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(54) **CRACKER APPARATUS**

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(57) **ABSTRACT**

Cracker apparatus, comprising

a container for providing at least one gaseous crackable source material, which container has an at least substantially open second end part forming an outlet opening,

dispenser means for receiving said gaseous crackable source material from said container and for controlling the flow of said gaseous crackable source material, and

cracker means for receiving said at least one gaseous crackable source material from said dispenser means.

The second end part of the source material container is arranged to be detachably coupled to the dispenser means, and the supply of new source material into the source material container is arranged through said outlet opening when said container is detached from the dispenser means.

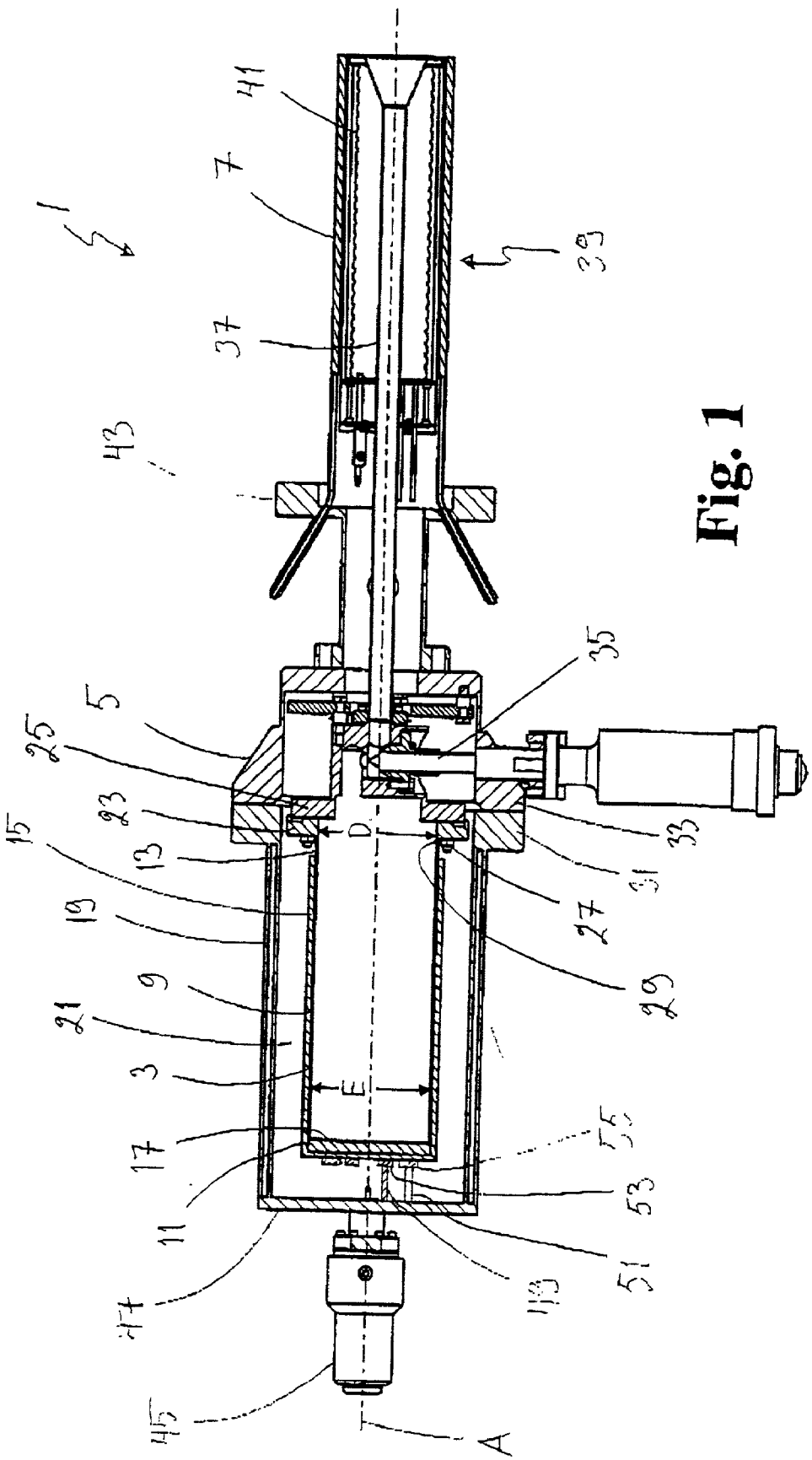
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Fig. 1

