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AUTOMATED ROBOTIC LENS LOAD SYSTEM

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1. Field of the Invention

The present invention relates generally to an automatic contact lens transfer system, and, more particularly, to a robotic end effector device having independently movable transfer tips each for individually picking up contact lenses at one location under controlled vacuum conditions, and, placing them at another location under controlled blow-off conditions.

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2. Description of the Prior Art

Early prior art methods for transferring soft contact lenses from process holding trays into the primary package blisters were essentially manual. The manual lens transfer method (manual lens load or M.L.L.) contained several drawbacks. Besides being very labor intensive, the process was inconsistent since it depended on human operation. Additionally, the number of people involved in the lens transfer process was restricted when production line floor space was limited, therefore resulting in limited throughput. Furthermore, the manual method of lens transfer, which comprised of the implementation of swabs to pick and place the lens, possibly posed an ergonomic threat to the personnel involved. Lastly, the damage to lens was at a level of 3.5 to 15% depending on the experience of the operator.

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To overcome the drawbacks to the manual lens transfer method, automatic lens transfer (automatic lens load or A.L.L.) systems were developed that incorporate robotic arms for connection with other process equipment

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1 to form an automated cell, each cell having the
throughput equivalent of six humans using the manual
method. Numerous cells could be used per production
line to meet capacity needs and increase throughput.
5 Since the automated method does not use human
intervention beyond that of parts feeding, the process
is more consistent than the manual lens transfer method
and the ergonomic issue was eliminated since the robotic
arm does the work.

10 The critical designs which give prior art A.L.L.
systems a competitive edge center around the process of
picking up and placing lenses. A robotic arm carries an
end effector which has the ability to pull or blow air
through small holes placed on the effector tips.

15 As shown in Figure 1, a robotic arm of a prior art
lens transfer robot carries an end effector assembly 10,
having three (3) independently movable end effector tips
20a,b,c, each assembly having a vacuum tube 35 and
blowoff tube 50 for respectively pulling or blowing air
20 through small holes placed on the surface 26 of an end
effector tip 25. Air cylinders 47a, 47b, and 47c, are
commanded by a robotic controller (not shown) to
independently extend or retract transfer tips 20a, 20b,
and 20c, respectively. To pick up the lens out of the
25 hydration tray, the tip is extended into a tray carrying
the hydrated lenses, and a vacuum is created at the
vacuum tube 35 of each effector tip by a single vacuum
plenum 40 having an interior chamber 45, vacuum
connection 41, and vacuum pump (not shown).
30 Essentially, the vacuum plenum pulls hydration solution
through the effector tip for a dwell period of



1 approximately 400 milliseconds at a vacuum level of
approximately 20 inches of H₂O. The cycle is repeated
for each effector tip so that after three contact lenses
are picked up by respective three end effector tips, the
5 robot arm indexes all three tips over three
corresponding primary blister pack cavities for
simultaneous lens transfer thereto. After indexing of a
lens carrying end effector over a primary blister
package, the vacuum supply is turned off and an air
10 supply is turned on to "blowoff" the lens from the tip
into an indexed blister cavity. Specifically, for a
dwell period of about 200 milliseconds, air at a
pressure of approximately 20 psi is supplied to each
transfer tip through each blowoff tube 50 to blow the
15 lens off the respective tip 25 for deposition into a
blister package cavity. A water separation unit is
designed into the system to remove excess solution from
the lens at pick up so that it may be deposited without
much spray at blowoff. Finally, after lens blowoff,
20 each of the air cylinders 47a,b,c of the effector
assembly retract the transfer tips and the cycle is
repeated for a new lens pick up.

The design of the end effector allows for three
lenses to be picked up, moved, and blown off into the
25 blister, thus, allowing for optimization of throughput
given the capacity of the robot arm to carry a load.

The provision of electrical and pneumatic controls
used to operate the end effectors are critical features.
There are, however, numerous drawbacks to the above-
30 described prior art automatic lens transfer end effector



1 devices, particularly, with respect to the end effector
assembly and tips as herein described:

5 Figure 2(a) shows a detailed cross-sectional view
of the prior art end effector tip 25, and Figure 2(b)
shows a detailed view of the array of orifices 30 at the
10 surface 26 of the tip. As shown in Figure 2(a), the
bores 28 connecting the surface orifices 30 to air and
vacuum tube supply (described below) are linear, which,
as will be discussed below, provides for the increased
possibility of lens transfer failures and requires
15 greater vacuum and air blowoff pressures to effectuate
transfers. For example, it is often the case that the
lenses are not placed accurately in the receiving
container resulting in blister rejection and decreased
throughput.

15 Additionally, the end effector of the prior art
uses a first common plenum (or chamber) for the vacuum
and a second common plenum for air that was shared by
all the end effector transfer tips. The common plenum
20 designs result in fluctuations of vacuum and air (as
lenses are picked up and discharged) in the end effector
tips, which, in turn, give erratic transfer performance
with respect to actually picking up lenses and blowing
them off. For example, as shown in Figure 1, the end
25 effector 20 uses a common plenum 45 for the vacuum and a
common plenum (not shown) for air blowoff that is shared
by all three end effector transfer tips. The common
plenum designs of the prior art result in vacuum and air
fluctuations in the end effector tips depending upon how
30 many lenses have been picked. For example, variations
in vacuum levels ranging from 20 inches of H₂O to 40

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1 inches of H₂O occur, making process optimization very
difficult. Additionally, given the large volume of the
end effector tip assembly 25, the linear orientation of
the orifices (Figure 2(a)) and elongated lengths of the
5 blow-off tube, air supply blowoff pressures ranging from
20 psi. to 40 psi. are required to be applied for
durations of 200 ms to effect lens blowoff.

