

SYSTEM, APPARATUS AND METHOD FOR VACUUM BASED REGULATION OF COMPONENT FLOW AND SINGULATION

5 Technical Field

The present disclosure relates generally to vacuum based systems, assemblies, devices, and methods for regulating the flow or motion of objects or components (e.g., semiconductor components) and/or separating objects or components that are displaced, transported, or delivered along a feeder track. More particularly, the present disclosure
10 relates to systems, assemblies, devices, and methods that provide at least one, and in some embodiments multiple separate or independent vacuum elements, chambers, or regions directed to periodically or intermittently applying vacuum forces that slows or stop the flow of components along the feeder track. In certain embodiments, such vacuum elements, chambers, or regions can be selectively or independently configurable.

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Background

It is often necessary to separate or singulate serially adjacent or sequentially arranged components in feeder tracks (such as quad flat packs with no leads (QFN)), prior to performing particular processes such as component testing or inspection.

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Various types of components can be transferred from a bulk or mass component source to a component destination using component feeder tracks. Typically, multiple components are transported serially (e.g., in a row) along a feeder track from a component inlet towards a component outlet. Each of these components is subsequently offloaded, output,
25 or ejected from the feeder track (e.g. singly or in a singular manner) to a component reception station. In general, a component located at the component reception station is transferred to a processing station (e.g., for testing, inspecting, sorting, or mounting). The semiconductor parlance for this process is known as “singulation”. The transfer of the component to the processing station is typically facilitated by a pick and place
30 mechanism.

Conventionally, to singulate a first component most recently transferred to and disposed on the component reception station the component needs to be isolated from the other components lined up within the feeder track (e.g., including a terminal component within the feeder track nearest to the feeder track outlet and subsequent components serially aligned within the feeder track) such that the component on the component reception station can be transferred to an appropriate processing station. Accordingly, an offloading of the first component from the feeder track's component terminal outlet of the feeder track to the component reception station must be accompanied by preventing the simultaneous or uninterrupted offloading, outputting, or ejection of subsequent components carried by the feeder track to or toward the component reception station until after the first component has been removed from the component reception station to the processing station and the component reception station has returned to the terminal outlet of the feeder track. To provide time for the component reception station to return to the terminal outlet of the feeder track, further movement or flow of components along the feeder track needs and has to be periodically disrupted, interrupted, or stopped. After the component has been removed from the component reception station and the component reception station has returned to the feeder track terminal outlet, component flow along the feeder track would be resumed so that a next component (i.e. the terminal component) can be transferred or offloaded from the feeder track to the component reception station.

There exist various systems, methods, and techniques directed to stopping the movement of components along a feeder track and/or preventing the output, discharge, or offloading of components from the terminal outlet of the feeder track to or toward the component reception station.

Some conventional systems deploy a mechanical stopping mechanism (a holder) that is used physically to halt the motion of a terminal component (i.e. the last component located at the terminal end of the feeder track component outlet) by applying mechanical force to that terminal component after the earlier terminal component has been offloaded, to await the return of the component receiving station after the component has been removed to the component processing station. The mechanical stopping mechanism acts

to stop not just the terminal component from being offloaded but also halts or effectuate a separation or the displacement or flow of the series of components already lined along the feeder track, towards the feeder track terminal outlet.

- 5 International patent application WO 2008/148866 describes the use of a movable mechanical stop element at an end of an electronic component feeder track for stopping the motion of electronic components traveling along a feeder track. In addition, Japanese patent application JP 200621928 discloses the use of a mechanical stopping mechanism for facilitating the separation of semiconductor components transported along a feeder
10 track. Units Per Hour (UPH) in such machines can typically reach 20000 to 30000 components per hour.

Japanese patent application JP 2006298578 discloses a feeder track that uses vacuum and air curtain simultaneously to achieve singulation. JP 2006298578 describes the use of a
15 cavity configured to alternately apply a uniform vacuum force or a uniform positive air pressure to the three terminal components along a feeder track (e.g., as shown in FIGs. 3a – 3c of JP 2006298578). The applied vacuum force applied to the three terminal components is directed to stopping component flow, and the positive pressure applied to the three terminal components is directed to restarting component flow.

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However, in JP 2006298578, the applied vacuum force cannot reliably stop component flow. This weakness would be aggravated more particularly, in situations in which fewer than three terminal components are present near the feeder track's component outlet. In such a case, vacuum leakage results in a significant decrease in the magnitude of the
25 vacuum force applied to the terminal component(s), thereby failing to stop component flow along the feeder track as intended.

Further, positive air pressure is provided to continuously move components from the mass component source into the feeder track. These components traveling at very high
30 speed will collide onto the rear end of the components that are already lined up near the terminal end of the feeder track and this continuous and repetitious impact will cause the

lined up components to inch forward or towards the terminal outlet of the feeder track. Over time, these continuous collisions will cause unintended offloading of the terminal components.

- 5 In order to successfully stop component flow, JP 2006298578 teaches the use of an air curtain mechanism that is disposed between the feeder track's component outlet and a component reception station. The air curtain mechanism is configured to generate an air curtain or stream by applying a positive air pressure through a channel or gap that separates the terminal end of the feeder track and the component reception station.

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- When a given component has been offloaded or transferred from the feeder track's component outlet to the component reception station, (a) vacuum force is applied to the feeder track cavity; and (b) while the air curtain mechanism would at the same time direct the air curtain between the feeder track outlet and the component reception station, in a direction perpendicular to the direction of component flow. The air curtain creates a positive air pressure adjacent to the feeder track outlet, within the gap between the feeder track outlet and the component reception station. As long as the positive air pressure provided by the air curtain is sufficiently strong, the terminal feeder track component that remains in motion as a result of inadequate vacuum force (e.g., due to vacuum leakage) will be unable to penetrate or breach the air curtain. The terminal component thus can remain within the feeder track while a component on the component reception station is transferred to a processing station.
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- After the component reception station is ready to receive a next component, (a) the application of the air curtain between the feeder track outlet and the component reception station is discontinued; (b) the application of the vacuum force to the feeder track chamber is discontinued; and (c) a positive air pressure is applied to the feeder track chamber, thereby enabling component flow along the feeder track and the transfer of another component from the feeder track outlet to the component reception station.
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However, existing systems are proving inadequate to deal with changes to the electronic components brought on as a result of technological advances in the semiconductor and electronics industry. Increasingly, the sizes of various types of semiconductor components are getting significantly smaller and thinner. This is to cater to the demand for increasingly compact electronic devices. Due to the significantly smaller sizes of many semiconductor components, the application of mechanical force by a fast moving conventional mechanical stopper to halt the displacement of semiconductor components along a feeder track can adversely affect the structural integrity of the semiconductor components and/or packages that carry such components.

In addition, technological developments and advances in the semiconductor and electronics industry have also resulted in semiconductor and electronic components containing increasingly complex internal structures, for instance, micro-electromechanical systems (MEMs). The complex internal structures of certain types of modern semiconductor devices can be easily damaged or undesirably altered by externally applied mechanical forces. It has been found that the application of mechanical force by a mechanical stopper in order to stop the displacement of semiconductor packages along a feeder track can damage or adversely affect the electrical and structural integrity of the components resulting in functional reliability issues for, or device failure of, the components.

Lastly, the use of positive air jet to move electronic components quickly along the feeder track in conventional systems also contributes to failure of such small and complex electronic components. Air-jets are used to increase UPH in such machines, sometimes reaching 25000 to 30000 units per hour. The components in the feeder track move extremely fast. The impact of such very fast moving electronic component colliding on other electronic components lined up serially near the terminal end of the feeder track has a similar effect to that resulting from a force applied by a mechanical stopper, which can cause reliability and operation issues in such devices. In some cases, such collision impact will result in failure of the components being processed.

It is apparent that conventional systems that use mechanical stopper devices would prove inadequate when handling smaller and more fragile electronic components and those which contain MEMs.

- 5 Unfortunately, the system disclosed by JP 2006298578 is undesirably complex, and exhibits undesirable limitations with respect to enhancing, optimizing, or maximizing a component separation rate. JP 2006298578 has a weakness in that the activation of the strong air-curtain exerts a mechanical force that causes ‘tapping’ of the terminal component against the roof of the feeder track. As explained, the effect of such
10 mechanical impact force may affect the structural and functional integrity of electronic components.

It is also apparent that none of the conventional systems deals with the problem of the collision impact brought on by the air-jetted fast moving electronic components on the
15 already stationary components lined up at the terminal end of the feeder track.

To deal with the introduction of increasingly small, fragile and complex electronic components, a new system and method for handling such components for singulation without damaging them has to be devised. The system and method must reduce or
20 minimize impact forces or obviate the use of impact forces on the electronic components being processed.

Accordingly, there is a need for improved manners of stopping the displacement of components along a feeder track and/or preventing the offload of components from the
25 feeder track to a component reception station. Particularly, there is a need for structurally simple systems, devices, and techniques that are capable of reliably stopping the displacement semiconductor components or packages transferred or transported along a feeder track in a manner that avoids damage or undesirable structural alteration to semiconductor components or packages, and which enhances, optimizes, or maximizes a
30 component separation rate.

Summary

Embodiments of the present disclosure provide structurally simple systems, devices, and techniques that are capable of (i) slowing down components carried by a feeder track as the components approach and/or reside near a feeder track component outlet, thereby
5 reducing the collision impact(s) on slower moving or stationary components along the feeder track; (ii) stopping a current leading or terminal component on the feeder track after a previous or earlier terminal component has been output by or offloaded from the feeder track, without the use of any mechanical force, in a manner that avoids damaging or undermining the structural and/or functional integrity of the current leading or terminal
10 component; and (iii) enhancing, optimizing, or maximizing a component separation rate.

In an embodiment, a vacuum based system for separating components includes a component delivery unit having a feeder track configured to carry components between a component inlet and a component outlet; and a component reception stage configured to
15 receive components from the feeder track. The component delivery unit can be fluidly coupled to a source of positive air or gas pressure, which can apply a positive air or gas pressure or flow to portions of the feeder track. The positive air or gas pressure or flow can exert a displacement force upon components carried by the feeder track, thereby facilitating or enabling the displacement or translation of components along the feeder
20 track from the component inlet to the component outlet.

The component delivery unit includes a vacuum assembly that is coupled to a vacuum source. The vacuum assembly is configured to periodically or intermittently apply vacuum pressure(s) or force(s) at a set of feeder track sites to periodically or
25 intermittently stop the motion of a leading feeder track component (i.e. the terminal or last component positioned at the terminal end of the feeder track) that is closest to the component outlet, and to at least decelerate the motion of other components (e.g., components trailing behind the leading component) carried by the feeder track, thereby preventing undesired or uncontrolled component output from the feeder track unless the
30 component reception stage is appropriately positioned relative to the feeder track and ready to receive a next component.

Vacuum pressures can be applied by way of vacuum elements disposed relative to distinct feeder track sites. In some embodiments, vacuum pressures can be applied to particular vacuum elements in an independent and/or configurable manner relative to other vacuum elements. In specific embodiments, one or more vacuum elements can be configured for selective fluid communication with the feeder track. Particular vacuum elements can be selectively activated (e.g., alone or in combination) to test whether a given vacuum element configuration can reliably and rapidly stop the motion of a leading component carried by the feeder track, such that output of the leading component from the feeder track is avoided unless the component reception stage is appropriately positioned and ready to receive another component.

The application of the positive air pressure or gas pressure or flow to the feeder track can occur in a continuous, generally continuous, or uninterrupted manner during component singulation operations, resulting in a continuous, generally continuous, or uninterrupted application of displacement force(s) upon components carried by the feeder track. One or more vacuum pressures can be periodically or intermittently applied while the positive air pressure or gas pressure or flow occurs (e.g., during continued or uninterrupted delivery of the positive air pressure or gas pressure or flow to the feeder track). Such vacuum pressures counter the displacement force(s) upon components carried by the feeder track, thereby periodically or intermittently stopping and/or decelerating component motion along the feeder track in a reliable manner, regardless of whether the feeder track carries one component or multiple components. In several embodiments, the prevention of unwanted or undesirable component output from the feeder track occurs solely in response to applied vacuum force(s), which counter the component displacement force(s) resulting from the positive air pressure or flow. Such embodiments avoid a need to modify or modulate the positive air pressure or flow or component displacement force(s), and further avoid a need to provide any type of air curtain between components or between the component delivery unit and the component reception stage based upon the timing of the applied vacuum forces. Embodiments of the present disclosure can thus

provide a simplified, more reliable singulation apparatus design, which can achieve higher component throughput than prior designs.

In accordance with an aspects of the disclosure, an apparatus for at least one of regulating
5 a flow of components and separating components includes a component delivery unit
having at least one feeder track configured to carry a series of components serially
displaceable along the at least one feeder track from a component inlet of the at least one
feeder track toward a component outlet of the at least one feeder track; and at least one
vacuum assembly fluidly couplable to at least two distinct sites on the at least one feeder
10 track and configured to apply a set of vacuum forces to the at least two distinct sites.
Such an apparatus can further include a component reception stage configured to receive
at least one component within a series of components offloaded from the component
outlet, where the component reception stage includes a receptacle suitably shaped to
receive at least one component.

15 In certain embodiments, the component delivery unit includes at least two feeder tracks
arranged in parallel. Additionally, the component reception stage include at least two
distinct component receptacles, each of the at least two distinct component receptacles
suitably shaped to receive at least one component. Moreover, the at least one vacuum
20 assembly can include at least two distinct vacuum assemblies, where each of the at least
two distinct vacuum assemblies is fluidly couplable to at least two distinct sites on each
of a corresponding feeder track.

The at least one vacuum assembly is configured to apply a first vacuum force at a first set
25 of feeder track sites of the at least one feeder track and a second vacuum force at a second
set of feeder track sites of the at least one feeder track. The at least one vacuum assembly
can be configured to selectively establish the magnitude of at least one of the first
vacuum force and the second vacuum force.

30 The at least one vacuum assembly includes a plurality of vacuum elements, each vacuum
element within the plurality of vacuum elements configured for selective fluid

communication with the feeder track. In multiple embodiments, the at least one vacuum assembly includes a first set of vacuum elements and a second set of vacuum elements distinct from the first set of vacuum elements. The first set of vacuum elements includes include a first set of vacuum openings exposed to the feeder track and the second set of vacuum elements includes a second set of vacuum openings exposed to the feeder track, where the first set of vacuum openings can be positioned closer to the component outlet than the second set of vacuum openings.

The first set of vacuum openings is configured to distribute a first vacuum force across a first number of components and the second set of vacuum openings is configured to distribute a second vacuum force across a second number of components. A first ratio defined by a magnitude of the first vacuum force to the first number of components can be different than a second ratio defined by a magnitude of the second vacuum force to the second number of components. Depending upon embodiment details, the first ratio can be greater than, equal to, or less than the second ratio.

The first set of vacuum openings can be configured to accommodate a first number of components and the second set of vacuum openings is configured to accommodate a second number of components, where the first and second numbers of components can be identical or different (e.g., the first number of components can be greater than or less than the second number of components). In certain embodiments, the first number of components equals one.

The first set of vacuum openings can be coupled to the at least one feeder track by a set of vacuum pathways disposed at an angle relative to the at least one feeder track. The apparatus can further include a set of air passages configured to provide a positive air or gas pressure flow to portions of the at least one feeder track in order to exert a displacement force upon components carried by the at least one feeder track. In some embodiments, the air passages are disposed at an angle relative to the at least one feeder track.

The first set of vacuum openings and the set of air passages are configured to enable a progressive displacement of the series of components along the at least one feeder track in a synchronous manner with respect to a cyclical application of the set of vacuum forces to the at least two distinct sites on the at least one feeder track.

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The first set of vacuum openings is configured to apply a vacuum force to at least one component in a manner that is sufficient to stop displacement of at least one component along the at least one feeder track. For instance, the first set of vacuum openings can be configured to apply a vacuum force to a leading component closest to the component outlet in a manner that is sufficient to stop displacement of the leading component.

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In several embodiments, the first set of vacuum openings includes a leading vacuum opening and a trailing vacuum opening. In some embodiments, the first set of vacuum openings includes a plurality of vacuum openings having different cross sectional areas.

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For instance, a leading vacuum opening can have a larger cross sectional area than a trailing vacuum opening. The first set of vacuum openings can include a vacuum opening having a different cross sectional area than a vacuum opening within the second set of vacuum openings. Additionally or alternatively, the first set of vacuum openings can provide a first aggregate cross sectional vacuum opening area and the second set of vacuum openings that provides a second aggregate cross sectional vacuum opening area that is distinct from the first aggregate cross sectional area. Moreover, the first set of vacuum openings can include a plurality of vacuum openings having different cross sectional areas and the second set of vacuum openings includes a plurality of vacuum openings having different cross sectional areas.

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The component delivery unit can carry or include a vacuum chamber fluidly coupled to one of the first set of vacuum openings and the second set of vacuum openings. In certain embodiments, the component delivery unit includes a first vacuum chamber fluidly coupled to the first set of vacuum openings and a second vacuum chamber fluidly coupled to the second set of vacuum openings.

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An apparatus in accordance with the present disclosure can further include a pressurized gas supply unit fluidly coupled to the component delivery unit and configured to provide a positive gas pressure to the component delivery unit to exert a displacement force upon the series of components, the displacement force sufficient to displace the series of components toward the component outlet. The pressurized gas supply unit can be configured to provide the positive gas pressure at one of a substantially constant flow rate and a substantially constant pressure. The at least one vacuum assembly is configured to apply the set of vacuum forces in an intermittent manner relative to the positive gas pressure, where the set of vacuum forces includes at least one vacuum force that is sufficient to intermittently stop displacement of a leading component closest to the component outlet. In multiple embodiments, the at least one vacuum assembly is configured to apply the set of vacuum forces during substantially uninterrupted application of the positive gas pressure to the component delivery unit.

A system in accordance with an aspect of the disclosure includes a component delivery unit having at least one feeder track having a component inlet and a component outlet, the at least one feeder track configured to carry a series of components displaceable along the at least one feeder track; a pressurized gas supply unit fluidly coupled to the component delivery unit and configured to supply a flow of pressurized gas that exerts a substantially constant displacement force upon the series of components along the at least one feeder track, the displacement force directed toward the component outlet; a component reception stage configured to receive a first component within the series of components from the at least one feeder track, the component reception stage including a set of sensors configured to detect receipt of the first component by the component reception stage; and a vacuum assembly fluidly coupled to the component delivery unit and configured to intermittently apply with respect to the flow of pressurized gas a set of vacuum forces at a set of feeder track sites, the set of vacuum forces sufficient to prevent output of a second component within the series of components from the component outlet. The application of the set of vacuum forces can be initiated upon detection of the receipt of the first component by the component reception stage.

In some embodiments, at least a portion of the vacuum assembly is carried internal to the component delivery unit. A vacuum assembly in accordance with the present disclosure can include at least one vacuum chamber fluidly coupled to the feeder track by way of a set of vacuum openings.

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The vacuum assembly can include a first set of vacuum elements configured to apply a first vacuum force to a first set of feeder track sites and a second set of vacuum elements configured to apply a second vacuum force to a second set of feeder track sites that is distinct from the first set of feeder track sites. Each of the first vacuum force and the
10 second vacuum force opposes the displacement force exerted upon the components. The vacuum assembly can be configured to selectively establish the magnitude of the first vacuum force relative to the magnitude of the second vacuum force.

