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Abstract

A pallet inspection system includes a frame configured to have a pallet receiving area to receive a wooden pallet to be inspected for having at least one mark indicating that wood in the pallet has been heat treated. Cameras are carried by the frame to generate images of the wooden pallet in response to the wooden pallet being in the pallet receiving area. A processor is to perform object detection on each image to detect if the mark is present, crop each image having the mark so that an area surrounding the mark within the image is removed, and perform image segmentation on each cropped image so that pixels within the cropped image are classified into regions. The processor determines readability of the regions in each cropped image based on respective readability criteria thresholds. The mark is classified in each cropped image as readable based on the mark meeting the respective readability criteria thresholds.

DETECTION OF HEAT TREATED MARKINGS ON A WOODEN PALLET

Related Applications

[0001] The present application is a divisional application of Australian patent application No. 2022367407, which claims the benefit of U.S. provisional application serial no. 63/262,453 filed October 13, 2021. Each of AU Patent App. No. 2022367407 and U.S. Provisional Patent Application No. 62/544,406 is incorporated herein by reference in its entirety so as to form a part of the present application.

Technical Field

[0002] The present disclosure relates to pallets, and more particularly, to detecting markings on a wooden pallet indicating that the wood in the pallet has been heat treated.

Background

[0003] Wooden pallets are used to transport a variety of bulk goods and equipment as required in manufacturing and warehousing operations. Wooden pallets used in international shipments are to be heat treated. One of the necessary steps for ensuring the safety of not only the product being shipped, but also the environment of the product's destination, is heat treatment.

[0004] Wood pallets are made from organic material. Trees do not grow in sterile surroundings. The ground they are rooted in, the air they are surrounded by, and the water they absorb are not only full of nourishing material, but also a plethora of pests. These pests, whether mature or in a larva stage, are unfortunately, all too easily transported from one area of the world to another in the pallet wood they inhabit. Therefore, governments, environmentalists, and pallet makers have come up with a variety of ways to kill them during the pallet production stage so they will not be introduced in places they did not originate and do not belong.

[0005] Heat treating a pallet is a phytosanitary process developed by the International Plant Protection Convention (IPPC), a treaty recognized by the World Trade Organization and overseen by the Food and Agriculture Organization. The goal is to prevent and to control the introduction and spread of pests and plant products. Once a pallet has been heat treated, it is stamped or marked with a

globally recognized image which allows for more efficient transportation of goods.

Summary

[0006] It is an object of the present invention to overcome and/or alleviate one or more of the disadvantages of existing arrangements and/or provide the consumer with a useful or commercial choice.

[0007] In one aspect, the invention provides a pallet inspection system comprising:

a rectangular-shaped frame configured to have a pallet receiving area to receive a wooden pallet to be inspected for having at least one mark indicating that wood in the pallet has been heat treated;

a plurality of cameras carried by said frame to generate images of the wooden pallet in response to the wooden pallet being in the pallet receiving area; and

a processor coupled to said plurality of cameras and configured to receive the images for processing, the processing comprising:

perform object detection on each image to detect if the mark is present,

crop each image having the mark so that an area surrounding the mark within the image is removed,

perform image segmentation on each cropped image so that pixels within the cropped image are classified into regions,

determine readability of the regions in each cropped image based on respective readability criteria thresholds, and

classify the mark in each cropped image as readable based on the mark meeting the respective readability criteria thresholds.

[0008] In another aspect, the invention provides a method for detecting heat treated marking on a wooden pallet comprising:

generating images of the wooden pallet;

performing object detection on each image to detect if a mark is present;

cropping each image having the mark so that an area surrounding the mark within the image is removed;

performing image segmentation on each cropped image so that pixels within the cropped image are classified into regions;

determining readability of the regions in each cropped image based on

respective readability criteria thresholds; and

classifying the mark in each cropped image as readable based on the mark meeting the respective readability criteria thresholds.

[0009] A pallet inspection system includes a rectangular-shaped frame configured to have a pallet receiving area to receive a wooden pallet to be inspected for having at least one mark indicating that wood in the pallet has been heat treated. A plurality of cameras are carried by the frame to generate images of the wooden pallet in response to the wooden pallet being in the pallet receiving area.

[0010] A processor is coupled to the plurality of cameras and is configured to receive the images for processing. The processing includes performing object detection on each image to detect if the mark is present, cropping each image having the mark so that an area surrounding the mark within the image is removed, and performing image segmentation on each cropped image so that pixels within the cropped image are classified into regions.

[0011] Readability of the regions is determined in each cropped image based on respective readability criteria thresholds. The mark in each cropped image is classified as readable based on the mark meeting the respective readability criteria thresholds.

[0012] The classified regions for each cropped image may include a boundary region, a symbol region, and an alphanumeric region, with the pixels in each region having a respective classification identifier associated therewith.

[0013] The boundary region may have a rectangular shape with first and second opposing sides, and a divider line extending between one of opposing sides. The symbol region and the alphanumeric region may be enclosed by the boundary region and separated by the divider line.

[0014] The classified regions may include a boundary region having a classification identifier associated therewith. Determining readability of the boundary region may include performing corner point detection to detect corner points, sampling the pixels between the detected corner points, and determining a number of the sampled pixels having the same classification identifier. The boundary region is identified as being readable based on the determined number of sampled pixels having the same classification identifier exceeding a boundary region threshold.

[0015] The classified regions may include a symbol region having a classification identifier associated therewith. Determining readability of the symbol

region may include sampling the pixels within the symbol region, and determining a number of the sampled pixels having the same classification identifier. The symbol region is identified as being readable based on the determined number of sampled pixels having the same classification identifier exceeding a symbol region threshold.

[0016] The classified regions may include an alphanumeric region having a classification identifier associated therewith. Determining readability of the alphanumeric region may include identifying the pixels within the alphanumeric region having the same classification identifier, and determining a readability score for the identified pixels. The readability score may be selected within a readability scoring range. The alphanumeric region is identified as being readable based on the readability score exceeding a readability score threshold.

[0017] The classified regions may include an alphanumeric region having alphanumeric characters. The processor may be further configured to perform the following for each mark classified as readable. Detect lines within the alphanumeric region, with each line including the alphanumeric characters. Perform optical character recognition to read the alphanumeric characters in each line.

[0018] The processor may be further configured to perform the following in response to the wooden pallet having a pair of marks that are each classified as readable. Compare the alphanumeric characters read in one of the marks to the alphanumeric characters read in the other mark. Classify the wooden pallet as being compliant in response to the respective alphanumeric characters in each mark matching.

[0019] The cameras may be positioned so that each side of the pallet receiving area has a single camera focused on a portion of a side view of the wooden pallet where the mark is expected to be located.

[0020] The cameras may be positioned so that each side of the pallet receiving area has a pair of cameras, with the pair of cameras providing overlapping images of an entire side view of the wooden pallet.

[0021] Another aspect is directed to a method for detecting heat treated markings on a wooden pallet using the pallet inspection system as discussed above. The method includes generating images of the wooden pallet, performing object detection on each image to detect if a mark is present, and cropping each image having the mark so that an area surrounding the mark within the image is removed. Image segmentation is performed on each cropped image so that pixels within the

cropped image are classified into regions. Readability of the regions in each cropped image is determined based on respective readability criteria thresholds. The mark in each cropped image is classified as readable based on the mark meeting the respective readability criteria thresholds.

Brief Description of the Drawings

[0022] FIG. 1 is an example schematic representation on the format of a heat treated marking for use on wooden pallets.

[0023] FIG. 2 is an image of a heat treated marking from a wooden pallet.

[0024] FIG. 3 is an exploded view of a wooden pallet showing locations on where the heat treated marking illustrated in FIG. 1 can be placed.

[0025] FIG. 4 is a partial side view of stacked wooden pallets having heat treated markings on the middle support blocks.

[0026] FIG. 5 is a partial upper perspective side view of stacked wooden pallets having heat treated markings on the outer bottom deck boards.

[0027] FIG. 6 is a partial side view of a wooden pallet having a heat treated marking on an outer edge of a connector board in the top deck.

[0028] FIG. 7 is a perspective view of a fully enclosed pallet inspection system for inspecting wooden pallets for heat treated markings.

[0029] FIG. 8 is a perspective side view of the fully enclosed pallet inspection system illustrated in FIG. 7.

[0030] FIG. 9 is a perspective end view of the fully enclosed pallet inspection system illustrated in FIG. 7.

[0031] FIG. 10 is a perspective view of the pallet inspection system illustrated in FIG. 7 with the upper enclosures removed.

[0032] FIG. 11 is a perspective view of the pallet inspection system illustrated in FIG. 10 with the lower enclosure removed.

[0033] FIG. 12 is a top view of the pallet inspection system illustrated in FIG. 10.

[0034] FIGS. 13a and 13b are partial views of one side of a wooden pallet being inspected by the pallet inspection system illustrated in FIG. 7.

[0035] FIGS. 14a and 14b are partial views of the other side of the wooden pallet illustrated in FIGS. 13a and 13b.

[0036] FIGS. 15a and 15b are partial views of one end of the wooden pallet

illustrated in FIGS. 13a and 13b.

[0037] FIGS. 16a and 16b are partial views of the other end of the wooden pallet illustrated in FIGS. 13a and 13b.

[0038] FIG. 17 is a block diagram of the pallet inspection system illustrated in FIG. 7.

[0039] FIG. 18 is a flow diagram for detecting heat treated markings on a wooden pallet using the pallet inspection system illustrated in FIG. 17.

[0040] FIG. 19 is a cropped image of a heat treated marking on a wooden pallet.

[0041] FIG. 20 is an image of corner point detection being performed for the boundary region of a heat treated marking.

[0042] FIG. 21 is an image of a symbol region of a heat treated marking being analyzed.

[0043] FIG. 22 is an image of alphanumeric characters that are readable within a symbol region of a heat treated marking.

[0044] FIG. 23 is an image of alphanumeric characters that are not readable within a symbol region of a heat treated marking.

[0045] FIG. 24 is an image of line detection being performed for the alphanumeric characters within a symbol region of a heat treated marking.

[0046] FIG. 25 is a display image of the alphanumeric characters within an alphanumeric region of a heat treated marking that have been read using optical character recognition.

[0047] FIG. 26 is a flow diagram for operating the pallet inspection system illustrated in FIG. 17.

Detailed Description

[0048] The present description is made with reference to the accompanying drawings, in which exemplary embodiments are shown. However, many different embodiments may be used, and thus the description should not be construed as limited to the particular embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete. Like numbers refer to like elements throughout.

[0049] Shipping products using wood packaging between countries is a process regulated by the International Plant Protection Convention (IPPC). Wooden

materials like pallets can potentially carry diseases or insects from one country into another where an infestation would negatively impact the ecosystem. Composed of 183 plus member countries, the IPPC has established requirements around the treatment of wood packaging leaving and entering their countries to prevent infestations that could be harmful to their local plant life.

[0050] According to International Standards For Phytosanitary Measures No. 15 (ISPM 15), wood materials greater than 6 mm in width require debarking and heat treatment or methyl bromide fumigation. If heat treated, the wooden pallet is to be treated for at least 30 minutes and maintain a core temperature of 133° F. After the heat treatment or fumigation, wooden pallets must then be stamped or branded with a compliance mark.

[0051] To indicate proper heat treatment or methyl bromide fumigation with wooden pallets, a 2” stamp or mark of compliance **20** is required, an example format of which is illustrated in FIG. 1. The illustrated format of the mark of compliance **20** occupies 2 lines. This format is not to be limiting. For example, the stamp or mark of compliance **20** may have a format that occupies a single line or occupies more than 2 lines. The stamp or mark of compliance **20** may also be referred to as an ISPM15 mark, a heat treated marking or a mark. An example image of an ISPM15 mark **20** on an area of a wooden pallet is illustrated in FIG. 2.

[0052] The ISPM15 mark **20** includes an external perimeter **22** and a divider line **24.** The external perimeter **22** is rectangular shaped, and the divider line **24** extends between one of opposing sides of the external perimeter **22.** The external perimeter **22** and the divider line **24** will be referred to as a boundary region **25**.

[0053] In the region on the left side of the divider line **24** is an IPPC certification symbol. The IPPC certification symbol includes a tree symbol **28** with the letters IPPC **30** adjacent the tree symbol **28.** This region will be referred to as a symbol region **29**.

[0054] In the region on the right side of the divider line **24** are alphanumerics. This region will be referred to as an alphanumeric region **31**. The alphanumerics include a country code **32**, a producer code **34** and a treatment code **36**. The country code **32** is two letters. As example, ES represents Spain, US represents the United States, GB represents Great Britain, and AU represents Australia. The producer code **34** is a series of unique alphanumerics to indicate the wood treatment agent or packaging manufacturer. This is a unique certification number that ensures that the

wood packaging material can be traced back to the wood treatment agent or packaging manufacturer. The treatment code **36** represents the treatment applied to the wood packaging material. HT is the code for heat treatment, and MB is the code for methyl bromide fumigation.

[0055] The ISPM15 mark **20** is typically required on every 24 inches along the wooden pallet. Non-compliance may result in shipments being rejected by customs, resulting in costly fees associated with the re-export of the goods for the importer.

[0056] Consequently, there is a need to automate detection of ISPM15 markings **20** on a wooden pallet. This is particularly needed in high volume industries where pallet pools provide a lower total industry cost than one-way pallets.

[0057] After the bulk goods and equipment are off loaded from the pooled pallets, the wooden pallets are returned to pallet inspection and repair facilities. As part of the inspection, ISPM15 markings **20** are to be detected. For the wooden pallet **40** to be compliant, a pair of ISPM15 markings **20** are to be identified and the alphanumerics in each alphanumeric region **31** need to match each other.

[0058] Referring now to FIG. 3, an exploded view of an example wooden pallet **40** will be discussed. The wooden pallet **40** is for discussion purposes on the different placement locations of the ISPM15 mark **20**. The wooden pallet **40** as illustrated is not to be limiting as other wooden pallet configurations are readily available.

[0059] The wooden pallet **40** includes a top deck **50**, a bottom deck **60**, and a plurality of wooden support blocks **70, 72** coupled between the top and bottom decks. The support blocks **40, 46** form a gap between the top and bottom decks **50, 60** for receiving a lifting member, such as fork lift tines.

[0060] The top deck **50** includes a pair of spaced apart wooden end deck boards **52**, and wooden intermediate deck boards **54** positioned between the end deck boards **52**. Also included within the top deck **50** are a pair of spaced apart wooden connector boards **56** and a wooden intermediate connector board **58**. The connector boards **56** and the intermediate connector board **58** are orthogonal to the end deck boards **52** and the intermediate deck boards **54**. The end deck boards **52** and the intermediate deck boards **54** are positioned on the connector boards **56** and are directly coupled to the support blocks **70, 72** via nails.

[0061] The bottom deck **60** includes bottom deck boards **62, 64** orientated in the same direction as the end deck boards **52** and the intermediate deck boards **54**

in the top deck **50**. The bottom deck boards **62, 64** may also be referred to as base boards, and are directly coupled to the support blocks **70, 72** via nails.

[0062] The support blocks include corner support blocks **70** and center support blocks **72** between the corner support blocks **70**. In total, there are 9 support blocks **70, 72** positioned in rows of 3. The outer rows each include a pair of outer support blocks **70** and a single center support block **72**, and the center row includes all center support blocks **72**. The corner support blocks **70** and the center support blocks **72** each have a rectangular shape.

[0063] The different placement locations of the ISPM15 mark **20** include, for example, the center support blocks **72** as indicated by the boxed numbers 1 and 2, the outer bottom deck boards **62** as indicated by the boxed number 3, and on an outer edge of connector boards **56** in the top deck **50** as indicated by the boxed number 4.

[0064] A side view of stacked wooden pallets **40** having the ISPM15 marking **20** on the middle support blocks **72** is illustrated in FIG. 4. An upper perspective view of stacked wooden pallets **40** having the ISPM15 marking **20** on the outer bottom deck boards **62** is illustrated in FIG. 5. A side view of a wooden pallet **40** having the ISPM15 marking **20** on an edge of a connector board **56** in the top deck **50** is illustrated in FIG. 6. When the ISPM15 marking **20** is on the edge of the connector board **56**, the alphanumerics are positioned to fit on a single line.