It would be highly desirable to provide an end
effector tip for a robotic lens transfer device that
incorporates a design that allows for individual vacuum
10 and air pressure plenums (or chambers) for each transfer
tip for increased control of the vacuum conditions.

It would also be highly desirable to provide an end
effector tip that is much smaller in volume and more
efficient in terms of controlling vacuum and air blowoff
15 to enable increased lens transfer successes and higher
throughputs.

SUMMARY OF THE INVENTION

20 It is an object of the present invention to provide
a robotic lens transfer device for transferring and
handling contact lenses that incorporates a design
allowing for individual vacuum and air pressure plenums
(or chambers) for each transfer tip of the end effector.

25 Another object of the invention is to provide an
automated Lens Load (A.L.L.) system for transferring
soft contact lenses from inspection holding trays into
the primary package blister in a quick and efficient
manner.

30 Still a further object of the invention is an
automated Lens Load (A.L.L.) system that includes a

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1 robotic lens transfer device that is provided with
intelligence from an upstream lens inspection operation.

5 Yet another object of the invention is to provide
an automated Lens Load (A.L.L.) system wherein the
intelligence provided by the upstream lens inspection
operation includes a matrix of good/bad lenses that are
to be transferred downstream at a lens transfer
operation.

10 Yet a further object of the invention is to provide
a control system for a robotic lens transfer device
having end effector transfer tips that permits the use
of reduced air blowoff values for shorter dwell times to
remove the lenses from transfer tips and which is
gentler on the lens resulting in far fewer edge defects
and more accurate placement.

15 It is another object of the invention to provide a
control system for a robotic lens transfer device that,
in conjunction with an inventive robotic end effector
tip, allows for the improved consistency of vacuum and
air pressure design resulting in increased lens transfer
rate, lens positioning, and product yield.

20 These and other objects of the present invention
are attained with a method of automatically transferring
contact lenses from a plurality of good cups positioned
at a first location to a plurality of packages
25 positioned at a second location wherein each good cup
contains a transferable contact lens therein for
placement in an individual blister package. The method
comprises a step of communicating positional information
of the good cup locations to a robotic device having an
30 arm with one or more end effectors thereon, each end

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1 effector having a tip in connection with vacuum and air
pressure supply means, each end effector independently
moveable with respect to the arm. Then, applying a
vacuum to the end effector tip to enable pick-up of a
5 transferable lens from a cup located at a good cup
location, and, controlling the robot to effect
positioning of one end effector tip within the cup
having said transferable lens therein to pick up the
lens. A further step includes controlling the robot to
10 remove the end effector tip from the good cup location
and position the end effector tip carrying the
transferable lens within a blister package cavity, and
finally, removing the vacuum and applying air pressure
to the end effector tip to deposit the lens into a
blister package cavity.

15 Further benefits and advantages of the
invention will become apparent from a consideration of
the following detailed description given with reference
to the accompanying drawings, which specify and show
preferred embodiments of the invention.
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BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram showing the
robotic end effector device and tip for the automatic
lens load system of the prior art.

25 Figure 2(a) is a cross-sectional view along
line "A-A" of the prior art end effector tip assembly of
Figure 2(b) showing the linearly oriented bores.

Figure 2(b) is a frontal view of the prior art
end effector tip showing the array of orifices at the
30 tip surface for pulling and blowing air.

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1 Figure 3 is a side, partial cross-sectional
view of the robotic end effector and end effector tip of
the invention.

5 Figure 4(a) is a cross-sectional view along
line "A-A" of the end effector tip assembly of Figure
4(b) showing the radially oriented bores.

 Figure 4(b) is a frontal view of the end
effector tip of the invention showing the array of
orifices at the tip surface for pulling and blowing air.

10 Figure 5(a) illustrates the positioning of the
end effector tip over the hydration cup carrying a good
transferrable lens therein with a vacuum applied prior
to lens pick.

15 Figure 5(b) illustrates the extension and
dwell of the end effector tip toward and within the
hydration cup for removing the contact lens therein.

 Figure 5(c) illustrates the retraction of the
end effector tip with the vacuum applied after lens
pick.

20 Figure 5(d) illustrates the extension of the
end effector tip within the blister package cavity prior
to lens blow-off.

25 Figure 5(e) illustrates the dwell of the end
effector tip within the blister package cavity and
activation of blow-off air pressure to accomplish lens
blow-off.

 Figure 5(f) illustrates the retraction of the
end effector tip with the vacuum applied after lens
placement.

30 Figure 6 illustrates the conveyance of
hydration cups carrying good/bad lenses out of hydration



1 and lens inspection stations having a bar code
1 identifier thereat.

5 Figure 7 illustrates an automatic lens load
cell wherein robotic arm picks good lenses from the
hydration cups at a lens pick location and transfers the
lenses to a blister package at a lens place location in
the manner as shown in Figures 5(a) - 5(f).

10 Figure 8 illustrates the vacuum pump and
regulator 138 shown mounted proximate the power enclosure
139 for the automatic lens load cell.

15 Figure 9 illustrates presents a block diagram
representation of the software architecture for
controlling the operations of an automated lens load
cell.