In accordance with an aspect of the disclosure, a process for at least one of regulating
15 component flow and separating components includes providing a component delivery unit having at least one feeder track configured to displace components from a component inlet toward a component outlet; providing a series of components to the at least one feeder track, the series of components including a first component and a second component that serially succeeds the first component; displacing the series of
20 components along the at least one feeder track toward the component outlet; and applying a set of vacuum forces to at least two distinct feeder track sites of the at least one feeder track to prevent output of the second component within the series of components from the component outlet.

25 The series of components can include a third component that serially succeeds the second component, and the process can further include adjusting at least one vacuum force within the set of vacuum forces to enable output of the second component within the series of components from the component outlet; and further adjusting the at least one vacuum force within the set of vacuum forces to prevent output of the third component
30 within the series of components from the component outlet after the second component has been at least partially output from the component outlet.

A process in accordance with an embodiment of the disclosure can also include providing a component reception stage configured to receive at least one component within the series of components offloaded from the component outlet. The component reception stage includes at least one receptacle or receiving structure suitably shaped to receive at least one component. The process can further include providing at least one vacuum assembly configured for applying the set of vacuum forces, where the at least one vacuum assembly is fluidly couplable to the at least two distinct sites of the at least one feeder track.

The component delivery unit can include at least one feeder track, and in some embodiments includes at least two feeder tracks arranged in parallel. In particular embodiments, the process can include providing at least two distinct vacuum assemblies configured for applying the set of vacuum forces, wherein the at least two distinct vacuum assemblies are fluidly couplable to the at least two distinct sites on each of a corresponding feeder track. In association with such a process, a component reception stage can include at least two distinct component receptacles, each of the at least two distinct component receptacles suitably shaped to receive at least one component.

Applying the set of vacuum forces to at least two distinct feeder track sites can include selectively establishing at least one of a magnitude of a first vacuum force at a first feeder track site and a magnitude of a second vacuum force at a second feeder track site distinct from the first feeder track site. The first vacuum force can be identical to or different from the magnitude of the second vacuum force.

A process in accordance with the present disclosure can include providing a plurality of vacuum elements fluidly couplable to the at least one feeder track, and wherein applying the set of vacuum forces to the at least two distinct feeder track sites comprises selectively establishing fluid communication between the at least one feeder track and particular vacuum elements within the plurality of vacuum elements. For instance, a process can include providing a first set of vacuum elements fluidly couplable to the at

least one feeder track and a second set of vacuum elements fluidly couplable to the at least one feeder track, the first set of vacuum elements distinct from the second set of vacuum elements. The first set of vacuum elements includes a first set of vacuum openings exposed to the at least one feeder track and the second set of vacuum elements
5 includes a second set of vacuum openings exposed to the at least one feeder track.

Applying a set of vacuum forces to at least two distinct feeder track sites can include distributing a first vacuum force across a first number of components using the first set of vacuum openings and distributing a second vacuum force across a second number of
10 components using the second set of vacuum openings. A first ratio defined by a magnitude of the first vacuum force to the first number of components can be identical to or different than (e.g., greater than or less than) a second ratio defined by a magnitude of the second vacuum force to the second number of components.

15 The first set of vacuum openings can be coupled to the at least one feeder track by way of a set of vacuum passages configured or disposed at an angle relative to the at least one feeder track. A process in accordance with the present disclosure can further include providing a set of air passages disposed at an angle relative to the at least one feeder track. Displacing the series of components along the at least one feeder track toward the
20 component outlet includes synchronizing a progressive displacement of serially disposed components along the feeder track toward the component outlet using the first set of vacuum openings and the set of air passages. Synchronizing the progressive displacement of serially disposed components along the feeder track includes cyclically adjusting at least one vacuum force within the set of vacuum forces. In multiple
25 embodiments, synchronizing the progressive displacement of serially disposed components along the feeder track comprises cyclically adjusting at least one vacuum force within the set of vacuum forces while providing at least one positive air pressure to the feeder track by way of the set of air passages, wherein the at least one positive air pressure exerts a substantially constant displacement force upon the series of
30 components.

The first set of vacuum openings can be positioned closer to the component outlet than the second set of vacuum openings. The first set of vacuum openings can be configured to accommodate a first number of components, and the second set of vacuum openings can be configured to accommodate a second number of components, where the first and second numbers of components can be identical or different (e.g., the first number of components can be less than or greater than the second number of components). In some embodiments, the first number of components equals one.

Applying a set of vacuum forces to at least two distinct feeder track sites can include establishing fluid communication between the feeder track and at least one of the first set of vacuum openings and the second set of vacuum openings. In several embodiments, at least one of the first set of vacuum openings and the second set of vacuum openings is coupled to a vacuum chamber carried by the component delivery unit.

A process in accordance with the present disclosure can further include providing a positive gas pressure to the at least one feeder track to exert a displacement force upon the series of components, the displacement force sufficient to displace the series of components toward the component outlet. The positive gas pressure can be provided at one of a substantially constant flow rate and a substantially constant pressure. Applying a set of vacuum forces to at least two distinct feeder track sites includes applying the set of vacuum forces in an intermittent manner relative to the positive gas pressure. For instance, applying a set of vacuum forces to at least two distinct feeder track sites can include applying the set of vacuum forces during an uninterrupted provision of the positive gas pressure to the feeder track.

In accordance with an aspect of the disclosure, a process for at least one of regulating component flow and separating components includes providing a component delivery unit having at least one feeder track configured to displace components from a component inlet toward a component outlet; providing a series of components to the component delivery unit, the series of components including a first component and a second component that serially succeeds the first component; providing a substantially

uninterrupted positive gas flow that exerts a displacement force upon the series of components to displace the series of components along the feeder track toward the component outlet; outputting the first component within the series of components from the component outlet; applying a set of vacuum forces to a set of feeder track sites; and
5 stopping displacement of the second component along the at least one feeder track solely as a result of applying the set of vacuum forces.

In accordance with an aspect of the disclosure, a process for at least one of regulating component flow and separating components includes providing a component delivery
10 unit having at least one feeder track and a selectable configuration of vacuum elements fluidly couplable to the at least one feeder track, the at least one feeder track configured to serially displace components from a component inlet toward a component outlet; establishing a first vacuum element configuration that defines a first set of vacuum elements fluidly coupled to the at least one feeder track at a first set of feeder track sites;
15 displacing a plurality of components along the at least one feeder track toward the component outlet; outputting a leading component from the component outlet while displacing the plurality of components along the at least one feeder track; applying a vacuum force to the first vacuum element configuration after the outputting of at least a portion of the leading component from the component outlet; and determining whether
20 the first vacuum element configuration prevents output of another component from the component outlet during applying the vacuum force to the first vacuum element configuration.

Such a process can further include providing a component reception stage configured to
25 receive a component from the component outlet; and offloading the first component within the series of components from the component outlet to the component reception stage. The component reception stage includes a receptacle suitably shaped to receive at least one component.

30 In certain embodiments, the component delivery unit includes at least two feeder tracks arranged in parallel. The at least one vacuum assembly comprises at least two distinct

vacuum assemblies, each of the at least two distinct vacuum assemblies fluidly couplable to the at least two distinct sites on each of a corresponding feeder track. The component reception stage can include at least two distinct component receptacles, each of the at least two distinct component receptacles suitably shaped to receive at least one component.

A process in accordance with the present disclosure can additionally include establishing a second vacuum element configuration that defines a second set of vacuum elements fluidly coupled to the at least one feeder track at a second set of feeder track sites, the second set of feeder track sites distinct from the first set of feeder track sites; displacing a plurality of components along the at least one feeder track toward the component outlet; outputting a component from the component outlet while displacing the plurality of components along the at least one feeder track; applying a vacuum force to the second vacuum element configuration after outputting the component from the component outlet; and determining whether the second vacuum element configuration prevents output of another component from the component outlet during applying the vacuum force to the second vacuum element configuration. The second set of feeder track sites can include a larger or smaller number of feeder track sites than the first set of feeder track sites.

In accordance with an aspect of the disclosure, a process for at least one of regulating component flow and separating components includes providing a component delivery unit having at least one feeder track and a selectable plurality of vacuum openings fluidly couplable to distinct positions of the at least one feeder track, the at least one feeder track configured to displace components from a component inlet toward a component outlet; displacing a plurality of components along the at least one feeder track toward the component outlet; cyclically applying a first set of vacuum forces to a first set of vacuum openings fluidly coupled to the at least one feeder track; outputting a component evaluation set from the component outlet as a result of alternatively transitioning between displacing the plurality of components along the at least one feeder track and cyclically applying the set of vacuum forces to the first set of vacuum openings, the component evaluation set including at least one component; determining at least one damage

measure corresponding to the component evaluation set, the at least one damage measure providing an indication of one of component structural damage and component functional damage; and establishing at least one of a second set of vacuum openings distinct from the first set of vacuum openings and a second set of vacuum forces distinct from the first set of vacuum forces based upon the at least one damage measure. Outputting the component evaluation set can include serially outputting individual components from the component outlet in a manner that prevents component output from the component outlet when the first set of vacuum forces is applied to the first set of vacuum openings.

10 In accordance with an aspect of the disclosure, a process for at least one of regulating component flow and separating components includes providing a component delivery unit having at least one feeder track fluidly couplable to a source of positive gas pressure and a selectable configuration of vacuum elements fluidly couplable to the at least one feeder track, the at least one feeder track configured to displace components from a component inlet toward a component outlet; applying a positive gas pressure to the at least one feeder track; exerting a displacement force upon a plurality of components carried by the at least one feeder track by way of the positive gas pressure; displacing the plurality of components along the at least one feeder track toward the component outlet; and determining a configuration of vacuum elements that counters the displacement force to prevent component output by the component outlet during a vacuum application interval. The configuration of vacuum elements can be a smallest configuration of vacuum elements that counters the displacement force. Additionally, applying the positive gas pressure can include applying a substantially constant gas pressure.

25 In accordance with an aspect of the disclosure, a system for separating components includes a component delivery unit having (a) at least one feeder track configured to carry a series of components displaceable along the at least one feeder track from a component inlet to a component outlet; and (b) a set of receiving elements; and a component reception stage having (a) a receiving structure configured to receive a component within the series of components output from the component outlet; and (b) a

set of engagement elements configured to matingly engage with the component delivery unit's set of receiving elements.

5 In some embodiments, the set of engagement elements includes a set of protruding members that extends away from the receiving structure toward the component delivery unit, and the set of receiving elements includes a set of recesses formed in the component delivery unit configured to receive the set of protruding members. The set of engagement elements can be configured to provide a bridge member between the component delivery unit and the receiving structure when the set of engagement elements and the set of
10 receiving elements exist in a partially engaged state. The bridge member is configured to support a component that is at least partially disposed between the component delivery unit and the component reception stage. In certain embodiments, at least one of the bridge member and the receiving structure is tapered to facilitate mating engagement to accommodate a positional error between the component delivery unit and the component
15 reception stage. The component reception stage is configured for displacement between a component reception position and a component dispatch position, and the bridge member and the receiving structure can be configured for least partial engagement when the component reception stage is located at the component dispatch position.

20 In accordance with an aspect of the disclosure, a process for separating components includes providing a component delivery unit that includes at least one feeder track and a set of receiving elements, the at least one feeder track configured to displace a series of components along the at least one feeder track from a component inlet to a component outlet; providing a component reception stage that includes a receiving structure and a set
25 of engagement elements, the receiving structure configured to receive a component within the series of components from the component outlet, the set of engagement elements configured to matingly engage with the set of receiving elements, the set of engagement elements configured to provide a bridge member between the component delivery unit and the component reception stage when the set of engagement elements and the set of receiving elements exist in a partially engaged state; outputting a
30 component from the component outlet to the component reception stage when the set of

engagement elements and the set of receiving elements exist in the partially engaged state; and supporting by way of the bridge member the component output from the component outlet.

5 **Brief Description of the Drawings**

Embodiments of the present disclosure are described hereinafter with reference to the drawings, in which:

FIG. 1 is a block diagram illustrating a representative component separation, singulation,
10 or isolation system 1 according to an embodiment of the disclosure.

FIG. 2A is a schematic side view illustrating portions of a component separation, singulation, or isolation apparatus according to an embodiment of the disclosure.

15 FIG. 2B is a plan view of an embodiment of the component separation apparatus corresponding to FIG. 2A.

FIG. 2C is a schematic side view illustrating portions of a component separation, singulation, or isolation apparatus according to another embodiment of the disclosure.

20 FIG. 2D is a plan view of an embodiment of the component separation apparatus corresponding to FIG. 2C.

FIG. 2E is a schematic side view illustrating portions of a component separation, singulation, or isolation apparatus according to yet another embodiment of the disclosure.

25 FIG. 2F is a plan view of an embodiment of the component separation apparatus corresponding to FIG. 2F.

30 FIG. 2G is a schematic side view illustrating portions of a component separation, singulation, or isolation apparatus according to a further embodiment of the disclosure.

FIG. 2H is a plan view of an embodiment of the component separation apparatus corresponding to FIG. 2G.

- 5 FIG. 2I is a schematic side view illustrating portions of a component separation, singulation, or isolation apparatus according to another embodiment of the disclosure.

FIG. 2J is a schematic top view illustrating portions of a component separation, singulation, or isolation apparatus according to another embodiment of the disclosure.

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FIG. 2K is a schematic top view illustrating a manner in which a component delivery unit and a component reception stage of FIG. 2J can be configured to matingly engage with each other.

- 15 FIG. 2L is a schematic top view illustrating portions of a component separation, singulation, or isolation apparatus according yet to another embodiment of the disclosure.

FIG. 2M is a schematic top view illustrating portions of a component separation, singulation, or isolation apparatus according to still another embodiment of the disclosure.

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FIG. 2N is a schematic side view illustrating portions of a component separation, singulation, or isolation apparatus according to another embodiment of the disclosure.

- 25 FIG. 3A is a schematic illustration of a representative configuration of vacuum openings according to an embodiment of the disclosure.

FIG. 3B is a schematic illustration of a representative configuration of vacuum openings according to another embodiment of the disclosure.

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FIG. 3C is a schematic illustration of a representative configuration of vacuum openings according to a further embodiment of the disclosure.

FIG. 3D is a schematic illustration of a representative configuration of first, second, and third vacuum openings respectively disposed within a first, a second, and a third feeder track region according to an embodiment of the disclosure.

FIG. 3E is a schematic illustration of representative vacuum opening shapes in accordance with particular embodiments of the disclosure.

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FIGs. 4A and 4B are schematic plan views of a component separation apparatus that includes a set of mating engagement elements carried by the component delivery unit and the component reception stage according to an embodiment of the disclosure.

FIGs. 4C – 4E are schematic illustrations of representative manners in which portions of one or more protruding bridge elements or members and/or one or more receiving elements or structures can be tapered or contoured in accordance with embodiments of the disclosure.

FIG. 5 is a flow diagram of a representative component separation, singulation, or isolation process in accordance with the present disclosure.

FIG. 6 is a flow diagram of a representative singulation apparatus configuration process according to an embodiment of the disclosure.

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Detailed Description

Embodiments of the present disclosure relate to systems, apparatuses, devices, methods, processes, and techniques for regulating the flow of components and/or separating, isolating, or singulating components, for instance semiconductor and electronic components carried by packages such as quad flat packs (QFP), quad flat packs with no leads (QFNs), and/or other types of packages. Particular embodiments of the present

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disclosure involve separating or isolating a component that is disposed on, or carried by, a component reception stage or unit from a set or series of components that are serially arranged and carried by a component delivery or transport unit, more specifically components that are transported along a feeder track, passage, or channel that is carried
5 by or forms a portion of the component delivery unit.

Depending upon embodiment details, a continuous or discontinuous flow or supply of pressurized air or gas can be provided, introduced, or supplied along the feeder track for facilitating the flow, displacement, transport, delivery, or transfer of the components
10 along the feeder track, e.g., from an object or component inlet of the feeder track to or toward an object or component outlet of the feeder track. In several embodiments, the flow of pressurized air applied to or along one or more portions of the feeder track is continuous or essentially continuous during component separation operations. Thus, such
15 flow of pressurized air can exert an essentially constant displacement force upon one or more components carried by the feeder track during component separation operations, where the displacement force includes a vector component directed toward the component outlet.

The flow or supply of pressurized air along the feeder track facilitates the output of
20 components from the feeder track's component outlet, which can correspond to an offload or transfer of components from the feeder track to the component reception stage. In selected embodiments, the component reception stage and/or the component delivery unit can include a set of mating engagement elements configured to enhance the accuracy and/or ease of offloading or transferring components from the feeder track onto the
25 component reception stage. Particular embodiments enable the component reception stage and the component delivery unit to matingly couple by way of the mating engagement elements.

When the mating engagement elements are in a fully engaged or fully mated position
30 relative to each other, the component reception stage is directly adjacent to or abutted against the component delivery unit, and a component offloaded from the component

delivery unit can be directly transferred to the component reception stage. When the mating engagement elements are in a partially engaged or partially mated position relative to each other, the component reception stage is proximate to (e.g., at least slightly separated from) the component delivery unit. The mating engagement elements can form a bridge member that supports or carries one or more portions of a component which is disposed at least partially between the component reception stage and the component delivery unit, for instance, if the component is output by or offloaded from the component delivery unit when the mating engagement elements are in a partially engaged or partially mated position. In some embodiments, portions of particular mating engagement elements can be tapered, contoured, or otherwise shaped to facilitate or enhance the likelihood of successful engagement with each other and successful abutment of the component reception stage against the component delivery unit when a component reception stage (re)positioning or (re)alignment error exists with respect to the component delivery unit.

Embodiments of the present disclosure include at least one vacuum assembly configured to regulate component flow along the feeder track, for instance, by periodically, cyclically, or intermittently decelerating components in motion and/or stopping the displacement of components traveling along the feeder track by way of one or more vacuum forces or negative pressures applied at or relative to particular (e.g., multiple distinct) feeder track locations. The deceleration of components and/or stopping of component displacement along the feeder track regulates component flow, and can prevent the offload or transfer of one or more components (i.e. the next component closest to the component outlet as well as one or more subsequent components) carried by the feeder track to the component reception stage.

The periodic, cyclical, or intermittent provision of vacuum force(s) to portions of the feeder track while positive air pressure(s) are provided that exert a displacement force upon objects or components along the feeder track results in a progressive, stepwise, discretized, incremental, and/or periodically, cyclically, or intermittently interrupted displacement or advancement of objects or components along the feeder track toward the

component outlet. Such progressive component displacement occurs in a synchronous, controlled, or regulated manner relative to the adjustment (e.g., the cyclical application or increase, and adjustment or release) of particular vacuum forces applied to portions of the feeder track. The adjustment of such vacuum forces, and hence the progressive
5 displacement of serially organized components along the feeder track, can be synchronized or coordinated with component output from the component outlet.

For instance, within a series of components that includes a first or leading component and a number of succeeding components that trail behind the leading component along the
10 feeder track, when the leading component has been at least partially or substantially output from the component outlet and offloaded onto the component reception stage, vacuum forces applied to the feeder track can be adjusted to prevent the output of one or more succeeding components from the component outlet until the component reception stage is ready to receive a next component. Vacuum forces applied to the feeder track
15 can be controlled or regulated such that progressive component displacement along the feeder track is synchronized with the controlled reception or capture of individual components by the component reception stage. More particularly, the application of vacuum forces to the feeder track can be coordinated or synchronized relative to individual component output from the feeder track and/or corresponding component
20 reception by the component reception stage when the component reception stage is empty and appropriately positioned relative to the component delivery unit, as further described in detail below.

