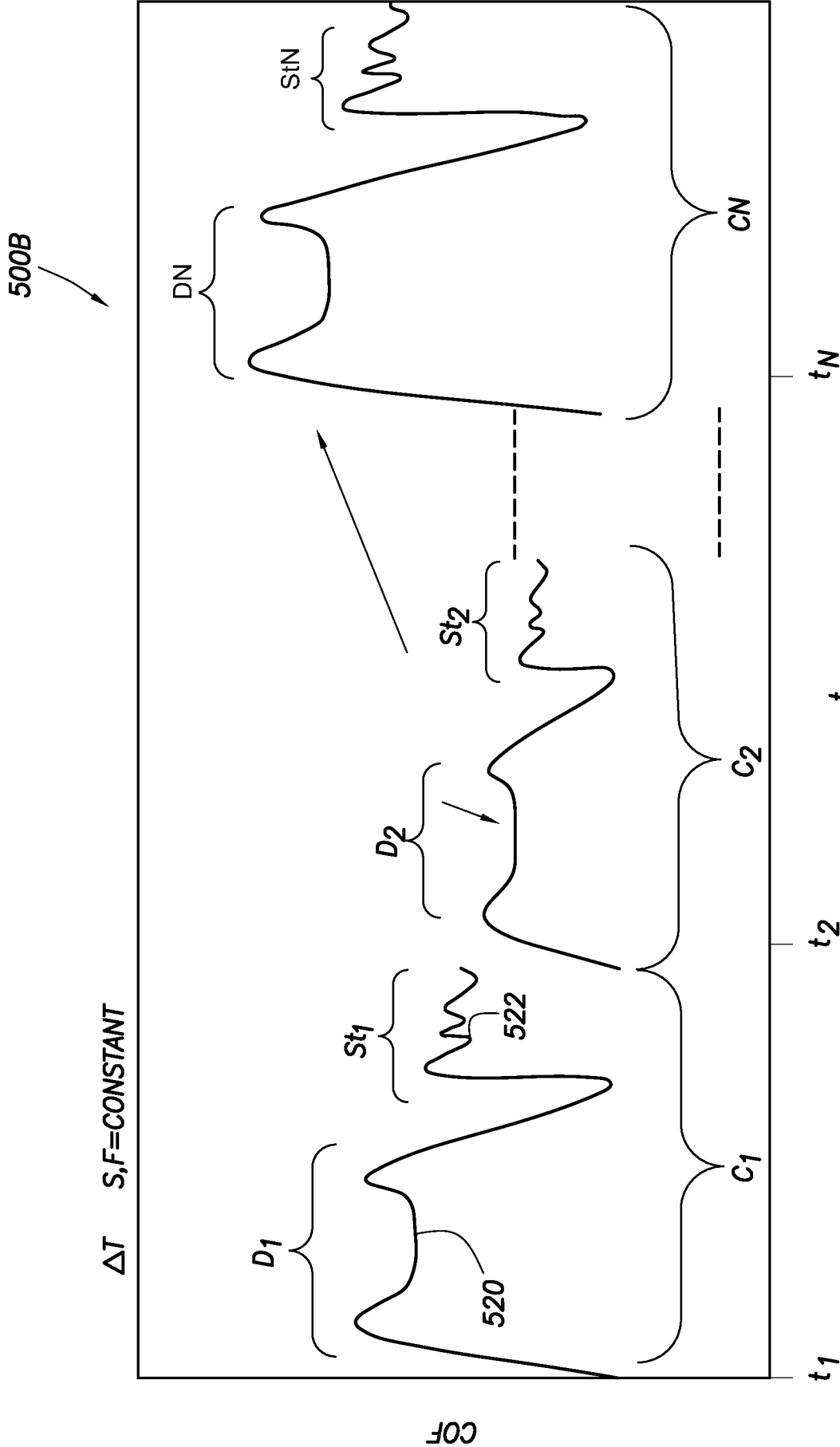