# CRACKER APPARATUS

## FIELD OF THE INVENTION

[0001] This invention relates to a cracker apparatus for cracking molecules. The invention relates specifically to a new and inventive cracker apparatus in which solid source material is gasified into crackable gaseous source material, which is then cracked into a desired product. This invention also relates to a new source material container for a cracker apparatus.

## BACKGROUND OF THE INVENTION

[0002] In a cracking process according to the present invention, one or more substances are dissociated into one or more products. Typically, a solid or liquid source material of high purity is evaporated into a gaseous crackable source material. This gas is then subjected to thermal and/or electrical cracking. A typical example is cracking of arsenic, where solid arsenic is turned into gaseous $As_4$, which is then e.g. thermally cracked into two atomic $As_2$. Different source materials can be cracked in this way. The product gas is typically used e.g. in molecular beam epitaxy (MBE) process, MBE is a growth process where a thin film of material is deposited onto a substrate surface by directing molecular or atomic beams onto the substrate. MBE is widely used e.g. in semiconductor device producing industry and in other industries where thin-film deposition of elemental semiconductors, metals and insulating layers is needed.

[0003] The prior art cracker apparatuses, as well as the cracker apparatus of the present invention, normally comprise:

[0004] a) a container for providing at least one gaseous crackable source material, having an outlet opening through which said gaseous crackable source material is arranged to flow out from said container,

[0005] b) dispenser means for receiving said gaseous crackable source material from said container, said dispenser means comprising dispenser valve means for controlling the flow of said gaseous crackable source material through said dispenser means; and

[0006] c) cracker means for receiving said at least one gaseous crackable source material from said dispenser means.

[0007] In a typical cracking process solid or liquid source material is present in the source material container. The container is heated, e.g. with electrical resistive heater, in such a way that a wanted flux of evaporating source material is created in the source material container. The gas is led through the outlet opening in to the dispenser means, where the gas flow to the actual cracker part of the apparatus is controlled with the valve means. The cracker apparatus has suitable connecting means, such as flanges and bolts, between the source material container, the dispenser means and the actual cracker means of the apparatus.

[0008] One problem of the prior art cracker apparatuses has been the difficulties when supplying new source material to the source material container. To sustain a sufficient gaseous source material flux there must normally be a reasonable amount of source material present in the container. This means, that the container is not totally empty at the time when new source material must be added. Some source material can be e.g. adhered on the walls of the container. U.S. Pat. No. 5,156,815 (Streetnan et al.) shows a cracker apparatus in which a source material container is provided with a detachable end part, i.e the end part, which is not connected to the dispenser means, can be opened. The problem with this kind of a system is, that source material, e.g. arsenic, tends to crystallize on the coolest walls of the container. The end part near the outlet opening is normally the one with higher temperature. The lid, i.e. the detachable part, of U.S. Pat. No. 5,156,815 is at the end part away from the outlet opening, which means that the solid source material covers the inside of that end part and makes it difficult to open. Opening of this container is usually achieved only with some violence, e.g. a hammer, which causes the risk of damaging the equipment. Pieces of possibly very harmful source material usually drop out from the container due to the powerful actions needed. The same risk is evident because of the fact that the detachable end part of this system is often positioned downwards, because the outlet opening of the source material container is usually positioned upwards.