Additionally, the deceleration and/or stopping of component displacement along the
25 feeder track by way of vacuum forces in accordance with embodiments of the disclosure can reduce impact forces upon components resulting from component collisions along the feeder track (e.g., when a given component hits or knocks an adjacent component as a result of forward momentum), thereby reducing or minimizing the likelihood of component damage. The embodiments of the present disclosure are thus suitable for
30 separating or singulating small, very small, delicate, and/or easily damaged components in a manner that preserves the structural and functional integrity of such components.

Accordingly, particular embodiments of the present disclosure enable a cyclical regulation of component flow along the feeder track, which can further enable the separation, singulation, or isolation of individual components (e.g., the separation of a component that is disposed on the component reception stage from other components that are positioned along the feeder track) by way of the vacuum assembly's application of one or more vacuum forces or pressures to the feeder track, for example, at particular sets of positions, segments, or regions along the feeder track, at one or more times. In certain embodiments, particular vacuum forces can be applied to different feeder track locations or regions in a selective and/or independent manner. In such embodiments, the vacuum assembly can include vacuum elements that are configured for selective fluid communication with or fluid coupling to the feeder track. In the context of the present disclosure, the term fluid communication implies, corresponds to, or extends to the flow of one or more fluids and/or gases (e.g., air and/or another gas, and/or a liquid) across an opening, along a pathway, and/or within a structure such as a chamber, channel, tube, duct, bore, or shaft in a manner understood by one of ordinary skill in the art. Such liquid or gaseous fluid communication can result from the application of one or more pressures, flows, or forces, for instance, positive gas flow(s) and/or applied vacuum force(s), in accordance with various embodiments of the disclosure.

The vacuum assembly is configured to apply sufficient vacuum force or pressure to cyclically, periodically, or intermittently decelerate or stop the motion of components traveling along the feeder track, thereby cyclically, periodically, or intermittently preventing the unwanted or uncontrolled output, discharge, or ejection of components from the component outlet, which can correspondingly prevent the transfer of components from the feeder track to the component reception stage at times other than when the component reception stage is (a) appropriately positioned relative to the feeder track; and (b) ready to receive a next component. The vacuum assembly can be configured to enable the control of at least one of the magnitude(s) and duration(s) of vacuum force(s) applied at one or more portions, regions, segments, positions, sites of the feeder track.

In various embodiments, the vacuum assembly is configured to apply vacuum force at least two distinct or different positions or sites along the feeder track to decelerate and/or stop the travel or flow of components along the feeder track. In some embodiments, at least one of vacuum force magnitude and duration at each of multiple distinct positions along the feeder track can be independently configured, controlled, selected, or varied. In certain embodiments, the vacuum assembly includes at least two physically isolated vacuum chambers, passages, structures, and/or elements (e.g., vacuum openings) that correspond to the at least two distinct positions along the feeder track.

In several embodiments, the vacuum assembly is configured to apply a first set of vacuum forces at a first set of feeder track locations, and a second set of vacuum forces at a second set of feeder track locations. Thus, the vacuum assembly can apply the first set of vacuum forces to a first set of components carried by the feeder track, and apply the second set of vacuum forces to a second set of components carried by the feeder track, where the second set of components trails behind the first set of components. The first set of vacuum forces has a magnitude that is sufficient to stop the motion of the first set of components along the feeder track, and the second set of vacuum forces has a magnitude that is sufficient to at least decelerate the motion of the second set of components along the feeder track. For instance, the first set of vacuum forces can have a magnitude that is sufficient to stop the motion of a leading component positioned closest to the component outlet, and the second set of vacuum forces can have a magnitude that is sufficient to at least decelerate the motion of a number of trailing components positioned behind the leading component, that is, one or more components disposed further away from the component outlet than the leading component.

In several embodiments, vacuum forces can be applied at or relative to one or more feeder track locations on a sustained or generally sustained basis during singulation operations, thereby preventing the output of a component from the component outlet, until the component reception stage is (a) (re)positioned directly adjacent to (e.g., abutted against) the component delivery unit; and (b) ready to receive a next component. When the component reception stage is (re)positioned directly adjacent to or against the

component delivery unit and ready to receive a next component, one or more applied vacuum forces can be temporarily decreased, disrupted, or terminated, such that component motion along the feeder track can resume and a next component can be output from the component outlet and transferred or offloaded onto the component reception stage. Once the component reception stage receives this newly or most recently offloaded component at a component reception stage receiving structure, (a) one or more vacuum forces can be applied to the component reception stage to securely retain or hold this newly or recently offloaded component on the receiving structure; and (b) one or more vacuum forces can be reapplied, reestablished, or increased at or relative to one or more feeder track locations, such that components in motion along the feeder track are decelerated and/or stopped, and component output from the component outlet is prevented.

The component reception stage can accordingly be transferred or transitioned away from the component delivery unit, such that the component that is carried by the component reception stage can be dispatched or transferred to a processing station. In association with component dispatch operations, a set of vacuum forces that hold the component on the component reception stage's receiving structure can be decreased or released, such that the component can be removed (e.g., by a pick and place device) from the component reception stage and transferred to the processing station. Following component dispatch to the processing station, the empty component reception stage (i.e., the component reception stage from which a component has been removed as a result of component dispatch to a processing station) can be repositioned directly adjacent to the component delivery unit. One or more vacuum forces applied at or relative to particular feeder track locations can then be temporarily reduced or disrupted, such that component motion along the feeder track can resume and a next or subsequent component can be offloaded from the component delivery unit's component outlet to the component reception stage.

In addition to the foregoing, prior to or upon the introduction of one or more components to the feeder track's component inlet and the displacement of such component(s) toward

the component outlet, vacuum forces applied to vacuum elements at, proximate to, and/or near the component outlet are established and/or increased, and cyclically, periodically, or intermittently applied. As a result, the likelihood of an uncontrolled or unpredictable discharge or ejection of one or more components (e.g., the high speed ejection of an initial or leading component that was input to the component inlet) from the component outlet is reduced or minimized. That is, when component displacement along the feeder track can occur, at least one set of vacuum forces is applied to at least one set of vacuum elements at, near, or proximate to the component outlet. Thus, embodiments of the disclosure are configured to prevent or avoid the discharge of components from the component outlet in the absence of the application of deceleration and/or stopping forces applied to such components as they traveled along the feeder track. In certain embodiments, vacuum force(s) directed to decelerating and/or stopping component flow along the feeder track can be applied without interruption until a vacuum switch, optical sensor, or other sensing element detects the presence or motion of a first or leading component on the feeder track, after which the cyclical, periodic, or intermittent application of vacuum forces can occur, e.g., in manners described herein.

Representative aspects of systems, devices, apparatuses, processes, methods, and/or techniques for separating components, for example semiconductor or electronic components carried by packages such as QFPs, QFNs, or other types of packages or structures are described in detail hereinafter with reference to FIG. 1, FIGs. 2A – 2N, FIGs. 3A – 3E, FIGs. 4A – 4E, FIG. 5, and FIG. 6, in which like or analogous elements or process portions are shown numbered with like or analogous reference numerals. Relative to descriptive material corresponding to one or more of FIGs. 1 to 6, the recitation of a given reference numeral can indicate simultaneous consideration of a FIG. in which such reference numeral is also shown. The embodiments provided by the present disclosure are not precluded from applications in which particular fundamental structural and/or operational principles present among the various embodiments described herein are desired.

In the context of the present disclosure, the term set is defined as a non-empty finite organization of elements that mathematically exhibits a cardinality of at least 1 (i.e., a set as defined herein can correspond to a singlet or single element set, or a multiple element set), in accordance with known mathematical definitions (for instance, in a manner corresponding to that described in *An Introduction to Mathematical Reasoning: Numbers, Sets, and Functions*, “Chapter 11: Properties of Finite Sets” (e.g., as indicated on p. 140), by Peter J. Eccles, Cambridge University Press (1998)).

Aspects of a Representative Vacuum Based Component Flow Regulation and/or Separation System

FIG. 1 is a block diagram illustrating a representative object or component flow regulation and/or separation, singulation, or isolation system 1 according to an embodiment of the disclosure. In an embodiment, a component source 5 carries a sequence of serially disposed or adjacent components, objects, or elements. The component source 5 supplies or provides components to a component separation, singulation, or isolation apparatus 10, which includes a component delivery or transfer unit 100 configured for controlling or regulating object or component flow, and a component reception or removal stage, platform, or unit 200 configured to receive components from the component delivery unit 100 in a manner that is synchronized with the component delivery unit’s regulation of object or component flow. The component delivery unit 100 includes a component inlet 122 at which components can be received by or input to the component delivery unit 100, and a component outlet 124 at which components can be offloaded, output, discharged, or ejected from the component delivery unit 100.

In accordance with various embodiments of the present disclosure, objects or components can include, for instance, semiconductor, electronic, and/or other types of devices carried by structures or packages such as QFPs, QFNs (e.g., QFNs carrying one or more devices such as an accelerometer, a gyroscope, a pressure sensor, or a medical device), camera module packages, and/or other types of packages. Particular systems, apparatuses, devices, structures, and/or processes in accordance with the present disclosure are

applicable to the control or regulation of flow as well as the separation or singulation of other types of objects or components including various types of packages, devices, elements, parts, structures, items, or products that are suited for serial displacement along a feeder track. For instance, certain embodiments of the present disclosure can be configured to control or regulate the flow of ingestible or pharmaceutical products (for instance, tablets, pills, or capsules, which can be conventional, or which can be non-conventional such as “smart pills” that carry electronic circuitry, e.g., in a manner identical, analogous, or similar to that described in U.S. Patent Publication No. 2010/0049120) along a feeder track, and possibly the separation or singulation of such products. Additionally or alternatively, a number of embodiments of the present disclosure can be configured to control or regulate the flow of objects or devices for which object-to-object collisions or impacts should be reduced, minimized, or avoided, for instance, ordnance-related trigger devices.

As indicated in FIG. 1, an air or gas source or unit 40 is fluidly couplable to each of the component source 5 and the component delivery unit 100, and is configured to provide or supply a positive pressure or flow of air or other gas to the component source 5 and the component delivery unit 100 in a manner that facilitates the flow, translation, or displacement of components from the component source 5 into and through the component delivery unit 100. More particularly, the positive air flow exerts a displacement force upon such components. The displacement force moves or transports the components through the component delivery unit 100. In several embodiments, a pressurized gas supply unit 40 is configured to provide a positive air or gas pressure or flow to the component delivery unit 100 in an uninterrupted, continuous, essentially continuous, or generally continuous manner during component singulation operations.

A vacuum or suction source 60 is fluidly couplable to each of the component delivery unit 100 and the component reception stage 200. As further detailed below, the component delivery unit 100 includes a set of elements or structures to which one or more vacuum or suction pressures (e.g., negative pressures) or forces are cyclically, periodically, or intermittently applied by way of the vacuum source 60 to cyclically,

periodically, or intermittently decelerate and/or stop the flow of components along or through the component delivery unit 100.

5 A periodic reduction in or cessation of one or more vacuum forces applied to the component delivery unit 100 results in a corresponding periodic acceleration or resumption of component motion or flow through the component delivery unit 100, as well as the transfer or offloading of an individual component from the component delivery unit 100 to the component reception stage 200.

10 Once a given component has been offloaded to the component reception stage 200, the (re)application of vacuum force(s) to the component delivery unit 100 for a given period of time, which can be defined as a vacuum application interval, temporarily slows, interrupts, and/or halts component flow along the component delivery unit 100, thereby facilitating the separation or singulation of the component carried by the component
15 reception stage 200 from an adjacent or neighboring component carried by the component delivery unit 100.

More particularly, during a component dispatch or retrieval interval during which component flow along the component delivery unit 100 is slowed, interrupted, or halted
20 by way of one or more applied vacuum forces, a component that is carried by the component reception stage 200 can be dispatched, transported, or transferred to a processing station 80, for instance, by way of a pick and place device (not shown). Following the dispatch of such a component to the processing station 80, the component reception stage 200 no longer carries a component, i.e., the component reception stage
25 200 can be defined as empty, and the empty component reception stage 200 is repositioned directly or essentially directly against the component delivery unit 100 such that the component delivery unit 100 can offload a next or subsequent component to the component reception stage 200. More particularly, when the empty component reception stage 200 is abutted against the component delivery unit 100 and is thus ready to receive
30 another component, one or more vacuum forces applied to the component delivery unit 100 can be reduced, interrupted, and/or discontinued during a component translation or

shift interval, thereby facilitating or resulting in the acceleration or resumption of component flow along the component delivery unit 100 and the offloading of another component from the component delivery unit 100 to the component reception stage 200. In general, the component dispatch interval is less than or equal to the vacuum application interval.

In multiple embodiments, one or more constant, substantially constant, or sustained positive air or gas pressures are applied to the component delivery unit 100 (e.g., at, proximate to, and/or near the component inlet 122), and one or more vacuum pressures or forces are cyclically, periodically, or intermittently applied to portions of the component delivery unit 100 (e.g., at, proximate to, and/or near the component outlet 124) relative to the application of the sustained or continuous positive gas pressure(s) in a manner that enables high rate component separation or singulation in the absence of (a) the periodic application and cessation of such positive air pressure(s) to portions of the component delivery unit 100; and/or (b) an air curtain separation mechanism between the component delivery unit 100 and the component reception stage 200. In several embodiments, the separation or singulation of components between the component delivery unit 100 and the component reception stage 200 (e.g., as a result of cessation of component flow along the component delivery unit 100) is due to the cyclical application of vacuum forces alone, rather than a combination of cyclically applied vacuum forces and one or both of (a) cyclical interruption of positive air pressure(s) at, proximate to, or generally near the component inlet 122; and (b) positive air pressure(s) provided by one or more air curtains. More particularly, in such embodiments (a) periodically applied and/or increased vacuum forces are solely responsible for periodically stopping the output of a leading component from the component delivery unit 100, and (b) periodically interrupted and/or decreased vacuum forces facilitate or result in the resumption of component motion due to displacement forces exerted upon components by positive air pressure(s), such that a component carried by the component reception stage 200 can be periodically dispatched to a processing station 80. In certain embodiments, a set of positive air or gas pressures can be applied or increased at or proximate to particular portions of the component delivery unit 100, such as at, proximate to, and/or near the

component outlet 124, to aid component offload from the component delivery unit 100 to the component reception stage 200, as further described below.

5 The system 1 can include one or more adjustable air pressure and/or air flow devices, gauges, meters, regulators, valves, or switches 42a, 42b coupled between the air source 40 and each of the component source 5 and the component delivery unit 100 (e.g., by way of piping, tubing, or the like, as would be readily understood by one of ordinary skill in the art) for establishing, varying, and/or optimizing an overall component flow rate through the component delivery unit 100. The system 1 can further include one or more
10 vacuum devices, gauges, regulators, meters, actuators, valves, or switches 62a, 62b coupled to the vacuum source 60 and each of the component delivery unit 100 and the component reception stage 200 for establishing, selecting, varying, or optimizing vacuum pressure(s) or force(s) in relation to a target or optimum overall component separation or singulation rate. As further described in detail below, the system 1 can also include one
15 or more sets of sensors configured to sense, monitor, or detect aspects of component position and/or motion. Such sets of sensors can include one or more types of sensing elements such as optical sensors, vacuum sensors, and electrical sensors, which can be configured to generate sensing signals corresponding to the location, position, or motion of one or more components, and/or the location, position, or motion of the component
20 reception stage 200 relative to the component delivery unit 100. In some embodiments, the system 1 can include a control unit 90 such as a computer system or embedded controller configured to automatically or programmably control particular air pressure or flow devices or regulators 42a, 42b, particular vacuum pressure devices or regulators 62a, 62b, and/or the motion of the component reception stage 200 relative to the component
25 delivery unit 100. A person of ordinary skill in the art will understand that in various embodiments, trigger signals or feedback signals corresponding to one or more sensing signals can be provided to the control unit 90 and/or other portions of the system 1 (e.g., one or more actuators) in a manner that enables such automated or programmable control.

Aspects of Representative Vacuum Based Component Separation Apparatus

FIG. 2A is a schematic side view illustrating portions of a component flow regulation and separation, singulation, or isolation apparatus 10 according to an embodiment of the disclosure, and FIG. 2B is a plan view of an embodiment of the component flow regulation and separation apparatus 10 of FIG. 2A. In an embodiment, the component separation apparatus 10 includes a component delivery unit 100 and a component reception stage 200, which can be positioned proximate or adjacent to the component delivery unit 100 at a component reception position X_r .

In various embodiments, the component reception stage 200 can be selectively moved, displaced, translated, or shifted relative to the component delivery unit 100. For instance, with respect to an X axis defined parallel, essentially parallel, or generally parallel to a direction of component travel along the component delivery unit 100, the component reception stage 200 can be displaced (e.g., in an alternating, reciprocating, or cyclical manner) between a component reception position X_r and a component dispatch position X_d . Each of the component reception position X_r and the component dispatch position X_d can be defined relative to a border, boundary, or edge of the component reception stage 200 that is closest to the component delivery unit 100. In various embodiments, the component reception position X_r is defined with respect to a position at which the component reception stage 200 and the component delivery unit 100 are directly adjacent to, abutted against, or essentially abutted against each other.

As a representative example to aid understanding, when the component reception stage 200 is positioned at the component reception position X_r and a component 20 is not already present on the component reception stage 200 (i.e., the component reception stage 200 is empty), a next component 20 can be offloaded from the component delivery unit 100 to the component reception stage 200. Component flow along the component delivery unit 100 can then be interrupted, and the component reception stage 200 can be displaced to the component dispatch position X_d . When the component reception stage 200 is positioned at the component dispatch position X_d , a component 20 carried thereby is accessible or retrievable (e.g., the component 20 can be accessed, retrieved, or removed

by a pick and place device), and the component 20 can be removed from the component reception stage 200 and dispatched to an appropriate processing station 80 (e.g., by way of the pick and place device). Following component dispatch to the processing station 80, the component reception stage 200 can be returned to or repositioned at the component reception position X_r . Component flow along the component delivery unit 100 can then be restarted, such that the component reception stage 200 can receive another component output (i.e. the next component or subsequent component) by the component delivery unit 100.

In multiple embodiments, the component reception stage 200 can be selectively displaced relative to (e.g., toward or away from) the component delivery unit 100, for instance, by way of reciprocating or periodic carriage-type or drawer-type motion, in a manner understood by one of ordinary skill in the art. One of ordinary skill in the art will also understand that a mechanical arm or translation mechanism (not shown), which can be a conventional type of translation mechanism, can be coupled to the component reception stage 200 to facilitate the aforementioned carriage-type motion. One of ordinary skill in the art will additionally understand that a set of sensors (e.g., a set of optical sensors) can be configured to detect one or more positions of the component reception stage 200 relative to the component delivery unit 100 such that the component reception stage 200 can reliably return to the component reception position X_r . Depending upon embodiment details, such sensors can be carried by one or both of the component delivery unit 100 and the component reception stage 200, and/or such sensors can be separate from the component delivery unit 100 and the component reception stage 200. Additionally, sensing signals output by such sensors can provide or be used to generate trigger or feedback signals for controlling, sequencing, or adjusting the motion of the component reception unit 200 relative to the component delivery unit 100. While the component reception stage 200 of FIG. 2A is depicted as having a particular shape (e.g., to facilitate coupling to a translation mechanism), one of ordinary skill in the art will further understand that the component reception stage 200 can have a wide variety of shapes, sizes, and/or configurations depending upon embodiment details.

The component delivery unit 100 includes a feeder track, passage, tube, or channel 120 having a component inlet 122 at a receiving portion or end of the component delivery unit 100, and a component outlet 124 at a component offloading or discharge portion or end of the component delivery unit 100. In various embodiments, the component inlet
5 122 and the component outlet 124 are on opposite ends or boundaries of the component delivery unit 100.