FIG.5B

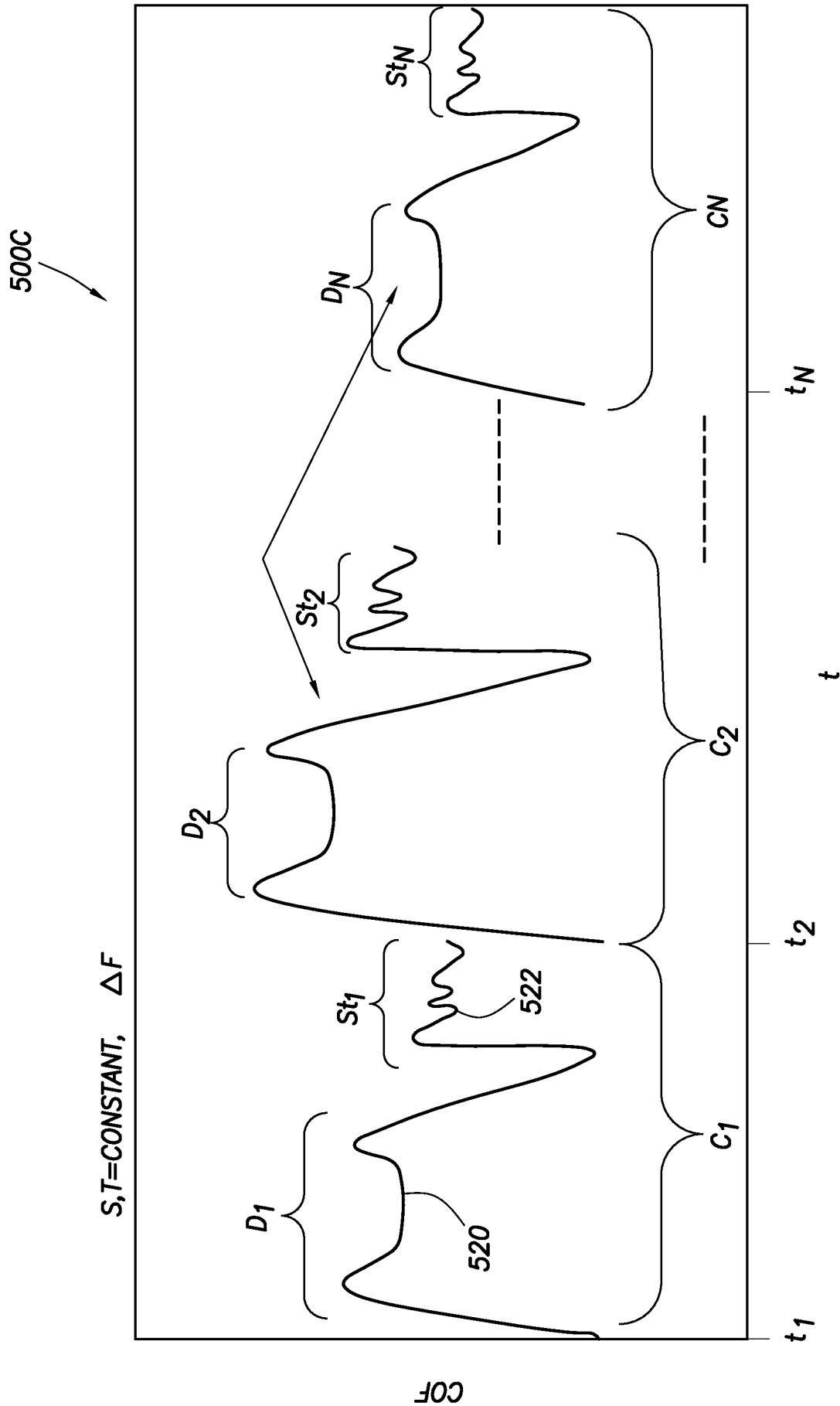