[0009] U.S. Pat. 5,681,535 (Clampitt) shows a cracker apparatus, which has a source material container shaped as a bottle with a cylindrical part of first diameter and a neck part with a diameter substantially smaller than the first diameter. The gaseous source material flows out of the bottle through the neck part. The neck is connected to the rest of the cracker apparatus. When new source material is added the neck end of the container bottle is detached from the rest of the apparatus and new material is fed in the container bottle through the narrow neck of it. The small neck part easily collects a layer of solid source material on it and on the bends of it. The narrow neck part makes it difficult to empty or clean the container if wanted, and to refill it with solid source material, which is often in the form of clumps of different sizes.

[0010] In the prior art cracking apparatuses the opening and/or detaching of the source material container has been difficult and time consuming. Furthermore, the known source material containers are difficult to clean and empty when needed.

[0011] The electrical power needed for the heaters of the source material containers in prior art cracker apparatuses has been arranged in a relatively complex way.

[0012] Accordingly, it is an objective of the present invention to provide an improved cracker apparatus and an improved source material container for such a cracker apparatus, which would eliminate or minimize drawbacks of the prior art technology.

## SUMMARY OF THE INVENTION

[0013] The present invention provides a cracker apparatus, comprising at least the following elements:

[0014] a) A container for providing at least one gaseous crackable source material. The source material container is formed as a mainly cylindrical vessel having a closed first end part, an at least substantially open second end part and a mainly cylindrical mantle part between said end parts. Said open second end

part is arranged to form an outlet opening through which said gaseous crackable source material is arranged to flow out from said container;

[0015] b) Dispenser means for receiving said gaseous crackable source material from said container. Said dispenser means comprise dispenser valve means for controlling the flow of said gaseous crackable source material through said dispenser means;

[0016] c) Cracker means for receiving said at least one gaseous crackable source material from said dispenser means.

[0017] Said second end part of the source material container is arranged to be detachably coupled to said dispenser means, and the supply of new source material into the source material container is arranged trough said outlet opening when said container is detached from the dispenser means.

[0018] According to this invention the whole source material container is arranged to be detached from the rest of the cracker apparatus for example when supplying new source material. This way there is no need for a separate closing cover or other detachable part in the source material container. The detachable connection between the source material container and the dispenser means is done with some suitable connecting means, such as flanges and bolts.

[0019] According to the present invention the second end part of the source material container, which is arranged to be detachably coupled to the dispenser means, is formed at least substantially open. This second end part forms the outlet opening of the source material container and is typically of substantially same diameter than the rest of the cylindrical container. Emptying, cleaning and refilling the container becomes easy because there is no narrow neck part or the like hindering the performed operations. The opening of the flange on the dispenser means side through which the gaseous source material flows after the outlet opening can be smaller than the opening of the flange on the outlet opening side.

[0020] The source material container according to this invention is easy to open because the second end part of the container is close to the dispenser means and its valve means. Dispenser valve means are always kept at a higher temperature than the source material chamber in order to ensure optimal operation of the apparatus by preventing the formation of solid source material on the valve means. The higher temperature means that normally no solid source material formation occurs on the joint surfaces between the container and dispenser means.

[0021] The source material container according to the invention is typically formed as a mainly cylindrical vessel having a mainly cylindrical mantle part between its end parts. The form of a substantially right circular cylinder is preferred. A container of cylindrical form is simple to handle. A cylindrical vessel is easy to cover with a resistive heater, insulation or a protective cover.

[0022] The dispenser means and cracker means of the present invention are of any suitable type. Because the basic inventive idea of this invention does not concern their function or structure these parts of the apparatus are not discussed any deeper in this text.

[0023] In a preferred embodiment of the invention the interior of the source material container is reachable only through said outlet opening. This way the structure of the apparatus becomes simpler.

[0024] In another preferred embodiment of the present invention the area of the outlet opening of the source material container covers substantially the whole cross-sectional area of the second end part container. In other words, the second end part is formed at least nearly open. Preferable, the second end part is totally open. This kind of a container is easy to empty, clean and refill.

