A universal joint (850) includes a centering device (800) for maintaining the joint at constant velocity. Each shaft (818, 819) of the joint (850) is connected to a ball stud (801, 802). Movement of one of the shafts (818) at an angle relative to the longitudinal axis of the coupling device (817) is transmitted to the other shaft (819) by the centering device (800) and the centering device (800) causes the other shaft (819) to likewise move at the same angle relative to the longitudinal axis of the coupling device.
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Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

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PATENT APPLICATION

INVENTION: UNIVERSAL JOINT HAVING CENTERING DEVICE

SPECIFICATION


Background of the Invention

1. Field of the Invention

The present invention relates to universal joints having centering devices.

2. General Background of the Invention

Universal joints are used in a multitude of industries, including the aerospace, automotive, and marine industries. The aerospace industry uses universal joints, for example, to transfer power to control surfaces. Universal joints are used in steering columns in automobiles to transfer power. Universal joints are used in boat motors. In addition, universal joints can be found in everything from tractors to robots.

Information about universal joints can be found, for example, in the Society of Automotive Engineers Universal Joint and Driveshaft Design Manual (AE-7) (1979), hereby incorporated by reference. General information about centering devices for universal joints can be found, for example, in this manual, especially at pages 103, 112-115, 123, 124, 323, and 324.

Summary of the Invention

The present invention claimed herein comprises a double universal joint of the type described in U.S. Patent
No. 5,277,659, but with a centering device to maintain the angular velocity ratio of the input shaft and the output shaft as close to unity as possible. The present invention also comprises the centering device itself.

The present invention comprises a universal joint including:

(a) first and second rings;
(b) first and second yokes disposed within the first and second rings, respectively;
(c) first and second shafts;
(d) first pin means pivotally interconnecting the first yoke and the first ring;
(e) second pin means pivotally interconnecting the first shaft and the first ring;
(f) third pin means pivotally interconnecting the second yoke and the second ring;
(g) fourth pin means interconnecting the second shaft and the second ring;
(h) a third shaft interconnecting the first yoke and the second yoke;
(i) a plurality of bearing means in each ring, the bearing means in the first ring receiving the first and second pin means, and the bearing means in the second ring receiving the third and fourth pin means; and
(j) centering means interconnecting the first shaft and the second shaft.

One embodiment of the present application also includes a universal joint comprising:

(a) first and second shafts;
(b) coupling means for transmitting torque from the first shaft to the second shaft;
(c) centering means interconnecting the first shaft and the second shaft for causing the second shaft to move at the same angle relative to the coupling means as does the first shaft.

The centering means can comprise a pair of balls and
sockets, with a ball and socket adjacent the pivot point of each of the first and second shafts, the balls being interconnected. The first yoke, the second yoke, and the third shaft can define a coupling member, and the balls of the centering means can be interconnected with a sleeve within the coupling member. In such a case, as the centering means oscillates within the coupling member, lubricant is continuously packed via a hole in the sleeve into the sleeve, providing feed of lubricant to the balls.

Advantageously, the centering means includes a spring means urging apart two wear means. Alternatively, the centering means includes spring means urging the two balls together.

The centering means can comprise a ball and socket adjacent the pivot point of each of the first and second shafts.

Preferably, there are means for allowing the first shaft to move up to 90° relative to the second shaft. The universal joint of the present invention is preferably a constant velocity universal joint.

Preferably, the centering means allows the joint to operate at constant velocity at all angles in a predetermined design range.

Brief Description of the Drawings

For a further understanding of the nature, objects, and advantages of the present invention, reference should be had to the following detailed description, read in conjunction with the following drawings, wherein like reference numerals denote like elements and wherein:

Fig. 1 is an exploded view of a universal joint in accordance with the present invention.

Fig. 2 is a side view of the embodiment of the invention shown in Fig. 1.

Fig. 3 is a sectional view of an alternative embodiment of the present invention.