[0065] Referring now to FIGS. 7-9, a pallet inspection station **100** that is fully enclosed is configured to inspect wooded pallets **40** for ISPM15 markings **20**. The pallet inspection station **100** includes a frame **102** with top and bottom covers **104, 106**. The frame **102** is rectangular shape and has a pallet receiving area **110** as illustrated in FIG. 9. Although not illustrated, a conveyor may be used to transport the wooden pallet **40** through the pallet inspection station **100** for inspection.

[0066] Referring now to FIGS. 10 and 11, the top covers **104** have been removed to expose the cameras **120** and the pallet receiving area **110**. In FIG. 12, both the top and bottom covers **104, 106** have been removed to expose the cameras **120** and the pallet receiving area **110**. The cameras **120** are mounted to the frame **102** via camera arm extensions **122**. Each camera arm extension **122** extends outwards and upwards from the frame **102** so that the cameras **120** look down at the wooden pallet **40** in the pallet receiving area **110**. The cameras **120** are positioned within a range of 20 to 45 degrees with respect to the wooden pallet **40** in the pallet

receiving area **110**. Lights are also carried on each side of the frame **102** and are positioned to illuminate each side of the pallet **40** for the respective cameras **120**.

[0067] In the illustrated embodiment, there are 8 cameras **120** total, with each side having 2 cameras **120**. The cameras **120** may be color or monochrome. In another embodiment, there may be 4 cameras **120** total, with each side having 1 camera **120**. In yet another embodiment, there may be more than 2 cameras **120** on each side.

[0068] The 8 cameras **120** are all triggered at the same time to generate images of the wooden pallet **40**. When the wooden pallet **40** arrives in the pallet receiving area **110**, movement of the wooden pallet **40** is stopped. After the wooden pallet **40** has been stopped by a stopper in the path of the pallet, then the 8 cameras **120** are triggered.

[0069] By having 2 cameras **120** on each side of the frame **102**, a full or complete side view of the wooden pallet **40** is obtained for processing. The 2 cameras **120** on each side provide overlapping images since a single camera **120** cannot provide a full or complete side view of the wooden pallet **40**.

[0070] As noted above in reference to FIG. 3, the ISPM15 markings **20** may be on different locations on a wooden pallet **40**. For example, these locations include the center support blocks **72** as indicated by the boxed numbers 1 and 2, the outer bottom deck boards **62** as indicated by the boxed number 3, and on an outer edge of connector boards **56** in the top deck **50** as indicated by the boxed number 4.

[0071] Although not illustrated, the ISPM15 mark **20** may be on the corner support blocks **70**, connector boards **56**, and intermediate connector board **58**. The bottom deck boards **62, 64** may also have the ISPM15 mark **20**. In yet another example, the ISPM15 mark **20** may be on the upper surface of any of the boards in the top deck **50** or on the bottom surface of any of the boards in the bottom deck **60**.

[0072] However, if the wooden pallets **40** being inspected are to have the ISPM15 marking **20** in the same location on each pallet, then 1 camera **120** per side may be used. In this case, each camera **120** is focused or positioned to view the same location on the side of the wooden pallet **40**.

[0073] Since there are 8 cameras **120**, 8 images are generated for inspection of a wooden pallet **40**. Partial end views of one side of a wooden pallet **40** being inspected are provided in FIGS. 13a and 13b. This is the back end of the wooden pallet **40** as it travels through the pallet inspection station **100** on a conveyor. The

image **150(1)** in FIG. 13a includes the left outer support block **70** and the center support block **72**. The image **150(2)** in FIG. 13b includes the right outer support block **70** and the center support block **72**. The images **150(1), 150(2)** collectively provide a full side view of the wooden pallet **40**, with the images overlapping at the center support block **72**.

[0074] Partial end views of the other side of the wooden pallet **40** are provided in FIGS. 14a and 14b. This is the front end of the wooden pallet **40** as it travels through the pallet inspection station **100** on the conveyor. A stopper **130** is used to stop the wooden pallet **40** prior to the cameras **120** being activated. The image **150(3)** in FIG. 14a includes the left outer support block **70** and the center support block **72**. In this image **150(3)**, an ISPM15 mark **20** is on the outer bottom deck board **62**. The image **150(4)** in FIG. 14b includes the right outer support block **70** and the center support block **72**.

[0075] Partial side views of the left side of the wooden pallet **40** are provided in FIGS. 15a and 15b. The image **150(5)** in FIG. 15a includes the left outer support block **70** and the center support block **72**. The image **150(6)** in FIG. 15b includes the right outer support block **70** and the center support block **72**.

[0076] Partial side views of the right side of the wooden pallet **40** are provided in FIGS. 16a and 16b. The image **150(7)** in FIG. 16a includes the left outer support block **70** and the center support block **72**. In this image **150(7)**, an ISPM15 mark **20** is on the outer bottom deck board **62**. The image **150(8)** in FIG. 16b includes the right outer support block **70** and the center support block **72**. The images **150(1)-150(8)** will be generally referred to below as images **150**.

[0077] Operation of the pallet inspection station **100** for detecting ISPM15 markings **20** will now be discussed. A block diagram of a pallet inspection system **95** with the pallet inspection station **100** is provided in FIG. 17, and a flow diagram **200** for detecting ISPM15 markings **20** on a wooden pallet **40** using the pallet inspection system **95** is provided in FIG. 18.

[0078] A conveyor **105** moves the wooden pallet **40** through the pallet inspection station **100** in the direction of the illustrated arrows. The conveyor **105** includes a sensor **132** at the entrance of the pallet inspection station **100** to detect arrival of the wooden pallet **40**. The sensor **132** is coupled to a controller 1**34**.

[0079] The sensor **132** may be configured as photoelectric sensor, for example. The photoelectric sensor includes a transmitter and receiver on opposite

sides of the conveyor **105**. The transmitter transmits a light signal, which may be visible or infrared, to the receiver. The wooden pallet **40** is detected when the light beam is blocked from getting to the receiver from the transmitter.

[0080] Upon arrival of the wooden pallet **40**, the controller **134** activates a stopper **130** in the path of the wooden pallet **40**. When activated, the stopper **130** is raised through gaps in the conveyor **105** to stop the pallet in a set location with respect to the cameras **120**. After the wooden pallet **40** is stopped by the stopper **132**, the controller **134** activates or triggers the cameras **120** to generate images **150** of the wooden pallet **40**.

[0081] The images **150** are sent to a processing unit **140** for processing. The processing unit **140** executes different machine learning algorithms, as will be discussed in greater detail below. The processing unit **140** may be a graphics processing unit (GPU), a central processing unit (CPU) or an edge computing device, for example.

[0082] In the flow diagram **200**, the generated images **150** of the wooden pallet **40** being inspected are received at Block **202**. The GPU **140** executes an object detection algorithm **150** at Block **204** that has been trained to locate an ISPM15 mark **20** within an image **150**.

[0083] The object detect algorithm **150** may operate based on artificial intelligence (AI) and machine learning (ML) to determine ISPM15 marks **20** within the images **150**. The object detect algorithm **150** is trained using annotated images that include different locations of where an ISPM15 mark **20** may be located. In the annotated images, bounding boxes are used to mark the different locations of an ISPM15 mark **20**.

[0084] In other embodiments, a segmentation algorithm may be used instead of the object detect algorithm **150**. A segmentation algorithm partitions an image into sets of pixels or regions. The purpose of partitioning is to understand better what the image represents. The sets of pixels may represent objects in the image that are of interest for a specific application, such as detecting an ISPM15 mark **20**. Instead of object detection, direct segmentation may be used to crop the image to be processed by the segmentation algorithm.

[0085] At Block **204**, if an image **150** does not have an ISPM15 mark **20**, then the image is discarded at Block **206**. If the image **150** has an ISPM15 mark **20**, then the image **150** is cropped at Block **208**. In the cropped image **250**, the ISPM15 mark

20 is cropped so that the area surrounding the ISPM15 mark **20** within the image **150** is removed, as illustrated in FIG. 19.

[0086] The cropped image **250** is then passed to a pixel segmentation algorithm **152** at Block **210**. Image segmentation is the process of classifying or assigning a label to every pixel in the cropped image **250** such that pixels with the same classification identifier share certain characteristics. The pixel segmentation algorithm **152** may operate based on artificial intelligence (AI) and machine learning (ML).

[0087] The cropped image **250** is segmented into a boundary region **25**, a symbol region **29** and an alphanumeric region **31**, as discussed above and as illustrated in FIG. 1. The pixels in the boundary region **25** may have the number 1 assigned as a classification identifier. The pixels in the symbol region **29** may have the number 2 assigned as a classification identifier. The pixels in the alphanumeric region **31** may have the number 3 assigned as a classification identifier. A fourth region will be a background region for the pixels that fall outside of the boundary region **25**, the symbol region **29** and the alphanumeric region **31**. The pixels in the background region may have the number 4 assigned as a classification identifier.

[0088] Outputs of the pixel segmentation algorithm **152** are provided to respective readability algorithms **154**. The respective readability algorithms **154** may operate based on artificial intelligence (AI) and machine learning (ML). The readability algorithms **154** analyze the regions based on readability criteria associated with each respective region. The readability criteria is used to determine if each respective region is legible enough to be read and understood by a person. The readability algorithms **154** do not read the regions.

[0089] The readability algorithms **154** include a first readability algorithm **154(1)** for the boundary region **25**, a second readability algorithm **154(2)** for the symbol region **29**, and a third readability algorithm **154(3)** for the alphanumeric region **25**. The readability algorithms **154** are executed by a processor at the same time. That is, the different regions are analyzed at the same time by their respective readability algorithm **154**.

[0090] The first readability algorithms **154(1)** is used to analyze the boundary region **25** at Block **212**. The first readability algorithm **154(1)** is trained to perform corner point detection to detect corner points, as illustrated in FIG. 20. Corner points **252** are detected for the external perimeter **22**, and corner points **254** are detected

for the divider line **24.** The pixels between the detected corner points **252, 254** are sampled, and a number of the sampled pixels having the same classification identifier 1 is determined.

[0091] The boundary region **25** is identified in Block **214** as being readable based on the determined number of sampled pixels having the same classification identifier 1 exceeding a boundary region threshold. The boundary region threshold includes a threshold for the external perimeter **22**, and a threshold for the divider line **24**.

[0092] The respective thresholds correspond to a percentage of the sampled pixels being resent. For example, the threshold for the external perimeter **22** may within a range of 70% to 100%, and the threshold for the divider line **24** may within a range of 95% to 100%. If the boundary region **25** is not readable, then the image **150** is discarded at Block **226**. If the boundary region **25** is readable, then the process continues to Block **224**.

[0093] The second readability algorithms **154(2)** is used to analyze the symbol region **29** at Block **218**. The second readability algorithm **154(2)** is trained to analyze the pixels in the tree **28**, and the pixels forming the IPPC letters **30** adjacent the tree, as illustrated by the image **260** in FIG. 21. Pixels within the tree **28** are sampled, and pixels within the IPPC letters **30** are sampled. A number of the sampled pixels having the same classification identifier 2 is determined.

[0094] The symbol region **29** is identified in Block **218** as being readable based on the determined number of sampled pixels having the same classification identifier 2 exceeding a symbol region threshold. The symbol region threshold includes a threshold for the tree **28**, and a threshold for the IPPC letters **30**.

[0095] The respective thresholds correspond to a percentage of the sampled pixels being present. For example, the threshold for the tree **28** may within a range of 75% to 100%, and the threshold for the IPPC letters **30** may also be within a range of 75% to 100%. The readability criteria associated with the IPPC letters **30** may be such that the IPPC letters **30** are visible but not necessarily legible. If only one of the IPPC letters is not visible, then the IPPC letters **30** is considered to be readable. If the symbol region **29** is not readable, then the image **150** is discarded at Block **226**. If the symbol region **29** is readable, then the process continues to Block **224**.

[0096] The third readability algorithms **154(3)** is used to analyze the

alphanumeric region **31** at Block **220**. The third readability algorithm **154(3)** is trained to analyze the pixels in the alphanumeric characters within the alphanumeric region **31**. Pixels within the alphanumeric region **31** having the same classification identifier 3 are identified.

[0097] A readability score is determined for the identified pixels, with the readability score being selected within a readability scoring range. The readability scoring range may vary between 1 to 5, for example. A 5 may correspond to all of the alphanumeric characters being readable, as illustrated by the image **262** in FIG. 22. A 1 may correspond to hardly any of the alphanumeric characters being visible, as illustrated by the image **264** in FIG. 23.

[0098] A 4 may correspond to one of the alphanumeric characters being partially visible but the alphanumeric character is still known. A 3 may correspond to one of the alphanumeric characters not being visible or missing, and a 2 may correspond to two or more alphanumeric characters not being visible or missing.

[0099] The use of a readability scoring range provides flexibility to the third readability algorithm **154(3)** in determining readability of the alphanumeric characters. Instead of the decision being binary, as was the case using the first and second readability algorithms **154(1), 154(2)**, the third readability algorithm **154(3)** allows for flexibility in making the determination. When the determination falls in the middle of the readability scoring range (i.e., 2 through 4), a sliding scale allows for a more general determination to be made on readability of the alphanumeric characters.

[00100] The alphanumeric region **31** is identified in Block **222** as being readable based on the readability score exceeding a readability score threshold. The readability score threshold may be 3.5, for example. If the alphanumeric region **31** is not readable, then the image **150** is discarded at Block **226**. If the alphanumeric region **31** is readable, then the process continues to Block **224**.

[00101] As an alternative to analyzing the symbol region **29** using the second readability algorithm **154(2)**, the third readability algorithm **154(3)** may be configured to analyze the symbol region **29**. That is, the readability criteria of the symbol region **29** would be based on a readability scale similar to the readability scale as discussed for the alphanumeric region **31**.

[00102] For the ISPM15 mark **20** to be readable, each of the boundary region **25**, the symbol region **29** and the alphanumeric region **31** needs to be readable. If

one of the three regions is not readable, then the ISPM15 mark **20** is classified as not readable in Block **226**. If all three regions are readable, then the ISPM15 mark **20** is classified as readable and the process continues to Block **228**.

[00103] After the ISPM15 marks **20** have been identified as readable in the received images **150**, the next step in the process is to determine if the wooden pallet **40** is compliant.

This determination is based on morphology. For the wooden pallet **40** to be compliant, there needs to be a pair of matching ISPM15 marks **20**. If there is only one ISPM15 mark **20** or if the alphanumeric characters in the two ISPM15 marks **20** do not match one another, then the wooden pallet **40** is classified as non-compliant.

[00104] A compliant pallet algorithm **156** is used to determine if the wooden pallet **40** has a pair of matching ISPM15 marks **20**. The compliant pallet algorithm **156** first detects lines **270** within the alphanumeric region **31** for each ISPM15 mark **20** at Block **230**, as illustrated by the image **266** in FIG. 24. There are 3 lines **270** in the alphanumeric region **31**, with each line **270** including alphanumeric characters.

[00105] After the lines **270** have been detected, then optical character recognition (OCR) is performed at Block **232** to read the alphanumeric characters in each line, as illustrated in display **268** in FIG. 25. A determination is made at Block **234** on if the alphanumeric characters within the pair of ISPM15 marks **20** match one another.

[00106] If the alphanumeric characters match, then the wooden pallet **40** is classified as compliant in Block **236**. If the alphanumeric characters do not match, then the wooden pallet **40** is classified as non-compliant in Block **238**. In other embodiments of the processing unit **140** receiving the images for processing, the processing unit **140** may not crop each image. Instead, the mark is detected using object detection, and readability is then determined in order to classify the mark. Based on the mark meeting the respective readability criteria thresholds, the mark is classified.