The component inlet 122 is coupled to receive components from the component source 5. The feeder track 120 is configured to facilitate the translation or displacement of
10 components 20 along or through the component delivery unit 100 between the component inlet 122 and the component outlet 124, for instance, as a result of one or more applied positive air or gas pressures. The components 20 carried by the feeder track 20 can be organized in a linear, serial, side-by-side, or adjacent manner. When the component reception stage 200 is positioned at the component removal position X_r , the component
15 outlet 124 is disposed proximate or adjacent to the component reception stage 200, in a manner that facilitates the transfer, offloading, or discharge of components 20 from the feeder track 120 to the component reception stage 200, as further detailed below.

In some embodiments, the component delivery unit 100 includes a bottom or base portion
20 110 and a top or cover portion 112. The feeder track 120 can be disposed between the bottom and top portions 110, 112. The feeder track 120 can form a smooth (e.g., low or relatively low friction) channel that extends from the component inlet 122 to the component outlet 124, along which components 20 can be displaced toward or to the component outlet 124. In an embodiment, at least a portion of the feeder track 112 can
25 be formed as a groove, recess, or channel in one or both of the component delivery unit's bottom portion 110 and top portion 112.

Aspects of Air Facilitated Component Displacement

At least one of the component delivery unit's bottom portion 110 and top portion 112 can
30 include a number of air or gas inlets, channels, or passages 134 that fluidly couple air openings 132 in or along the feeder track 120 to the air source 40, and which facilitate the

delivery of pressurized air or gas to one or more portions, regions, segments, or sites of the feeder track 120. In some embodiments, at least some air inlets 134 can be fluidly coupled to an air chamber 130 that is carried by a portion of the component distribution unit 100. The air chamber 130 can be fluidly coupled to the air source 40 by way of an air introduction port 138 of the component delivery unit 100.

The air inlets 134 can be configured to distribute pressurized air along portions of the feeder track's length in a manner that facilitates or results in the displacement of components 20 carried by the feeder track toward or to the component outlet 124. More particularly, the air inlets 134 can be disposed at an angle relative to the feeder track's length, such that pressurized air arriving at the feeder track 120 from the air inlets 134 provides a force vector directed along a component travel direction toward the component outlet 124. Still more particularly, the air inlets 134 can be disposed at an acute angle relative to a component travel path between the component inlet 122 and the component outlet 124, such that pressurized air is introduced along portions of the feeder track 120 at a corresponding acute angle, thereby causing the pressurized air to flow along the feeder track's length in a manner that displaces or forces components 20 toward or to the component outlet 124.

In particular embodiments, the component delivery unit 100 includes one or more air inlets 134 coupled or connected to the feeder track 20 at or proximal to the feeder track's component inlet 122. The component delivery unit 100 can further include one or more air inlets 134 coupled or connected to the feeder track 120 at particular positions along the feeder track's length. The number, configuration, distribution, and/or arrangement of air inlets 134 along the feeder track 120 can be selected and/or varied, for instance depending on the length and/or diameter of the feeder track 120, the size and/or type of components 20 carried by the feeder track 120, and/or a desired or target overall speed or flow rate of components 20 along the feeder track 120. Depending upon embodiment details and/or component type, the number of air inlets 134 and/or the flow or pressure of air provided to the air inlets 134 can be sufficient for displacing the components 20 along

the feeder track 120 at a predetermined, selectable, or desired rate of travel or component flow.

5 A set, series, or sequence of components 20 introduced to the feeder track 120 can travel or flow along the feeder track 120 toward the component outlet 124 in response to translational or displacement forces applied to the components 20 by the above described pressurized air or gas, which is delivered to the feeder track 120 by way of the air inlets 134 and air openings 132. In the absence of applied deceleration or stopping forces, components 20 traveling along the feeder track 120 can move toward, to, and past the
10 component outlet 124 in an unhindered and/or continuous or essentially continuous manner.

To aid understanding, in the description herein a component 20 that is carried by the component delivery unit 100 and which has a leading edge that has reached or
15 approximately reached the component outlet 124 as a result of component displacement along the feeder track 120 is defined as a leading component 20b (e.g., a leading component 20b within the feeder track 120). A component 20 that has been output from the component outlet 124 and transferred to the component reception stage 200 is defined as an offloaded component 20a. Components 20 that are carried by the component
20 delivery unit 100, and which are successively positioned behind the leading component 20b in a direction away from the component outlet 124 are defined as trailing components 20c-e.

Individual leading components 20b can be successively discharged or ejected from (e.g.,
25 pushed out of) the component displacement unit 100 in response to the displacement force(s) exerted upon trailing components 20c-e along the feeder track 120. Once a given leading component 20b becomes an offloaded component 20a by way of its transfer to the component reception stage 200, subsequent motion of components 20 along the feeder track 120 should be paused, interrupted, or disrupted in order to prevent an
30 undesired or uncontrolled discharge or ejection of additional components 20 from the component outlet 124. More particularly, component discharge from the component

outlet 124 should be stopped, interrupted, or restrained until the most recent offloaded component 20a is dispatched to a processing station 80, and the empty component reception stage 200 is (a) appropriately (re)positioned at the component reception position X_r ; and (b) ready to receive a next offloaded component 20a. Embodiments of the present disclosure selectively apply vacuum forces in a cyclical, periodic, or intermittent manner to a current leading component 20b and possibly one or more trailing components 20c-e along the feeder track 120 in order to facilitate an interruption or cessation of component motion, as described in detail hereafter.

In some embodiments, one or more vacuum forces or negative pressures can be applied (e.g., at, proximate, and/or generally near the component outlet 124) in a sustained or generally sustained manner with respect to one or more positive air or gas pressures or flows that are continuously applied (e.g., at, proximate, and/or generally near the component inlet 122) to the component delivery unit 100, thereby preventing component discharge from the component delivery unit 100 until the empty component reception stage 200 is directly adjacent or abutted against the component delivery unit 100 at the component reception position X_r . Once the empty component reception stage 200 is abutted against the component delivery unit 100, particular vacuum forces applied to portions of the component delivery unit 100 can be temporarily decreased and/or interrupted such that component flow along the component delivery unit 100 resumes as a result of the displacement force(s) exerted upon the components 20 by positive air or gas pressure(s) or flow(s). As a result of the resumption of such component flow, a next component 20 can be output or offloaded from the component delivery unit's component outlet 124 to the component reception stage 200. Following the transfer of a component 20 from the component delivery unit 100 to the component reception stage 200, one or more vacuum forces or negative pressures applied to portions of the component delivery unit 100 can be increased and/or (re)applied, such that component output from the component delivery unit 100 is prevented or avoided until (a) the component 20 currently carried by the component reception stage 200 has been removed from the component reception stage 200 and dispatched to a processing station 80; and (b) the empty

component reception stage 200 has been repositioned directly adjacent to the component delivery unit 100 at the component reception position X_r .

Aspects of Vacuum Facilitated Component Deceleration and/or Motion Cessation

5 In various embodiments, the component separation apparatus 10 includes at least one set of vacuum elements or structures configured to apply a set of vacuum forces to particular portions of the component delivery unit 100, as well as a set of vacuum elements or structures configured to apply a set of vacuum forces to portions of the component reception stage 200. Vacuum forces applied to the component delivery unit 100 can
10 decelerate one or more components 20 in motion along the feeder track 120, stop the displacement of one or more components 20 along the feeder track 120, and/or prevent the offload or transfer of components 20 from the feeder track 120 onto the component reception stage 200 at particular times (e.g., in an automatic, programmably specified manner). Vacuum forces applied to the component reception stage 200 can facilitate
15 component retention on the component reception stage 200, and in certain embodiments can facilitate the interruption or disruption of component motion along the feeder track 120.

The component delivery unit 100 can include one or more sets of vacuum elements or a
20 vacuum assembly configured to apply, supply, or provide one or more vacuum or suction forces or vacuum pressures at a number of positions, locations, sites, segments, regions, or zones along the feeder track 120. Such vacuum forces can be applied at particular times (e.g., periodically, cyclically, or intermittently), for instance, based upon the presence or absence of a component 20 on the component reception stage 200 and the
25 component reception stage's position relative to the component delivery unit 100, as further described below. Additionally, in several embodiments such vacuum forces can be selectively applied to distinct sets or subsets of vacuum elements. Thus, particular vacuum elements (e.g., distinct sets or subsets of vacuum elements) can be fluidly couplable to the feeder track 120 in a selectable or configurable manner.

At least one of the component delivery unit's bottom portion 110 and top portion 112 can include a number of vacuum elements or structures that are configurable to couple portions of the feeder track 120 to the vacuum source 60. Such vacuum elements facilitate the application or delivery of vacuum forces to, at, or along particular positions or portions of the feeder track 120, and hence to components 20 in motion along the feeder track 120. The applied vacuum forces are intended to counter and/or overcome the displacement force(s) exerted upon the components 20 by the positive air pressure delivered by the air inlets 134 to the air openings 132, and correspondingly counter and at least substantially overcome component motion and/or component momentum toward or to the component outlet 124.

In general, the component delivery unit 100 can include a number of vacuum openings that are exposed to the feeder track 120 to facilitate the application of vacuum forces at particular feeder track sites. For instance, the component delivery unit 100 can include a first set of vacuum openings exposed to the feeder track 120, as well as a second set of vacuum openings exposed to the feeder track 120, which is distinct from the first set of vacuum openings. In the embodiment shown in FIGs. 2A and 2B, the component delivery unit's bottom portion 110 includes a first vacuum passage 144 that fluidly couples a first vacuum opening 142 of the feeder track 120 to a first vacuum port 148 of the component delivery unit 100. The bottom portion 110 additionally includes a vacuum chamber 150 that is fluidly coupled by way of a plurality of second vacuum passages 154 to a corresponding plurality of second vacuum openings 152 disposed along a portion of the feeder track 120 proximate to and/or generally near the first vacuum opening 142. The vacuum chamber 150 is further fluidly coupled to a second vacuum port 158 of the component delivery unit 100. Each of the first vacuum port 148 and the second vacuum port 158 can be coupled to the vacuum source 60 (e.g., by way of a shared or separate vacuum lines and one or more vacuum actuators, switches, gauges, or valves 62a, one or more of which can be selectively or programmably actuatable).

The first vacuum opening 142 can be disposed relative to a terminal or end-most feeder track location that corresponds or is expected to correspond to a position at which a

leading component 20b can be positioned along the feeder track 120 prior to the leading component's offloading to the component reception stage 200. That is, the first vacuum opening 142 can be disposed relative to an end-most feeder track location that is next to or approximately adjacent to the feeder track's component outlet 124. In an embodiment, an approximate midpoint of the first vacuum opening 142 can be disposed at a feeder track location that corresponds to an expected approximate midpoint of the leading component 20b when the leading edge of the leading component 20b is approximately aligned with the component outlet 124. One of ordinary skill in the art will understand that a feeder track location at which the first vacuum opening 142 is disposed can depend upon component dimensions and/or embodiment details.

The plurality of second vacuum openings 152 can be successively disposed along the feeder track 120 such that the second vacuum openings 152 are distributed along a portion of the feeder track 120 that corresponds or is expected to correspond to locations at which a number (e.g., approximately 2 – 10 or more) of trailing components 20c-e can reside. Thus, the plurality of second vacuum openings 152 can be positioned along a portion of the feeder track 120 that extends a predetermined distance away from the first vacuum opening 142 toward the component inlet 122.

In several embodiments, the first vacuum opening 142 is configured to apply a first vacuum force to the leading component 20b, and the plurality of second vacuum openings 152 are configured to apply a second vacuum force to or across the plurality of trailing components 20c-e in a distributed manner. The first vacuum force should be sufficient to significantly decelerate and at least briefly stop the motion of the leading component 20b, and the second vacuum force can be sufficient to at least decelerate the motion of the plurality of trailing components 20c-e. In particular embodiments, the first vacuum force is sufficient to reliably stop the motion of the leading component 20b, and the second vacuum force is sufficient to significantly decelerate or substantially stop the motion of the trailing components 20c-e.

Depending upon embodiment details, the magnitude and/or duration of the first and second vacuum forces can be equal, approximately equal, or different. In some embodiments, the magnitude and/or duration of the first vacuum force can be greater than the magnitude and/or duration of the second vacuum force in order to facilitate rapid, predictable, or reliable cessation of the leading component's motion. Additionally or alternatively, the sizes or surface areas (e.g., individual surface areas, or aggregate surface areas) of the first vacuum opening 142 and the second vacuum openings 152 can be equal, approximately equal, or different. In several embodiments, the size of the first vacuum opening 142 can be larger than the sizes of individual second vacuum openings 152 in order to more effectively stop the motion of the leading component 20b.

In particular embodiments, the magnitude of the first vacuum force relative to that of the second vacuum force, and/or the size of the first vacuum opening 142 relative to the sizes of the individual second vacuum openings 152, can be defined or determined such that the vacuum force applied to the surface area of the leading component 20b is greater than or equal to (a) the vacuum force applied to the surface area of any individual trailing component 20c-e; and/or (b) the net or overall or aggregate vacuum force applied to the surface areas of the set of trailing components 20c-e exposed to the plurality of second vacuum openings 152.

Aspects of Representative Alternative Vacuum Opening Configurations

The number and/or spatial organization of particular vacuum openings, such as first vacuum openings 142, second vacuum openings 152, and/or other vacuum openings associated with a singulation apparatus 10 can vary depending upon embodiment details. More particularly, several embodiments of the present disclosure can include vacuum openings arranged in accordance with a spatial pattern or distribution that can be expected to reliably stop the motion of a leading component 20b and at least decelerate the motion of one or more trailing components 20c-e with respect to a target or maximum attainable component singulation rate.

FIG. 3A is a schematic illustration of a representative configuration of first and/or second vacuum openings 142, 152 along portions of a feeder track 120 according to an embodiment of the disclosure. In an embodiment, a first feeder track region 143 can include, carry, contain, or be coupled or exposed to a plurality of first vacuum openings 142a-b, including a number of smaller diameter first vacuum openings 142a as well as a number of larger diameter vacuum openings 142b. Additionally, a second feeder track region 153 can include, carry, contain, or be coupled or exposed to a plurality of second vacuum openings 152. The first feeder track region 143 corresponds to a portion of the feeder track 120 at which a leading component 20b is expected to reside; and the second feeder track region 153 corresponds to a portion of the feeder track 120 along which one or more trailing components 20c-e are expected to reside as they travel toward the first feeder track region 143 and the component outlet 124. The direction of component travel along the feeder track 120 is indicated in FIG. 3A by an arrow.

The smaller diameter first vacuum openings 142a and the larger diameter first vacuum opening(s) 142b can be disposed relative to each other in a manner expected to enhance a likelihood of reliably and rapidly stopping the motion of the leading component 20b. For instance, multiple smaller diameter first vacuum openings 142a can be disposed relative to the periphery of a single larger diameter vacuum opening 142b (e.g., in a manner identical, similar, or generally analogous to that shown in FIG. 3A).

FIG. 3B is a schematic illustration of a representative configuration of first and/or second vacuum openings 142, 152 along portions of a feeder track 120 according to another embodiment of the disclosure. In an embodiment, a first feeder track region 143 can carry a plurality of first vacuum openings 142a-b such as a set of smaller diameter first vacuum openings 142a and a set of larger diameter first vacuum openings 142b. A second feeder track region 153 can carry a plurality of second vacuum openings 152, which can be nonuniformly spaced with respect to the direction of component flow along the feeder track 120. In the embodiment shown in FIG. 3B, the spatial density of second vacuum openings 152 increases with decreasing distance from the plurality of first vacuum openings 142a-b. Such a spatial density of second vacuum openings 152 can

more effectively decelerate or stop the motion of a set of components 20 within the second feeder track region 153 as the component(s) 20 more closely approach the first feeder track region 143.

5 FIG. 3C is a schematic illustration of a representative configuration of first and/or second vacuum openings 142, 152 along portions of a feeder track 120 according to yet another embodiment of the disclosure. In an embodiment, a first feeder track region 143 can carry a plurality of first vacuum openings 142a-b such as a set of smaller diameter first vacuum openings 142a and a set of larger diameter first vacuum openings 142b. A
10 second feeder track region 153 can carry a plurality of second vacuum openings 152a-b such as a set of smaller diameter second vacuum openings 152a and a set of larger diameter second vacuum opening 152b. The plurality of second vacuum openings 152a-b can be disposed relative to each other in a variety of manners, for instance, in a manner that is likely to increase an effective vacuum force applied to any given component 20
15 within the second feeder track region 153 as the component 20 moves closer to the first feeder track region 143.

Depending upon embodiment details, a first feeder track region 143, a second feeder track region 153, and/or another feeder track region can include vacuum openings 142a-b,
20 b, 152a-b having different or distinct shapes and/or cross sectional areas. Thus, a given feeder track region 143, 153 or a given set of vacuum openings under consideration can include vacuum openings having different shapes and/or cross sectional areas. Within any given feeder track region 143, 153, vacuum openings having particular shapes and/or cross-sectional areas can be disposed in a manner expected to facilitate the deceleration
25 or cessation of component motion or flow.

FIG. 3D is a schematic illustration of a representative configuration of first, second, and third vacuum openings 142, 152, 162 respectively disposed within a first, a second, and a third feeder track region 143, 153, 163 according to an embodiment of the disclosure. As
30 indicated in FIG. 3D, within one or more feeder track regions 143, 153, 163, particular vacuum openings 142, 152, 162 can be spatially organized or arranged based upon

vacuum opening cross sectional area. For instance, within the first feeder track region 143, a vacuum opening 142c having a largest cross sectional area can be disposed closest to the component outlet 124; a vacuum opening 142b having a next largest cross sectional area can be disposed further from the component outlet 124; and one or more vacuum openings having a smallest cross sectional area can be disposed furthest from the component outlet 124. Additionally or alternatively, within the second feeder track region 153, a vacuum opening 153c having a largest cross sectional area can be disposed closest to the first feeder track region 143; a vacuum opening 153b having a next largest cross sectional area can be disposed further from the first feeder track region 143; and one or more vacuum openings having a smallest cross sectional area can be disposed furthest from the first feeder track region 143. In embodiments that include one or more additional feeder track regions such as a third feeder track region 163, then within such a third feeder track region 163, a vacuum opening 163b having a largest cross sectional area can be disposed closest to the second feeder track region 153, and one or more vacuum openings having a smaller or smallest cross sectional area can be disposed further away from the second feeder track region 153.

In embodiments of the disclosure that include at least one feeder track region 143, 153, 163 in which a plurality of vacuum openings are disposed, a vacuum opening that is disposed closest to the component outlet 124 within the feeder track region 143, 153, 163 can be defined as a leading vacuum opening, and a vacuum opening that is disposed furthest from the component outlet 124 within the feeder track region 143, 153, 163 can be defined as a trailing vacuum opening. The leading and trailing vacuum openings can be identical or different with respect to shape and/or cross sectional area. For instance, a leading vacuum opening can have a larger (e.g., substantially larger) cross sectional area than a trailing vacuum opening to facilitate the cyclical or periodic deceleration and/or cessation of component motion along the feeder track 120 and/or the prevention of unintended or undesirable component output from the component outlet 124.

As indicated above, embodiments of the present disclosure can include vacuum openings that exhibit identical or different shapes, sizes, dimensions, or cross sectional areas. FIG.