FIG.5C

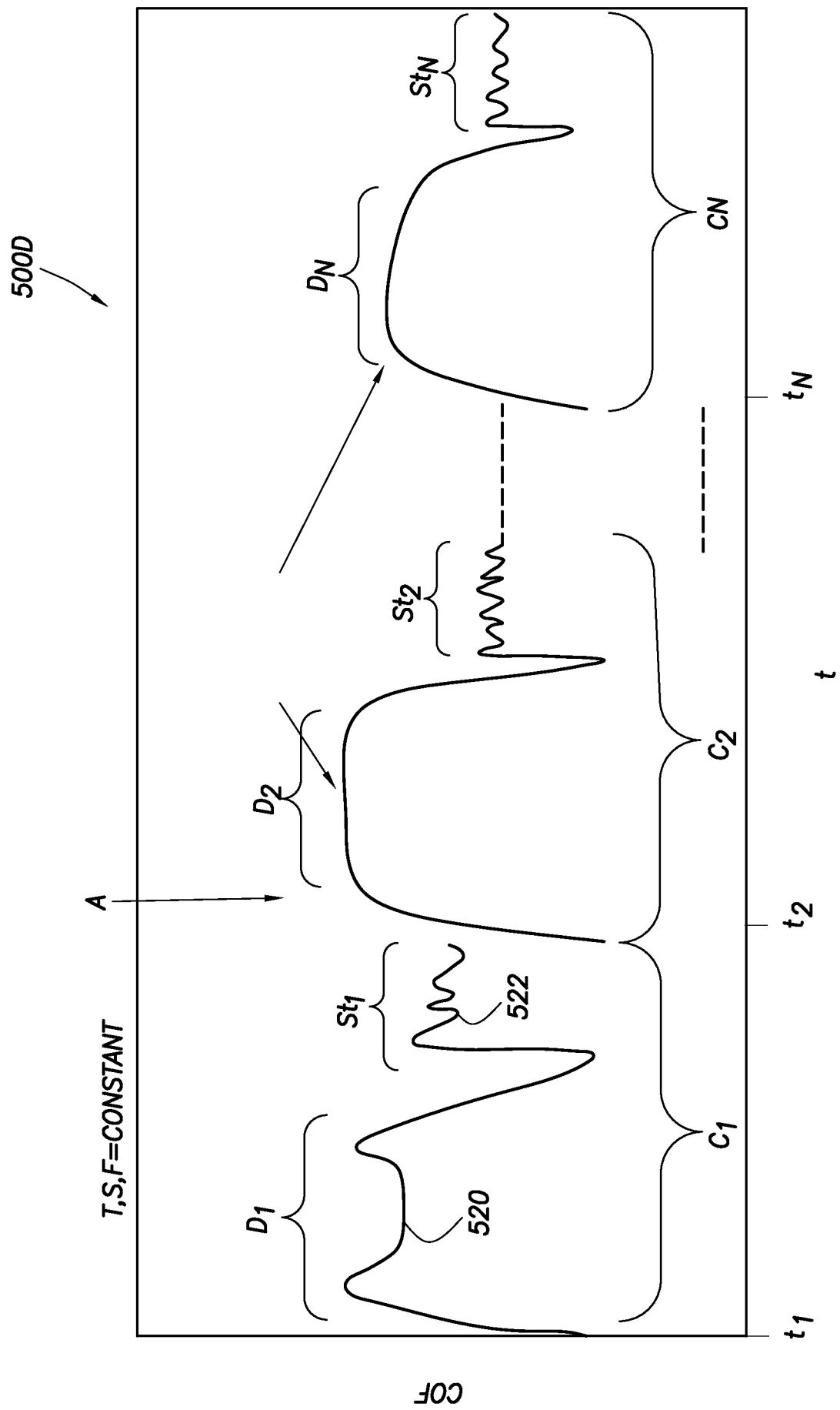