15 **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

To overcome the drawbacks in the prior art design,
the end effector device 75 of the invention, shown in
Figure 3, is designed to have an individual vacuum
plenum for each end effector assembly. As shown in
20 Figure 3, the end effector assembly 75 of the invention
is of a streamlined, integral design of a drastically
reduced volume and having a dedicated vacuum plenum for
each tip. The advantage of such a design is that the
vacuum level for each tip is not effected by what is
25 happening on the other two end effector assemblies,
hence, process optimization is easier. For instance, in
the end effector of the invention, vacuum levels of a
constant pressure are expected with virtually no
fluctuation. While vacuum levels of 22 to 30 inches of
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1 H₂O may be used, a level of 26 inches of H₂O is preferred.

5 Figure 3 illustrates a side, partial cross-sectional view of one transfer lens end effector assembly 75 comprising an lens end effector frame 77, an
10 air cylinder 79 mounted on a shelf 81 of the end effector frame for providing vertical extension and retraction of the end effector tube/plenum assembly 80 and integral lens end effector nozzle tip 60 relative to
15 the frame 77. As shown in Figure 3 and Figures 5(a)-5(f), vertical extension and retraction of the end effector tube/plenum assembly 80 and lens transfer tip 60 is accomplished by the cooperation of air cylinder 79 that is connected to guide shaft 85 at one end and connected with the tube/plenum assembly 80 at the other end.

20 As shown in Figure 3, the end effector tube/plenum assembly 80 and lens transfer tip 60 is short in comparison with the prior art tip (Figure 1) and much lower in volume. The lens transfer tip 60 is integrally connected with an individual vacuum plenum 87, and, comprises a blowoff tube 90 that is also short in comparison with the prior art lens blowoff tube (Figure 1) and integrally connected with an individual air
25 supply plenum 97.

30 As shown in Figure 4(a) and 4(b), the lens end effector nozzle tip 60 pulls and blows air through radially oriented holes on a convex surface 61 thereof. Figure 4(a) shows a detailed cross-sectional view of the improved end effector tip 60, and, Figure 4(b) shows a detailed view of the array of orifices 65 at the convex

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1 surface 61 of the tip. the convex surface 61 is of
substantially the same radius as that of the human eye.
As shown in Figure 4(a), the bores 68 connecting the
surface orifices 65 with the air and vacuum plenums are
oriented radially within the tip 60. The advantages of
5 this radially oriented tip design are that the
occurrence of lenses sticking to the tip 60 are
dramatically reduced, and the rate of successful
transfers is increased due to the fact that the semi-
spherical surface of the lens is more responsive to
10 vacuum and blow off pressure emanating from radially
oriented orifices of the tip. This is contrary to the
prior art linear tip design (Figure 2(a)) in which the
occurrence of lenses sticking to the tip and inaccurate
lens placement was increased.

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End effector lens transfer movement

The operation of the robot arm and end effector
assembly of the invention, as shown in Figures 5(a)
through 5(f), is as follows:

20

First, as shown in Figure 5(a), the end effector
assembly 75 is positioned so that one effector tip 60 is
indexed over a contact lens carrying hydration cup 18.
At the time of this positioning, a vacuum is applied to
the end effector tip. The individual end effector
25 assembly 75 including vacuum plenum 87 is then extended
downward all the while controlling speed and
deceleration. The robot then remains stationary in the
hydration tray cup for a set dwell period, while the
lens is sucked up by the applied vacuum onto the tip by
30 vacuum. In the preferred embodiment, the set vacuum

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1 dwell period is 60 ms within a desired range of 40 to
100 ms and the suction force that the vacuum pump
creates for the end effector tip is preferably
approximately 26 inches of H_2O within a desired
5 operation range of 22 to 30 or variation in vacuum
pressure inches of H_2O and a net change between lens
pick ups of 4 inches of H_2O . As shown in Figure 5(b),
the vacuum force is indicated as lines 72, and acts
through the effector tip 60 and vacuum nozzle 85 to the
vacuum plenum 87 (Figure 3). The contact lens 15 and
10 hydration solution are picked up (Figure 5(b)) from the
hydration cup 18 and the robot end effector tip is then
vertically retracted (Figure 5(c)) all the while
controlling speed and acceleration. This process is
repeated two more times until each end effector tip has
15 acquired a lens.

As shown in Figure 7, the excess hydration solution
is separated by a water separation apparatus 133 located
within the vacuum plenum. In the preferred embodiment,
the water separation vacuum plenum 133 is about three
20 (3) liters in volume and has a tube in the bottom (not
shown) which allows water coming from the end effector
tips to be removed and not ingested in the vacuum pump
and regulator 138 to which it is attached. (See Figure
8). The pump and regulator are positioned adjacent the
25 apparatus illustrated in Figure 7. In the preferred
embodiment, the water separation vacuum plenum has one
port attached to the vacuum pump and regulator, and
three ports for each respective tip of the end effector.

After three contact lenses 15 are picked up and
30 held by the three end effectors of the robot arm, the

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1 robot arm indexes all three end effectors over three
corresponding primary blister packages 19 for
simultaneous lens transfer thereto. The lens transfer
operation for one end effector is shown in Figures 5(d)
through 5(f).