[00107] Another aspect is directed to a method for operating the pallet inspection system **95** as described above. Referring now to the flow diagram **300** in FIG. 25, from the start (Block **302**), the method includes generating images **150** of the wooden pallet **40** at Block **304**, and performing object detection on each image **150** at Block **306** to detect if an ISPM15 mark **20** is present. Each image **150** having the ISPM15 mark **20** is cropped at Block **308** so that an area surrounding the mark

within the image is removed.

[00108] Image segmentation is performed on each cropped image **250** at Block **310** so that pixels within the cropped image **250** are classified into regions. Readability of the regions in each cropped image **250** is determined at Block **312** based on respective readability criteria thresholds. The ISPM15 mark **20** in each cropped image **250** is classified at Block **314** as readable based on the ISPM15 mark **20** meeting the respective readability criteria thresholds. The method ends at Block **316**.

[00109] Many modifications and other embodiments will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is understood that the foregoing is not to be limited to the example embodiments, and that modifications and other embodiments are intended to be included within the scope of the appended claims.

CLAIMS:

1. A pallet inspection system comprising:

a rectangular-shaped frame configured to have a pallet receiving area to receive a wooden pallet to be inspected for having at least one mark indicating that wood in the pallet has been heat treated;

a plurality of cameras carried by said frame to generate images of the wooden pallet in response to the wooden pallet being in the pallet receiving area; and

a processor coupled to said plurality of cameras and configured to receive the images for processing, the processing comprising:

perform object detection on each image to detect if the mark is present,

crop each image having the mark so that an area surrounding the mark within the image is removed,

perform image segmentation on each cropped image so that pixels within the cropped image are classified into regions,

determine readability of the regions in each cropped image based on respective readability criteria thresholds, and

classify the mark in each cropped image as readable based on the mark meeting the respective readability criteria thresholds.

2. The pallet inspection system according to Claim 1 wherein the classified regions for each cropped image comprise a boundary region, a symbol region, and an alphanumeric region, with the pixels in each region having a respective classification identifier associated therewith.

3. The pallet inspection system according to Claim 2 wherein the boundary region has a rectangular shape with first and second opposing sides, and a divider line extending between one of opposing sides, with the symbol region and the alphanumeric region being enclosed by the boundary region and separated by the divider line.

4. The pallet inspection system according to Claim 1 wherein the classified regions comprise a boundary region having a classification identifier associated therewith, and wherein determining readability of the boundary region comprises the following:

perform corner point detection to detect corner points;

sample the pixels between the detected corner points;

determine a number of the sampled pixels having the same classification identifier; and

identify the boundary region as being readable based on the determined number of sampled pixels having the same classification identifier exceeding a boundary region threshold.

5. The pallet inspection system according to Claim 1 wherein the classified regions comprise a symbol region having a classification identifier associated therewith, and wherein determining readability of the symbol region comprises the following:

sample the pixels within the symbol region;

determine a number of the sampled pixels having the same classification identifier; and

identify the symbol region as being readable based on the determined number of sampled pixels having the same classification identifier exceeding a symbol region threshold.

6. The pallet inspection system according to Claim 1 wherein the classified regions comprise an alphanumeric region having a classification identifier associated therewith, and wherein determining readability of the alphanumeric region comprises the following:

identify the pixels within the alphanumeric region having the same classification identifier;

determine a readability score for the identified pixels, with the readability score being selected within a readability scoring range; and

identify the alphanumeric region as being readable based on the readability score exceeding a readability score threshold.

7. The pallet inspection system according to Claim 1 wherein the classified regions comprise an alphanumeric region having alphanumeric characters, and wherein said processor is further configured to perform the following for each mark classified as readable:

detect lines within the alphanumeric region, with each line including the alphanumeric characters; and

perform optical character recognition to read the alphanumeric characters in each line.

8. The pallet inspection system according to Claim 7 wherein said processor is further configured to perform the following in response to the wooden pallet having a pair of marks that are each classified as readable:

compare the alphanumeric characters read in one of the marks to the alphanumeric characters read in the other mark; and

classify the wooden pallet as being compliant in response to the respective alphanumeric characters in each mark matching.

9. The pallet inspection system according to Claim 1 wherein said plurality of cameras are positioned so that each side of the pallet receiving area has a single camera focused on a portion of a side view of the wooden pallet where the mark is expected to be located.

10. The pallet inspection system according to Claim 1 wherein said plurality of cameras are positioned so that each side of the pallet receiving area has a pair of cameras, with the pair of cameras providing overlapping images of an entire side view of the wooden pallet.

11. A method for detecting heat treated marking on a wooden pallet comprising:

generating images of the wooden pallet;

performing object detection on each image to detect if a mark is present;

cropping each image having the mark so that an area surrounding the mark within the image is removed;

performing image segmentation on each cropped image so that pixels within the cropped image are classified into regions;

determining readability of the regions in each cropped image based on respective readability criteria thresholds; and

classifying the mark in each cropped image as readable based on the mark meeting the respective readability criteria thresholds.

12. The method according to Claim 11 wherein the classified regions for each cropped image comprise a boundary region, a symbol region, and an alphanumeric region, with the pixels in each region having a respective classification identifier associated therewith.

13. The method according to Claim 12 wherein the boundary region has a rectangular shape with first and second opposing sides, and a divider line extending between one of opposing sides, with the symbol region and the alphanumeric region being enclosed by the boundary region and separated by the divider line.

14. The method according to Claim 11 wherein the classified regions comprise a boundary region having a classification identifier associated therewith, and wherein determining readability of the boundary region comprises the following:

performing corner point detection to detect corner points;

sampling the pixels between the detected corner points;

determining a number of the sampled pixels having the same classification identifier; and

identifying the boundary region as being readable based on the determined number of sampled pixels having the same classification identifier exceeding a boundary region threshold.

15. The method according to Claim 11 wherein the classified regions comprise a symbol region having a classification identifier associated therewith, and wherein determining readability of the symbol region comprises the following:

sampling the pixels within the symbol region;

determining a number of the sampled pixels having the same

classification identifier; and

identifying the symbol region as being readable based on the determined number of sampled pixels having the same classification identifier exceeding a symbol region threshold.

16. The method according to Claim 11 wherein the classified regions comprise an alphanumeric region having a classification identifier associated therewith, and wherein determining readability of the alphanumeric region comprises the following:

identifying the pixels within the alphanumeric region having the same classification identifier;

determining a readability score for the identified pixels, with the readability score being selected within a readability scoring range; and

identifying the alphanumeric region as being readable based on the readability score exceeding a readability score threshold.

17. The method according to Claim 11 wherein the classified regions comprise an alphanumeric region having alphanumeric characters, and further comprising the following for each mark classified as readable:

detecting lines within the alphanumeric region, with each line including alphanumeric characters; and

performing optical character recognition to read the alphanumeric characters in each line.

18. The method according to Claim 17 further comprising the following in response to the wooden pallet having a pair of marks that are each classified as readable:

comparing the alphanumeric characters read in one of the marks to the alphanumeric characters read in the other mark; and

classifying the wooden pallet as being compliant in response to the respective alphanumeric characters in each mark matching.

19. The method according to Claim 11 wherein the wooden pallet is received in a pallet receiving area, and wherein each side of the pallet receiving area

has a single camera focused on a portion of a side view of the wooden pallet where the mark is expected to be located.

20. The method according to Claim 11 wherein the wooden pallet is received in a pallet receiving area, and wherein each side of the pallet receiving area has a pair of cameras, with the pair of cameras providing overlapping images of an entire side view of the wooden pallet.

CHEP Technology Pty Limited
Patent Attorneys for the Applicant/Nominated Person
SPRUSON & FERGUSON

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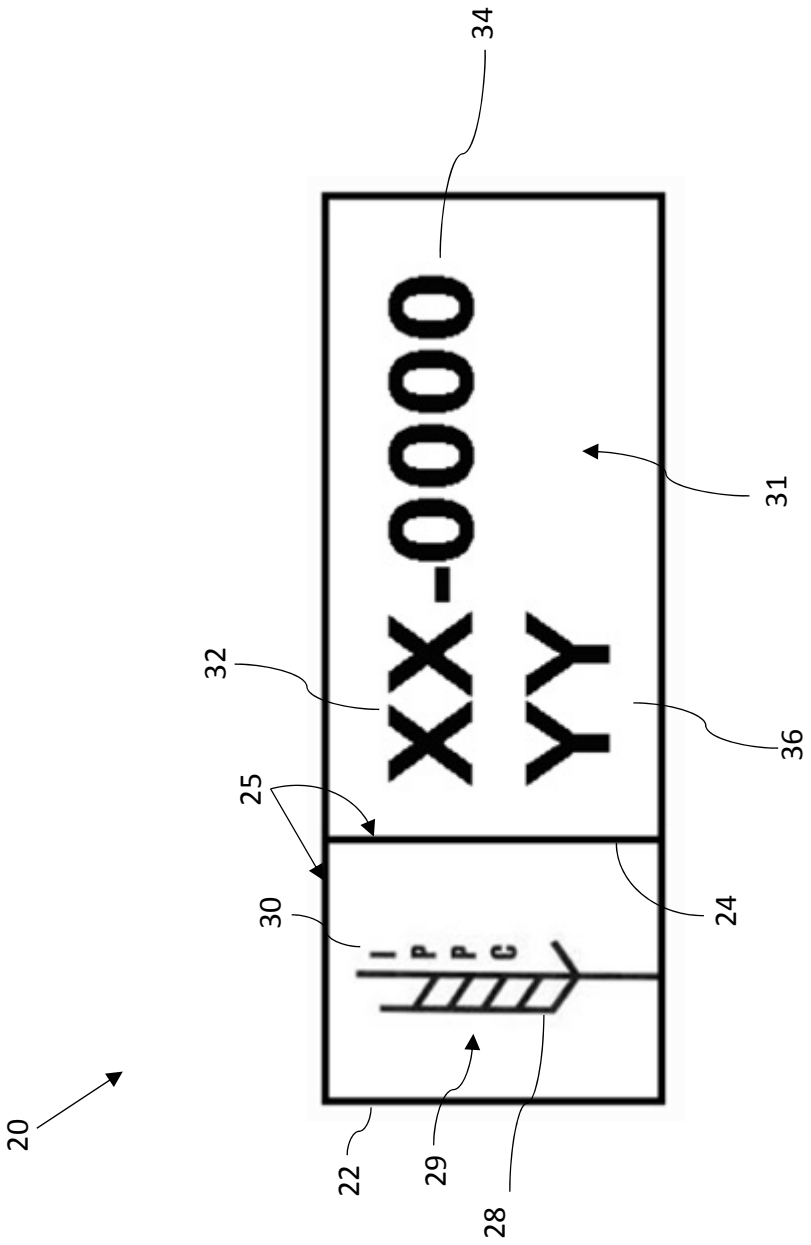

FIG. 1

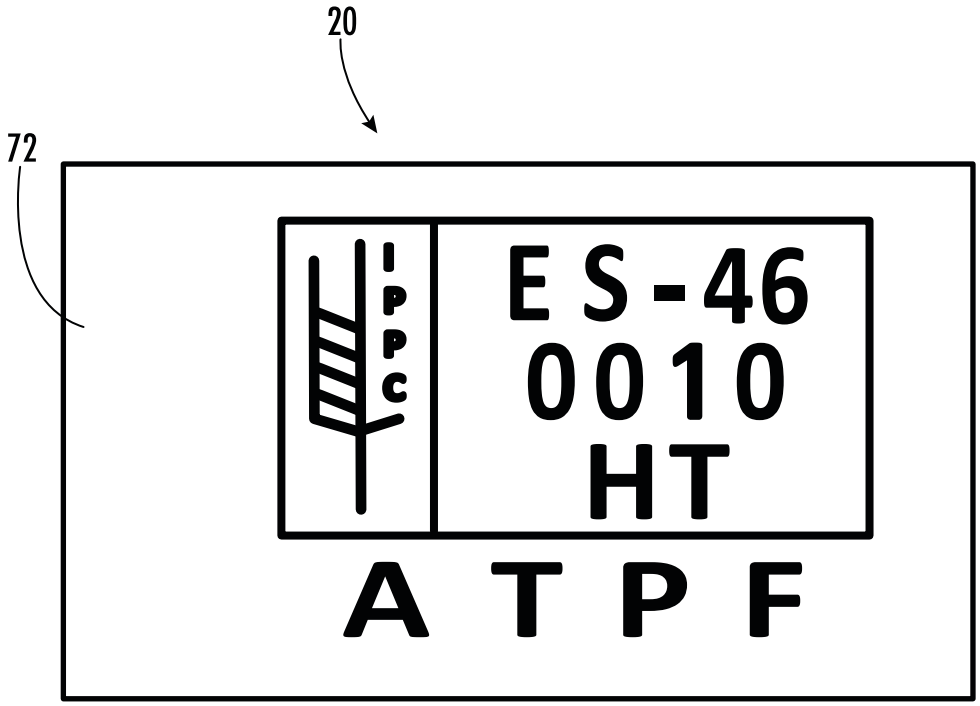

FIG. 2

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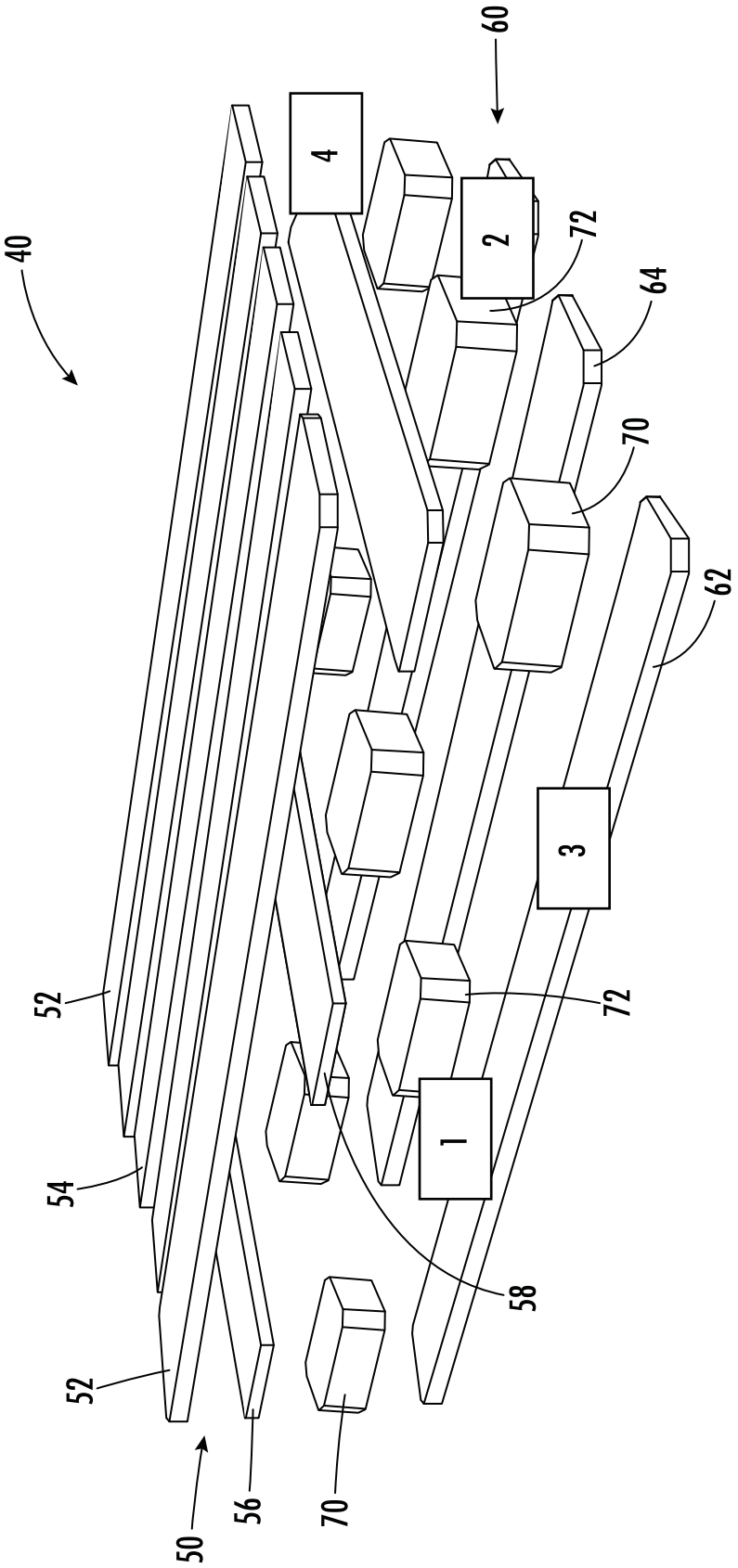