Fig. 4 is a sectional view of the pivot ring of the first and second embodiments of the present invention.
Fig. 5 is a sectional view taken along the lines 5-5 in Fig. 6.

Fig. 6 is a partially cut-away view of a third embodiment of the universal joint of the present invention.

Fig. 7 is an exploded view of a fourth embodiment of the universal joint of the present invention.

Fig. 8 is a side view of the fourth embodiment of the present invention.

Fig. 9 is a sectional view of the fourth embodiment of the present invention.

Fig. 10 is a sectional view of the pivot ring of the fourth embodiment of the present invention.

Fig. 11 is a sectional view taken along the lines 11-11 in Fig. 12.

Fig. 12 is a partially cut-away view of a fifth embodiment of the universal joint of the present invention.

Fig. 13 is a sectional view, similar to Fig. 12, of a sixth embodiment of the present invention.

Fig. 14 is a sectional view taken along the lines 14-14 in Fig. 13.

Fig. 15 is a sectional view of a fifth embodiment of the present invention.

Fig. 16 is a sectional view of the fifth embodiment of the present invention, showing the input and output shafts at an angle.

Fig. 17 is a sectional view of a sixth embodiment of the present invention, showing the input and output shafts at an angle.

Fig. 18 is a sectional view of the sixth embodiment of the present invention.

Fig. 19 is a sectional view of a seventh embodiment of the present invention, showing the input and output shafts at an angle.

Fig. 20 is a sectional view of the seventh embodiment of the present invention.

Fig. 21 is a sectional view of an eighth embodiment of the present invention.
Parts List:
The following is a list of suitable parts and materials for the various elements of the present invention.

5  10 Universal joint
11 hemispherical split-cup yoke (AISI 4340 metal alloy)
12 ball (AISI 4340)
13 shaft (AISI 4340)
14 shaft (AISI 4340)
15 ring (AISI 4340)
16 notches in yoke 11
17 inner ring member (AISI 4340)
18 outer ring member (AISI 4340)
19 channel in ring 15
15  20 lubricant ports in ring 15
21 long pin (AISI 1060 with a hardness of 60-65 Rockwell C)
22 short pin (AISI 1060 with a hardness of 60-65 Rockwell C)
20  23 bevel in yoke 11
31 needle bearings
32 races
33 holes in ring 15
34 holes in races 32
25  35 band of material, preferably metal with an inner surface induction hardened to a depth of 0.075 cm to a hardness of Rockwell C 60
41 hole in ball 12
42 hole in yoke 11
30  100 universal joint
113 shaft (AISI 4340)
134 channel in races 32
200 universal joint
213 shaft (AISI 4340)
35  300 universal joint
310 universal joint
311 hemispherical split-cup yoke (AISI 4340)
312 dual trunnion (AISI 4340)
313 shaft (AISI 4340)
314 shaft (AISI 4340)
315 ring (AISI 4340)
5 316 notches in yoke 311
   317 inner ring member (AISI 4340)
   318 outer ring member (AISI 4340)
   319 channel in ring 315
   320 lubricant port in ring 315
10 321 long pin (AISI 1060 with a hardness of 60-65 Rockwell C)
    322 short pin (AISI 1060 with a hardness of 60-65 Rockwell C)
    323 beveled inner radial surface of yoke 311
15 324 beveled inner surface of yoke 311
    325 beveled flat surface of yoke 311
    326 Lubricant port in ring 315
    327 flush-fitting NPT allen-head plug
    328 flush-fitting NPT allen-head plug
20 330 closed-end needle bearing assembly (modified Torrington bearing number M-1081-20H)
    332 races
    333 holes in ring 315
    334 holes in races 332
25 336 internal snap rings
    337 snap-ring grooves in holes 333
    338 polytetrafluoroethylene (PTFE) spacer rings
    339 rubber O-ring (Bruna-N 90 Durometer, such as Parker No. 2-016)
30 340 shaft (AISI 4340)
    341 hole in dual trunnion 312
    342 hole in yoke 311
    410 universal joint
    415 ring (AISI 4340)
35 419 channel in ring 415
    500 universal joint
    511 hemispherical split-cup yoke (AISI 4340)
513 shaft (AISI 4340) of universal joint 310
514 shaft (AISI 4340) of universal joint 500
530 closed-end needle bearing assembly (modified INA bearing number BA1610S or BA1610.1S or F207360.1)
531 needle bearings
532 races
539 elastomer-type lip seal, such as seal found in INA bearing number BA1610S or BA1610.1S or F207360.1)
540 shaft (AISI 4340) of universal joint 500
550 coupling member comprising hemispherical split-cup yokes 511 and shaft 613
600 universal joint of the sixth embodiment of the invention
610 universal joint of the seventh embodiment of the invention
613 shaft (AISI 4340) of universal joint 500
614 shaft (AISI 4340) of universal joint 600
615 rings of universal joints 600 and 610 (same as rings 415, but additionally including grooves 616 for rings 617)
616 grooves in ring 615 for rings 617
617 Retaining ring made of injection molded plastic, as shown in Figure 65 on page 67 of the SAE Manual
621 pin means integral with and of shafts 614 and 640
630 closed-end needle bearing assembly (can be the same as assembly 530, but with a groove for ring 617)
640 shaft (AISI 4340) of universal joint 600
700 centering device of joint 500
711 socket of centering device 700
712 ball stud (plain medium carbon steel forgings, heat treated to a typical hardness range of BHN 255-285) of centering device 700
738 elastomer-type lip seal, such as the type described in the above-mentioned SAE design manual on page 114)
739 rubber O-ring (Bruna-N 90 Durometer)
740 groove in centering plate 770
770 centering plate of centering device 700
centering pin of centering device 700
centering sleeve of centering device 700
lubrication bore in ball-pin centering plate 774
(preferred, but optional)