5 After the robot arm indexes the lens carrying end
effector tips over a primary blister package 19 (Figure
5(d)), with vacuum still applied, the end effector tips
are vertically extended into the blister pack cavities
to a position fixed above the bottom of the cavity all
10 the while controlling speed and deceleration. The end
effector tips remains stationary within respective
blister cavities while the vacuum supply used to pick up
the lens is turned off. Immediately thereafter, a jet
of air, indicated as line 73 in Figure 5(e), is valved
15 to each tip through blowoff tube 90 for a fixed time
period to release the lens from each tip into the
blister pack cavity. The blowoff dwell time for the jet
of air is approximately 60 milliseconds within a desired
range of 20 to 80 ms and the blowoff pressure is about 8
20 psi, within a desired range of 4 to 12 psi. The tip 60
having radially oriented orifices and operating at these
vacuum and air pressure levels enables more accurate
blow off, with less possibility of H₂O being blown back
into the blister pack. Consequently, there is a marked
25 decrease of rejected blister packages and a
corresponding increase in blister package throughput
rates.

After blowoff, the robot then retracts vertically
from the lens load position as shown in Figure 5(f) all
30 the while controlling speed and acceleration. The

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1 vacuum is then re-energized to the tip 60 (Figure 5(f))
and re-positioned over the hydration cups for the next
lens pick cycle.

5 Automatic lens load system

Figures 6 and 7 illustrate a plan view of one
automatic lens load cell 100 which contains equipment
responsible for transfer of hydration trays to/from the
position where the lenses are removed, transfer of
Blister Packs to/from the position where the lenses are
10 placed into them, and robotic transfer of the lenses.
In the preferred embodiment there are three identical
cells for increasing the volume throughput of contact
lenses.

15 As shown in the Figure 6, a plurality of hydration
trays 101 each tray comprising thirty-two (32) hydration
cups, each containing an individual contact lens, is
conveyed out of a hydration station 110 by conveyor 103
for manual inspection at a lens inspection station 120.
In the preferred embodiment, each hydration tray 101
20 contains cups arranged in a 4X8 matrix and is
additionally bar code tagged for identification by a bar
code scanner 105 at the lens inspection station.
Specifically, the bar code tag is to assure lot
integrity and to assign a good lens/bad lens matrix to
25 the particular hydration tray for later transmission to
the barcode supervisor computer 150, as shown by broken
lines 98 in Figure 6. As will be explained in greater
detail below, when the hydration tray 101 is conveyed
downstream for automatic lens transfer, the robot
30 assembly at a lens pick location will pick up only the

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1 good lenses remaining in the hydration tray by virtue of
the good lens/bad lens matrix assigned to that pallet.

5 At the lens inspection station 120, the lenses
containing defects are identified by operators and the
bad lenses are removed from this associated hydration
cup.

10 The hydration trays with the remaining good lens cups,
is scanned by a bar code reader 105 to associate the
positional information of the removed hydration cups
within the 4X8 matrix with the particular tray. This
information is transmitted to the supervisor computer
150, which, in the preferred embodiment, is a DEC '486
computer, connected by a STAR node local network. Thus,
the supervisor computer 150 stores a data model
15 representative of each tray which includes the tray
identification number, lot number, and a matrix of tray
locations indicating which tray locations contain lenses
which are empty and consequently the locations of good
lenses to be transferred.

20 Tray transfer

As shown in Figure 7, each hydration tray is
conveyed downstream from the lens inspection station to
the hydration tray infeed station 130, where they remain
in a stacked queue, indicated as 132. In the manner
25 described below, each individual hydration tray is
removed (de-stacked) from the stack via an escapement
(not shown) located at the bottom of the infeed station
130 and are transported to the lens pick location 140
via a tray transfer conveyor 108 in the direction
30 indicated by arrow "A". In the preferred embodiment,



1 tray transfer conveyor 108 is a twin belt conveyor which
are driven by a 1/3HP, 120VAC, single phase motor (not
shown). As will be explained, all transfer of hydration
trays between the positions where destack, reject, lens
5 unload, and up-stack occur is accomplished by the tray
transfer conveyor 108.

Tray Destack

During tray destack, a single tray is
10 separated from the remaining stack of trays waiting to
be introduced into automatic lens load cell. Tray
destack is performed using a tray elevator (not shown)
to lower the bottom tray in the stack to the singulate
position, then to the transfer position. At the
15 singulate position, destack singulators are used to
separate this bottom tray from the remaining trays in
the stack.

A tray elevator then performs vertical
transfer of hydration trays in either and up or down
direction, as required. Preferably, the tray elevator
20 consists of a DC motor connected to a lead screw/nut
combination by a timing belt. Rotation of the DC motor
shaft causes a rotation in the nut, which in turn drives
the lead screw in a vertical direction, up or down,
depending on the rotational direction of the motor
25 shaft. The DC Motor is controlled by a four quadrant
regenerative drive controller which is a Minarik RG-310U
Regenerative DC Motor Speed Controls.

The tray elevator used for destack is equipped with
tray elevator outriggers (not shown) which is an
30 assembly for supporting the outside edges of the

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1 hydration tray. This assembly prevents flexing of the
hydration tray when force is applied to these outside
edges during singulation of a tray.

5 Two Destack Singulators separate a single hydration
tray from the bottom of the stack of trays. Each
singulator consists of an air cylinder which, during
singulation, moves an escapement horizontally into
position to support the one end of the stack of
remaining trays, while simultaneously rotating a cam
10 (not shown) to apply a vertical force to one end of the
tray being singulated, forcing separation of this tray
from the stack.