FIG. 3

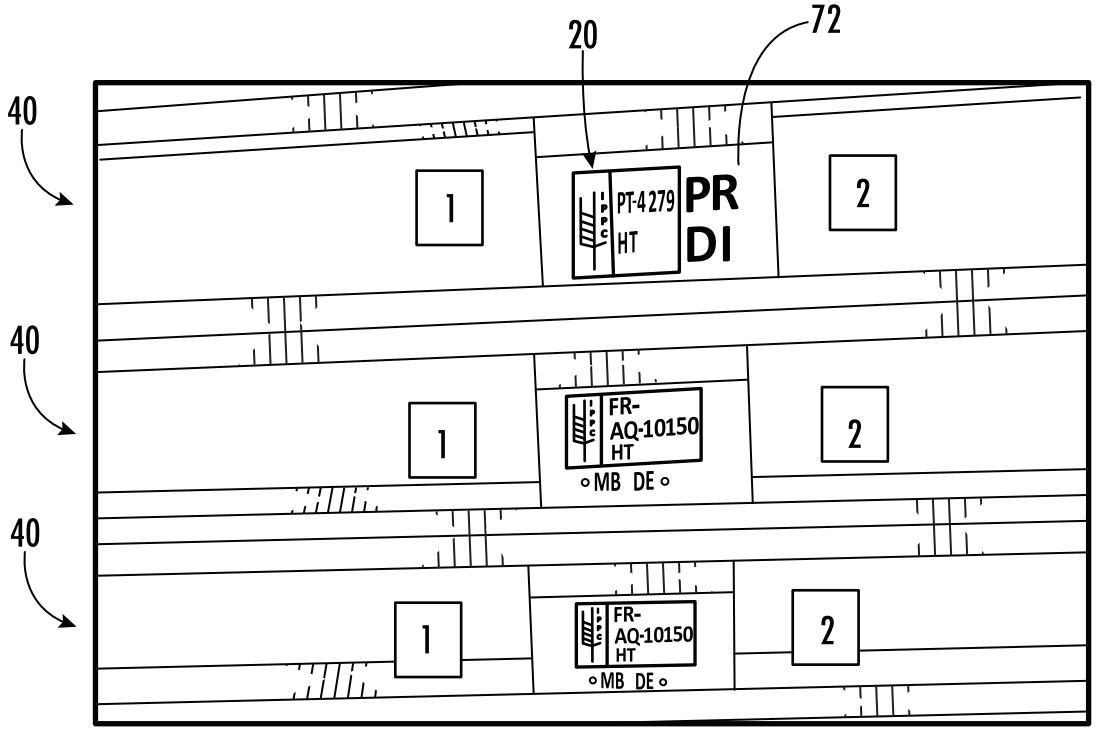

FIG. 4

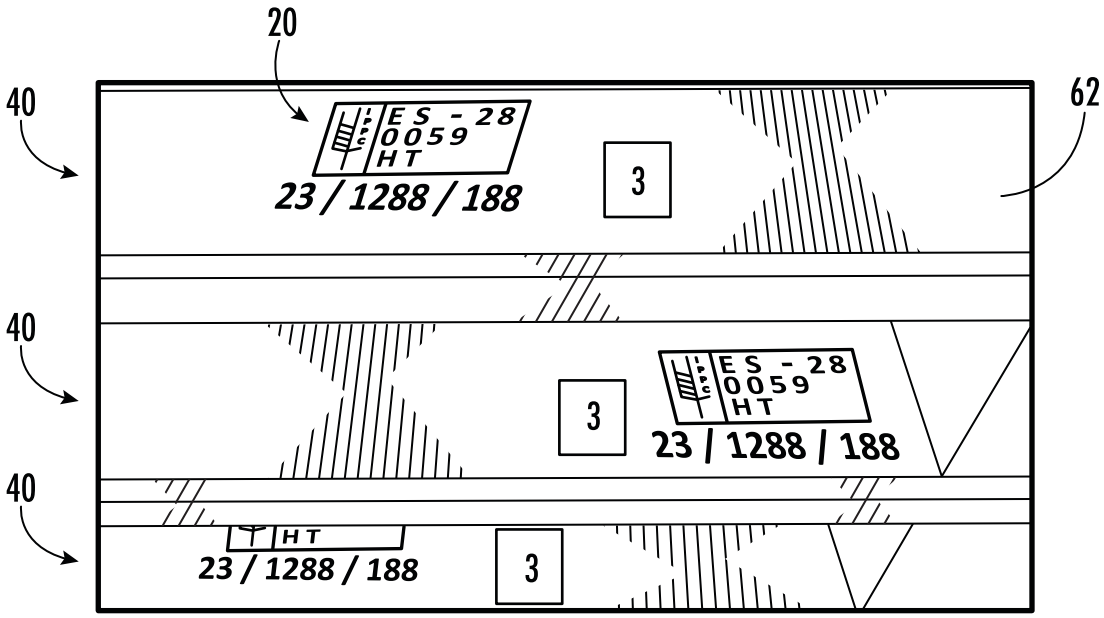

FIG. 5

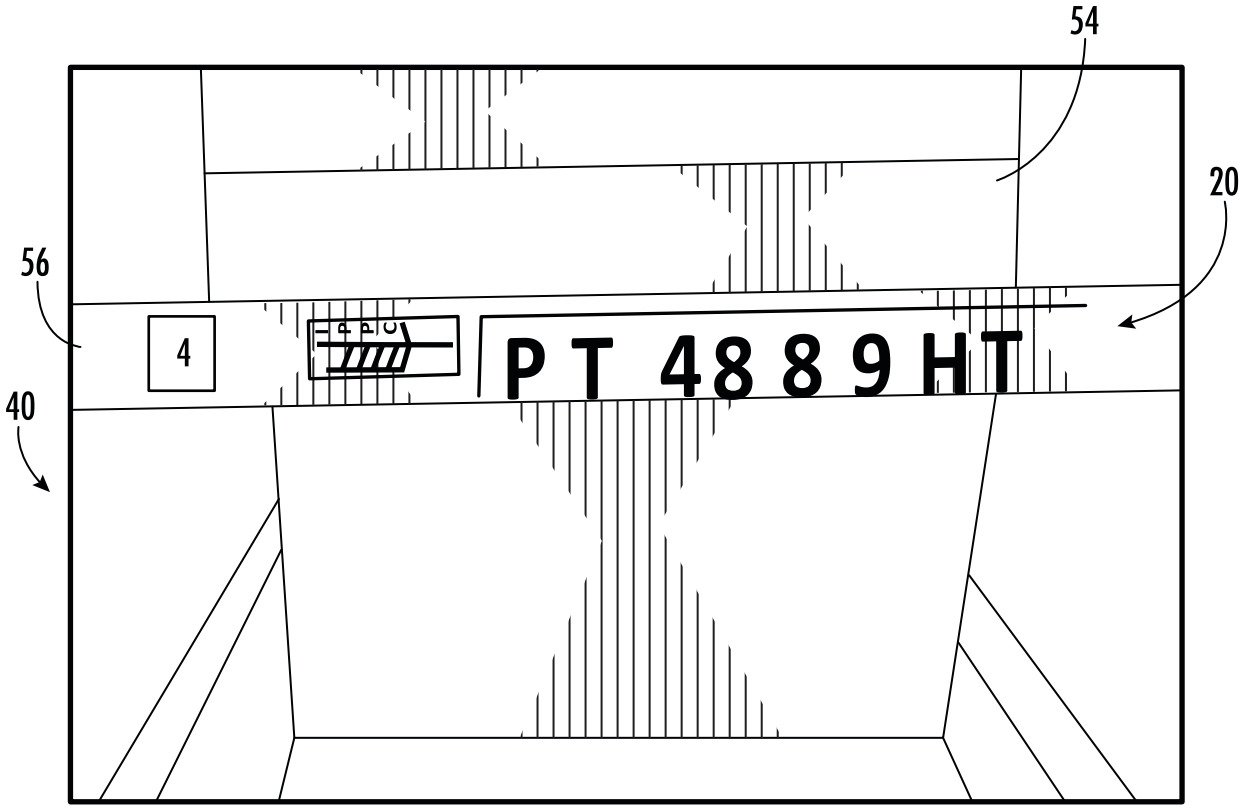

FIG. 6

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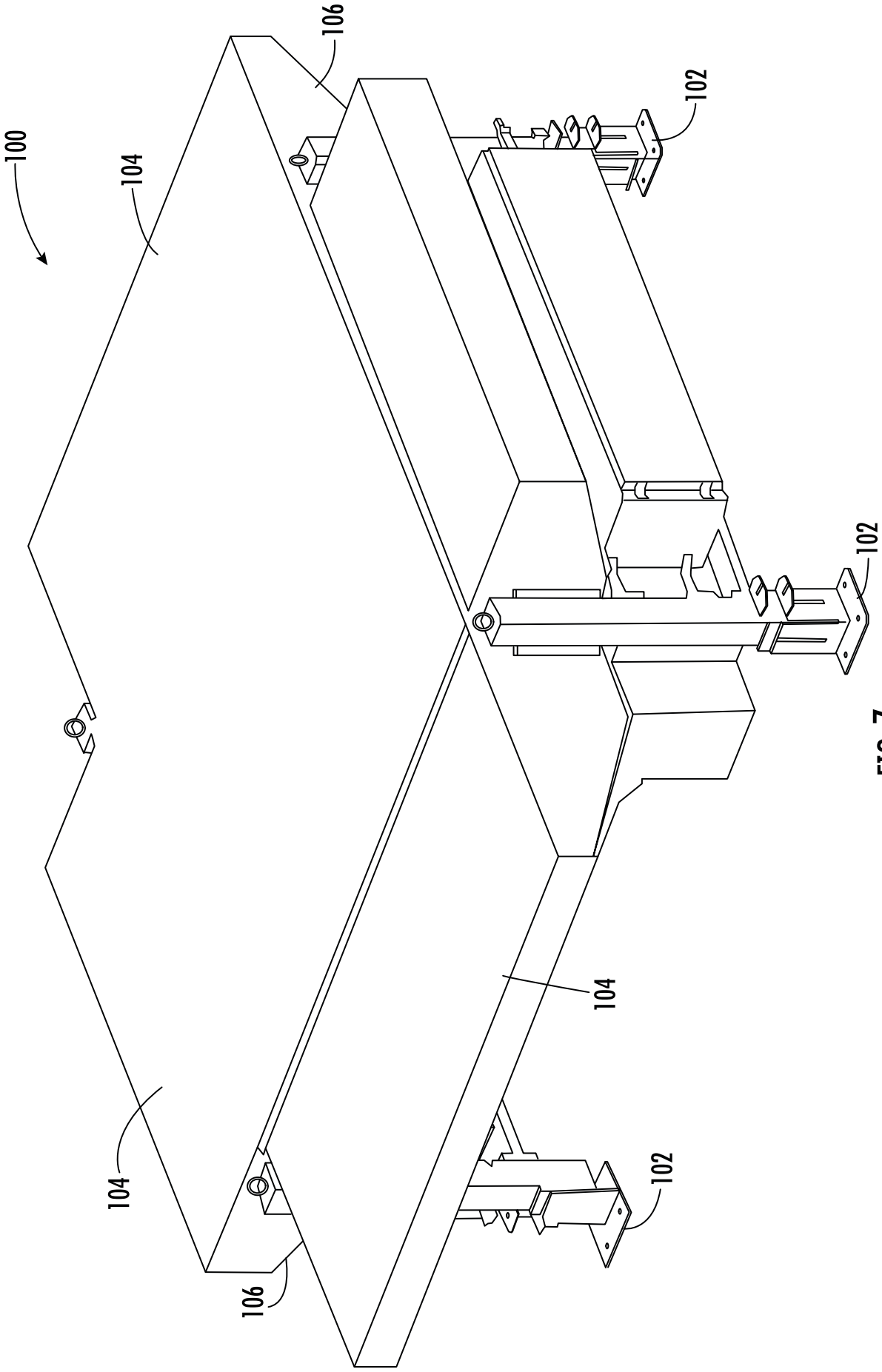

FIG. 7

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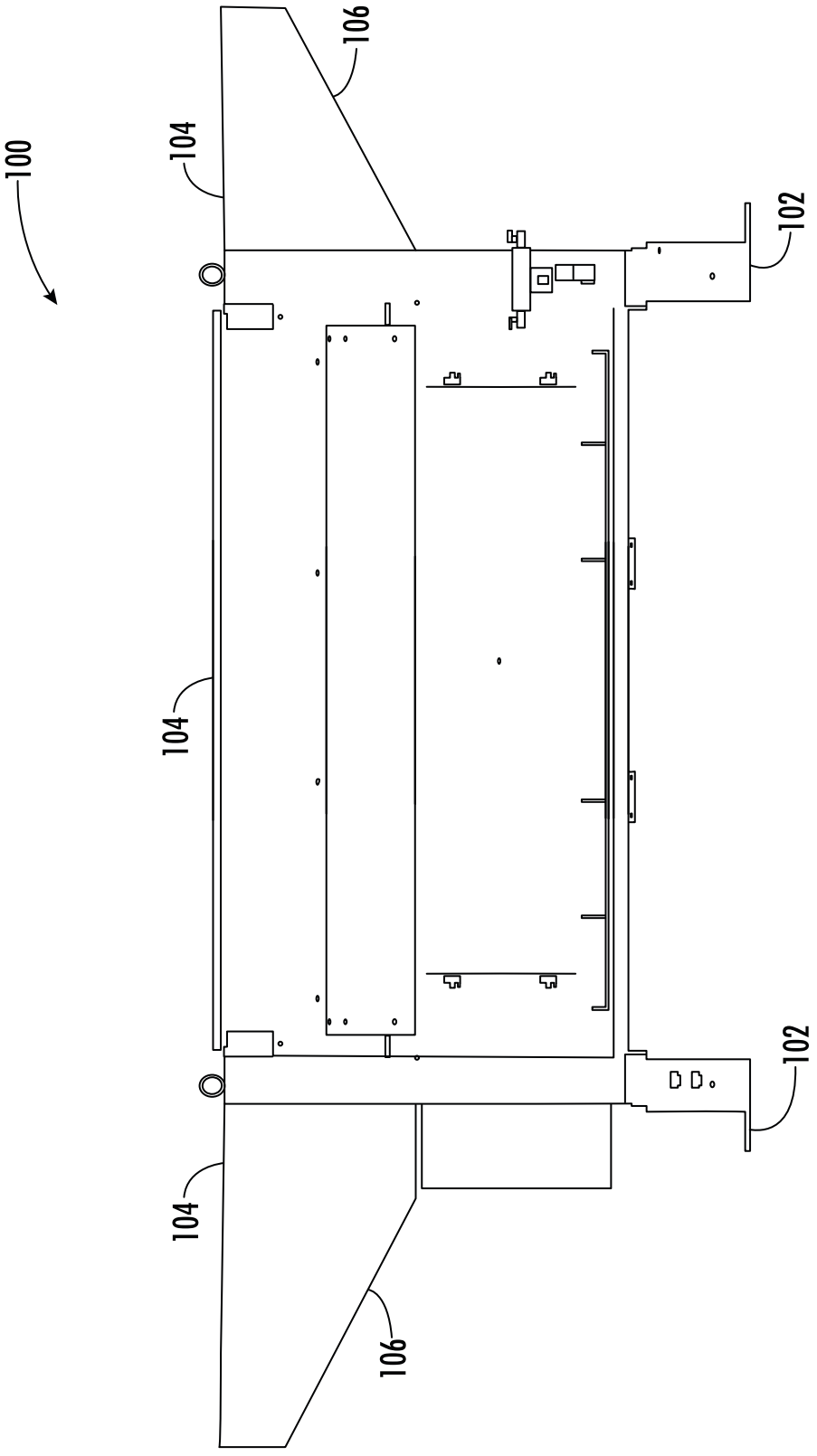