ball-pin centering plate
spring
bore in coupling member 550
cavities in shafts 514 and 540
hole in centering sleeve 772
centering device of joint 850
ball stud
ball stud
centering sleeve of centering device 800
spring of centering device 800
cylindrical wear plate of centering device

cylindrical wear plate of centering device 800
centering pin
notch in wear plate 805
hole in coupling member 817
socket
socket
seal means
seal means
hole in shaft 818
hole in shaft 819
bore of coupling member 817
coupling member
shaft
shaft
O-ring
O-ring
notch in wear plate 806
lubricant hole in sleeve 803
lubricant bore in ball stud 802
lubricant bore in ball stud 801
constant velocity plane
pin means integral with and of shafts 818 and 819
O-ring groove in wear plate 805
O-ring groove in wear plate 806
universal joint

**Detailed Description of the Preferred Embodiments**

The embodiments of the present invention shown in Figures 1-14 are described in U.S. Patent No. 5,277,659.

Universal joint 500 (Figures 15 and 16) includes an input shaft 514, an output shaft 540, and a coupling member 550 comprising two hemispherical split-cup yokes 511 and a shaft 613. Ring 415 interconnects shafts 514 and 540 with yokes 511 in the same manner that ring 415 interconnects shafts 314 and 340 with yokes 311 in joint 300.

Universal joint 500 differs from universal joint 300 in that joint 500 includes a centering device 700. Centering device 700 includes a pair of ball studs 712, each connected to a centering plate 770, which in turn is connected to a centering pin 771. The ball stud 712 may be integrally formed with the centering plate 770 and centering pin 771. Centering pins 771 are received in centering sleeve 772, which in turn is received in bore 776 in coupling member 550.

Received within cavities 777 in shafts 514 and 540 are springs 775, sockets 711 of centering device 700, and elastomer-type lip seals 738. Ball studs 712 are received in sockets 711.