Bar Code tray identification

15 As shown in Figure 7, after a tray is destacked
(singulated) for lens unloading, a bar code scanner 106
scans the hydration tray for identification at or near
the lens pick station 140. The bar code scanner 106
further transmits the tray identification number via
20 serial link 109 to the supervisor computer 150 (Figure
6) so that the previously entered lens inspection data
119 for that same tray may be appropriately transmitted
back to the robot controller for robot manipulator and
end effector tip control.

25 Tray Reject

If the bar code identifier on the hydration tray was
not successfully scanned, the tray is transferred to a
tray reject station (not shown) which consists of
30 lifting the tray from the conveyor 108 and pushing the
tray onto a latching magazine. Specifically, a tray

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1 reject operation is performed using a tray elevator that
raises the hydration tray which is to be rejected,
pushes up and interlocks with any previously rejected
trays, until captivated by an escapement mechanism.

5 Tray Positioning

For those trays whose identification number could
be read, the trays are repeatedly positioned and
physically located for lens removal. Specifically, lens
unload tray positioning involves a tray elevator that
10 raises the hydration tray to allow the Lens Unload Tray
Positioners (not shown) to locate the tray at a
repeatable position for unloading lenses.

A tray elevator, as described above, performs
vertical transfer of the hydration trays in either an up
15 or down direction, as required, and consists of a DC
motor connected to a lead screw/nut combination by a
timing belt. However, the tray elevator used at the
lens unload position is not equipped with tray elevator
outriggers.

20 In the preferred embodiment, two (2) lens unload
tray positioners (not shown) are used to position each
hydration tray for unload at respective two lens unload
locations 142a and 142b as shown in Figure 7, therefore,
a total of four (4) positioners. A single Lens Unload
25 Tray Positioner consists of an air cylinder which guides
a positioning wedge under one side of the hydration
tray. During engagement, the positioning wedge uses
three (3) features to repeatedly position an hydration
tray in the robot's X, Y and Z axis. The Z-Axis Wedge
30 drives the hydration tray in the robot's X, Y and Z

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1 axis. The Z-Axis Wedge drives the hydration tray up
into positioning rails (not shown), the Y-Axis Wedge
centers the hydration tray, and when completely engaged,
the hydration tray is captivated between the X-Axis
5 Blocks.

Tray Up-stacking

As shown in Figure 7_, after all of the lenses have
been removed by the robot end effector in the manner
described above with respect to Figures 5(a) - 5(f), the
10 empty tray is lowered to the tray transfer conveyor 108
for transference to the hydration tray up-stacker
station 135 where the tray is lifted from the conveyor
108 for loading onto a latching magazine.

15 The tray up-stack pushes the recently emptied tray
into the stack of trays which were processed previously.
Specifically, the tray stack operation uses a tray
elevator, in the manner described above, to raise the
hydration tray which is to be rejected, pushing up and
interlocking with any previously rejected trays, until
20 captivated by an escapement mechanism.

Blister transfer

As shown in Figure 7, simultaneous with the
conveyance of the hydration pallets as discussed above,
25 individual blister packages are introduced into the
automatic lens load cell from the bottom of a blister
pack dispenser (not shown) which may comprise a
conventional stacking and dispense mechanisms for
removing individual blister packs at a blister dispense
30 station 115. Specifically, as shown in Figure 7, the

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1 blister pack 105 is dispensed onto a blister transfer
index conveyor 107 that, as will be explained in further
detail below, transfers blister packs between the
dispense position, load positioning, inspection, and
5 rejection. Preferably, the blister transfer index
conveyor 107 consists of a DC gearmotor, connected to
the input shaft of a mechanical cam index mechanism. A
single rotation of this input shaft is broken down into
two functional segments, a 270 degree index segment, and
10 a 90 degree dwell segment. During the 270 degree index
segment, the output shaft of the index mechanism
performs two complete rotations. During the 90 degree
dwell segment, the output shaft remains stationary. The
output shaft of the index mechanism drives a continuous
15 belt which is equipped with flexible lugs spaced at 12
inch centers and used to push the blister packs along
the guide rails, twelve inches at a time.

As mentioned above, the blister packs 105 are
indexed to the lens place location 145 where the blister
pack is clamped down, the lens cavities are supported
20 from below, to position the blister pack to receive
three lenses from the robot end effector assembly in the
manner described above. Specifically, the positioning
of the Blister Packs at the repeatable lens place
location 145 for lens placement by the robot is
25 accomplished by a lens load positioner (not shown).
After a new blister pack 105 has been indexed into the
approximate lens load position by the blister transfer
index conveyor 107, an air cylinder moves a positioning
plate (not shown) in a downward direction to position
30 the blister pack. During this downward motion, four (4)



1 bullet shaped positioning pins (not shown) insert into
"dimples" in the blister pack, moving the blister pack
from the approximate to the final lens load position,
and insuring a repeatable position in the X/Y plane of
5 the robot. When this downward motion has completed, the
positioning plate is forcing the bottom surface of each
of the six Blister "cavities" (where the lenses are
placed) against the Cavity Support, insuring a
repeatable robot Z axis location of the bottom surface
10 of the blister cavities.