[0025] In a preferred embodiment of the present invention an electrical heating means is arranged around at least a substantial part of the source material container. Preferably a vacuum vessel means is arranged detachably around the source material container and around the electrical heating means. This way a vacuum zone is formed around at least a substantial part of the source material container. Vacuum is needed to ensure that no contamination reaches the process. At the same time vacuum zone acts as a thermal insulation and thereby saves energy.

[0026] In a further preferred embodiment of the present invention the electrical heating means is arranged detachably around at least a substantial part of the source material container. Also the vacuum vessel means can be arranged detachably around the electrical heating means. By arranging the different parts individually detachable easier maintenance of the apparatus is achieved. This way the different parts can be easily replaced without having to replace the whole apparatus.

[0027] In another preferred embodiment of the present invention the cracker apparatus further comprises

[0028] at least two substantially concentric metal circles arranged on the outside of the first end part of the source material container, the metal circles arranged in galvanic contact with the electrical heating means, and

[0029] at least two metal rods arranged on the inside of the vacuum vessel means. Where said metal rods are arranged into galvanic contact with said metal circles when the vacuum vessel means is attached hermetically around the source material container. In this kind of an arrangement electrical power for the electrical heating means is arranged from outside of the vacuum vessel means via said metal rods and said metal circles. This makes the supply of electrical power easy. When the vacuum vessel is attached on the source material container, the rods come into contact with the rings, this way forming a galvanic contact between the outside of the vacuum vessel means and the electrical heating means. There is no additional electrical wiring needed for the electrical heating means around the source material container.

[0030] In another especially preferred embodiment of the present invention the crackable source material is arsenic. Arsenic suits well to be gasified and cracked in the apparatus according to the present invention.

## BRIEF DESCRIPTION OF THE DRAWING

[0031] **FIG. 1** is a cross-sectional view of a cracker apparatus in accordance with the invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0032] **FIG. 1** illustrates a cracker apparatus **1** according to a preferred embodiment of the present invention. The cracker apparatus **1** of this embodiment comprises three main components: a source material container **3**, dispenser means **5** and cracker means **7**. The source material container **3** is a cylindrical vessel having a cylindrical mantle part **9**, a closed first end part **11** and an open second end part **13**. The source material container **3** is made of a material, which is durable in the high temperatures present in the apparatus when in use, e.g. titanium. A resistive electrical heating means **15** is arranged detachably outside the bottom **17** of the container and around a substantial part of the mantle **9** of the container **3**. There is a cylindrical vacuum vessel **19** detachably arranged around the source material container **3** and the electrical heating means **15**. The zone **21** between the source material container **3** and the vacuum vessel **19** is hermetically sealed in order to be able to keep up a substantial vacuum around a substantial part of the container **3**.

[0033] The source material container **3** has a flange **23** surrounding its second end part **13**. This flange **23** is detachably attached to the flange **25** of the dispenser means with bolts **27**. The opening of flange **23** determines the outlet opening **29** of the source material container **3**. The diameter D of the outlet opening **29** is substantially the same as the diameter E of the cylindrical source material container **3**. The diameter of the opening on the flange **25** on the dispenser means is substantially smaller than the diameter D of the outlet opening **29**. The vacuum vessel **19** is detachably connected to the dispenser means **5** via flange **31** on the vacuum vessel and flange **33** on the dispenser means side. Connection between flanges **31** and **33** is gas tight in order to be able to retain the vacuum zone **21** inside the vacuum vessel **19**.

[0034] The dispenser means **5** comprise the needle valve means **35**. Because the structure of a needle valve is well known as such it is not described in more detail here.

[0035] The dispenser means **5** is connected to the thermal cracker means part **7** of the apparatus **1**. The cracker means **7** comprises a tube **37** through which the gaseous source material is arranged to flow and in which tube the gaseous source material is arranged to be cracked. In The cracking zone **39** of the apparatus an electrical resistive heating means **41** is arranged around the tube **37**. The structure of a thermal cracker is well known as such and therefore not described in more detail here.