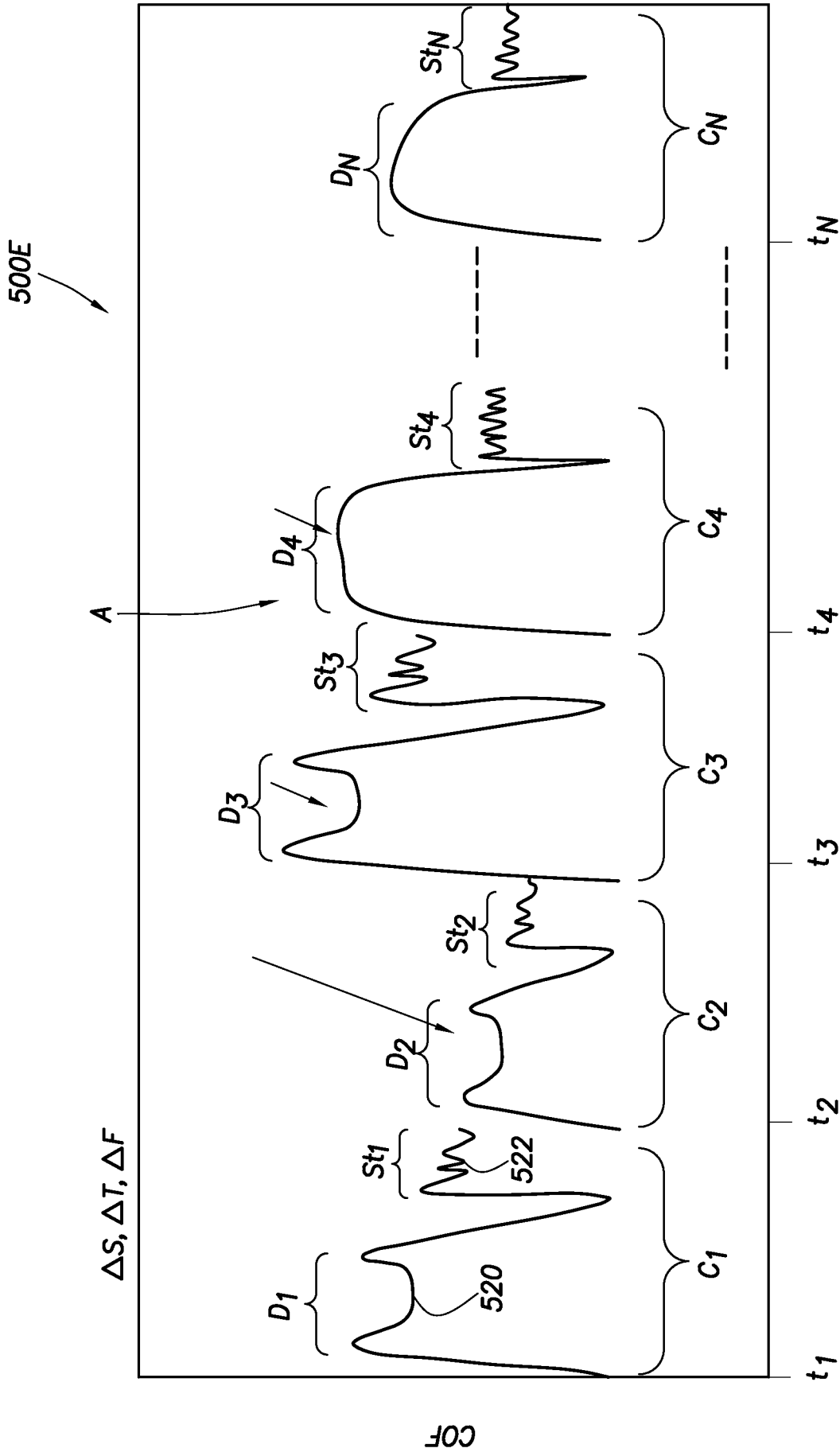