Rubber O-rings 739 are received in grooves 740 in each centering plate 770. O-rings 739 and sealing rings 738 serve to contain lubricant (not shown) in cavities 777 and bore 776. The lubricant can flow from one cavity 777 to the other through lubrication bores 773 in ball-pin centering plate 774, and can flow from either cavity 777 into bore 776 via bores 773 and a hole 778 in the wall of sleeve 772. The lubricant can be pre-loaded in bore 776, cavities 777, and bores 773, or it can be pumped into them via an optional grease zerk (not shown in the drawings) which communicates with bore 776.

Closed-end needle bearing assembly 530 includes races
532, needle bearings 531, and elastomer-type lip seal 539. When joint 500 operates at an angle, centering pins 771 and centering sleeve 772 of centering device 700 must orbit within the space provided in bore 776 in coupling member 550. The closer that ball 712 is to the pivot point of shafts 514 and 540, the smaller the orbital path of centering plate 770 will be. This is significant because the amount of orbiting which occurs in the twin ball and centering plate-type double Cardan joint is harder to control. The smaller the orbital path, the less wear on mating parts and seals.

Joint 500 is the first ring-type universal joint with a centering device. Joint 500 is the first self-supported double ring joint.

Centering device 700 allows joint 500 to operate at constant velocity at all angles within the design range of joint 500 (0-90 degrees).

The center of ball stud 712 and socket 711 of centering device 700 can be placed adjacent the pivot point of the input shaft 514 and output shaft 540. The center of ball stud 712 and socket 711 of centering device 700 can be placed closer to the pivot point of the input shaft 514 and output shaft 540 than in other universal joints. The closer the ball stud 712 and socket 711 are placed to this pivot point the smaller the magnitude of oscillation of the ball stud 712 in the socket 711 will be. Conversely, the other centering devices of which the inventor is aware are located at the center of the joint making the degree or magnitude of oscillation equal to the total joint angle.

Centering device 700 incorporates two ball studs 712 and sockets 711 which will experience oscillations in the socket at one half of the total joint angle.

The location of ball studs 712 and sockets 711 in relation to the pivot point of the input and output shafts 514 and 540 can control the degree of oscillation of centering plate 770 in relation to coupling member 550. This is why not much room is needed in bore 776.
Like the Double Cardan twin ball and centering plate-type centering devices, centering device 700 allows joint 500 to operate at all angles in the design range, where the instantaneous angular velocity ratio is unity. In other words, joint 500 will operate at constant velocity at all angles. The centering device of other double-Cardan joints will only allow the joints to operate at true constant velocity at one design angle and at 0 degrees.

Centering device 700 includes two ball-pin centering plates 774 which are allowed to oscillate within bore 776 in coupling member 550 as joint 500 rotates at an angle.

Joint 500 is assembled in the same manner as is joint 300. Ball-pin centering plates 774 are held together by being pressed (i.e., press fit) into sleeve 772, and sockets 711 are inserted into cavities 777 after springs 775 are received in cavities 777. A metal ring, for example, can hold sealing rings 738 in place. The metal ring can be press-fit into cavity 777.

Lubricant may be stored in bore 776 and supplied to ball studs 712 and sockets 711 via a single hole 778 in centering sleeve 772.

As centering device 700 oscillates within coupling member 550 lubricant is continuously packed via hole 778 into sleeve 772 and ball-pin centering plates 774, providing positive pressure or feed of lubricant to ball studs 712 and sockets 711.

Centering device 700 functions as a self-aligning bearing and provides internal supporting and centering means for universal joint 500.

For high-speed applications, additional bearings can be added as described in the Society of Automotive Engineers Universal Joint and Driveshaft Design Manual (AE-7) (1979), especially at pages 103, 112-115, 123, 124, 323, and 324.