FIG. 8

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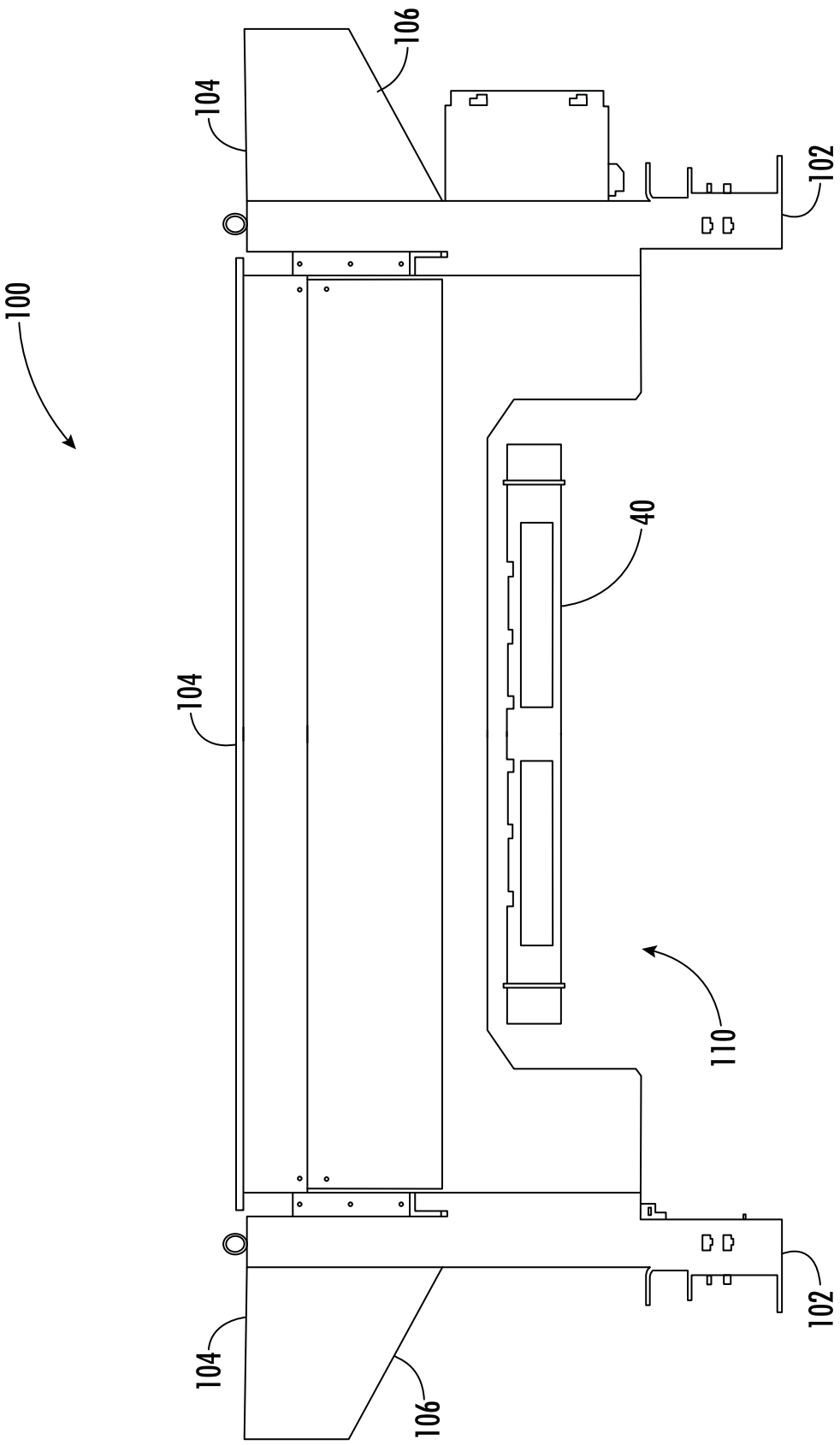

FIG. 9

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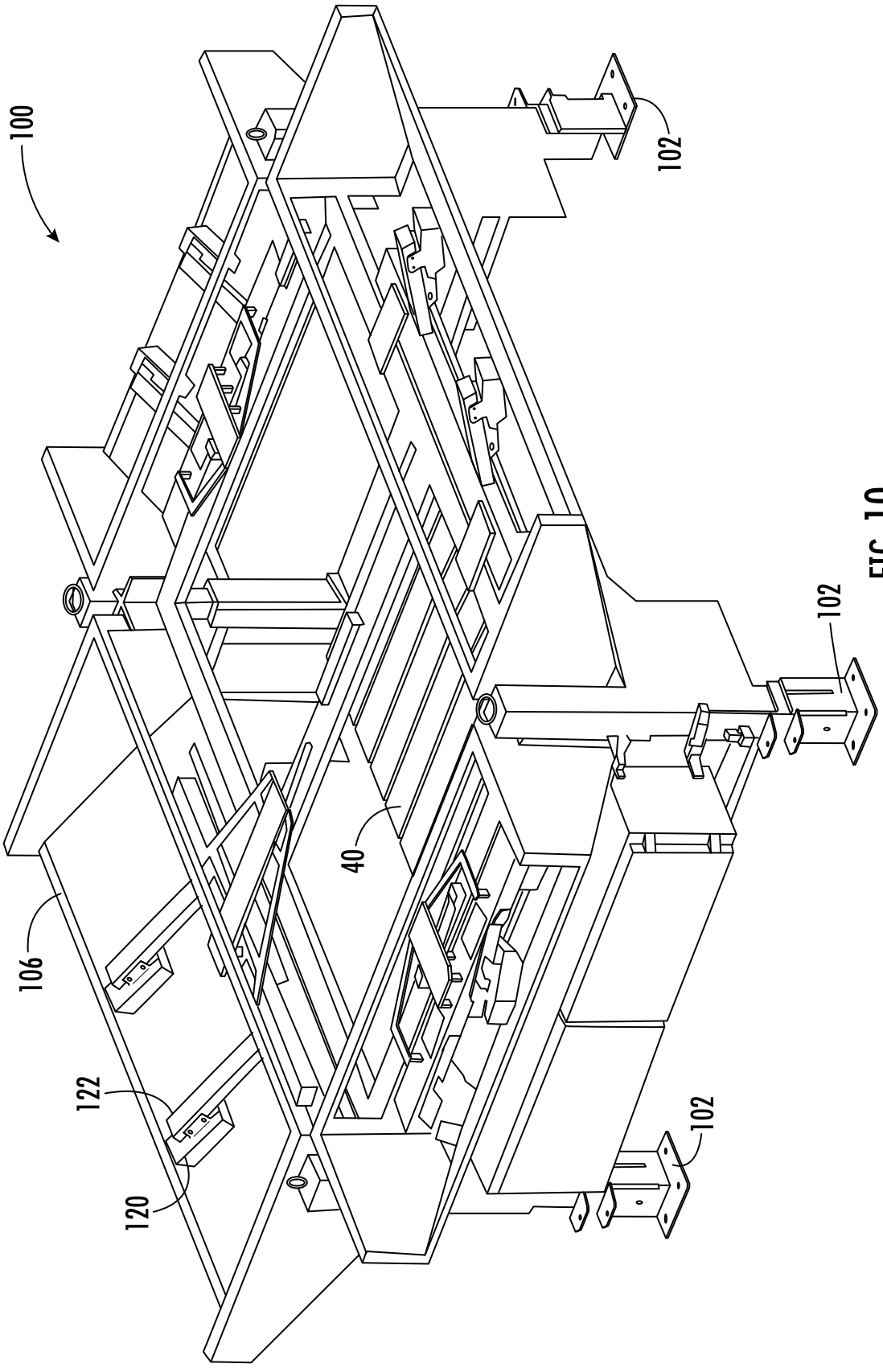

FIG. 10

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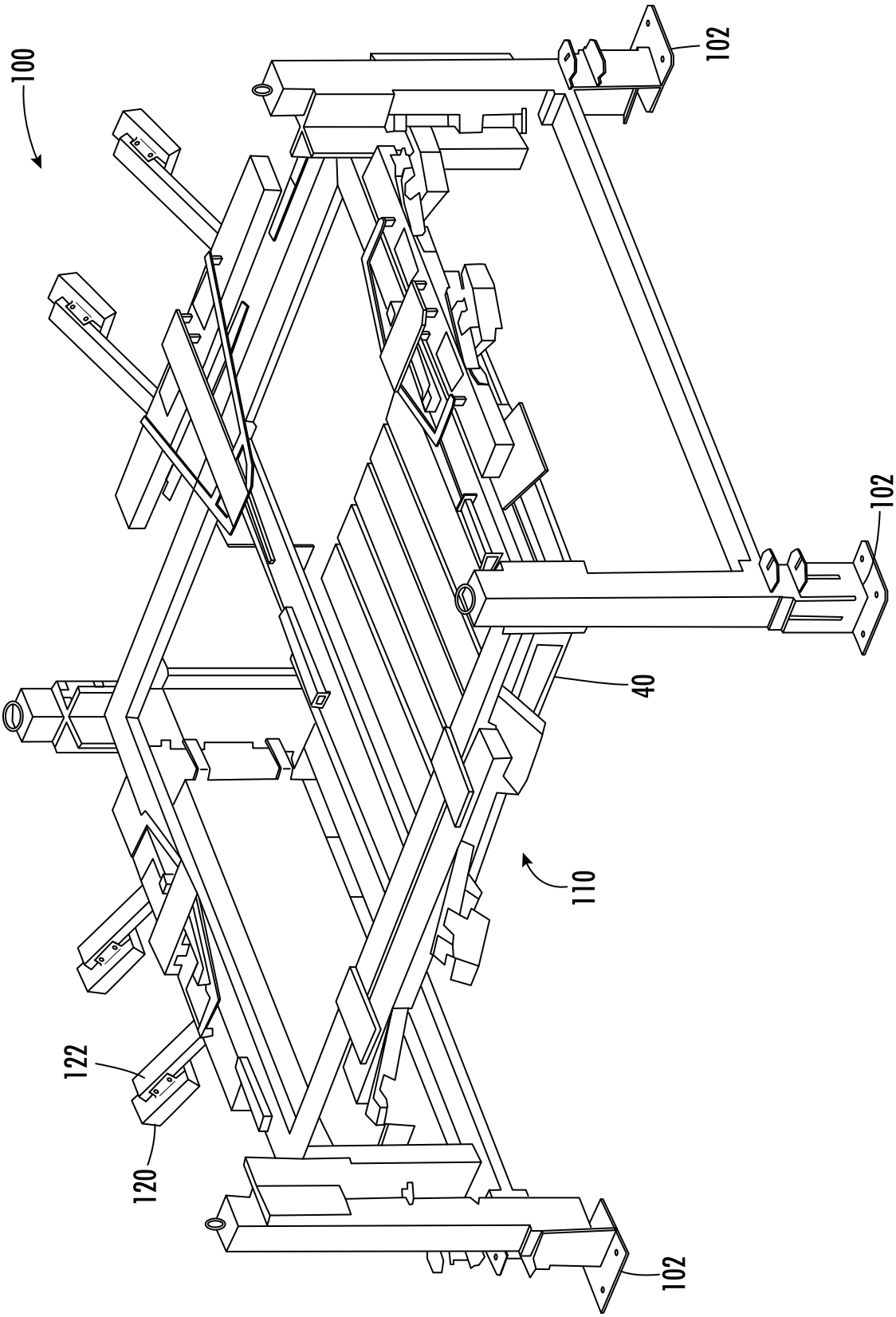

FIG. 11

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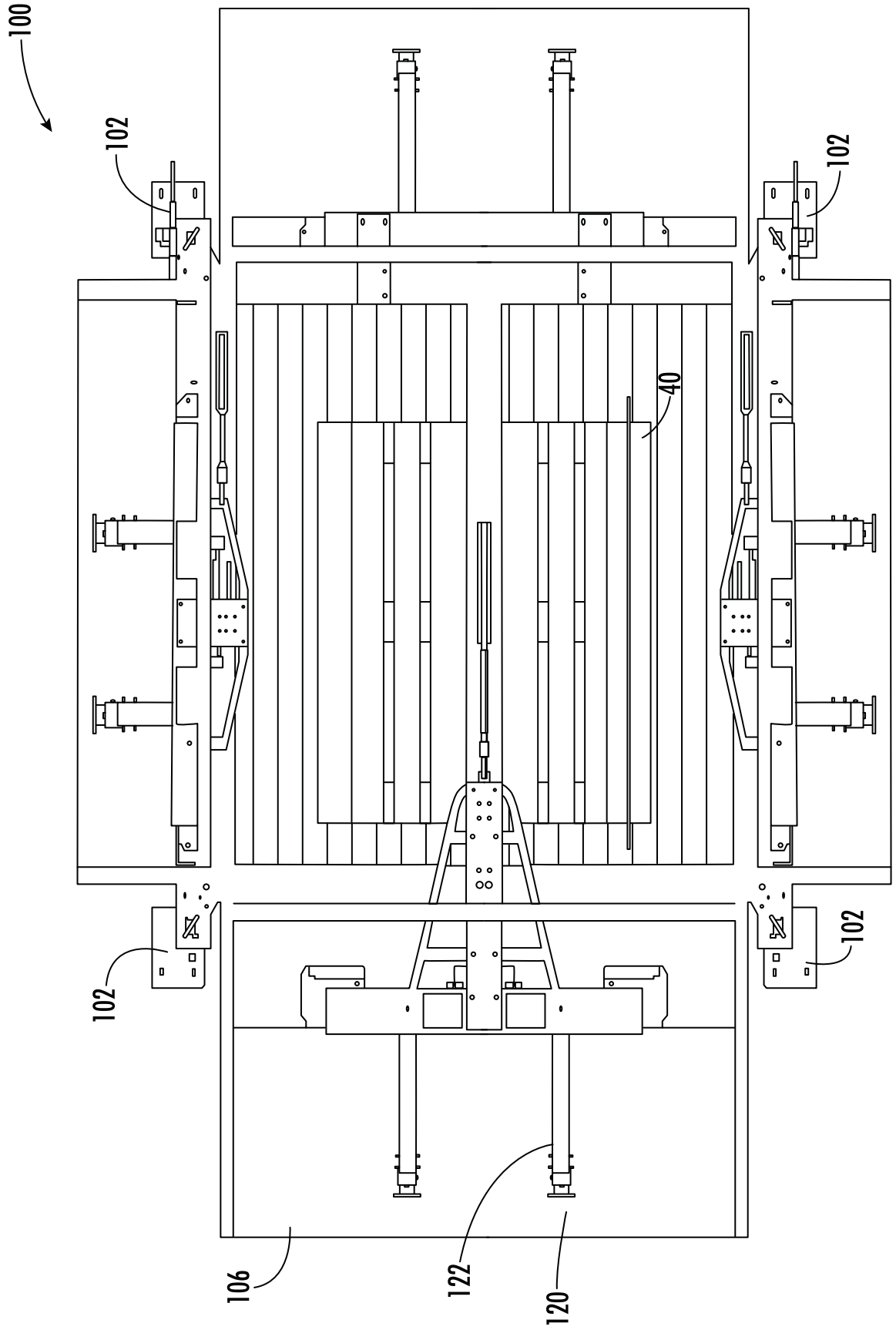