10 Since a blister package comprises six primary
package cavities, two pick/place lens placement
sequences are performed, after which, the positioning
clamp is released to allow the blister pack index to a
subsequent blister inspection station (not shown) for
15 optical verification that a lens has been placed in each
of the six (6) positions in the blister pack 105. If
the presence of six lenses is not verified, a reject
gate (not shown) positioned along the conveyor 107
diverts the deficient blister pack 105 to a reject belt
20 conveyor (not shown) during the next index. Preferably,
the blister reject gate consists of an air cylinder (not
shown) which when retracted, causes fingers of the
reject gate to lower, with the tips of these fingers
entering mating notches in the blister transfer guide
25 rails. When the next index occurs, the failed blister
pack is pushed up onto the fingers. At this time, the
air cylinder extends, causing the fingers (which are
supporting the blister pack) to raise until the reject
gate is parallel with the reject conveyor.
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1 Blister packages which are not rejected are
indexed onto a continuous running flat topped flexible
link end of line conveyor system to transfer each the
blister pack to the heat seal area 190 where foil is
sealed to the open faces of the blister packs.

Robot Assembly

As shown in Figure 7, a robot 175, which, in the
preferred embodiment, is an Adept One® four (4) axis
robot, includes the above-described end effector device
75 mounted on the end of a Z-axis quill assembly (not
shown) for removing lenses three at a time from the
hydration trays at the lens pick location 140 for
placement into the blister package at the lens place
location 145. Figure 7 illustrates the robot 175 in a
first lens pick position 176 and a second lens place
position 177 as commanded by the auto lens load robot
controller 180 which controls all of the robot's
movements, and, in the preferred embodiment is an Adept
A-series microcontroller. Preferably, the robot
controller 180 receives the good lens/bad lens matrix
data 119 from the supervisor computer 150, and,
in a manner known to those skilled in the art, instructs
the robot 175 and end effector assembly 75 to pick up
three good lenses at a time from the hydration tray 101
at the lens pick position. As shown in Figure 7, a bar
code scanner 106 is positioned to scan the hydration
tray for identification at or near the lens pick station
140 and further transmits the tray identification number
109 to the supervisor computer 150 so that the
previously entered lens inspection data 119 for that



1 same tray is appropriately transmitted back to the robot
controller for robot and end effector control. In the
preferred embodiment, the supervisor computer is
connected to each bar code reader as well as the robot
and inspection controllers via a STAR node. If the bar
5 code identifier on the hydration tray was not
successfully scanned during destack, the tray is
transferred to the Tray Reject Station. Tray Reject
consists of lifting the tray from the conveyor, pushing
the tray into a latching magazine. Additionally, via
10 RS-232 serial links, the supervisor computer controls
the all the vacuum and lens blow-off dwell times for the
robot end effector tips and all power for the lens load
system is distributed from the electrical supply box 139
to power the hydration tray de-stacker and up-stacker
15 elevator motors (not shown), the blister package
transfer index motor and conveyor (not shown), the
vacuum pump and end of line conveyor motors, etc.

20 Robotic Control System

As shown in Figure 7, the robotic control system
for each automated lens load cell includes an Adept MC
controller 180 for controlling the robot manipulator
used to transfer the lenses. The manipulator is an
Adept One, 4-axis, servo driven, SCARA robot equipped
25 with optional Hyperdrive.

Software Architecture

The software developed to control the equipment
contained within the cell consists of up to sixteen (16)
30 separate concurrent "tasks" on the Adept V+ Operating

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1 System/Programming Language. A "task" is a single
program executing continuously. All sixteen tasks are
prioritized and scheduled to share a portion of the
execution time of each processor major cycle (each major
5 cycle is 16 msec in duration) thus giving the effect
that all tasks are executing simultaneously. The
following sections provide an overview of the major
equipment which is controlled by, or communicates to,
the Adept Controller.

10 In the preferred embodiment, the Automated
Lens Load System uses fourteen (14) of these tasks to
control the operations associated with each cell. Each
task has been assigned a specific control
responsibility, and "soft" signal communication and
15 global data structures are used to allow intertask
communication. Figure 9 presents a block diagram
representation of this software architecture with each
task represented as a block in the diagram. Connections
between the blocks represent a communications link
20 between the two tasks connected. Each task and any
associated intertask communication is described in
further detail in the following sections.

Robot Control Task

25 The Robot Control Task 200 is responsible for
controlling all operations involving transfer of lenses
using the Robot Adept manipulator. This task
communicates with the Tray Transfer Control Task 205 and
the Blister Transfer Control Task 210 2) to request new
Inspection Trays to remove lenses from, and new Blister
30 Packs to place them into, respectively.



Tray Transfer Control Task

1 The Tray Transfer Control Task 205 is
responsible for supervisory control of all Inspection
Tray operations. This task responds to "soft" signal
communications requests for trays from the Robot Control
5 Task 200. When a new tray is requested, this task then
communicates with the Tray Destack 215, Tray Reject 220,
Lens Unload Tray Positioning 225, Tray Stack 230 and
Host Communications Control Tasks 235 to control the
10 timing of these individual operations. After this task
receives indication that all active operations involving
these sub-tasks is complete, this task controls the
transfer of trays along the Tray Transfer Conveyor 103
(Figure 7).

15 Blister Transfer Control Task

 The Blister Transfer Control Task 210 is
responsible for supervisory control of all Blister Pack
operations. This task responds to "soft" signal
communications requests for new blister pack from the
20 Robot Control Task 200. When a new blister pack is
requested, this task then communicates with the Blister
Dispense task 250, Lens Load Blister Positioning task
255, Blister Inspection task 260, and Blister Reject
Control Task 265 to control the timing of these
25 individual operations. After this task receives
indication that all active operations involving these
sub-tasks is complete, this task controls the transfer
of Blister Pack along the Blister Index Conveyor and
30 onto the End of Line Conveyor.