[0036] A mounting flange **43** is arranged between the cracking zone **39** of the cracker means and the dispenser means **5**. The mounting flange **43** is needed when the apparatus **1** is attached to any equipment it is meant to be used with, e.g. an MBE-apparatus,

[0037] A feed through means **45** is arranged on the outside of the first end **47** of the vacuum vessel **19**. At least a part of the electric power needed in the apparatus **1** is led via this feed through **45**.

[0038] The feed through means **45** itself is arranged through the first end **47** of the vacuum vessel **19**. On the inside of said first end **47** the feed through **45** is connected to two metal rods **49** and **51** which are arranged in such a way, that they touch the outside of the first end part **11** of the source material container **3** when the container **3** and the vacuum vessel **19** are arranged in working position.

[0039] Two substantially concentric metal circles **53** and **55** are arranged on the outside of the first end part **11** of the source material container **3**. As shown in the FIGURE, the inner metal circle **53** is arranged in galvanic contact with metal rod **49** and the outer metal circle **55** is arranged in galvanic contact with metal rod **51** when the container **3** and the vacuum vessel **19** are arranged in working position. The metal circles **53** and **55** are arranged in galvanic contact with the electrical heating means **15**. The electric current is arranged to be led from the feed through means **45** to the heating means **15** through the vacuum zone **21** via the metal rods **49** and **51** and the metal circles **53** and **55**. In the embodiment of **FIG. 1** the inner metal circle **53** is arranged a first distance away from the middle point of the circular first end part **11** of the source material container **3**, i.e. from the longitudinal axis A of the apparatus **1**. The axis A is shown with a broken line. The outer metal circle **55** is arranged concentrically as a band around the inner circle **53**, a second distance away from the longitudinal axis A. Thus, the circles **53** and **55** are both shown as two different parts in the cross-sectional view of **FIG. 1**. The inner metal rod **49** is arranged a substantially same first distance away from the axis A as the inner metal ring **53**. The outer metal rod **51** is arranged a substantially same second distance away from the axis A as the outer metal ring **55**. With this arrangement the electrical circuit from the feed through means **45** to the electric heater **15** is established regardless of the positioning of the vacuum vessel **19** around the axis A.

[0040] When using the cracker apparatus of **FIG. 1** solid source material to be cracked, e.g. arsenic, is present in the source material container **3**. The source material is evaporated by heating the container **3** with the resistive heater **15** to a suitable temperature. With arsenic the suitable temperature is around 350° C. so that a suitable flux of gaseous $As_4$ is generated in the source material container **3**. The gaseous source material flows through outlet opening **29** of the source material container into dispenser means **5**. The amount of gas flowing through the dispenser means **5** is controlled with the needle valve means **35** of the dispenser means **5**. The dispenser means **5** and especially its valve means **35** are kept at a temperature somewhat higher than the temperature maintained in the source material container **3** to ensure that no crystallization of solid material takes place in the valve means. Solid source material in the valve means **35** could cause malfunction of the valve means **35** by blocking of the narrow ducts through which the gaseous source material is to be led. From the dispenser means **5** the gaseous source material flows through tube **37** to the actual cracker means part **7** of the apparatus. The tube **37** and the gas in the tube are heated with resistive heater **41** to such an extent, that source material gas is cracked into smaller molecules, e.g. $As_4$ is cracked into $As_2$. The product gas is then led out of the apparatus **1**.

[0041] Controlling temperatures, pressures, gas flows etc. in a cracker apparatus of the kind shown in **FIG. 1** is well known as such, and therefore not discussed any further in this text:

[0042] The source material container **3** according to the invention has to be detached from the dispenser means **5** for various reasons, for example when the amount of solid

source material in the source material container **3** has reached a minimum value for the cracking process to work properly. Prior detaching the container **3** of **FIG. 1** the process has to be stopped, i.e. electric power to the heating means **15** of the source material container is cut. After the apparatus **1** or at least the container **3** has cooled down to a suitable temperature for it to be handled, the vacuum vessel **19** is detached from the dispenser means **5**. This leaves the source material container **3** and the electrical resistive heating means **15** around it visible. It is now possible to either remove the heating means **15** separately or to detach it at the same time with the source material container **3**. The container **3** is detached by opening the bolts **27**. Now the container can be replaced with a new one, or it could be emptied, cleaned or refilled and reassembled.