FIG. 12

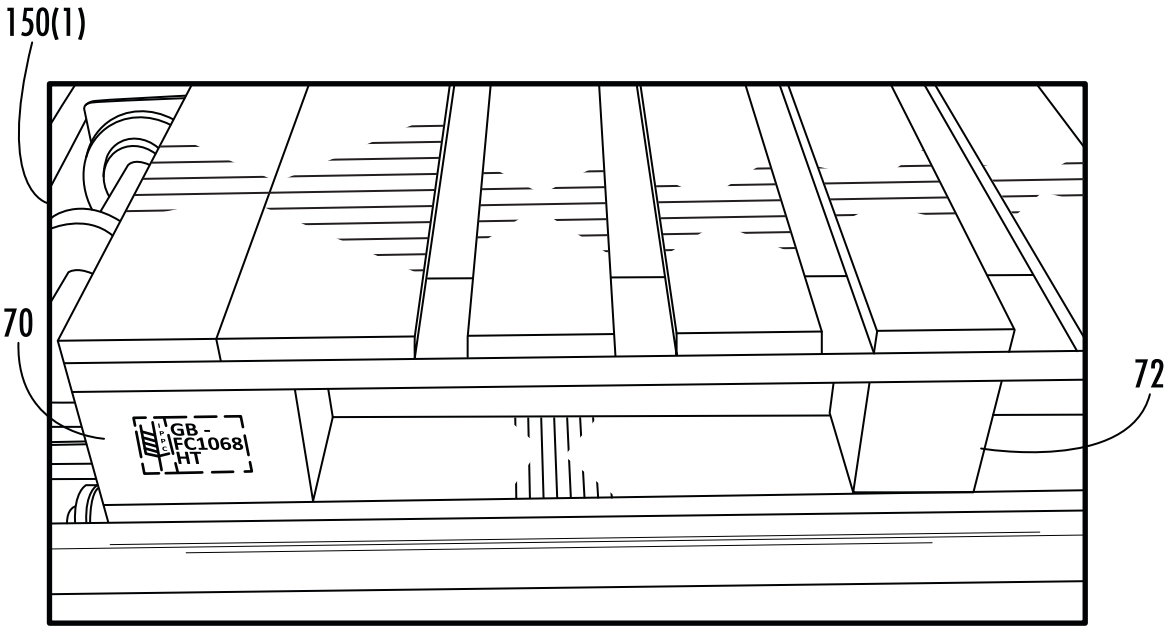

FIG. 13A

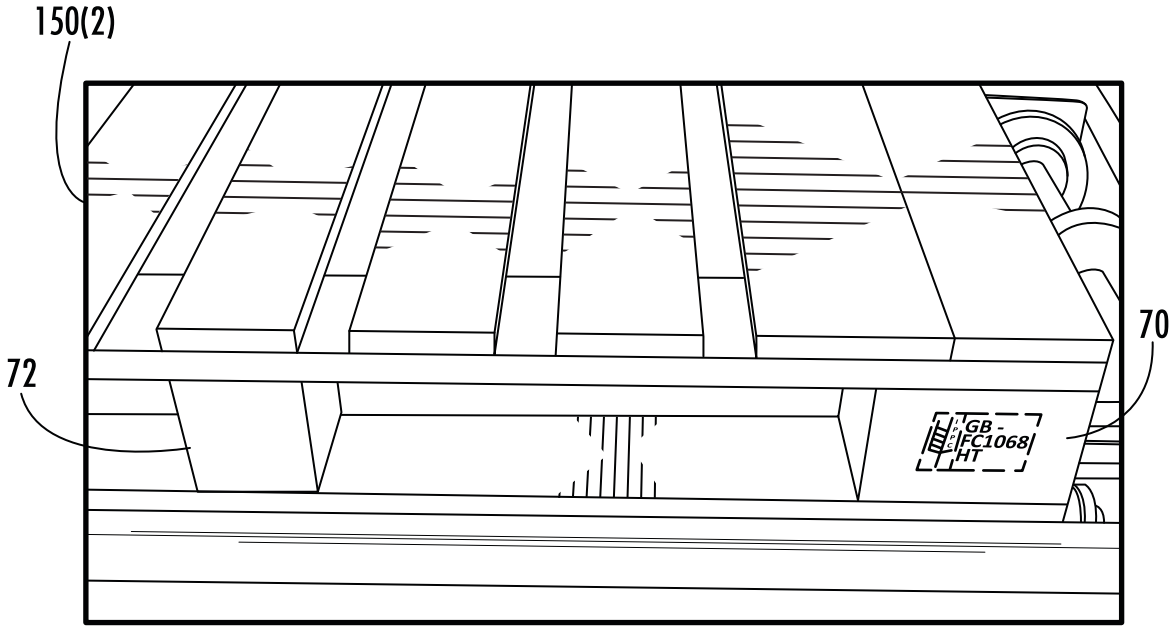

FIG. 13B

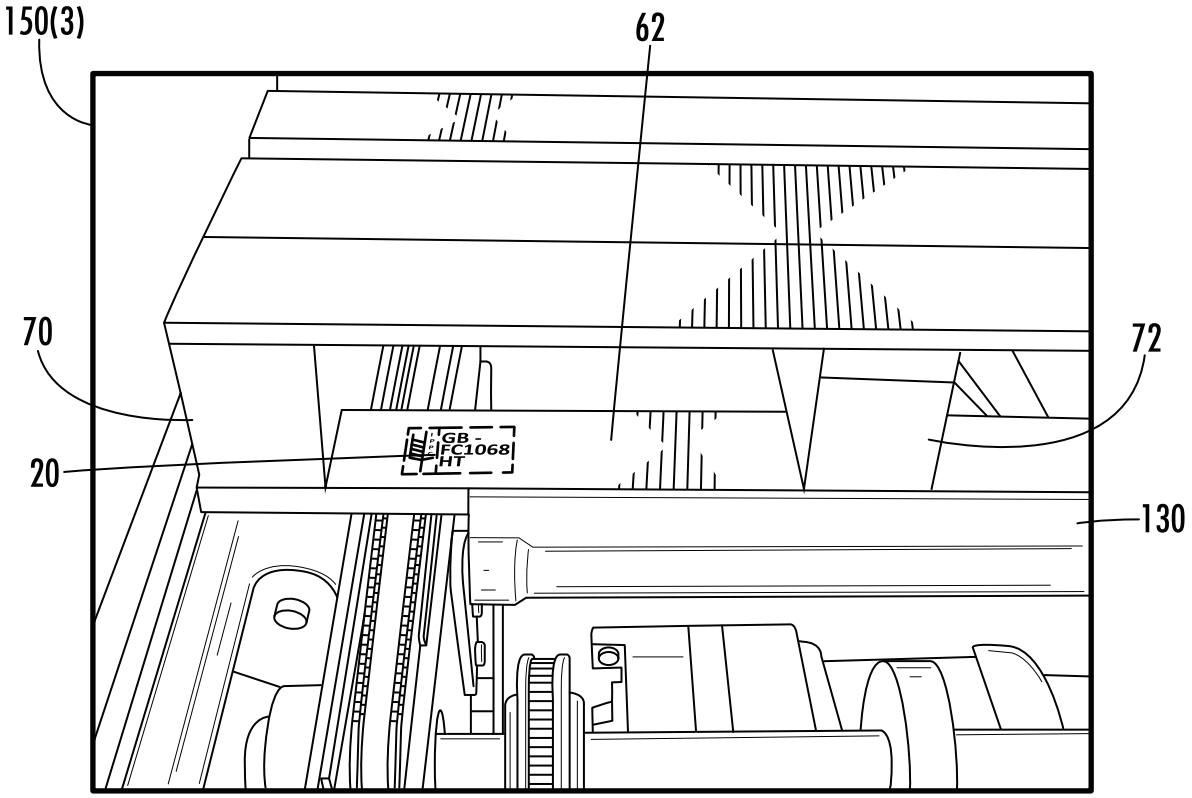

FIG. 14A

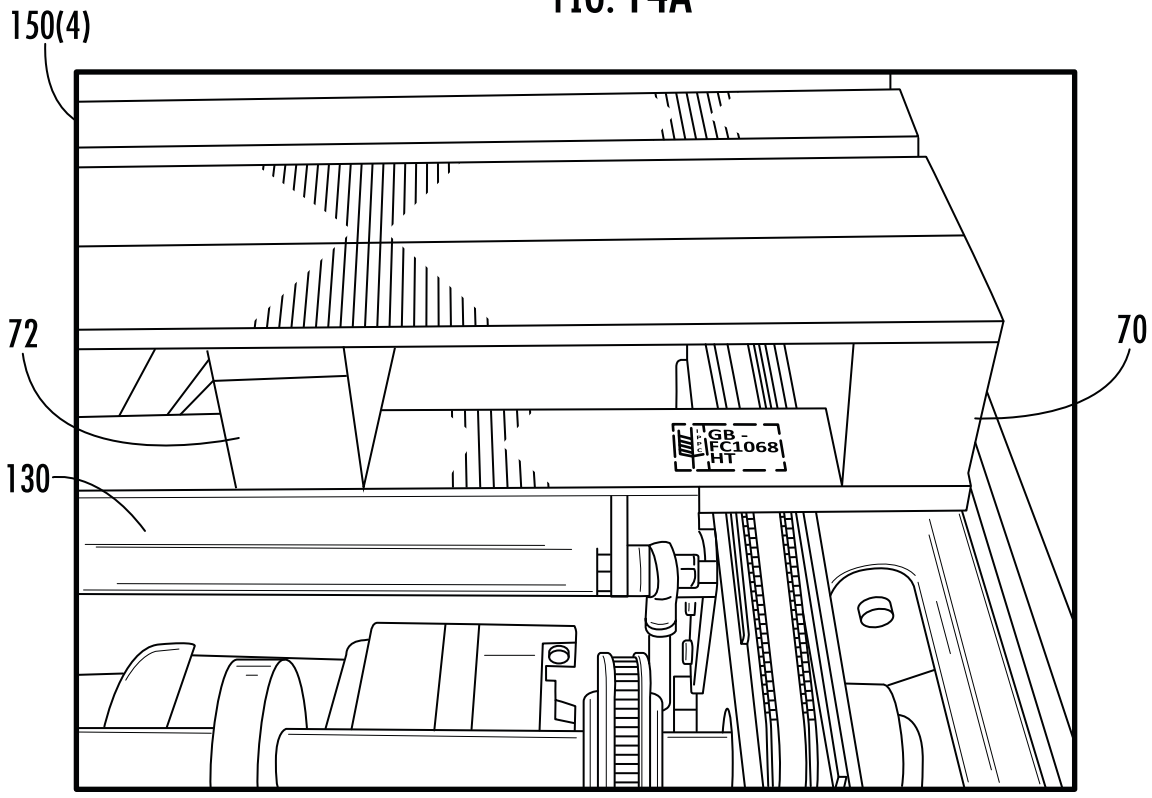

FIG. 14B

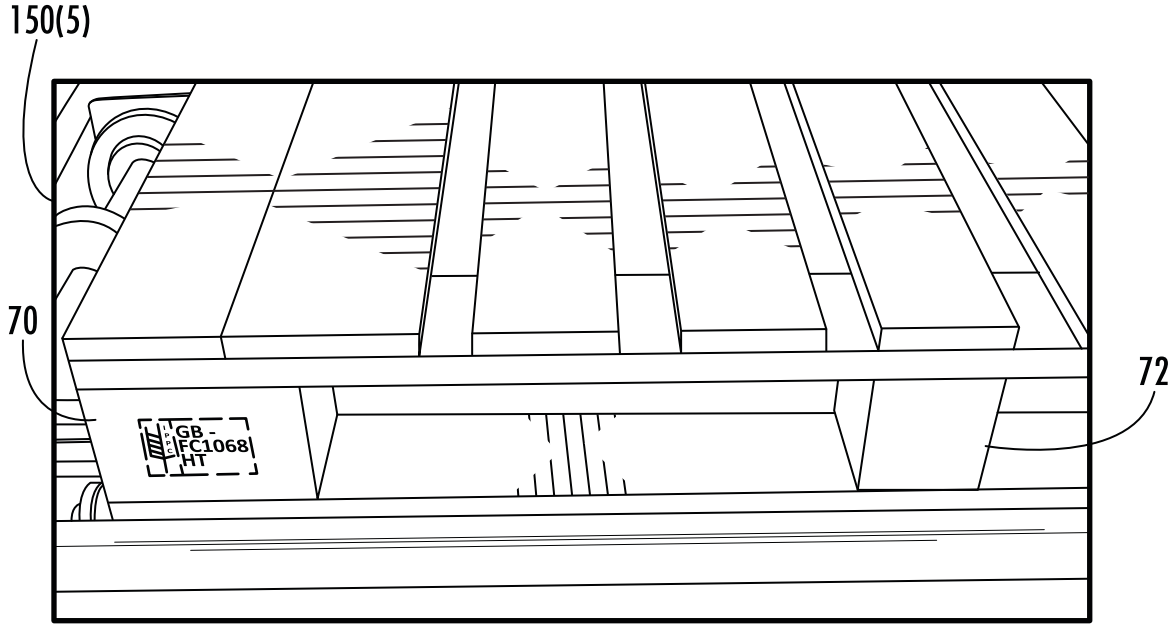

FIG. 15A

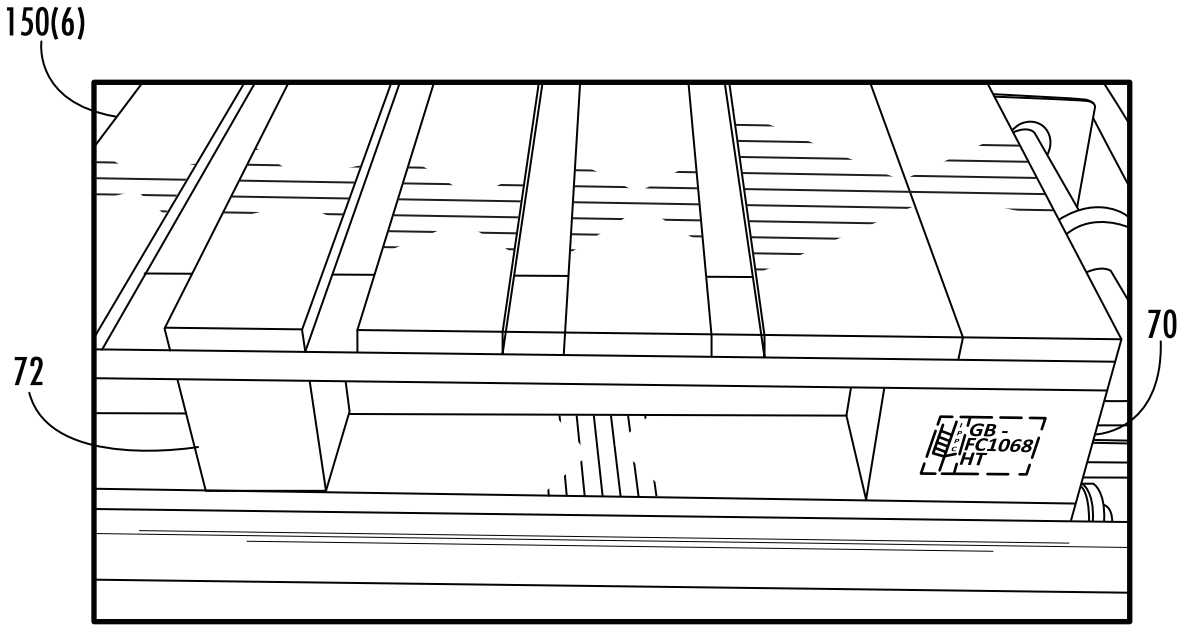