FIG. 5D



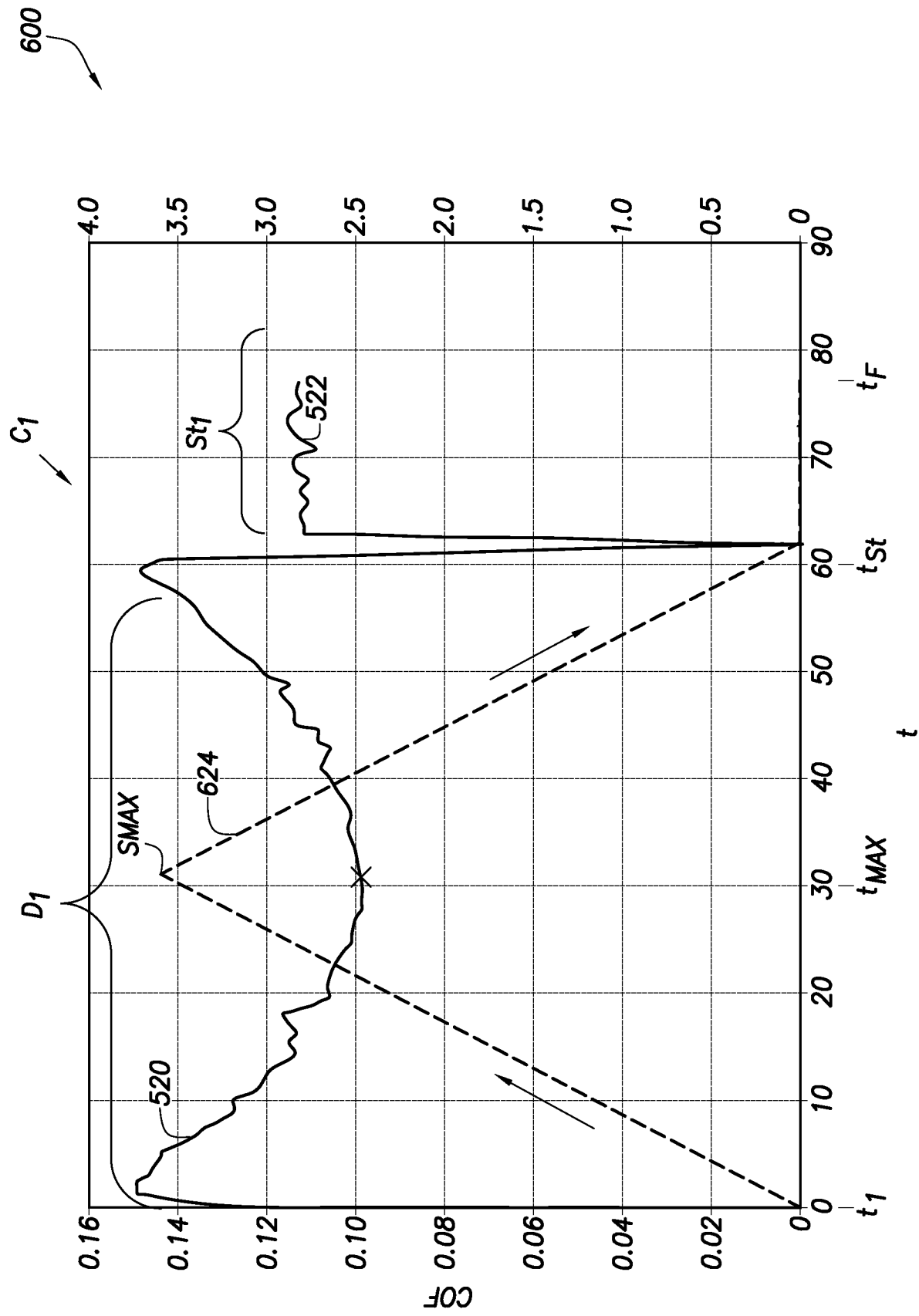