3E is a schematic illustration of representative vacuum opening shapes in accordance with particular embodiments of the disclosure. Such shapes include an ellipsoidal or oval shape, a diamond-type shape, and a circular or generally circular shape. Embodiments of the present disclosure also encompass additional and/or other types of vacuum opening shapes (e.g., triangular, square, or more complex polygonal shapes). FIG. 3E additionally indicates certain representative vacuum opening dimensions, which can be suitable for separating or singulating components 20 such as QFN and/or other types of packages.

As indicated in FIGs. 3A – 3C, the first vacuum openings 142a,b provide a first aggregate or collective vacuum opening area, and the second vacuum openings 152a,b provide a second aggregate vacuum opening area. Depending upon the number of first vacuum openings 142a,b and second vacuum openings 152a,b as well as the sizes of the first vacuum openings 142a,b relative to the sizes of the second vacuum openings 152a,b, the first aggregate vacuum opening area can be less than, approximately equal to, equal to, or greater than the second aggregate vacuum openings area. In some embodiments, the second aggregate vacuum opening area exceeds the first aggregate vacuum opening area.

In addition or as an alternative to the foregoing, one or more vacuum openings (e.g., first vacuum openings 142a-b, second vacuum openings 152a-b, and/or other vacuum openings) can have different types of shapes, cross-sectional areas, or relative distributions. For instance, some or all vacuum openings can have an elliptical, triangular, square, rectangular, diamond, or other type of shape, depending upon embodiment details.

In general, the component delivery unit 100 can include multiple distinct sets of vacuum openings. A given set of vacuum opening can have an identical or a different number of individual vacuum openings relative to another set of vacuum openings. Different sets of vacuum openings can include vacuum openings having different shapes or cross-sectional areas. Additionally, a given set of vacuum openings can be configured to provide an aggregate or collective cross sectional vacuum opening area that is identical to or

different from that provided by another set of vacuum openings. Furthermore, a given set of vacuum openings can be configured to apply, deliver, or distribute vacuum force(s) across an identical or different feeder track length and/or number of components than another set of vacuum openings, where the magnitude of the vacuum force(s) applied by a particular set of vacuum openings can be identical to or different than the magnitude of the vacuum force(s) applied by another set of vacuum openings. A ratio of a first vacuum force applied by a first set of vacuum openings to a first feeder track length (or a first number of components) can be identical to or different from a ratio of a second vacuum force applied by a second set of vacuum openings to a second feeder track length (or a second number of components).

As a representative example, a first set of vacuum openings can be disposed proximate to the component outlet 124, such as within a first feeder track region 143; and a second set of vacuum openings can be disposed further away from the component outlet 124 than the first set of vacuum openings, such as within a second feeder track region 153. The first set of vacuum openings can be configured to distribute a first vacuum force across a first number of components 20, for instance, a single leading component 20b, or a leading component 20b and one immediately adjacent trailing component 20c. The second set of vacuum openings can be configured to distribute a second vacuum force across a second number of components, for instance, approximately 1 – 10 or 1 – 20 (e.g., 2 – 12) trailing components 20 that follow or trail behind the first number of components.

A first ratio (e.g., a first vacuum suction, pressure, or ratio) defined by the magnitude of the first vacuum force to the first number of components can be greater than a second ratio defined by the magnitude of the second vacuum force to the second number of components. Additionally or alternatively, a first ratio defined by the magnitude of the first vacuum force to a first feeder track length or distance across which the first vacuum force is applied can be greater than a second ratio (e.g., a second vacuum suction, pressure, or force ratio) defined by the magnitude of the second vacuum force to a second feeder track length or distance across which the second vacuum force is applied. Such a first ratio indicates that the first vacuum force can provide a greater stopping force on a

per-component or distance normalized basis than the second vacuum force. This can enhance the likelihood that a leading component's motion is reliably stopped, thereby preventing undesirable output of the leading component output from the component outlet 124 when the first and second vacuum forces are applied.

5

Aspects of Cyclical Component Offloading and Dispatch

When the component reception stage 200 is empty (i.e., an offloaded component 20a is not present or detected on the component reception stage 200) and positioned at the component reception position X_r , the component reception stage 200 can receive a first or
 10 next offloaded component 20a by way of the component delivery unit's output of a leading component 20b from the component outlet 124.

Referring again to FIGs. 2A and 2B component reception stage 200 can carry or include a receiving structure 210 that is configured to aid component transfer, retention, or capture.
 15 The receiving structure 210 can include a set of structural features such as a groove, slot, or recess configured to match or generally conform to the shape of an offloaded component 20a; and/or a barrier or abutment 212 configured to limit or prevent displacement of the offloaded component 20a beyond a predetermined position on the component reception stage 200. The size or surface area of the receiving structure 210
 20 can approximately match the size or surface area of an offloaded component 20a.

The component reception stage 200 can further include a set of sensors or sensing elements 220 configured to detect the presence or absence of an offloaded component 20a upon the component reception stage 200. More particularly, particular sensors within
 25 the set of sensors 220 can be configured or arranged to detect whether at least a portion of the offloaded component 20a has reached or is disposed at one or more positions relative to portions of the receiving structure 210. For instance, particular sensing elements 220a can be configured to detect the presence of a component 20a relative to or at a portion or region of the receiving structure 210 that is offset away from the abutment 212, and/or
 30 other sensing elements 220b can be configured to detect the presence of a component 20a

that abuts or resides directly adjacent to the abutment 212. The set of sensors 220 can include, for instance, an optical sensor and/or a vacuum pressure sensor.

5 In addition or as an alternative to the foregoing, a set of sensors can be carried by the component delivery unit 100, and/or disposed separate from the component delivery unit 100 and the component reception stage 200. Such sensors can be configured to detect one or more component edge, boundary, or border transitions corresponding to component output from the component delivery unit's component outlet 124.

10 As indicated above, the component reception stage 200 additionally includes a set of vacuum elements or structures. In an embodiment, the component reception stage 200 includes a set of vacuum passages 244, 246 that couple at least one vacuum opening 242 disposed adjacent or proximate to the abutment 212 (e.g., within a portion of the receiving structure 210) to a vacuum port 248 of the component reception stage 200. The
15 vacuum port 248 can be coupled to the vacuum source 60, for instance, by way of a vacuum actuator, switch, gauge, or valve 62b. Depending upon embodiment details, the component reception stage's vacuum opening(s) 242 can be organized in a variety of manners. For instance, the component reception stage 200 can include a single vacuum opening 242; or multiple vacuum openings, which can have identical or different sizes
20 and/or shapes in a manner analogous to that described above with reference to one or more of FIGs. 3A – 3C.

In various embodiments, when the set of sensors 220 detects the presence of an offloaded component 20a relative to, proximate or adjacent to, and/or against the abutment 212, a
25 vacuum force delivered or directed to the component reception stage's vacuum opening(s) 242 can be automatically established or increased in order to slow or stop the forward motion of the offloaded component 20a toward the abutment 212, and/or retain the offloaded component 20a in a fixed, predetermined, or predictable position or location (e.g., directly adjacent to or against the abutment 212). Additionally, when (a)
30 the set of sensors 220 detects that a leading edge of the offloaded component 20a has reached, touches, or is against the abutment 212; and/or (b) a set of sensors such as a set

of sensors carried by the component delivery unit 100 detects that a leading and/or trailing edge of a component undergoing offload has exited the component delivery unit 100, then at least one set of vacuum forces applied or delivered at one or more feeder track locations is increased (e.g., substantially increased) or applied such that the leading component 20b carried by the feeder track 120 is positioned and securely retained within the component delivery unit 100 (e.g., proximate or adjacent to the component outlet 124). Thus, the application or adjustment of vacuum forces to (a) the set of vacuum elements or structures 244, 246, 248 corresponding to the component reception stage 200, as well as (b) one or more sets of vacuum elements or structures 142, 144, 148, 150, 152, 154, 158 corresponding to the component delivery unit 100 occurs in a cooperative, controlled, or synchronized manner, for instance, an essentially simultaneous manner, with respect to component offload from the feeder track 120. Such vacuum force application or adjustment can be controlled in an automatic or programmable manner to facilitate cyclical, periodic, or intermittent singulation operations in accordance with embodiments of the disclosure based upon trigger or feedback signals corresponding to sensing signals output by one or more sets of sensors.

In some embodiments, zero or essentially zero vacuum force is delivered to the component reception stage's vacuum opening 242 when the set of sensors 220 fails to detect the presence of an offloaded component 20. In other embodiments, at least a low level vacuum force is delivered to the vacuum opening 242 at all times when the component reception stage 200 is located at the component reception position X_r . Once the set of sensors 220 detects an offloaded component 20a, the magnitude of the vacuum force delivered to the vacuum opening 242 can be increased to a level sufficient to securely retain the offloaded component 20a at or within the receiving structure 210.

In addition to the foregoing, when the set of sensors 220 detects the presence of the offloaded component 20a, vacuum forces applied to the component delivery unit 100 can be established or increased in order to pause or disrupt the motion of components 20 along the feeder track 120. Thus, in response to the set of sensors 220 detecting an offloaded component 20a proximate or adjacent to the abutment 212, vacuum forces are

applied (a) to the component reception stage's vacuum opening 242; and (b) at or along particular portions of the feeder track 120. As a result, the offloaded component 20a is securely held by the component reception stage 200, and the motion or flow of components 20 along the feeder track 120 is interrupted or disrupted, thereby preventing the output of the current leading component 20b and any trailing components 20c-e from the component outlet 124 to the component reception stage 200.

Once the offloaded component 20a is retained upon the component reception stage 200, the component reception stage 200 can be shifted to the component dispatch position X_d . When the component reception stage 200 has arrived at the component dispatch position X_d , the vacuum force applied to retain the offloaded component 20a upon the component reception stage 200 can be released or decreased in order to facilitate the removal or dispatch of the offloaded component 20a to a processing station 80. The component reception stage 200 can subsequently be shifted back to the component reception position X_r , and the vacuum forces applied to one or more portions of the feeder track 120 can be decreased or discontinued. As a result, component flow along the feeder track 120 can resume, and a current leading component 20b adjacent to the component outlet 124 can be output as a next offloaded component 20a. When the set of sensors 220 detects the presence of another offloaded component 20a proximate or adjacent to the abutment 212, the sequence of events described above repeats, thereby continuing component separation or singulation operations.

Structural Aspects that Further Aid Component Separation or Singulation

As indicated in FIG. 2A, in an embodiment the component delivery unit's top portion 112 can include an overhang or projection 114 that extends beyond the component outlet 124. When the component reception stage 200 is located at the component reception position X_r , the projection 114 covers or overlaps at least a portion of the component reception stage 200 at which an offloaded component 20a can reside. Thus, the projection 114 can cover or overlap at least a portion of the component reception stage's receiving structure 210. In an embodiment, the projection 114 extends such that it is approximately aligned with the component reception stage's abutment 212. The projection 114 can facilitate

smooth or consistent transfer of a leading component 20b onto the component reception stage 200, increase the effectiveness of the vacuum force applied to stop the motion of an offloaded component 20a, and reduce or eliminate the likelihood that the offloaded component's momentum results in vertical component displacement that could carry the offloaded component 20a beyond the abutment 212.

In addition or as an alternative to the foregoing, the component delivery unit 100 and the component reception stage 200 can include particular structural elements or features that enable the component delivery unit 100 and the component reception stage 200 to matingly engage in a manner that facilitates or enhances reliable component offload to the component reception stage 200.

FIGs. 4A and 4B are schematic plan views of a component separation apparatus 10 that includes a set of mating engagement elements carried by the component delivery unit 100 and the component reception stage 200 according to an embodiment of the disclosure. More particularly, in an embodiment the component reception stage 200 includes a set of protruding bridge elements or members 205, and the component delivery unit 100 includes a corresponding set of recesses or receiving elements or structures 105. The set of bridge members 205 and the set of receiving elements 105 are configured to matingly engage. In an alternate embodiment, the component reception stage 200 can include a set of receiving elements 105, and the component delivery unit 100 can include a set of protruding bridge members 205. The set of bridge members 205 provides at least one support surface that can carry or support at least a portion of a component 20, and which (a) facilitates component travel to the component reception stage's receiving structure 210; (b) enhances a likelihood that a component 20a that is misaligned following its output from the feeder track 120 continues to move toward or to the component reception stage's abutment 212; and/or (c) reduces a likelihood that a component 20a that is output from the component delivery unit 100 when the component reception stage 200 is proximate to the component reception position X_r but not abutted against the component delivery unit 100 will fall into a gap between the component delivery unit 100 and the component reception stage 200. Thus, a pair of bridge members 205 can have a lateral

spacing relative to each other that is approximately equal to or slightly less than a transverse component dimension (e.g., a component width) relative to the direction of component travel along the feeder track 120. In an alternate embodiment, the set of bridge members 205 can be a single or unitary bridge member 205 that is configured to mate with a single receiving element 105. Such a single or unitary bridge member 205 can be dimensioned to support or carry at least a substantial portion of a component's width.

In several embodiments, the set of bridge members 205 is fully mated or engaged with the set of receiving elements 105 when the component reception stage 200 is located at the component reception position X_r , i.e., when the component reception stage 200 is directly adjacent to or abutted against the component delivery unit 100. Additionally, the set of bridge members 205 is or remains at least partially or slightly mated or engaged, or is very nearly or approximately mated or engaged, with the set of receiving elements 105 when the component reception stage 200 is located at the component dispatch position X_d . When the set of bridge members 205 is fully engaged with the set of receiving elements 105, each bridge member within the set of bridge members 205 extends into and is completely received by a corresponding receiving element within the set of receiving elements 105. When the set of bridge members 205 is partially engaged with the set of receiving elements 105, a portion of each bridge member 205 extends at least slightly (e.g., somewhat or very slightly) into a corresponding receiving element 105, or extends to a terminal border or boundary of the corresponding receiving element 105 at an exterior or outer surface of the component delivery unit 100. In general, the set of bridge members 205 and the set of receiving elements 105 can have a longitudinal extent that is equal or approximately equal to (e.g., nearly identical to, or slightly greater than) the longitudinal extent or length of a component 20.

In view of the foregoing, the set of bridge members 205 remains at least partially, slightly, or essentially engaged with the set or receiving elements 105 as the component reception stage 200 repeatedly or recurrently travels between the component reception position X_r and the component dispatch position X_d during singulation operations. Thus,

in the event that a component 20 is output from the component outlet 124 at any given time when the component reception stage 200 is displaced away from the component dispatch unit 100, such a component 20 can be supported by the set of bridge members 205. As a result, embodiments of the present disclosure can maximize or enhance the likelihood that a component 20 that is partially or fully supported by the set of bridge members 205 can be subsequently transferred onto or captured by the component reception stage 200, or otherwise retrieved or salvaged.

In certain embodiments, portions of one or more mating engagement elements can be tapered, contoured, or shaped in a manner that aids or enhances a likelihood of successful mating when the component reception stage 200 and the component delivery unit 100 are misaligned relative to each other, for instance, as a result of a positioning error when the component reception stage 200 is returned to the component reception position X_r .

FIGs. 4C – 4E are schematic illustrations of representative manners in which portions of one or more protruding bridge elements or members within the set of bridge members 205 and/or one or more receiving elements or structures within the set of receiving elements 105 can be tapered or contoured in accordance with embodiments of the disclosure. As indicated in FIG. 4A, a receiving element within the set of receiving elements 105 can have a widened opening that is configured for tolerance of bridge member positional error(s). Alternatively, as indicated in FIG. 4B, a bridge member within the set of bridge members 205 can have a narrowed terminal portion that is configured for tolerance of bridge member positional error(s). Alternatively, a receiving element within the set of receiving elements 105 and a corresponding bridge member within the set of bridge members 205 can each include structural features such as widened or narrowed portions, respectively, to facilitate successful mating and reliable positioning of the component reception stage 200 against or directly adjacent to the component delivery unit 100 in view of potential component reception stage (re)alignment or (re)positioning errors or uncertainty.

In particular embodiments, the set of bridge members 205 can include one or more vacuum elements configured to hold a component 20 in a fixed position relative to the bridge members 205 in the event that (a) the presence of a component 20a on the bridge members 205 is detected, and component detection at component reception stage's
 5 receiving structure 210 does not occur within a given amount of time (e.g., approximately 0.25 – 1.0 second); or (b) a component 20a is already carried by the receiving structure 210, and another component 20b has been undesirably output by the feeder track 120 onto the set of bridge members 205 as the component reception stage 200 is displaced away from the component reception X_r position toward the component dispatch position
 10 X_d . In particular embodiments, a singulation apparatus 10 can be configured to interrupt or halt singulation operations in response to detecting one or both of the preceding situations.

Aspects of a Representative Implementation

15 In a representative implementation configured for separating or singulating components 20 having dimensions of approximately 3mm x 3mm x 0.95 mm (e.g., in QFN packages), one or more vacuum chambers 140 can have dimensions of approximately 2.5mm x 2.5 mm x 20 mm. A circular or generally circular vacuum opening 142, 152 along the feeder track 120 can be approximately 0.5mm in diameter. Additionally, a circular or generally
 20 circular vacuum opening 242 carried by the component reception stage 200 can be approximately 0.8mm in diameter. Such a representative implementation can be expected to provide reliable component separation, singulation, or isolation rates of approximately 10,000 – 40,000 components or units per hour (UPH), for instance, approximately 20,000 – 30,000 QFN packages per hour, for QFN packages having the
 25 above dimensions. Moreover, such a representative implementation can result in zero, essentially zero, negligible, or minimal component damage (e.g., structural and/or functional damage) for components 20 having approximately the aforementioned dimensions, even when the components 20 include or carry delicate or easily damaged devices or structures such as MEMs devices. The absence or substantial absence of
 30 structural and/or functional damage in combination with the attainment of high or very high UPH values when singulating small or very small and/or fragile or easily damaged

components 20 is a surprisingly superior result compared to prior component singulation systems and techniques.

Embodiments of the present disclosure can provide a component singulation system architecture that is scalable with respect to successive or new generations of component technology. More particularly, as components 20 (e.g., packages and the electrical, optical, MEMs, nanoelectromechanical systems (NEMs), microfluidic, nanofluidic, biotechnological, ordnance trigger devices and/or other types of devices, elements, or structures carried thereby) increase in complexity, increase in fragility, and/or decrease in size as a result of technological evolution, embodiments in accordance with the present disclosure can be correspondingly or appropriately scaled or adapted based upon component dimensions in a manner that provides surprisingly superior singulation performance over prior component singulation systems and techniques.

In some implementations, particular openings, channels, and/or passages (e.g., which are configured for applying positive air or gas pressures or flows, or negative pressures or vacuum forces) can be formed by way of a drilling process. Additionally or alternatively, particular openings, channels, and/or passages can be formed by way of spatial alignment or mating engagement between distinct or separate sections of material. For instance, a first section of material that includes a first set of machined or etched grooves, channels, or recesses that is configured to mate (e.g., in a side-by-side manner) with a second section of material that includes a second set of machined or etched grooves, channels, or recesses to provide a given type of structural element that facilitates or enables gaseous fluid communication. The first and second sections of material, when aligned or mated, can form a given section or portion of the feeder track 120. In addition to the foregoing, one or more openings can be chamfered, or be coupled to chamfered locations, sites, portions, or areas of the component delivery unit 100 (e.g., chamfered segments or end regions of passages or channels), in a manner understood by one of ordinary skill in the art.