Tray Destack Control Task

1 The Tray Destack Control Task (Task3) is
responsible for controlling all operations associated
with the Tray Destack Station. When the Tray Transfer
Control Task requests that a new tray be destacked, this
5 task controls all of the equipment associated with this
operation, and responds back to the Tray Transfer
Control Task when the destack operation has been
completed.

10 Tray Reject Control Task

 The Tray Reject Control Task (Task4) is
responsible for controlling all operations associated
with the Tray Reject Station. When the Tray Transfer
Control Task requests that a tray be rejected, this task
15 controls all of the equipment associated with this
operation, and responds back to the Tray Transfer
Control Task when the reject operation has been
completed.

20 Lens Unload Tray Positioning Control Task

 The Lens Unload Tray Positioning Control Task
225 (Task5) is responsible for controlling all
operations associated with the Lens Unload Tray
Positioning Station. When the Tray Transfer Control
25 Task requests that either an empty tray be removed from,
or a new tray be supplied to, Lens Unload Tray Position
'A' or 'B', this task controls all of the equipment
associated with these operations, and responds back to
the Tray Transfer Control Task when the requested
30 operation has been completed.

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Tray Stack Control Task

1 The Tray Stack Control Task 230 (Task6) is
responsible for controlling all operations associated
with the Tray Stack Station. When the Tray Transfer
Control Task requests that a tray be stacked, this task
5 controls all of the equipment associated with this
operation, and responds back to the Tray Transfer
Control Task when the stack operation has been
completed.

10 Host Communications Task

 The Host Communications Task 235 (Task7) is
responsible for serial communication with the Host
Computer to obtain information about each tray which has
been passed through the bar code reader during the
15 destack operation. When the Tray Transfer Control Task
requests that a tray be destacked, and this operation
has been completed, this task initiates communications
with the Host Computer to determine if the tray
identification number was not successfully read ("Tray
20 Unscannable"), successfully read but not a member of the
current lot ("Tray Bad"), or successfully read with
associated lens location data ("Tray Good"). If a "Tray
Good" response was received, the global lens location
data structure is updated with an associated series of
25 32 pass/fail indicators which reflect the status of each
of the 32 potential lens locations in the tray. This
task then responds back to the tray transfer control
task when the Host Communications sequence has been
completed.

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Blister Dispense Control Task

1 The Blister Dispense Control Task 240 (Task8)
is responsible for controlling all operations associated
with the Blister Dispense Station. When the Blister
Transfer Control Task requests that a new blister Pack
5 be dispensed onto the Blister Transfer Index Conveyor,
this task controls all of the equipment associated with
this operation, and responds back to the Blister
Transfer Control Task when the dispense operation has
10 been completed.

Lens Load Blister Positioning Control Task

15 The Lens Load Blister Positioning Control Task
245 (Task9) is responsible for controlling all
operations associated with the Lens Load Blister
Positioning Station. When the Blister Transfer Control
Task requests that either a filled Blister Pack be
released from, or an empty Blister Pack be positioned
at, the Lens Load Blister Position, this task controls
all of the equipment associated with these operations,
20 and responds back to the Blister Transfer Control Task
when the requested operation has been completed.

Blister Inspection Control Task

25 The Blister Inspection Control Task 250
(Task10) is responsible for controlling the interface
with the Blister Inspection System. When the Blister
Transfer Control Task requests that a Blister Pack be
inspected, this task controls the digital I/O
communication with the Blister Inspection System
30 (supplied by Vistakon). After Blister Inspection has

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1 been completed, and the pass/fail results received from
the Blister Inspection System, this task communicates
this information to the Blister Transfer Control Task.

5 Blister Reject Control Task

The Blister Reject Control Task 255 (Task11)
is responsible for controlling all operations associated
with the Blister Reject Station. When the Blister
Transfer Control Task requests that a Blister Pack be
10 rejected from the Blister Transfer Index Conveyor, this
task controls all of the equipment associated with this
operation, and responds back to the Blister Transfer
Control Task when the reject operation has been
completed.

15 Operator Interface Task

The Operator Interface Task 260 (Task12)
controls all of the System Message operations. In
particular, this task controls the communication of
message text to the two alpha-numeric displays located
20 on the Operator Interface, and Power Distribution
Enclosure. In addition, this task controls all related
operations such as Message Advance, Alarm Silence, and
Message Acknowledge functions. All tasks communicate to
the Operator Interface Task using global data structures
25 to report new messages and request clearing of active
messages.

System Control and Monitor Task

30 The System Control and Monitor Task 265
(Task13) control all cell operations which are not

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1 specific to a particular task. These functions include
Cell Start-up in Automatic or Manual Mode, Cell Reset,
End of Lot Purge, and Cycle Start/Stop. In addition,
this task handles interruptions in normal cell
5 operations due to Loss of Air Pressure or Control Power,
and operating/closing of safety enclosures.

While the invention has been particularly shown and
described with respect to the preferred embodiments
thereof, it will be understood by those skilled in the
art that the foregoing and other changes in form and
10 details may be made therein without departing from the
spirit and scope of the invention, which should be
limited only by the scope of the appended claims.