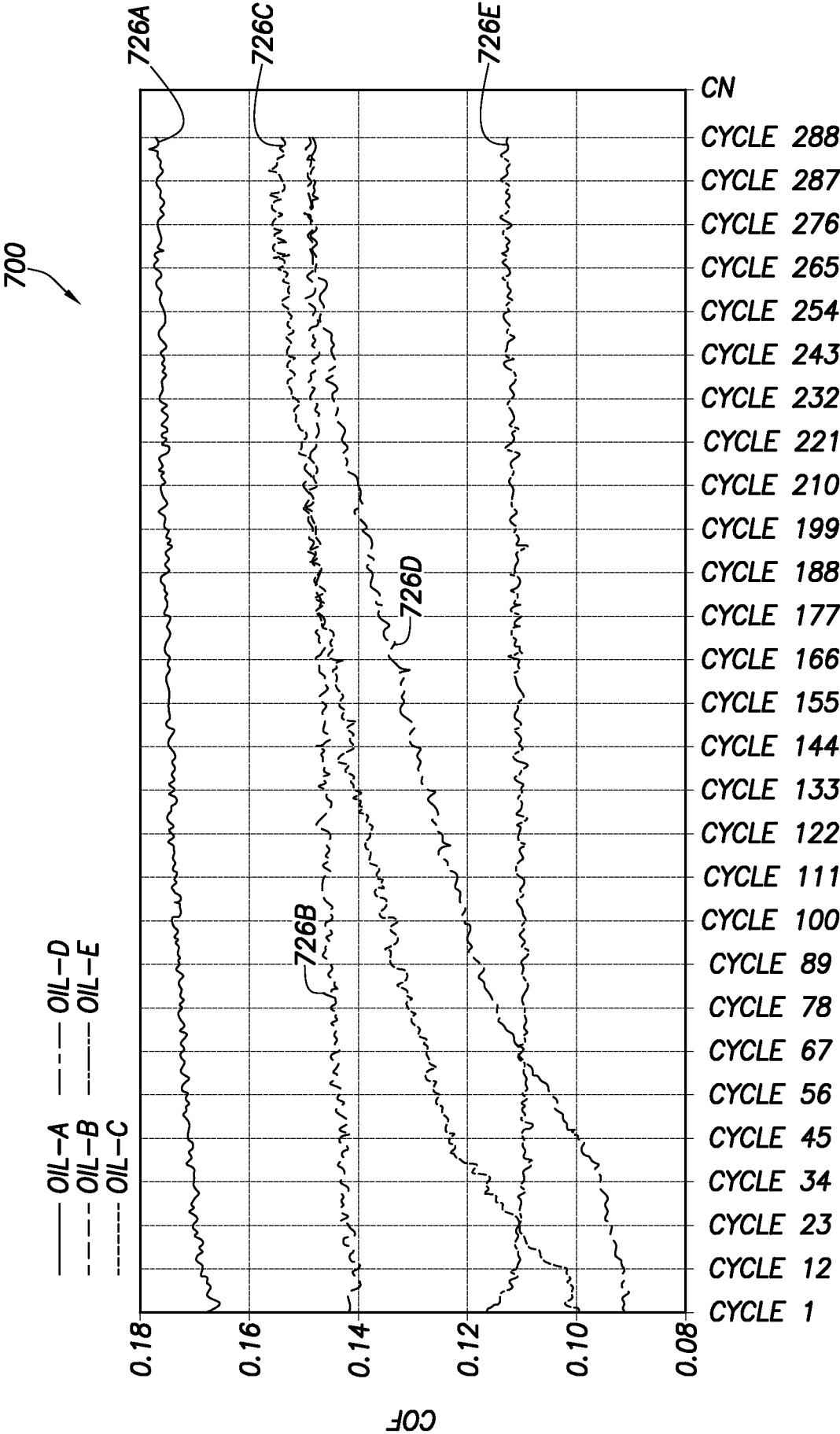