Additional Representative Apparatus Embodiments

The present disclosure encompasses multiple variations upon aspects of the component delivery unit 100 and/or the component reception stage 200. A component delivery unit 100 in accordance with the present disclosure can exhibit a variety of structural variations that facilitate the deceleration and/or stopping of component motion along one or more feeder tracks 120. For instance, certain component delivery unit embodiments can omit a vacuum chamber, and rely upon one or more individual vacuum passages coupled to corresponding individual vacuum openings to periodically or cyclically disrupt or interrupt component motion or flow along the feeder track 120. Alternatively, particular embodiments can include multiple vacuum chambers, and possibly omit individual vacuum passages coupled to corresponding individual vacuum openings. Moreover, in some embodiments, a component delivery unit 100 can include multiple feeder tracks 120 that are disposed or arranged in parallel with respect to each other to facilitate batch component flow regulation and singulation.

A number of representative component delivery unit embodiment variations are described in detail hereafter with respect to FIGs. 2C – 2N. While such embodiments are depicted as having particular vacuum opening shapes and/or organizations for ease of understanding, any given embodiment can include a different number of vacuum openings, one or more other vacuum opening types or shapes, and/or one or more other vacuum opening spatial configurations or distributions (e.g., in a manner analogous or generally analogous to that indicated above with respect to FIGs. 3A – 3C).

FIG. 2C is a schematic side view illustrating portions of a component separation, singulation, or isolation apparatus 10 according to another embodiment of the disclosure, and FIG. 2D is a plan view of an embodiment of the component separation apparatus 10 of FIG. 2C. As indicated in FIGs. 2C and 2D, a component delivery unit 100 can include a first vacuum passage 144a that couples a first vacuum opening 142a along the feeder track 120 to a first vacuum port 148a; and a second vacuum passage 144b that couples a second vacuum opening 142b along the feeder track 120 to a second vacuum port 148b.

The first vacuum opening 142a can be disposed proximate or adjacent to the component outlet 124, relative to a feeder track site or location at which a leading component 20b is expected to reside. The second vacuum opening 142b can be disposed relative to a feeder track site or location further away from the component outlet 124 (i.e., in a direction toward the component inlet 122). For instance, the second vacuum opening 142b can be disposed at a feeder track location at which a particular trailing component 20d is expected to reside.

Depending upon embodiment details, the magnitude and/or duration of vacuum force delivered to each of the first and second vacuum openings 142a, 142b can be equal, approximately equal, or different. In some embodiments, the component delivery unit 100 is configured to apply a stronger vacuum force to the first vacuum opening 142a than the second vacuum opening 142b, thereby exerting a stronger deceleration or stopping force on the leading component 20a than upon one or more trailing components 20c-e. In other embodiments, the component delivery unit 100 is configured to apply approximately equal vacuum forces to the first and second vacuum openings 142a, 142b. Particular embodiments that apply equal vacuum forces to the first and second vacuum openings 142a, 142b can rely upon a single vacuum port 148a that couples the first and the second vacuum passages 144a, 144b rather than separate vacuum ports 148a, 148b.

FIG. 2E is a schematic side view illustrating portions of a component separation, singulation, or isolation apparatus 10 according to yet another embodiment of the disclosure, and FIG. 2F is a plan view of an embodiment of the component separation apparatus 10 of FIG. 2E. The component delivery unit embodiment shown in FIGs. 2E and 2F relies upon a single vacuum passage 144 and a single vacuum opening 142 to decelerate and/or stop component motion or flow along the feeder track 120. The vacuum opening 142 can be disposed relative to a feeder track site or location at which a leading component 20b is expected to reside, for instance, at a feeder track location expected to correspond to an approximate midpoint of the leading component 20b.

In order to reliably slow or stop component motion along the feeder track 120 using a single vacuum opening 142, a vacuum force may need to be larger in magnitude or longer in duration than would be the case when vacuum force(s) can be applied by way of multiple openings. Additionally or alternatively, a positive air pressure that facilitates component flow along the feeder track may need to be limited or reduced.

FIG. 2G is a schematic side view illustrating portions of a component separation, singulation, or isolation apparatus 10 according to a further embodiment of the disclosure, and FIG. 2H is a plan view of an embodiment of the component separation apparatus 10 of FIG. 2G. As indicated in FIGs. 2G and 2H, a component delivery unit 100 can include a plurality of vacuum chambers 150a, 150b that are fluidly coupled to the feeder track 120. In an embodiment, a first vacuum chamber 150a is coupled to the feeder track 120 by way of a plurality of first vacuum passages 154a and a corresponding plurality of first vacuum openings 152a; and a second vacuum chamber 150b is coupled to the feeder track 120 by way of a plurality of second vacuum passages 154b and a corresponding plurality of second vacuum openings 152b. The first and second vacuum chambers 150a, 150b can respectively be coupled to the vacuum source 60 by way of a first and second port 158a, 158b.

The plurality of first vacuum openings 152a can be disposed relative to one or more feeder track locations at which particular components 20 are expected to reside, for instance, at a feeder track location expected to correspond to a portion of the leading component 20b and a feeder track location expected to correspond to a portion of a first trailing component 20c behind the leading component 20b. The plurality of second vacuum openings 152b can be disposed or distributed relative to a portion of the feeder track 120 extends away from the plurality of first vacuum openings 152a toward the component inlet 122, e.g., spanning a distance along the feeder track that is expected to correspond to the locations of 2 – 12 components 20 that trail behind or follow the first trailing component 20c. Depending upon embodiment details, the plurality of first and second vacuum openings 152a,b can have identical or different cross sectional areas.

The magnitude and/or duration of a vacuum force applied to the first vacuum chamber 150a can be approximately the same as or different than (e.g., stronger and/or longer) than the vacuum force applied to the second vacuum chamber 150b. More particularly, the magnitude and/or duration of vacuum forces applied to one or both of the first and second vacuum chambers 150a, 150b can be selected or varied in order to adjust or optimize component deceleration and/or stopping capabilities in view of a target or desired component singulation rate.

FIG. 2I is a schematic side view illustrating portions of a component separation, singulation, or isolation apparatus 10 according to another embodiment of the disclosure, in which one of the component delivery unit's top and bottom portions 110, 112 includes a number of pressurized air delivery elements, and the other of the component delivery unit's top and bottom portions 110, 112 includes a number of vacuum force application elements. More particularly, in one embodiment the component delivery unit 100 includes a bottom portion 110 having an air chamber 130 formed therein, which is fluidly coupled to the feeder track 120 (e.g., a lower or bottom surface of the feeder track 120) by way of a plurality of air passages 134 and a corresponding plurality of air openings (not shown). The air chamber 130 can be coupled to the air source 40 by way of a port 138 carried by the component delivery unit's bottom portion 110.

The air passages 134 are oriented at a first angle relative to the length of the feeder track 120, and are configured to supply pressurized air to the feeder track 120 in a manner identical or analogous to that described above to displace components 20 along the feeder track 120 toward or to the component outlet 124. In some embodiments, the air passages 134 can be disposed along a substantial portion of the feeder track's length, for instance, along the majority of the feeder track's length between the component inlet 122 and the component outlet 124, up to a feeder track location that is near or generally near the component outlet 124.

The component delivery unit 100 further includes a top portion 112 having a vacuum chamber 150 formed therein, which is fluidly coupled to the feeder track 120 (e.g., an

upper or top surface of the feeder track 120) by way of a plurality of vacuum passages 154 and a corresponding plurality of vacuum openings (not shown). The vacuum chamber 150 can be coupled to the vacuum source 60 by way of a port 158 carried by the top portion 112.

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The vacuum passages 154 are oriented at a second angle relative to the feeder track's length, and are configured to selectively (e.g., periodically, cyclically, intermittently, or programmably) apply or deliver (e.g., at particular times based upon cyclical component offloading and discharge) vacuum forces to particular feeder track locations corresponding to expected positions of the leading component 20a and a number (e.g., 2 – 20) of trailing components 20c-d. Such vacuum forces can counter or stop component flow along the feeder track 120, and prevent the unintended, undesired, or uncontrolled output of the leading component 20b from the component outlet 124 until the component reception stage 200 is ready to receive the leading component 20b as a next offloaded component 20a at the component reception position X_r .

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As indicated in FIG. 2I, in certain embodiments a portion of the component displacement unit's top portion 112 along which vacuum passages 154 are disposed can overlap with or reside above a portion of the component displacement unit's bottom portion 110 along which air passages 134 are disposed. Thus, vacuum forces directed to decelerating or stopping component motion as well as positive air pressures directed to initiating or maintaining component motion can be applied along a same section or segment of the feeder track 120.

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FIG. 2J is a schematic top view illustrating portions of a component separation, singulation, or isolation apparatus 10 according to another embodiment of the disclosure. In an embodiment, a component delivery unit 100 carries or includes multiple feeder tracks 120 (i.e., at least two feeder tracks 120), where each feeder track 120 is disposed or arranged parallel to another feeder track 120. Such multiple feeder tracks 120 can facilitate the control or regulation of multiple parallel component flows, where any given component flow along a given feeder track 120 includes a number of components serially

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disposed along the given feeder track 120. Each feeder track 120 includes a component inlet 122 and a component outlet 124. Additionally, each feeder track 120 can carry, include, or be exposed to a number of vacuum openings 142, 152 as well as air openings 132 in a manner identical, analogous, or generally analogous to embodiments described
5 above.

A component reception stage 200 corresponding to the component delivery unit 100 of FIG. 2J carries or includes multiple receiving structures 210 (i.e., at least two receiving structures 210). Each distinct receiving structure 210 of the component reception stage
10 200 corresponds to and is configured to receive components 20 from a distinct corresponding feeder track 120 of the component delivery unit 100. Thus, each receiving structure 210 is separated from another receiving structure 210 by a distance that corresponds to or equals a separation distance between the component delivery unit's parallel feeder tracks 120. Each receiving structure 210 is shaped in a manner that
15 facilitates or enables component offload from a corresponding feeder track's component outlet 124. Each given receiving structure 210 can include structural elements (e.g., an abutment 212) in a manner identical, analogous, or generally analogous to that described above.

The component reception stage 200 can include a number of sensors or sensing elements 220 associated with a given receiving structure 210, where such sensors 220 can be configured to detect the presence of one or more portions of a component 20 relative to the given receiving structure 210. The component reception stage 200 can further carry or include at least one vacuum opening 242 corresponding to each receiving structure
20 210, and a set of associated vacuum passages, in a manner identical, analogous, or
25 generally analogous to that described above.

FIG. 2K is a schematic top view illustrating a manner in which the component delivery unit 100 and the component reception stage 200 of FIG. 2J can be configured to matingly
30 engage with each other. In an embodiment, the component reception stage 200 can include multiple sets of protruding bridge members 205, and the component delivery unit

100 can include multiple sets of receiving elements 105. Any given set of bridge members 205 of the component reception stage 200 is configured to matingly engage with a corresponding set of receiving elements 105 of the component delivery unit 100 in a manner that is identical, analogous, or generally analogous to that described above.

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FIG. 2L is a schematic top view illustrating portions of a component separation, singulation, or isolation apparatus 10 according to yet another embodiment of the disclosure. In an embodiment, a component delivery unit 100 can have a structure that is identical, analogous, or generally analogous to that described above. However, a component reception stage 200 can be configured for reciprocating motion along an axis that is normal or perpendicular to a direction of component travel or flow along a feeder track 120 of the component delivery unit 100. For instance, a component reception stage's reciprocating motion can be defined with respect to a Y axis that is normal to an X axis that defines a direction along which components travel on the feeder track 120.

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15 Such reciprocating Y axis motion of the component reception stage 200 can occur by way of a mechanical arm or translation mechanism, which can be a conventional type of reciprocating displacement mechanism in a manner readily understood by one of ordinary skill in the art.

20 A component reception stage 200 configured for Y axis reciprocating motion (i.e., reciprocating motion in a direction that is normal or perpendicular to the direction of component flow along a feeder track 120) can include at least one receiving structure 210, and in a number of embodiments such a component reception stage 200 can include multiple receiving structures 210. In a configuration involving a first receiving structure 210a and a second receiving structure 210b, while one component 20 is removed, retrieved, or dispatched from the first receiving structure 210a to a processing station 80 (e.g., when the first receiving structure 210a is positioned at a first Y axis component dispatch position Y_{d1}), another component 20a can simultaneously be offloaded from the feeder track's component outlet 124 to the second receiving structure 210b (e.g., when
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30 the second receiving structure 210b is positioned at a Y axis component reception position Y_r).

Once (a) the first receiving structure 210a is empty; and (b) the second receiving structure 210b has received an offloaded component 20a (i.e., the second receiving structure 210b has been loaded with a component 20a from the feeder track's component outlet 124), the component reception stage 200 can be translated along the Y axis to a position at which a component 20a can be offloaded from the feeder track 120 onto the first receiving structure 210a (e.g., when the first receiving structure 210a is positioned at the Y axis component reception position Y_r), and a component 20 carried by the second receiving structure 210b can simultaneously be offloaded or dispatched to a processing station 80 (e.g., when the second receiving structure 210b is positioned at a second Y axis component dispatch position Y_{d2}).

FIG. 2M is a schematic top view illustrating portions of a component separation, singulation, or isolation apparatus 10 according to still another embodiment of the disclosure. In an embodiment, at least one component delivery unit 100 is configured to sequentially output or offload components 20a in a controlled or regulated (e.g., cyclical, periodic, or intermittent) manner to a component reception stage 200 that carries or includes multiple receiving structures 210, and which is configured for rotary, rotational, or turret-type motion, for instance, about a central component reception stage axis. Such a component stage can include or be coupled to a mechanical displacement mechanism configured for stepwise rotational motion, which can be conventional. In general, the component reception stage 200 can include at least one receiving structure 210 and in certain embodiment multiple receiving structures 210, where one or more receiving structures 210 that are disposed relative to or about the component reception stage's periphery.

In the embodiment shown, a first component delivery unit 100a is configured to output a component 20a from a first feeder track 120a to a first receiving structure 210a of the component reception stage 200 when the first receiving structure 210a is appropriately positioned or aligned relative to the first feeder track 120a. Additionally, a second component delivery unit 100b is configured to simultaneously or generally

simultaneously output a component 20a from a second feeder track 120b to a second receiving structure 210b of the component reception stage 200 when the second receiving structure 210b is appropriately aligned with the second feeder track 120b. Simultaneous or generally simultaneous with component offload onto the first and second receiving structures 210a, 210b, a component 20 carried by a third receiving structure 210c can be dispatched to a first processing station 80a, and a component 20 carried by a fourth receiving structure 210d can be dispatched to a second processing station 80b.

The component reception stage 200 can include a plurality of sensors or sensing elements 220 that facilitate the detection of portions of components 20 relative to each receiving structure 210a-d. Appropriate alignment or positioning of the first and/or second receiving structures 210a,b with respect to the first and/or second feeder tracks 120a,b, respectively, can be detected or determined by way of one or more sensors or sensing elements (e.g., optical sensors) associated with or carried by one or both of the first component delivery unit 100a and the second component delivery unit 100b and/or the component reception stage 200. Additionally or alternatively, appropriate alignment or positioning of the third and/or fourth receiving structures 210c,d with respect to the first and/or second processing stations 80a,b, respectively, can be detected or determined by way of one or more sensors or sensing elements (e.g., optical sensors) associated with or carried by one or both of the first processing station 80a, the second processing station 80b and/or the component reception stage 200.

Once components 20a have been offloaded onto the first and second receiving structures 210a,b and components 20 have been dispatched from the third and fourth receiving structures 210c,d to an appropriate processing station 80a,b, the component reception stage 200 can be rotated (e.g., clockwise or counter-clockwise), such that the first and second receiving structures 210a,b are aligned for component dispatch to the first and second processing stations 80a,b, respectively; and the third and fourth receiving structures 210c,d are aligned to receive offloaded components 20a from the first and second feeder tracks 120a,b, respectively.

After components 20 have been dispatched from the first and second receiving structures 210a,b to the first and second processing station 80a,b, respectively, and components 20a have been offloaded from the first and second feeder tracks 120a,b to the third and fourth receiving structures 210c,d, the component reception stage 200 can be rotated again, such that pairwise component offload operations from the two feeder tracks 120a,b and pairwise component dispatch operations to the two processing stations 80a,b can continue in a simultaneous or generally simultaneous manner. The synchronous or generally synchronous offload of component pairs 20a from the two feeder tracks 120a,b simultaneous with the synchronous or generally synchronous dispatch of component pairs 20 to the two processing stations 80a,b repeatedly occurs for each stepwise rotation of the component reception stage 200.

FIG. 2N is a schematic side view illustrating portions of an object or component flow regulation and/or separation, singulation, or isolation apparatus 10 according to another embodiment of the disclosure, in which the apparatus 10 need not include a component reception stage 200. Rather, objects or components 20 are serially displaced in a controlled or regulated manner along at least one feeder track 120 by way of the cyclical, periodic, or intermittent application of vacuum forces at particular feeder track locations (e.g., in manners described herein), and such objects or components 20 are sequentially output from each feeder track's component outlet 124 to a component destination, carrier, container, or receptacle 1000. In a representative embodiment, a component destination 1000 can correspond to a chemical processing station.

The present disclosure also encompasses other variations upon aspects of an apparatus 10 for controlling object or component flow and/or separating or singulating objects or components. For instance, in certain embodiments, portions of one or more vacuum assemblies (e.g., one or more vacuum chambers 150), and/or portions of one or more positive air pressure delivery assemblies (e.g., one or more air chambers 130) can be disposed external to a component delivery unit 100, rather than being carried internal to the component delivery unit 100.

Aspects of Representative Component Separation or Singulation Processes

FIG. 5 is a flow diagram of a representative object or component flow regulation and/or separation, singulation, or isolation process 300 in accordance with the present disclosure. By way of the selective (e.g., periodic or cyclical) application of one or more vacuum forces or pressures to portions of the feeder track 120, the process 300 facilitates or effectuates the deceleration of components 20 in motion along the feeder track 20, the termination of component motion or flow along the feeder track 120 (e.g., cessation of a leading component's motion, and at least deceleration of trailing component motion), and/or the prevention of unintended, undesired, or uncontrolled component transfer, discharge, ejection, or offload from the feeder track 120 unless the component reception stage 200 is appropriately positioned relative to the component reception position X_r and ready to receive a next component 20.

In an embodiment, a first process portion 310 involves the displacement, transfer, transport, or delivery of a plurality of components 20 (e.g., packaged semiconductor or electronic devices) along the feeder track 120, for example, from the component inlet 122 toward and/or to the component outlet 124. In multiple embodiments, a plurality of components 20 is displaced along the feeder track 120 in series (e.g., in a row).

Following the arrival of at least one component 20 to a location adjacent or proximate to the component outlet 124, a second process portion 320 involves the output of a leading component 20b within the plurality or series of components 20 from the component outlet 124, and the transfer of this component to the component reception stage 200 as an offloaded component 20a when the component reception stage 200 is located at the component reception position X_r . Thus, the second process portion 320 can involve the offload of a first component 20 in a component series to the component reception stage 200 (e.g., the offloaded component 20a can be defined as a first component 20).

A third process portion 330 involves detecting the presence of the offloaded component 20a on the component reception stage 200 (e.g., by way of one or more sensing elements or devices such as an optical sensor or a vacuum sensor). In response to the detection of

the offloaded component 20a on the component reception stage 200, a fourth process portion 340 involves applying a set of vacuum forces at or along one or more positions or portions of the feeder track 120 to stop further component output from the feeder track's component outlet 124. The fourth process portion 340 thus involves stopping the motion of a leading component 20b or a second component 20 in a component series which is positioned adjacent or proximate to the component outlet 124 (e.g., the leading component 20b can be defined as a second component 20 in the component series). The fourth process portion 340 can additionally involve the deceleration or stopping of the motion of other components 20 along the feeder track 120. The fourth process portion 440 thus prevents the output of another component 20 (e.g., a most recently arrived leading component 20b adjacent to the component outlet 124, or the second component 20 in the component series) at an undesirable or inappropriate time with respect to the component reception stage's recurrent or cyclical positioning relative to the component reception position X_r .