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What is Claimed:

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1. A method of automatically transferring contact lenses from a plurality of cups located at a first location to a plurality of packages previously
5 positioned at a second location, each said cup containing a transferable contact lens therein for placement in an individual package, said method comprising the steps of:

10 (a) communicating positional information of good cup locations station to a robotic device having an arm with one or more end effectors thereon, each end effector having a tip in connection with a corresponding vacuum supply and air pressure supply means, said one or
15 more end effectors each independently moveable with respect to said arm;

(b) applying a predetermined vacuum level of 22 to 30 inches of H₂O to said end effector tip to enable pick-up of a transferable lens from a cup located
20 at a good cup location;

(c) controlling said robot to effect positioning of one end effector tip within said cup having said transferable lens therein to pick up said transferable lens;

25 (d) controlling said robot to remove said end effector tip from the good cup location and position said end effector tip carrying said transferable lens within a blister package cavity location;

30 (e) removing said vacuum and applying air pressure by said air pressure supply means to said end

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1 effector tip to deposit said lens into said blister
package cavity.

2. The method of automatically transferring
5 contact lenses as claimed in Claim 1 wherein the step
(b) of applying a vacuum includes applying a vacuum of
about 26 inches of H₂O.

3. The method of automatically transferring
10 contact lenses as claimed in Claim 2 wherein the vacuum
applied of 26 inches of H₂O remains constant within $\pm$ 4
inches of H₂O.

4. The method of automatically transferring
15 contact lenses as claimed in Claim 1 wherein the step
(e) of applying said air pressure includes applying an
pressure in the range of 4 to 12 psi.

5. The method of automatically transferring
20 contact lenses as claimed in Claim 4 wherein the step of
applying said air pressure includes applying a pressure
of about 8.0 psi.

6. The method of automatically transferring
25 contact lenses as claimed in Claim 2 wherein the step
(c) of controlling said robot to effect positioning of
said end effector tip within said cup means positions
said tip for a predetermined vacuum dwell time of 40 to
100 milliseconds.

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1 7. The method of automatically transferring
contact lenses as claimed in Claim 6 wherein said
predetermined vacuum dwell time is about 60
milliseconds.

5 8. The method of automatically transferring
contact lenses as claimed in Claim 4 wherein the step
(c) of controlling said robot to effect positioning of
said end effector tip within said blister package cavity
10 positions said tip for a predetermined blow-off dwell
time of 20 to 80 milliseconds.

15 9. The method of automatically transferring
contact lenses as claimed in Claim 8 wherein said
predetermined blow-off dwell time is about 60
milliseconds.

20 10. A contact lens transfer device particularly
adapted to transfer wet soft contact lenses from a first
location to a second location, said contact lens
transfer device comprising:

25 (a) an input registration device for registering a
plurality of first contact lens carriers in a
predetermined x-y array, each of said carriers having a
contact lens therein,

30 (b) an output registration device for registering
a plurality of second contact lens carriers in a
predetermined x-y array, each of said carriers adapted
to receive a contact lens therein,

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1 (c) a robotic transfer device, said device having
a transfer head with a plurality of individually
actuatable end effectors mounted thereon, each end
effector having,

5 (i) an individually actuatable drive for
reciprocating said end effector from a first
transport position to a second pick-up and
release position,

10 (ii) individually valved vacuum and air
pressure supply lines for each end effector to
supply negative and positive pressure to a low
volume plenum in said end effector for pick-up
and release of individual contact lenses,

15 (iii) a convex lens transfer tip mounted
on each end effector, each tip having a
plurality of openings therein to provide
negative and positive pressure to a concave
20 side of said soft contact lens,

(d) a control computer for receiving x-y
positional data for each of said plurality of contact
lens carriers, and selectively actuating said robotic
25 transfer device, one of said individually actuatable
drives and one of said individually valved vacuum supply
lines associated with said drive to pick-up a contact
lens from one of said plurality of contact lens
carriers.

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1 11. A contact lens transfer device as claimed in
claim 10, wherein said first contact lens carriers are
good lens cups, each of said cups having a contact lens
therein which has met predetermined inspection
5 parameters.

10 12. A contact lens transfer device as claimed in
claim 10, wherein said second contact lens carriers are
individual blister packages intended for packaging of
the contact lens.

15 13. A contact lens transfer device as claimed in
claim 12, wherein said blister packages are provided in
a predetermined array.

15 14. A contact lens transfer device as claimed in
claim 10, wherein said robotic transfer device is a four
axis robotic drive.

20 15. A contact lens transfer device as claimed in
claim 10, wherein said transfer head further includes
three individually actuatable end effectors.

25 16. A contact lens transfer device as claimed in
claim 10, wherein said each end effector includes a
vacuum plenum connected to one of said individually
valved vacuum lines.

30 17. A contact lens transfer device as claimed in
claim 16, wherein each end effector also includes a blow
off tube that extends through said vacuum plenum, said



1 blow off tube being connected to one of said
1 individually valved air pressure supply lines.

5 18. A contact lens transfer device as claimed in
claim 17, wherein each end effector further includes a
5 low volume common plenum between said lens transfer tip
and said blow off tube.

10 19. A contact lens transfer device as claimed
in claim 10, wherein said control computer further
10 actuates said individually actuable drive and said
robotic transfer drive to move a contact lens from said
first location to said second location.

15 20. A contact lens transfer device as claimed in
claim 10, wherein said control computer further actuates
said individually actuable drive and one of said
individually valved air pressure lines to release a
contact lens into said second contact lens carrier.

20 21. A contact lens transfer device as claimed
in claim 11, wherein each of the openings in said convex
tip is formed along a radius of said convex surface.

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