FIG.6



C₁-C_N
FIG. 7

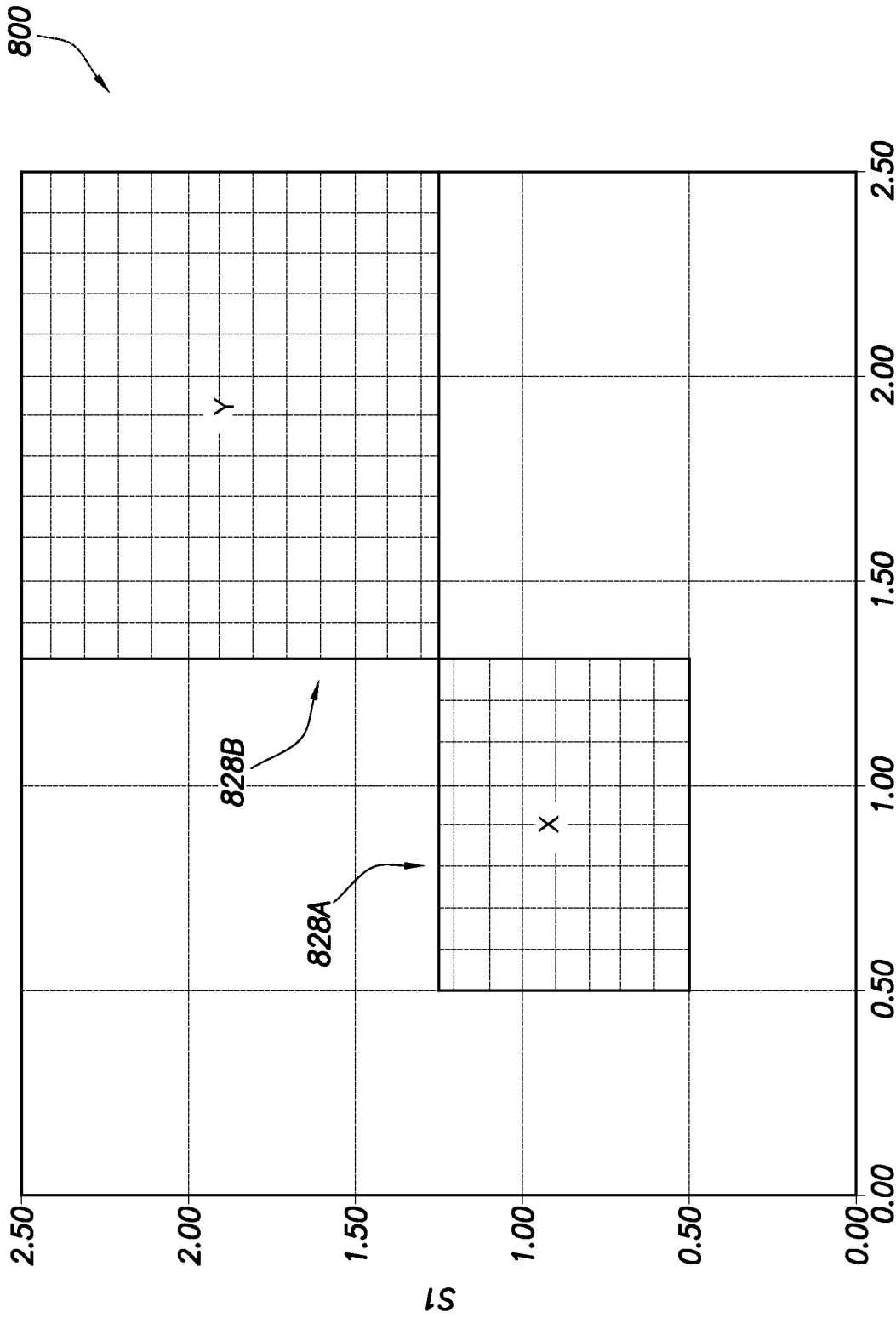


FIG.8

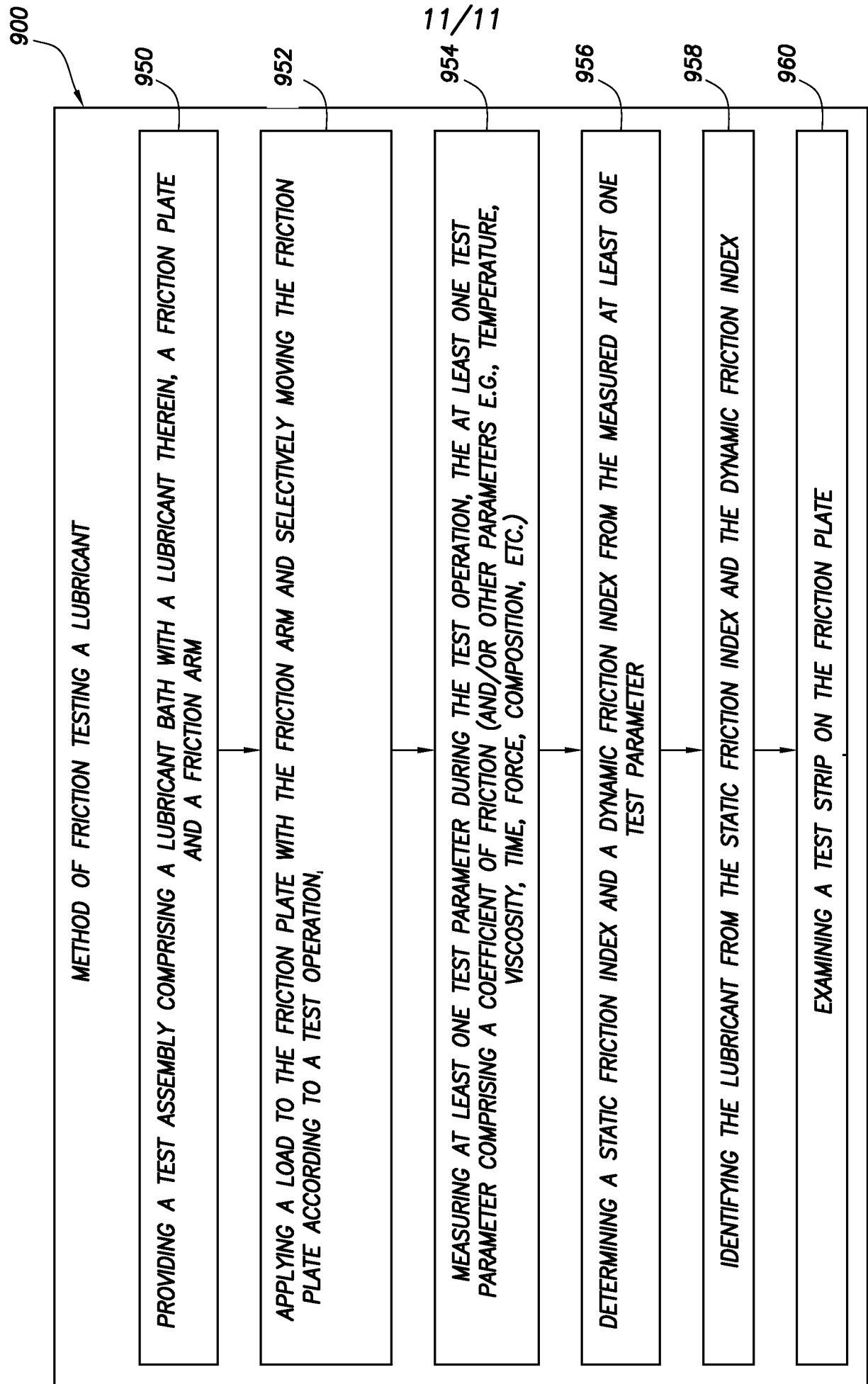


FIG.9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US14/36316

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G01N 19/02, 33/26, 33/30 (2014.01)

USPC - 73/9, 10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) Classification(s): G01N 19/00, 19/02, 33/26, 33/28, 33/30 (2014.01)

USPC Classification(s): 73/9, 10, 32R, 54.01, 54.02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

MicroPatent (US-G, US-A, EP-A, EP-B, WO, JP-bib, DE-C,B, DE-A, DE-T, DE-U, GB-A, FR-A); IP.Com, Google scholar, Google; Search terms used: friction testing lubricant friction plate friction arm, dynamic static coefficient, test strip additive, wet clutch, JASO,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 5,932,790 A (HOFFMAN, C. et al.) August 3, 1999; figure 1; column 1, line 4- column 3, line 55.	1, 3/1 --- 2, 3/2
Y	US 5,989,390 A (LEE, J.) November 23, 1999; figure 1- 3C; column 1, lines 11-40; column 2, lines 10-49; column 4, line 45- column 5, line 16.	2, 3/2
A	US 4,051,713 A (BAO, F. et al.) October 4, 1977; figures 1-5; column 1, lines 5-10 and column 1, line 35- column 2, line 38; column 2, lines 52- column 5, lines 36.	1-3

☐

Further documents are listed in the continuation of Box C.

☐

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

25 July 2014 (25.07.2014)

Date of mailing of the international search report

05 SEP 2014

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

Shane Thomas

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US14/36316

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 4-13
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.