[**0043**] The mounting of the container is done by fitting the flanges **23** and **25** suitably together and then tightening the bolts **27**. Then if the electrical heating means **15** was not already present on the container **3**, it is mounted on the container **3**. Now the vacuum vessel **19** can be installed on the container **3** by setting the flanges **31** and **33** together and attaching them together with suitable connecting means, such as bolts or some quick coupling means (not shown in the FIGURE). When the vacuum vessel **19** is mounted on the source material container **3** the galvanic connection of metal rods **49** and **51** with metal rings **53** and **55** is formed automatically, as described above.

[**0044**] The descriptions above and the accompanying drawings should be interpreted in an illustrative and not in a limited sense. While the invention has been disclosed in connection with the preferred embodiment or embodiments thereof, it should be understood that there may be other embodiments which fall within the spirit and scope of the invention as defined by the following claims. For example structural details, such as the size and form of metal rods **49** and **51** and rings **53** and **55**, can be varied. Although the invention is illustrated in the FIGURES as an on-axis cracking apparatus it can be constructed as an off-axis apparatus as well,

What is claimed is:

**1**. Cracker apparatus, comprising

a) a container for providing at least one gaseous crackable source material, which source material container is formed as a mainly cylindrical vessel having a closed first end part, an at least substantially open second end part and a mainly cylindrical mantle part between said end parts, said open second end part forming an outlet opening through which said gaseous crackable source material is arranged to flow out from said container,

b) dispenser means for receiving said gaseous crackable source material from said container, said dispenser means comprising dispenser valve means for controlling the flow of said gaseous crackable source material through said dispenser means;

c) cracker means for receiving said at least one gaseous crackable source material from said dispenser means;

whereby said second end part of the source material container is arranged to be detachably coupled to said dispenser means, and the supply of new source material into the source material container is arranged trough said outlet opening when said container is detached from the dispenser means.

**2**. The cracker apparatus of claim 1 wherein the interior of the source material container is reachable only through said outlet opening.

**3**. The cracker apparatus of claim 1 wherein the area of said outlet opening covers substantially the whole cross-sectional area of said second end part.

**4**. The cracker apparatus of claim 1 wherein an electrical heating means is arranged around at least a substantial part of the source material container.

**5**. The cracker apparatus of claim 4 wherein a vacuum vessel means is arranged detachably around the source material container and around the electrical heating means whereby a vacuum zone is formed around at least a substantial part of the source material container.

**6**. The cracker apparatus of claim 5 wherein the electrical heating means is arranged detachably around at least a substantial part of the source material container.

**7**. The cracker apparatus of claim 6 comprising

at least two substantially concentric metal circles arranged on the outside of the first end part of the source material container, the metal circles arranged in galvanic contact with the electrical heating means, and

at least two metal rods arranged on the inside of the vacuum vessel means, said metal rods being arranged into galvanic contact with said metal circles when the vacuum vessel means is attached hermetically around the source material container, whereby electrical power for the electrical heating means is arranged from outside of the vacuum vessel means via said metal rods and said metal circles.

**8**. The cracker apparatus of claim 1 wherein crackable source material is arsenic.

**9**. A cracker source material container for providing at least one gaseous crackable source material for a cracker means, which source material container is formed as a mainly cylindrical vessel having a closed first end part, an at least substantially open second end part and a mainly cylindrical mantle part between said end parts, said open second end part forming an outlet opening through which said gaseous crackable source material is arranged to flow out from said container into said cracker means, which said second end part of the source material container is arranged to be detachably coupled to said cracker means, and the supply of new source material into the source material container is arranged through said outlet opening when said container is detached from said cracker means.

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