Figures 17 and 18 show a sixth embodiment of the invention, universal joint 600. Joint 600 is substantially similar to joint 500.
Figures 19 and 20 show a seventh embodiment of the invention, universal joint 610. Joint 610 is substantially similar to joint 600, but does not include bores 773 and hole 778. Joint 610, however, preferably does include bores 773 and hole 778 to allow lubricant to flow through ball-pin centering plates 774.

Universal joint 850 (Figure 21) is similar to joint 500, but has a centering device 800 instead of centering device 700.

Centering device 800 differs from centering device 700 primarily by the addition of spring 804 and wear plates 805 and 806. Spring 804 removes slack which can result from wearing on bearing surfaces of wear plates 805 and 806. Spring means such as shown in Figures 15-20 could be used in holes to remove slack due to wear of ball studs 801 and 802 and sockets 810 and 811.

Centering device 800 is assembled by placing spring 804 over sleeve 803. Cylindrical wear plates 805 and 806 are placed over each end of spring 804. Ball studs 801 and 802 are pressed into sleeve 803 forming an assembly. A heavy press fit or shrink fit is preferable. The assembly is then inserted into bore 816 of coupling member 817. The center of the assembly is locked in the constant velocity plane 827 by pressing centering pin 807 into hole 809 of coupling member 817 and into notch 808 of cylindrical wear plate 805 and notch 822 of cylindrical wear plate 806.

Socket 810 is received in hole 814 in shaft 818, and socket 811 is received in hole 815 in shaft 819. Ball stud 801 is received in socket 810, and ball stud 802 is received in socket 811.

O-ring 820 is received in O-ring groove 836 in wear plate 805 and O-ring 821 is received in O-ring groove 837 in wear plate 806.

The lubricant can be pre-loaded in holes 814 and 815, bores 824 and 825, and in sleeve 803, or it can be pumped into them via an optional grease zerk (not shown in the drawings) which communicates with all passageways in
centering device 800.

Lubricant can travel through lubricant bore 824 in ball stud 801, lubricant bore 825 in ball stud 802, and lubricant hole 823 in sleeve 803.

O-rings 820 and 821 and seal means 812 and 813 help to keep lubricant in centering means 800. O-rings 820 and 820 help to keep lubricant from leaking between cylindrical wear plates 805 and 806 and bore 816. Seal means 812 and 813 (elastomeric seals, for example) help to keep lubricant from leaking out of holes 814 and 815.

Pin means 831 are integral with shafts 818 and 819.

The bigger spring 804 is advantageous over the smaller springs 775 because, among other things, one needs to remove less material from the input and output shafts when using spring 804, since it is not necessary to make room for springs 775. Most importantly, however, larger spring 804 removes slack which may be caused as ball studs 801 and 802 wear. The wear may be so insignificant that the springs may not be necessary.

Centering device 800 works in the same manner as centering device 700.

Whenever "press-fit" has been used herein, "shrink-fit" could also have been used. Press fitting involves forcing together, for example, a pin into a hole of slightly smaller diameter than the pin, simply by mechanical force. Shrink fitting involves heating the part containing the hole and cooling the pin so that the diameter of the hole can be even smaller compared to the diameter of the pin than is possible with press fitting, resulting in a tighter fit of parts.

Instead of making a 90° joint by attaching two yokes of 45° joints with a shaft, a 90° joint can be made by attaching two balls or two dual trunnions with a shaft. This type of 90° joint may prove easier to manufacture.

The foregoing embodiments are presented by way of example only; the scope of the present invention is to be limited only by the following claims.
CLAIMS:

1. A universal joint comprising:
   (a) first and second rings;
   (b) first and second yokes disposed within the first and second rings, respectively;
   (c) first and second shafts;
   (d) first pin means pivotally interconnecting the first yoke and the first ring;
   (e) second pin means pivotally interconnecting the first shaft and the first ring;
   (f) third pin means pivotally interconnecting the second yoke and the second ring;
   (g) fourth pin means interconnecting the second shaft and the second ring;
   (h) a third shaft interconnecting the first yoke and the second yoke;
   (i) a plurality of bearing means in each ring, the bearing means in the first ring receiving the first and second pin means, and the bearing means in the second ring receiving the third and fourth pin means; and
   (j) centering means interconnecting the first shaft and the second shaft.