FIG. 15B

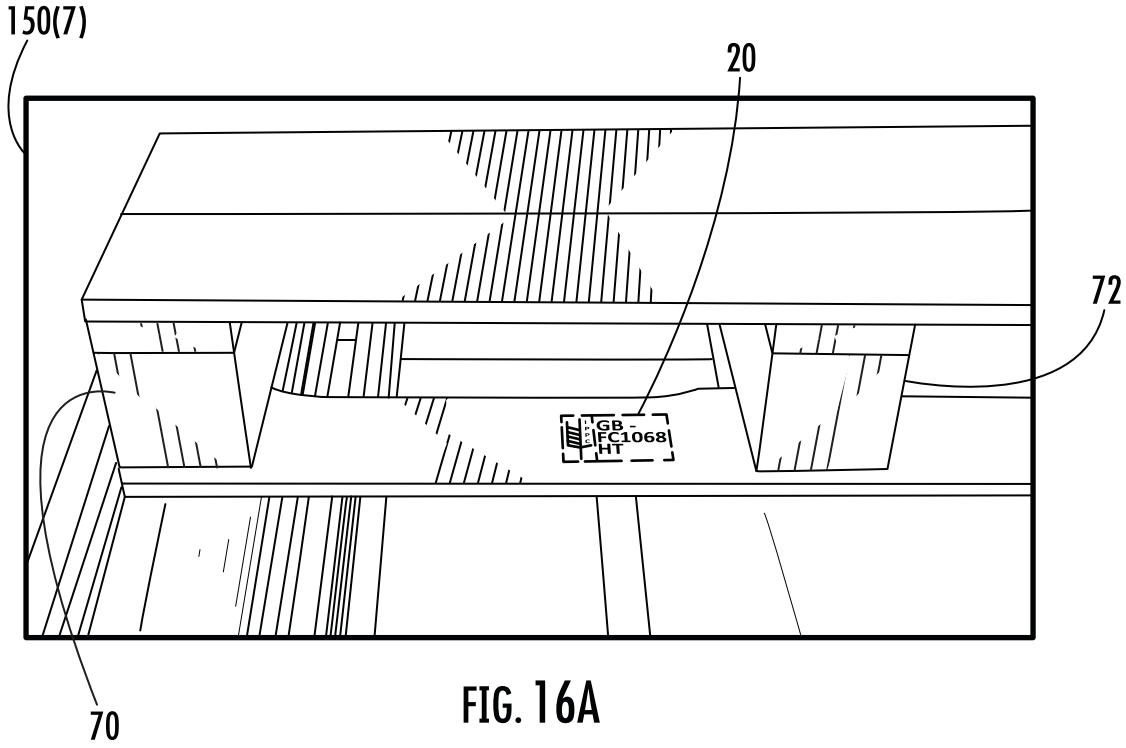

FIG. 16A

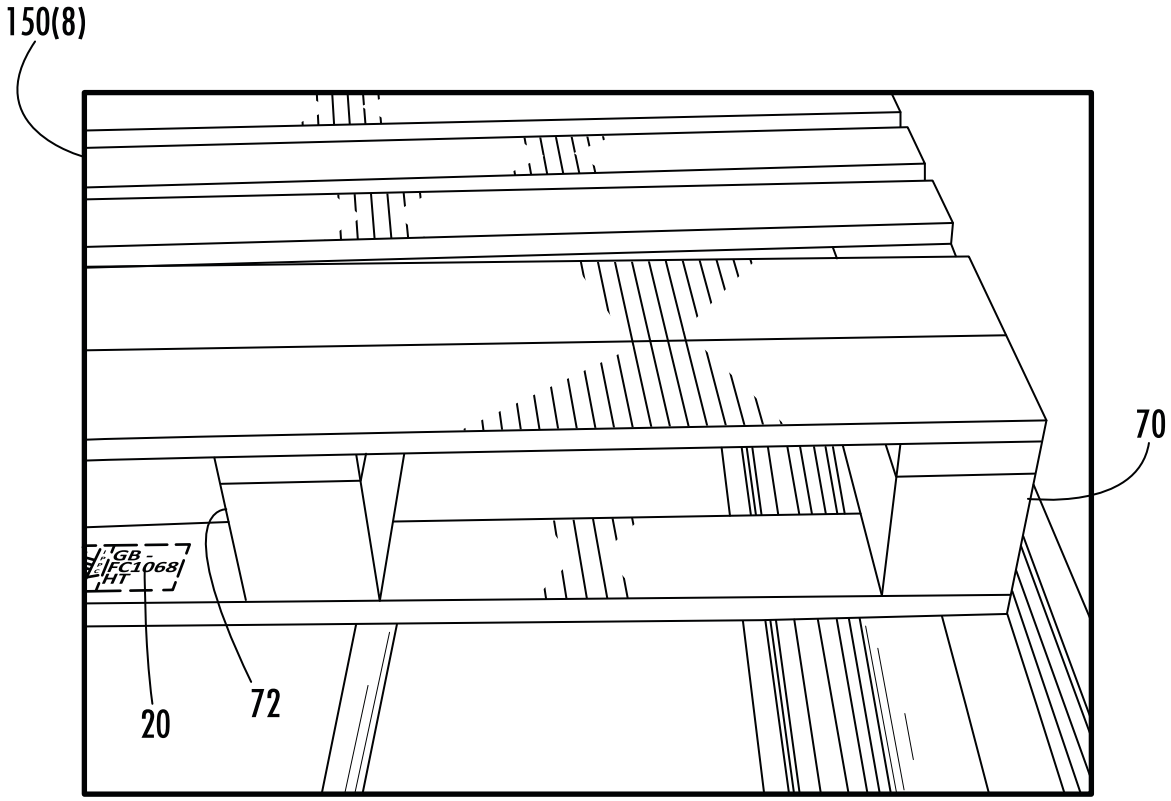

FIG. 16B

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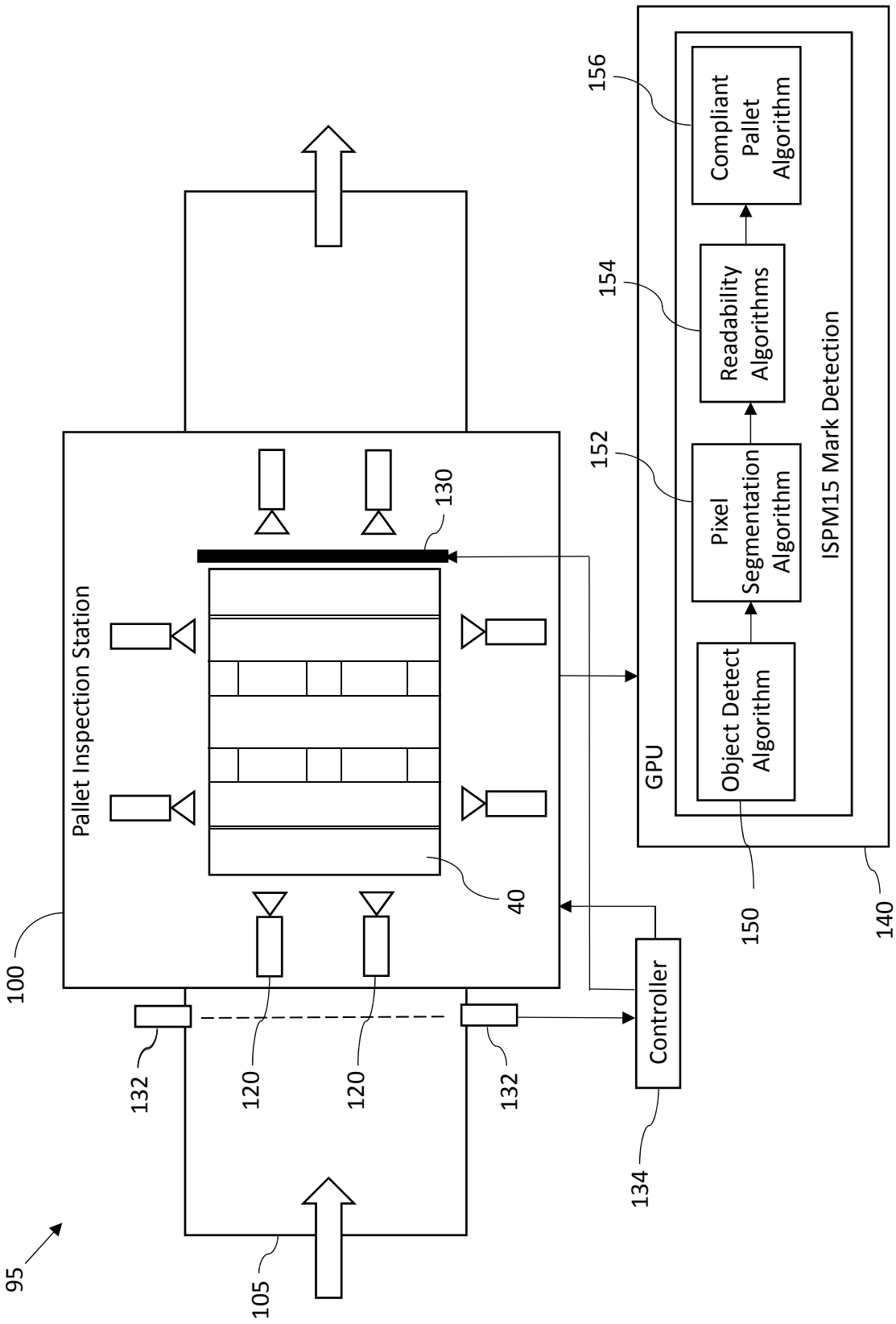

FIG. 17

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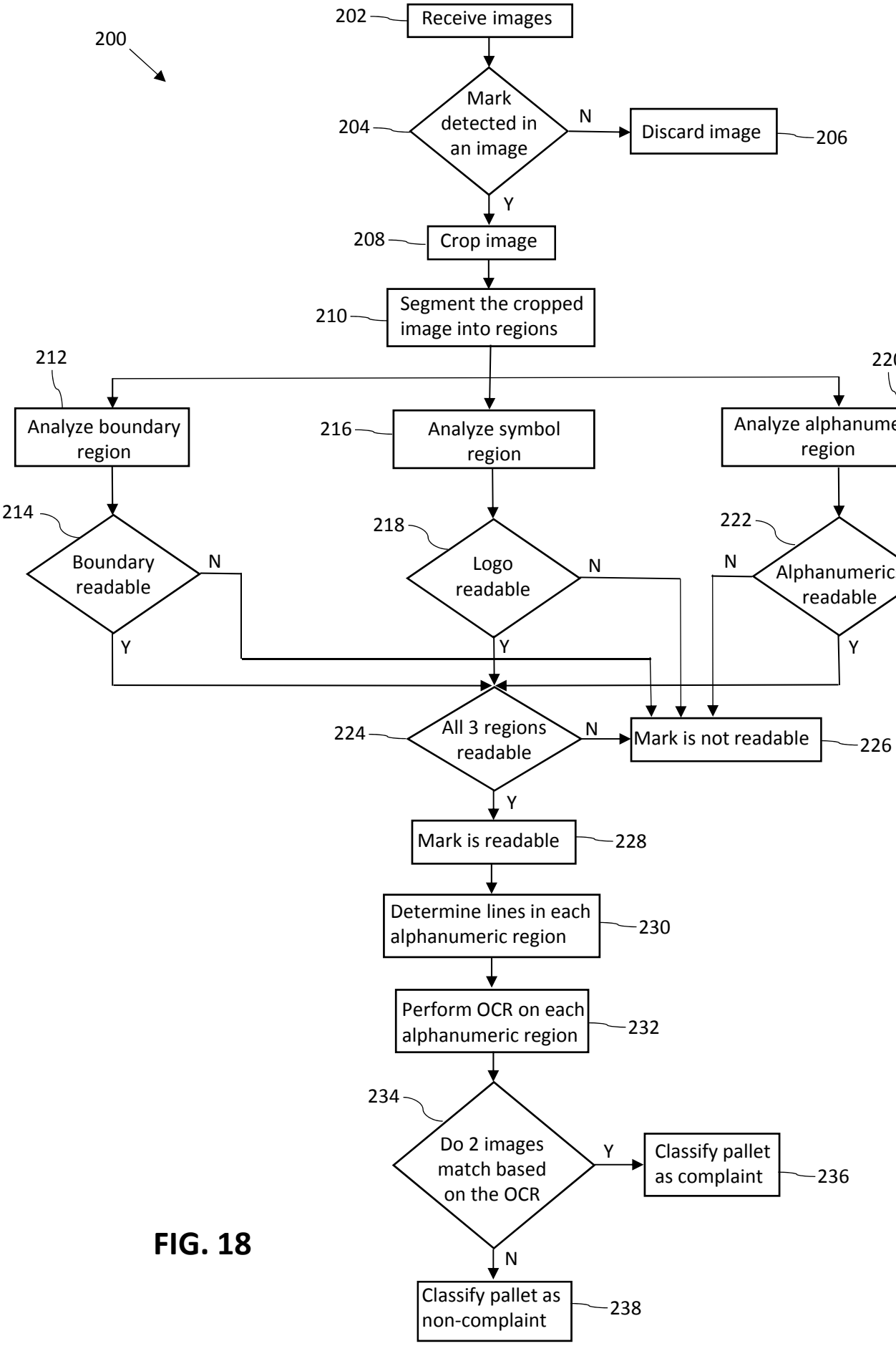