Simultaneous or essentially simultaneous with the fourth process portion 340, a fifth process portion 350 involves applying or increasing a vacuum force upon the offloaded component 20a, thereby securing the offloaded component 20a to the component reception stage 200. Additionally, a sixth process portion 360 involves shifting or displacing the component reception stage 200 to a component dispatch position X_d ; decreasing or discontinuing the vacuum force applied to the offloaded component 20a; and dispatching the offloaded component 20a to a processing station 80. Following component dispatch to the processing station 80, a seventh process portion 370 involves repositioning the component reception stage 200 at the component reception position X_r , adjacent or proximate to the component outlet 124. The fifth through seventh process portions 350 – 370 can be performed concurrent or substantially concurrent with the fourth process portion 340.

An eighth process portion 380 involves discontinuing and/or decreasing the application of one or more vacuum forces directed to the feeder track 120, thereby enabling the reinitiation of component flow, after which the process 400 can return to the first process

portion 310, such that the component reception stage 200 can receive a next offloaded component 20a from the component delivery unit 100.

5 In multiple embodiments, one or more automatic vacuum gauges, switches, or valves 62a, 62b are coupled to a controller such as the computer system 90 to facilitate the automatic (a) application of vacuum pressures or forces to the feeder track at appropriate times based upon the component reception stage's position or location with respect to the component delivery unit 100; (b) establishment or adjustment of vacuum force magnitude(s) and/or duration(s) at or along particular feeder track locations in order to
10 enhance, attain, or maximize a component separation or singulation rate.

In several embodiments, one or more portions of the process 300 can be automatically managed or performed by way of the execution of a set of program instructions. Such program instructions can reside on one or more computer readable media, for instance,
15 within a memory and/or a data storage device corresponding to the computer system 90.

For embodiments involving multiple feeder tracks 120 (e.g., spatially organized in parallel with respect to each other, or otherwise spatially disposed) configured to simultaneously or generally simultaneously displace or translate serially ordered
20 components from a component inlet 122 of each feeder track 120 to a component outlet 124 of each feeder track, multiple processes 300 in accordance with the foregoing description can occur in a synchronized and simultaneous or generally simultaneous manner.

25 Alternatively, certain embodiments involving multiple feeder tracks 120 can be configured such that components are output from individual feeder tracks 120 in a sequenced or alternating manner, in which case multiple processes 300 in accordance with the foregoing description can occur in a correspondingly sequenced or alternating manner.

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Aspects of Representative Singulation Apparatus Configuration Processes

In general, a feeder track 120 can have a component output rate that depends upon the magnitudes of (a) one or more positive air pressures or flows applied to one or more portions of the feeder track 120 in a manner that results in component motion along the feeder track 120, with respect to (b) one or more vacuum forces or negative air pressures or flows applied to one or more portions of the feeder track 120 in a manner that counters component motion to thereby stop and/or decelerate the flow of components 20 along the feeder track 120.

In particular embodiments, a singulation rate can be defined as a rate at which a component reception stage 200 can be recurrently positioned or driven relative to a component reception position X_r and a component dispatch position X_d to successfully receive a component 20 from the feeder track 120 and successfully facilitate component dispatch to a processing station 80. Thus, a singulation rate can be defined as a rate at which a component 20 carried by the component reception stage 200 can be separated or isolated from a set of components 20 carried by the feeder track 120 for the purpose of component dispatch to the processing station 80. A singulation rate can additionally or alternatively be defined as a reciprocation rate at which the component reception stage 200 is recurrently positioned or driven relative to the component reception position X_r and/or the component dispatch position X_d .

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In the event that the feeder track's component output or ejection rate exceeds the singulation rate, one or more components 20 will be undesirably ejected from the feeder track 120 after the component reception stage 200 has moved away from the component reception position X_r , before the component reception stage 200 has returned to the component reception position X_r and is ready to receive a next component 20. Consequently, such undesirably ejected components 20 will not be successfully dispatched to a processing station 80, and successful singulation of each component output by the feeder track 120 will not occur.

30 In order to achieve or attain a target singulation rate (i.e., a target rate at which successful component separation for each component 20 carried by the feeder track 120 can occur)

and avoid undesirable component output from the feeder track 120, a feeder track component output or ejection rate should be synchronized with or match the target singulation rate. For a given singulation rate under consideration, a feeder track component output rate can be adjusted based upon the magnitudes of one or more positive air pressures or flows applied to portions of the feeder track 120; a particular configuration of active vacuum elements to which vacuum forces or negative air pressures or flows are applied to portions of the feeder track 120; and/or the magnitudes of one or more such vacuum forces.

FIG. 6 is a flow diagram of a representative object or component flow regulation and/or singulation apparatus configuration process 400 according to an embodiment of the disclosure. The process 400 can facilitate the determination, testing, optimization, and/or verification of a set of object or component flow regulation and/or singulation parameters that enables an apparatus 10 under consideration to reliably control object or component flow and/or singulate or separate each component 20 carried by a feeder track 120 under particular operating conditions.

In an embodiment, the process 400 includes a first process portion 402 that involves establishing, defining, or selecting a trial singulation rate. A trial singulation rate can correspond to or be defined by an intended, estimated, or expected attainable rate at which components 20 can be recurrently offloaded from the feeder track 120 to the component reception stage 200 for each iterative displacement of the component reception stage 200 from the component reception position X_r to the component dispatch position X_d and back to the component reception position X_r . Such cyclical component reception stage displacement involves the transfer of a component to a processing station 80 when the component reception stage 200 is positioned at the component dispatch position X_d . In an embodiment, a trial singulation rate can be an initial or test component reception stage reciprocation rate.

The process 400 further includes a second process portion 404 that involves establishing, defining, or selecting the magnitudes of one or more positive air pressures and/or flow

rates to be applied to portions of the feeder track 120 to facilitate component motion along the feeder track 120. In general, the second process portion 404 involves establishing one or more positive air pressures or flow rates that can provide an unhindered or unrestricted component flow along the feeder track 20 that gives rise to a
5 feeder track component output rate that exceeds the trial singulation rate in the absence of applied vacuum forces.

The process 400 includes a third process portion 406 that involves establishing or selecting an initial configuration of active vacuum elements along the feeder track 120 to
10 which vacuum forces will be applied or delivered. The third process portion 406 can also involve establishing or selecting the magnitudes of one or more vacuum forces to be applied to the initial configuration of vacuum elements. In several embodiments, an initial configuration of active vacuum elements includes one or more vacuum openings 142a-b configured to apply vacuum force(s) to a leading component 20b, such that the
15 motion of the leading component 20b can be stopped; and possibly one or more vacuum openings 152a-b configured to apply vacuum force(s) to a set of trailing components 20c-e, such that the motion of the trailing component(s) 20c-e can at least be decelerated and possibly stopped. Vacuum elements configured for stopping the motion of a leading component 20b can be referred to as leading vacuum elements, and vacuum elements
20 configured for decelerating or stopping the motion of one or more trailing components 20c-e can be referred to as trailing vacuum elements.

The process 400 also includes a fourth process portion 410 that involves testing the singulation performance of the apparatus 10 in accordance with the trial singulation rate,
25 the set of positive air pressures / flows, and the initial set of active vacuum elements and corresponding vacuum forces established by way of the first through third process portions 402 – 406. During the fourth process portion 410, components 20 are introduced into the component inlet 122, and displaced along or through the feeder track 120 by the positive air pressures / flows. Once a first component 20a has been offloaded to the
30 component reception stage 200, vacuum force(s) can be applied to the component reception stage's vacuum opening(s) 242 to retain the first component 20a in a fixed

position. Additionally, vacuum force(s) can be simultaneously applied to the current configuration of active vacuum elements along the feeder track 120. The component reception stage 200 is then transferred or displaced from the component reception position X_r to the component dispatch position X_d , and the first component 20a is transferred to a processing station 80 or otherwise removed from the component reception stage 200. The component reception stage 200 is subsequently transferred back to the component reception position X_r to receive a next component 20 from the component outlet 124, and so on.

The process 400 includes a fifth process portion 420 that involves determining whether the singulation operations currently under test were successful. In the event that component output by the feeder track 120 occurred after the component reception stage 200 was displaced away from the component reception position X_r , while it carried the first component 20a, before the component reception stage 200 returned to the component reception position X_r and was ready to receive a second or next component 20b, the singulation operations were unsuccessful. That is, component ejection from the feeder track 120 occurred in a manner that was not appropriately synchronized with the component reception stage's recurrent motion relative to the component reception position X_r . Consequently, the vacuum forces that were applied along the feeder track 120 by way of the current configuration of active vacuum elements while the component reception stage 200 is cycled from the component reception position X_r to the component dispatch position X_d and back to the component reception position X_r were inadequate to effectively stop the motion of a leading component 20b carried by the feeder track 120.

If singulation was unsuccessful (i.e., undesirable component output from the feeder track occurred), a sixth process portion 430 involves determining whether more vacuum elements can be considered for addition to the configuration of active vacuum elements. If so, a seventh process portion 432 involves increasing a number of active vacuum elements to which vacuum forces can be applied in order to more effectively stop the motion of a leading component 20b and/or at least decelerate the motion of a set of trailing components 20c-e carried by the feeder track 120. That is, the seventh process

portion 432 involves adjusting the configuration of active vacuum elements to include a larger number of vacuum elements along the feeder track 120 to which vacuum forces can be applied, thereby increasing the likelihood that undesirable component ejection from the feeder track 120 can be prevented. Following the seventh process portion 432, the process 400 can return to the fourth process portion 410 to (re)test singulation performance.

When an active vacuum element configuration (e.g., the initial vacuum element configuration selected in association with the third process portion 406) includes an insufficient number of vacuum elements to reliably stop the motion of a leading component 20b carried by the feeder track 120 in synchrony with the component reception stage's recurrent positioning relative to the component reception position X_r , the fourth, fifth, sixth, and seventh process portions 410, 420, 430, 432 can facilitate the identification of an active vacuum element configuration (e.g., corresponding to a threshold or smallest active vacuum element configuration) that can provide successful or reliable singulation performance for the target singulation rate under consideration.

In the event that additional vacuum elements are not available for selection as active vacuum elements, an eighth process portion 434 can involve increasing one or more vacuum forces applied to a current set of active vacuum elements. Following the eighth process portion 434, the process 400 can return to the fourth process portion 410 to retest singulation performance.

If singulation was successful, a ninth process portion 440 can involve determining whether a current set of singulation parameters is acceptable. Such singulation parameters can include (a) one or more positive air pressure or flow rate magnitudes; (b) vacuum element configuration data that identifies an active vacuum element configuration that can reliably stop the motion of a leading component 20b when the singulation apparatus 10 operates at the target singulation rate; and/or (c) one or more vacuum pressure or vacuum force magnitudes corresponding to the current active vacuum element configuration.

If further modification, testing, or optimization of singulation parameters is to occur, a tenth process portion 450 can involve determining whether to test singulation performance using an alternate active vacuum element configuration, for instance, which includes a smaller number of active vacuum elements. If a smaller set of active vacuum elements is to be considered, an eleventh process portion 452 can involve selectively decreasing a number of active vacuum elements under consideration, followed by returning to the fourth process portion 410 to retest singulation performance.

10 If the number of active vacuum elements is to remain the same, a twelfth process portion 454 can involve selectively decreasing the magnitudes of one or more vacuum forces applied to the active vacuum elements. After the twelfth process portion 454, the process 400 can return to the fourth process portion 410 to retest singulation performance.

15 When an active vacuum element configuration includes a number of vacuum elements that may be more than sufficient to reliably stop the motion of a leading component 20b carried by the feeder track 120 in synchrony with the component reception stage's recurrent positioning relative to the component reception position X_r , the fourth, fifth, tenth, and eleventh process portions 410, 420, 450, 452 can facilitate the identification of
20 a smaller or smallest active vacuum element configuration that can provide successful or reliable singulation performance in view of the target singulation rate.

If in the ninth process portion 440 it is determined that a current set of singulation parameters is acceptable, a thirteenth process portion 460 can involve saving or storing
25 (for instance, in a memory or on a data storage device, e.g., within a data structure) the current set of singulation parameters, for instance, as a set of operational singulation parameters for the target singulation rate under consideration. Finally, a fourteenth process portion 470 can involve initiating singulation operations in accordance with the current or operational set of singulation parameters.

As an alternative or in addition to a process 600 corresponding to FIG. 6, (e.g., simultaneously or in parallel with, or sequenced with respect to the foregoing), in some embodiments a fifth process portion 420 can involve determining or evaluating the success, failure, suitability, or acceptability of the singulation operations currently under test with respect to structural and/or functional component damage. More particularly, the fifth process portion 420 can involve determining or generating one or more component damage measures that indicate whether one or more components 20 within one or more component evaluation sets exhibit structural and/or functional damage. For instance, a first component damage measure can indicate or correspond to a number or percentage of components that exhibit structural damage; and/or a second component damage measure can indicate or correspond to a number or percentage of components that exhibit functional damage.

If more than a predetermined or acceptable number or percentage of components exhibit structural and/or functional damage (e.g., in the event that the first or second component damage measures are undesirably large, or exceed corresponding component damage thresholds), the process 600 can proceed to test the selective activation of additional and/or fewer sets of vacuum elements, and/or the selective adjustment of vacuum forces applied to particular vacuum elements, in a manner identical or analogous to that described above in relation to FIG. 6 in order to establish an operational set of singulation parameters that (a) consistently or generally consistently results in zero, essentially zero, minimal, or an acceptable level of structural and/or functional component damage, and which also simultaneously (b) provides a highest or suitably high component throughput (e.g., in accordance with a measured or indicated UPH value), and (c) consistently prevents or avoids undesirable, unintended, or untimely component output from the component outlet 124 during singulation operations.

As a representative example to aid understanding, in some embodiments, a first process 600a corresponding to FIG. 6 can be performed to determine a first operational set of singulation parameters that consistently prevents or avoids undesirable component output from the component outlet during singulation operations at a highest or high component

throughput. If singulation operations in accordance with the first operational set of singulation parameters results in zero, essentially zero, minimal, or an acceptable level of component damage, the first operational set of singulation parameters can be retained and used as part of a production worthy component manufacturing process.

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In the event that an undesirable or unacceptable level of component damage is indicated, a corollary, associated, second, or next process 600b can be performed to arrive at a second operational set of singulation parameters that defines an appropriate vacuum element configuration and/or one or more vacuum force levels for providing a highest,
10 high, or acceptable component throughput, as well as zero, essentially zero, minimal, or an acceptable level of component damage. The second operational set of singulation parameters can be retained and used as part of a production worthy component manufacturing process.

15 In certain embodiments, one or more portions of a singulation apparatus configuration process 400 can be automatically managed or performed by way of the execution of a set of program instructions. Such program instructions, and/or particular sets of singulation parameters, can be stored on one or more computer readable media, for instance, a memory and/or a data storage device corresponding to a control unit 90 such as a
20 computer system.

A process 600 such as that described above can be adapted in accordance with essentially any type of component delivery unit 100 and/or component reception stage 200 embodiment under consideration (e.g., involving multiple feeder tracks 120, and/or
25 iterative component reception stage motion along a Y axis or rotationally about a central component reception stage axis).

Aspects of systems, apparatuses, devices, and processes are described above for facilitating or effectuating the separation, singulation, or isolation of components,
30 particularly the repeated, cyclical, or recurring separation of a component that is carried

by a component reception stage from other components that are carried along a feeder track toward or to the component reception stage.

5 A set of vacuum forces or pressures can be selectively applied relative to feeder track locations to decelerate and/or stop components in motion along the feeder track, thereby preventing an unintended, undesired, or uncontrolled discharge, ejection, or offload of one or more components from the feeder track. In various embodiments, the prevention of undesired component ejection from the feeder track occurs solely by way of a set of vacuum forces applied relative to one or more sites or positions along the feeder track. In 10 particular embodiments, the application of a vacuum force at a set of positions corresponding to a leading component carried by the feeder track is sufficient by itself to prevent the transfer of components from the feeder track to the component reception stage when the component reception stage already carries a previously withdrawn or offloaded component, or when the component reception stage is not yet ready to receive a 15 next component from the feeder track.

Particular vacuum forces or pressures can be applied at a set of positions, regions, segments, or zones along the feeder track by way of a set of vacuum elements such as vacuum openings, vacuum pathways, and/or vacuum chambers. The duration and/or 20 magnitude of applied vacuum forces applied by way of one or more vacuum elements can be controlled (e.g., selected and/or varied), for instance, depending upon a length and/or size (e.g., cross-sectional area or diameter) of the feeder track; component size and/or type; peak or average component displacement speed along the feeder track; and/or desired rate of component throughput (e.g., a target component singulation rate). In 25 certain embodiments, the duration and/or magnitude of vacuum force(s) applied by way of particular vacuum elements can be controlled independently from vacuum force(s) applied by way of other vacuum elements along the feeder track.

30 Certain embodiments of the disclosure are described above for addressing at least one of the previously indicated problems. While features, functions, advantages, and alternatives associated with the present disclosure have been described in the context of

those embodiments, other embodiments may also exhibit such advantages, and not all embodiments need necessarily exhibit such advantages to fall within the scope of the disclosure. It will be appreciated that several of the above-disclosed structures, features and functions, or alternatives thereof, can be desirably combined into other devices, systems, or applications. The above-disclosed structures, features and functions, or alternatives thereof, as well as various presently unforeseen or unanticipated alternatives, modifications, variations or improvements thereto that may be subsequently made by one of ordinary skill in the art, are encompassed by the following claims.

Claims

1. An apparatus for at least one of regulating a flow of components and separating components comprising:

5 a component delivery unit comprising at least one feeder track configured to carry a series of components serially displaceable along the at least one feeder track from a component inlet of the at least one feeder track toward a component outlet of the at least one feeder track; and
at least one vacuum assembly fluidly couplable to at least two distinct sites on the
10 at least one feeder track and configured to apply a set of vacuum forces to the at least two distinct sites.

2. The apparatus of claim 1, further comprising a component reception stage configured to receive at least one component within a series of components offloaded
15 from the component outlet.

3. The apparatus of claim 2, wherein the component reception stage includes a receptacle suitably shaped to receive at least one component.

20 4. The apparatus of claim 1, wherein the component delivery unit comprises at least two feeder tracks arranged in parallel.

5. The apparatus of claim 4, wherein the at least one vacuum assembly comprises at least two distinct vacuum assemblies, each of the at least two distinct vacuum assemblies
25 fluidly couplable to at least two distinct sites on each of a corresponding feeder track.

6. The apparatus of claim 2, wherein the component reception stage includes at least two distinct component receptacles, each of the at least two distinct component receptacles suitably shaped to receive at least one component.

7. The apparatus of claim 1, wherein the at least one vacuum assembly is configured to apply a first vacuum force at a first set of feeder track sites of the at least one feeder track and a second vacuum force at a second set of feeder track sites of the at least one feeder track.

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8. The apparatus of claim 7, wherein the at least one vacuum assembly is configured to selectively establish the magnitude of at least one of the first vacuum force and the second vacuum force.

10 9. The system of claim 1, wherein the at least one vacuum assembly comprises a plurality of vacuum elements, each vacuum element within the plurality of vacuum elements configured for selective fluid communication with the feeder track.

10. The system of claim 1, wherein the at least one vacuum assembly comprises a
15 first set of vacuum elements and a second set of vacuum elements distinct from the first set of vacuum elements.