2. A universal joint comprising:
   (a) first and second shafts;
   (b) coupling means for transmitting torque from the first shaft to the second shaft;
   (c) centering means interconnecting the first shaft and the second shaft for causing the second shaft to move at the same angle relative to the coupling means as does the first shaft.

3. The universal joint of claims 1 or 2, wherein the centering means comprises:
   a pair of balls and sockets, with a ball and socket adjacent the pivot point of each of the first and second shafts, the balls being interconnected.

4. The universal joint of claim 3, wherein:
the first yoke, the second yoke, and the third shaft define a coupling member; and
the balls of the centering means are interconnected with a sleeve within the coupling member.

5. The universal joint of claim 4, wherein:
as the centering means oscillates within the coupling member, lubricant is continuously packed via a hole in the sleeve into the sleeve, providing feed of lubricant to the balls.

6. The universal joint of claims 1 or 2, wherein:
the centering means comprises:
a ball and socket adjacent the pivot point of each of the first and second shafts.

7. The joint of any preceding claim, further comprising means for allowing the first shaft to move up to 90° relative to the second shaft.

8. The joint of any preceding claim, wherein the universal joint is a constant velocity universal joint.

9. The joint of any preceding claim, wherein the centering means allows the joint to operate at constant velocity at all angles in a predetermined design range.

10. The joint of claim 3, wherein the centering means includes a spring means urging apart two means.

11. The joint of claim 3, wherein the centering means includes spring means urging the two balls together.
## INTERNATIONAL SEARCH REPORT

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(5) :F16C 1/24; F16D 3/16
US CL :464/7, 118, 125, 147, 905

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)

U.S. : 464/7, 11, 114, 117, 118, 125, 126, 147, 905

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)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>US, A, 2,737,791 (DILLMAN ET AL) 13 March 1956, entire reference.</td>
<td>all</td>
</tr>
<tr>
<td>A</td>
<td>US, A, 2,780,079 (WAHLBERG) 05 February 1957, entire reference.</td>
<td>all</td>
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<tr>
<td>A</td>
<td>US, A, 2,986,022 (STOKELY) 30 May 1961, entire reference.</td>
<td>all</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C. See patent family annex.

* 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 document 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

**Date of the actual completion of the international search**

16 August 1994

**Date of mailing of the international search report**

AUG 22 1994

**Name and mailing address of the ISA/US**

Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Facsimile No. (703) 305-3230

**Authorized officer**

[Signature]

EILEEN DUNN

**Telephone No.**

(703) 308-0771

Form PCT/ISA/210 (second sheet)(July 1992)
### DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>US, A, 3,064,453 (BARSNESS ET AL) 20 November 1962, entire reference.</td>
<td>all</td>
</tr>
<tr>
<td>A</td>
<td>US, A, 4,508,522 (NUMAZAWA ET AL) 02 April 1985, entire reference.</td>
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</tr>
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<td>A</td>
<td>US, A, 4,579,546 (PASTOR) 01 April 1986, entire reference.</td>
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<tr>
<td>A</td>
<td>US, A, 4,955,741 (KOMAYAMA) 11 September 1990, entire reference.</td>
<td>all</td>
</tr>
<tr>
<td>A</td>
<td>US, A, 5,094,651 (CORNAY) 10 March 1992, entire reference.</td>
<td>all</td>
</tr>
</tbody>
</table>
INTERNATIONAL SEARCH REPORT

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international 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.: 7-9
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 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 an additional fee, this Authority did not invite payment of any additional fee.

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.
☐ No protest accompanied the payment of additional search fees.