FIG. 18

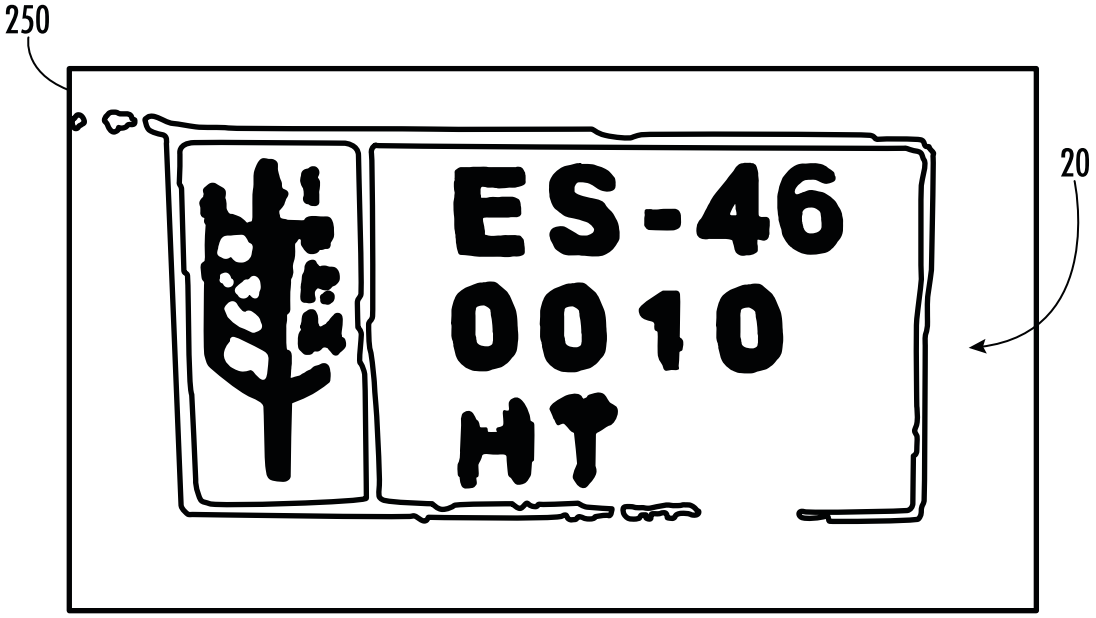

FIG. 19

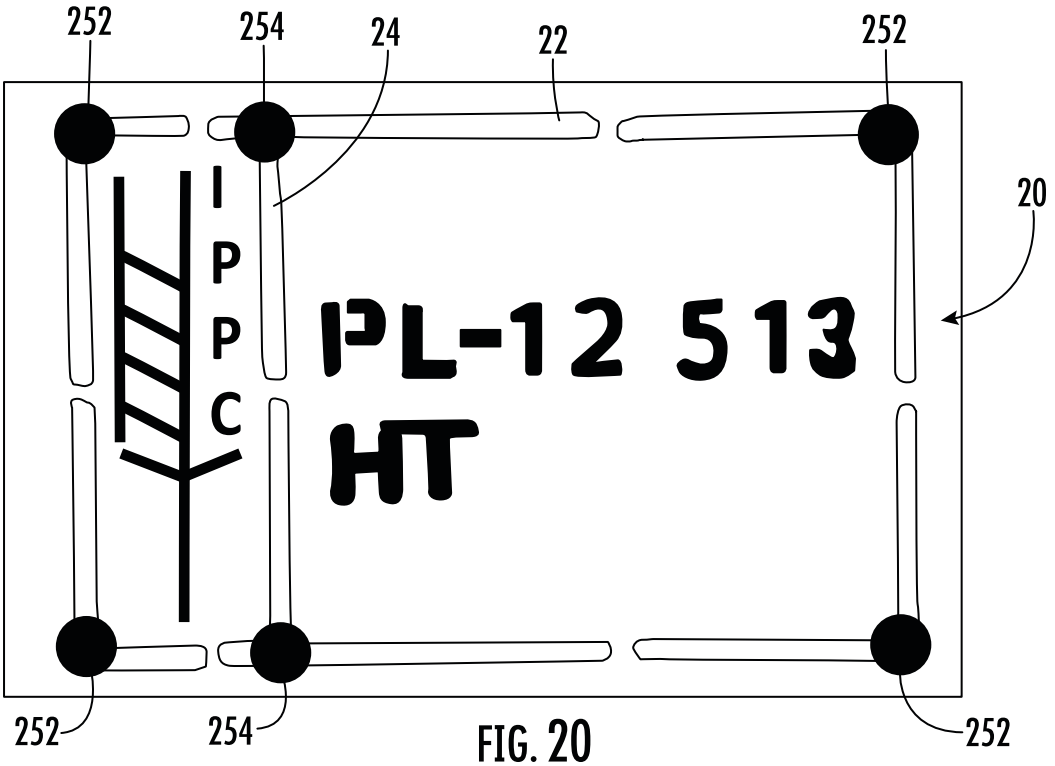

FIG. 20

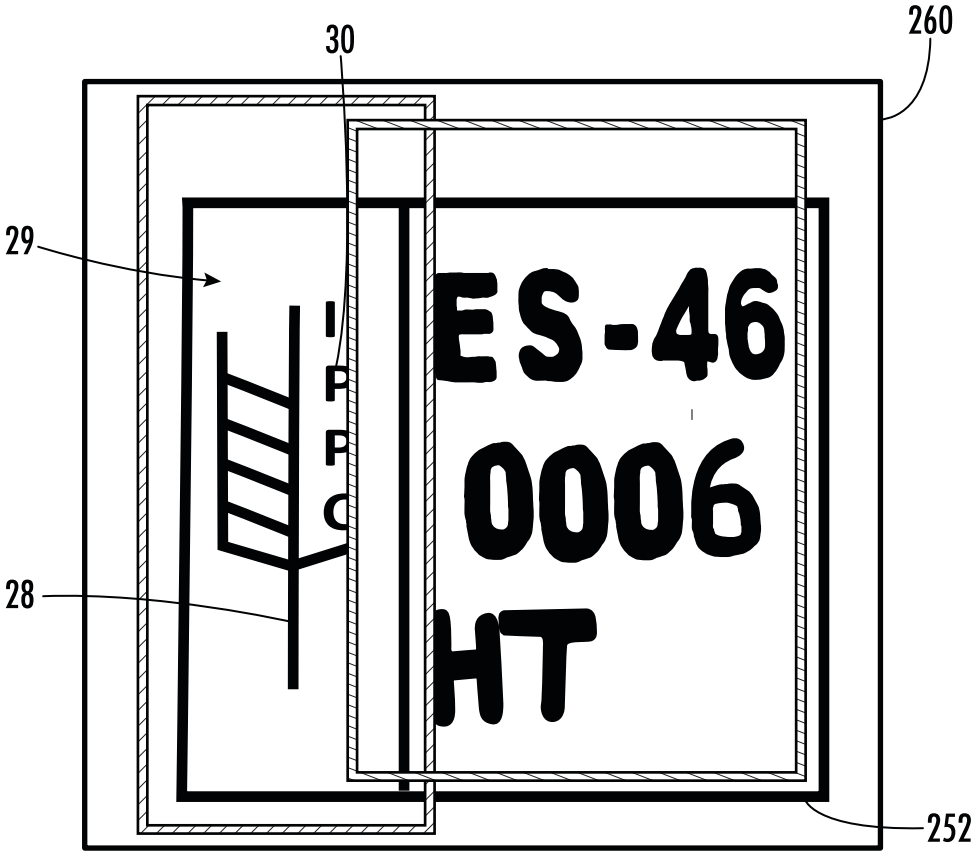

FIG. 21

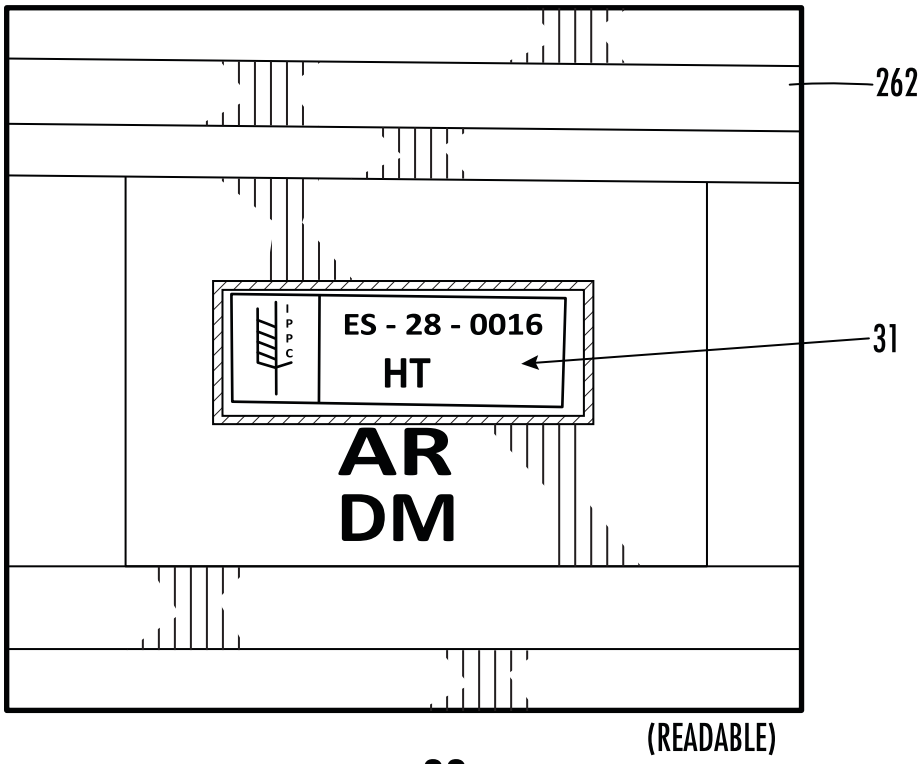

FIG. 22

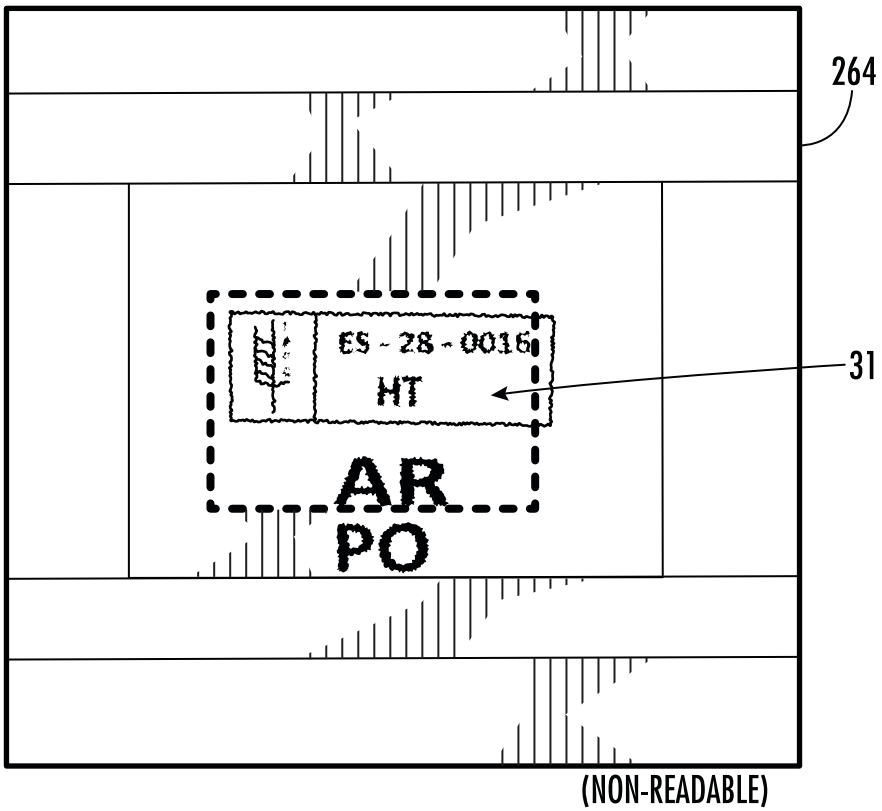

FIG. 23

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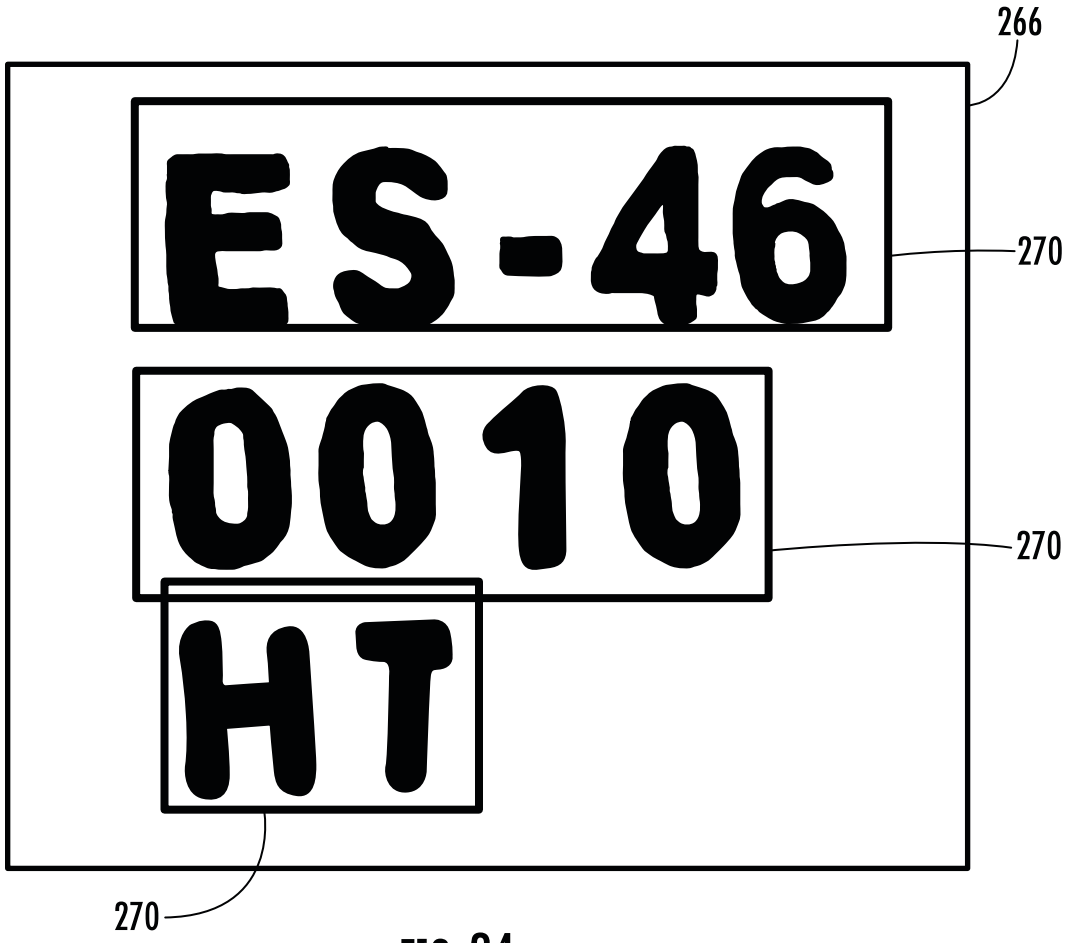

FIG. 24

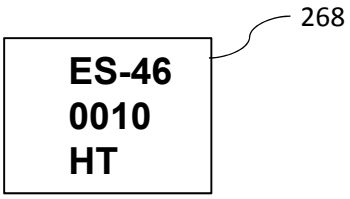

FIG. 25

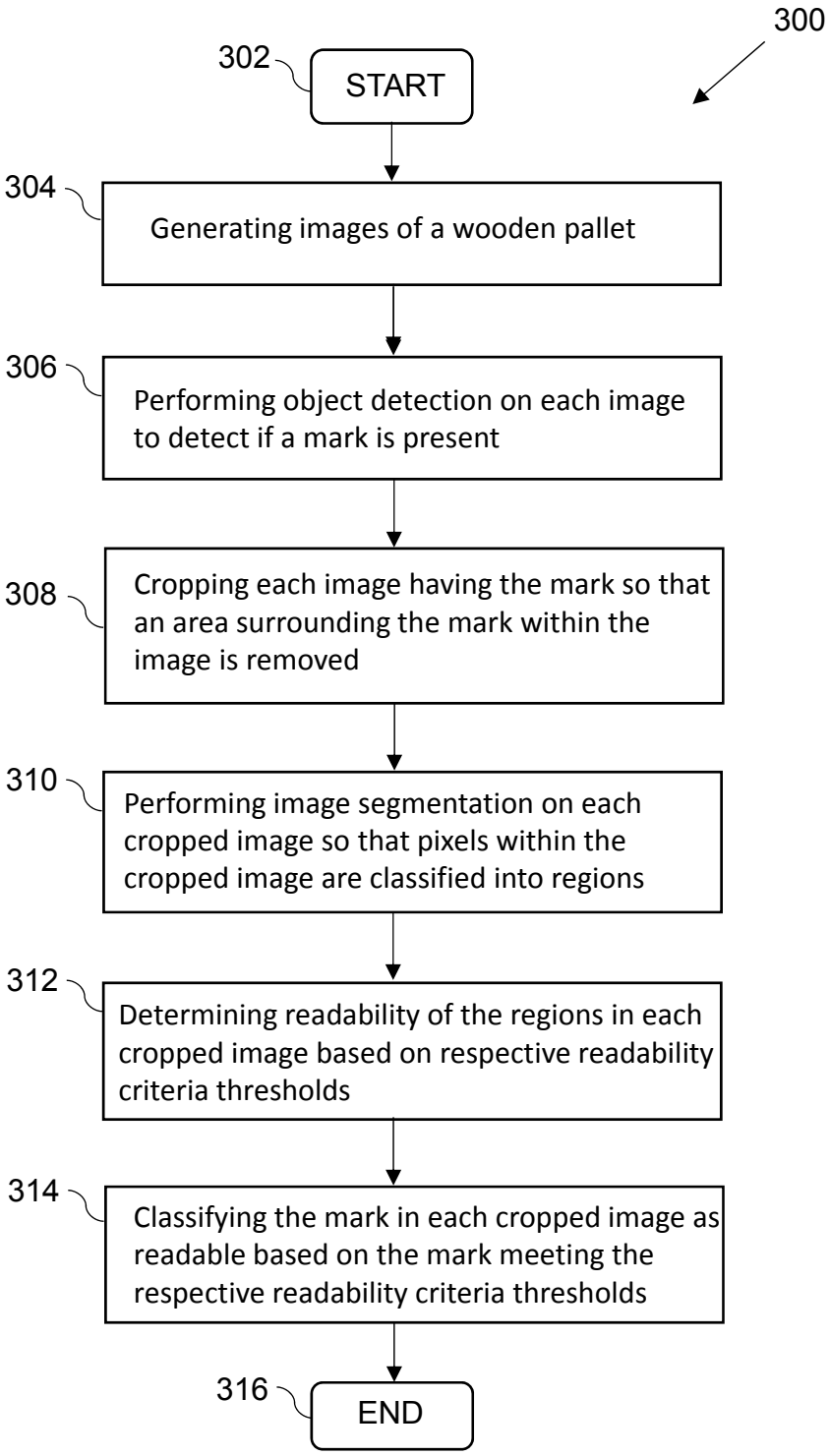

FIG. 26