11. The system of claim 10, wherein the first set of vacuum elements includes a first
20 set of vacuum openings exposed to the feeder track and the second set of vacuum elements includes a second set of vacuum openings exposed to the feeder track.

12. The system of claim 11, wherein the first set of vacuum openings is configured to
25 distribute a first vacuum force across a first number of components and the second set of vacuum openings is configured to distribute a second vacuum force across a second number of components.

13. The system of claim 11, wherein a first ratio defined by a magnitude of the first
30 vacuum force to the first number of components is different than a second ratio defined by a magnitude of the second vacuum force to the second number of components.

14. The system of claim 13, wherein the first ratio is greater than the second ratio.

15. The system of claim 11, wherein the first set of vacuum openings is positioned closer to the component outlet than the second set of vacuum openings.

5 16. The system of claim 11, wherein the first set of vacuum openings is configured to accommodate a first number of components and the second set of vacuum openings is configured to accommodate a second number of components.

10 17. The apparatus of claim 16, wherein the first number of components is different from the second number of components.

18 The apparatus of claim 16, wherein the first number of components is equal to the second number of components.

15 19. The apparatus of claim 16, wherein the first number of components is less than the second number of components.

20. The apparatus of claim 16, wherein the first number of components equals one.

20 21. The apparatus of claim 11, wherein the first set of vacuum openings is coupled to the at least one feeder track by a set of vacuum pathways disposed at an angle relative to the at least one feeder track.

25 22. The apparatus of claim 21, further comprising a set of air passages disposed at an angle relative to the at least one feeder track.

23. The apparatus of claim 22, wherein the first set of vacuum openings and the set of air passages are configured to enable a progressive displacement of the series of components along the at least one feeder track in a synchronous manner with respect to a cyclical application of the set of vacuum forces to the at least two distinct sites on the at least one feeder track.

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24. The apparatus of claim 11, wherein the first set of vacuum openings is configured to apply a vacuum force to at least one component in a manner that is sufficient to stop displacement of at least one component along the at least one feeder track.

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25. The apparatus of claim 11, wherein the first set of vacuum openings is configured to apply a vacuum force to a leading component closest to the component outlet in a manner that is sufficient to stop displacement of the leading component.

10 26. The apparatus of claim 11, wherein the first set of vacuum openings includes a vacuum opening having a different cross sectional area than a vacuum opening within the second set of vacuum openings.

15 27. The apparatus of claim 11, wherein the first set of vacuum openings provides a first aggregate cross sectional vacuum opening area and the second set of vacuum openings that provides a second aggregate cross sectional vacuum opening area that is distinct from the first aggregate cross sectional area.

20 28. The apparatus of claim 11, wherein the first set of vacuum openings includes a plurality of vacuum openings having different cross sectional areas.

25 29. The apparatus of claim 11, wherein the first set of vacuum openings includes a plurality of vacuum openings having different cross sectional areas and the second set of vacuum openings includes a plurality of vacuum openings having different cross sectional areas.

30. The apparatus of claim 11, wherein the first set of vacuum openings includes a leading vacuum opening and a trailing vacuum opening.

30 31. The apparatus of claim 30, wherein the leading vacuum opening is larger in cross sectional area than the trailing vacuum opening.

32. The apparatus of claim 11, wherein the component delivery unit comprises a vacuum chamber fluidly coupled to one of the first set of vacuum openings and the second set of vacuum openings.

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33. The apparatus of claim 11, wherein the component delivery unit comprises a first vacuum chamber fluidly coupled to the first set of vacuum openings and a second vacuum chamber fluidly coupled to the second set of vacuum openings.

10 34. The apparatus of claim 1, further comprising a pressurized gas supply unit fluidly coupled to the component delivery unit and configured to provide a positive gas pressure to the component delivery unit to exert a displacement force upon the series of components, the displacement force sufficient to displace the series of components toward the component outlet.

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35. The apparatus of claim 34, wherein the pressurized gas supply unit is configured to provide the positive gas pressure at one of a substantially constant flow rate and a substantially constant pressure.

20 36. The apparatus of claim 34, wherein the at least one vacuum assembly is configured to apply the set of vacuum forces in an intermittent manner relative to the positive gas pressure, and wherein the set of vacuum forces includes at least one vacuum force that is sufficient to intermittently stop displacement of a leading component closest to the component outlet.

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37. The system of claim 36, wherein the at least one vacuum assembly is configured to apply the set of vacuum forces during uninterrupted application of the positive gas pressure to the component delivery unit.

30 38. A system comprising:
a component delivery unit comprising:

at least one feeder track having a component inlet and a component outlet, the
at least one feeder track configured to carry a series of components
displaceable along the at least one feeder track; and

a pressurized gas supply unit fluidly coupled to the component delivery unit
and configured to supply a flow of pressurized gas that exerts a
substantially constant displacement force upon the series of components
along the at least one feeder track, the displacement force directed toward
the component outlet;

a component reception stage configured to receive a first component within the
series of components from the at least one feeder track, the component
reception stage comprising a set of sensors configured to detect receipt of the
first component by the component reception stage; and

a vacuum assembly fluidly coupled to the component delivery unit and configured
to intermittently apply with respect to the flow of pressurized gas a set of
vacuum forces at a set of feeder track sites, the set of vacuum forces sufficient
to prevent output of a second component within the series of components from
the component outlet.

39. The system of claim 38, wherein at least a portion of the vacuum assembly is
carried internal to the component delivery unit.

40. The system of claim 39, wherein the vacuum assembly comprises at least one
vacuum chamber fluidly coupled to the feeder track by way of a set of vacuum openings.

41. The system of claim 38, wherein application of the set of vacuum forces is
initiated upon detection of the receipt of the first component by the component reception
stage.

42. The system of claim 38, wherein the vacuum assembly comprises a first set of
vacuum elements configured to apply a first vacuum force to a first set of feeder track

sites and a second set of vacuum elements configured to apply a second vacuum force to a second set of feeder track sites that is distinct from the first set of feeder track sites.

43. The system of claim 42, wherein each of the first vacuum force and the second
5 vacuum force opposes the displacement force.

44. The system of claim 42, wherein the vacuum assembly is configured to selectively establish the magnitude of the first vacuum force relative to the magnitude of the second vacuum force.

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45. A method for at least one of regulating component flow and separating components comprising:

providing a component delivery unit having at least one feeder track configured to displace components from a component inlet toward a component outlet;

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providing a series of components to the at least one feeder track, the series of components including a first component and a second component that serially succeeds the first component;

displacing the series of components along the at least one feeder track toward the component outlet; and

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applying a set of vacuum forces to at least two distinct feeder track sites of the at least one feeder track to prevent output of the second component within the series of components from the component outlet.

46. The method of claim 45, wherein the series of components includes a third
25 component that serially succeeds the second component, the method further comprising:

adjusting at least one vacuum force within the set of vacuum forces to enable output of the second component within the series of components from the component outlet; and

further adjusting the at least one vacuum force within the set of vacuum forces to
30 prevent output of the third component within the series of components from

the component outlet after the second component has been at least partially output from the component outlet.

47. The method of claim 45, further comprising providing a component reception
5 stage configured to receive at least one component within the series of components offloaded from the component outlet.

48. The method of claim 47, wherein the component reception stage includes a receptacle suitably shaped to receive at least one component.

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49. The method of claim 45, further comprising providing at least one vacuum assembly configured for applying the set of vacuum forces, the at least one vacuum assembly fluidly couplable to the at least two distinct sites of the at least one feeder track.

15 50. The method of claim 45, wherein the component delivery unit comprises at least two feeder tracks arranged in parallel.

51. The method of claim 50, further comprising providing at least two distinct vacuum assemblies configured for applying the set of vacuum forces, wherein the at least
20 two distinct vacuum assemblies are fluidly coupable to the at least two distinct sites on each of a corresponding feeder track.

52. The method of claim 48, wherein the component reception stage includes at least two distinct component receptacles, each of the at least two distinct component
25 receptacles suitably shaped to receive at least one component.

53. The method of claim 45, wherein applying the set of vacuum forces to at least two distinct feeder track sites comprises selectively establishing at least one of a magnitude of a first vacuum force at a first feeder track site and a magnitude of a second vacuum force
30 at a second feeder track site distinct from the first feeder track site.

54. The method of claim 53, wherein the magnitude of the first vacuum force is different from the magnitude of the second vacuum force.

55. The method of claim 45, further comprising providing a plurality of vacuum elements fluidly couplable to the at least one feeder track, and wherein applying the set of vacuum forces to the at least two distinct feeder track sites comprises selectively establishing fluid communication between the at least one feeder track and particular vacuum elements within the plurality of vacuum elements.

56. The method of claim 45, further comprising providing a first set of vacuum elements fluidly couplable to the at least one feeder track and a second set of vacuum elements fluidly couplable to the at least one feeder track, the first set of vacuum elements distinct from the second set of vacuum elements.

57. The method of claim 56, wherein the first set of vacuum elements includes a first set of vacuum openings exposed to the at least one feeder track and the second set of vacuum elements includes a second set of vacuum openings exposed to the at least one feeder track.

58. The method of claim 57, wherein applying a set of vacuum forces to at least two distinct feeder track sites comprises distributing a first vacuum force across a first number of components using the first set of vacuum openings and distributing a second vacuum force across a second number of components using the second set of vacuum openings.

59. The method of claim 58, wherein a first ratio defined by a magnitude of the first vacuum force to the first number of components is different than a second ratio defined by a magnitude of the second vacuum force to the second number of components.

60. The method of claim 59, wherein the first ratio is greater than the second ratio.

61. The method of claim 57, wherein the first set of vacuum openings is coupled to the at least one feeder track by a set of vacuum passages disposed at an angle relative to the at least one feeder track.

5 62. The method of claim 61, further comprising providing a set of air passages disposed at an angle relative to the at least one feeder track.

63. The method of claim 62, wherein displacing the series of components along the at least one feeder track toward the component outlet comprises synchronizing a
10 progressive displacement of serially disposed components along the feeder track toward the component outlet using the first set of vacuum openings and the set of air passages.

64. The method of claim 63, wherein synchronizing the progressive displacement of serially disposed components along the feeder track comprises cyclically adjusting at
15 least one vacuum force within the set of vacuum forces.

65. The method of claim 64, wherein synchronizing the progressive displacement of serially disposed components along the feeder track comprises cyclically adjusting the at least one vacuum force within the set of vacuum forces while providing at least one
20 positive air pressure to the feeder track by way of the set of air passages, wherein the at least one positive air pressure exerts a substantially constant displacement force upon the series of components.

66. The method of claim 57, wherein the first set of vacuum openings is positioned
25 closer to the component outlet than the second set of vacuum openings.

67. The method of claim 66, wherein the first set of vacuum openings is configured to accommodate a first number of components and the second set of vacuum openings is configured to accommodate a second number of components.

68. The method of claim 67, wherein the first number of components is different from the second number of components.

69. The apparatus of claim 67, wherein the first number of components is equal to the second number of components.

70. The method of claim 67, wherein the first number of components is less than the second number of components.

71. The method of claim 67, wherein the first number of components equals one.

72. The method of claim 57, wherein the first set of vacuum openings includes a vacuum opening having a different cross sectional area than a vacuum opening within the second set of vacuum openings.

73. The method of claim 57, wherein the first set of vacuum openings provides a first aggregate cross sectional vacuum opening area and the second set of vacuum openings that provides a second aggregate cross sectional vacuum opening area that is distinct from the first aggregate cross sectional area.

74. The method of claim 57, wherein applying a set of vacuum forces to at least two distinct feeder track sites comprises establishing fluid communication between the feeder track and at least one of the first set of vacuum openings and the second set of vacuum openings.

75. The method of claim 57, wherein at least one of the first set of vacuum openings and the second set of vacuum openings is coupled to a vacuum chamber carried by the component delivery unit.

76. The method of claim 45, further comprising providing a positive gas pressure to the at least one feeder track to exert a displacement force upon the series of components,

the displacement force sufficient to displace the series of components toward the component outlet.

77. The method of claim 76, wherein the positive gas pressure is provided at one of a substantially constant flow rate and a substantially constant pressure.

78. The method of claim 77, wherein applying a set of vacuum forces to at least two distinct feeder track sites comprises applying the set of vacuum forces in an intermittent manner relative to the positive gas pressure.

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79. The method of claim 77, wherein applying a set of vacuum forces to at least two distinct feeder track sites comprises applying the set of vacuum forces during an uninterrupted provision of the positive gas pressure to the feeder track.

80. A method for at least one of regulating component flow and separating components, the method comprising:

providing a component delivery unit having at least one feeder track configured to displace components from a component inlet toward a component outlet;

providing a series of components to the component delivery unit, the series of components including a first component and a second component that serially succeeds the first component;

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providing a substantially uninterrupted positive gas flow that exerts a displacement force upon the series of components to displace the series of components along the feeder track toward the component outlet;

outputting the first component within the series of components from the component outlet;

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applying a set of vacuum forces to a set of feeder track sites; and

stopping displacement of the second component along the at least one feeder track solely as a result of applying the set of vacuum forces.

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81. A method for at least one of regulating component flow and separating components, the method comprising:

5 providing a component delivery unit having at least one feeder track and a selectable configuration of vacuum elements fluidly couplable to the at least one feeder track, the at least one feeder track configured to serially displace components from a component inlet toward a component outlet;

establishing a first vacuum element configuration that defines a first set of vacuum elements fluidly coupled to the at least one feeder track at a first set of feeder track sites;

10 displacing a plurality of components along the at least one feeder track toward the component outlet;

outputting a leading component from the component outlet while displacing the plurality of components along the at least one feeder track;

15 applying a vacuum force to the first vacuum element configuration after the outputting of at least a portion of the leading component from the component outlet; and

determining whether the first vacuum element configuration prevents output of another component from the component outlet during applying the vacuum force to the first vacuum element configuration.

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82. The method of claim 81, further comprising:

providing a component reception stage configured to receive a component from the component outlet; and

25 offloading the first component within the series of components from the component outlet to the component reception stage.

83. The method of claim 82, wherein the component reception stage includes a receptacle suitably shaped to receive at least one component.

30 84. The method of claim 81, wherein the component delivery unit comprises at least two feeder tracks arranged in parallel.

85. The method of claim 84, wherein the at least one vacuum assembly comprises at least two distinct vacuum assemblies, each of the at least two distinct vacuum assemblies fluidly coupable to the at least two distinct sites on each of a corresponding feeder track.

5

86. The method of claim 83, wherein the component reception stage includes at least two distinct component receptacles, each of the at least two distinct component receptacles suitably shaped to receive at least one component.

10 87. The method of claim 81, further comprising:
establishing a second vacuum element configuration that defines a second set of vacuum elements fluidly coupled to the at least one feeder track at a second set of feeder track sites, the second set of feeder track sites distinct from the first set of feeder track sites;
15 displacing a plurality of components along the at least one feeder track toward the component outlet;
outputting a component from the component outlet while displacing the plurality of components along the at least one feeder track;
applying a vacuum force to the second vacuum element configuration after
20 outputting the component from the component outlet; and
determining whether the second vacuum element configuration prevents output of another component from the component outlet during applying the vacuum force to the second vacuum element configuration.

25 88. The method of claim 87, wherein the second set of feeder track sites includes a larger number of feeder track sites than the first set of feeder track sites.

89. The method of claim 87, wherein the second set of feeder track sites includes a smaller number of feeder track sites than the first set of feeder track sites.

30

90. A method for separating components, the method comprising:

providing a component delivery unit having at least one feeder track and a selectable plurality of vacuum openings fluidly couplable to distinct positions of the at least one feeder track, the at least one feeder track configured to displace components from a component inlet toward a component outlet;

5 displacing a plurality of components along the at least one feeder track toward the component outlet;

cyclically applying a first set of vacuum forces to a first set of vacuum openings fluidly coupled to the at least one feeder track;

outputting a component evaluation set from the component outlet as a result of

10 alternatively transitioning between displacing the plurality of components along the at least one feeder track and cyclically applying the set of vacuum forces to the first set of vacuum openings, the component evaluation set including at least one component;

determining at least one damage measure corresponding to the component

15 evaluation set, the at least one damage measure providing an indication of one of component structural damage and component functional damage; and

establishing at least one of a second set of vacuum openings distinct from the first set of vacuum openings and a second set of vacuum forces distinct from the first set of vacuum forces based upon the at least one damage measure.

20

91. The method of claim 90, wherein outputting the component evaluation set comprises serially outputting individual components from the component outlet in a manner that prevents component output from the component outlet when the first set of vacuum forces is applied to the first set of vacuum openings.

25

92. A method for at least one of regulating component flow and separating components, the method comprising:

providing a component delivery unit having at least one feeder track fluidly couplable to a source of positive gas pressure and a selectable configuration of

30 vacuum elements fluidly couplable to the at least one feeder track, the at least

one feeder track configured to displace components from a component inlet toward a component outlet;

applying a positive gas pressure to the at least one feeder track;

exerting a displacement force upon a plurality of components carried by the at

5 least one feeder track by way of the positive gas pressure;

displacing the plurality of components along the at least one feeder track toward the component outlet; and

determining a configuration of vacuum elements that counters the displacement force to prevent component output by the component outlet during a vacuum

10 application interval.

93. The method of claim 92, wherein the configuration of vacuum elements is a smallest configuration of vacuum elements that counters the displacement force.

15 94. The method of claim 92, wherein applying the positive gas pressure comprises applying a substantially constant gas pressure.

95. A system for separating components, the system comprising:

a component delivery unit comprising:

20 at least one feeder track configured to carry a series of components displaceable along the at least one feeder track from a component inlet to a component outlet; and

a set of receiving elements; and

a component reception stage comprising:

25 a receiving structure configured to receive a component within the series of components output from the component outlet; and

a set of engagement elements configured to matingly engage with the set of receiving elements.

96. The system of claim 95, wherein the set of engagement elements comprises a set of protruding members that extends away from the receiving structure toward the component delivery unit.

5 97. The system of claim 96, wherein the set of receiving elements comprises a set of recesses formed in the component delivery unit configured to receive the set of protruding members.

10 98. The system of claim 95, wherein the set of engagement elements is configured to provide a bridge member between the component delivery unit and the receiving structure when the set of engagement elements and the set of receiving elements exist in a partially engaged state.

15 99. The system of claim 98, wherein the bridge member is configured to support a component that is at least partially disposed between the component delivery unit and the component reception stage.

20 100. The system of claim 98, wherein the component reception stage is configured for displacement between a component reception position and a component dispatch position, and wherein the bridge member and the receiving structure are configured for least partial engagement when the component reception stage is located at the component dispatch position.

25 101. The system of claim 98, wherein at least one of the bridge member and the receiving structure is tapered to facilitate mating engagement to accommodate a positional error between the component delivery unit and the component reception stage.

30 102. A method for separating components, the method comprising:
providing a component delivery unit that includes at least one feeder track and a set of receiving elements, the at least one feeder track configured to displace a

series of components along the at least one feeder track from a component inlet to a component outlet;

5 providing a component reception stage that includes a receiving structure and a set of engagement elements, the receiving structure configured to receive a component within the series of components from the component outlet, the set of engagement elements configured to matingly engage with the set of receiving elements, the set of engagement elements configured to provide a bridge member between the component delivery unit and the component reception stage when the set of engagement elements and the set of receiving elements exist in a partially engaged state;

10 outputting a component from the component outlet to the component reception stage when the set of engagement elements and the set of receiving elements exist in the partially engaged state; and

15 supporting by way of the bridge member the component output from the component outlet.