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(54) **WASHING MACHINE**

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(57) **ABSTRACT**

A washing machine includes a cabinet, an outer tank, an inner tank, a circulation tube, and a circulation pump. The outer tank is held in the cabinet. The inner tank is rotatably mounted in the outer tank so as to accommodate and stir laundry. The circulation tube draws washing water kept in the outer tank and returns it to the outer tank. The circulation pump is located at some midpoint in the circulation tube so as to circulate the washing water. The washing machine further includes, at some midpoint in the circulation tube, a washing water-condition detector for detecting the condition of the washing water. This structure ensures the amount of washing water circulating through the washing water-condition detector, without depending on the operation of the inner tank. Thus, the washing machine can detect the degree of contamination of washing water with high accuracy while maintaining its washing efficiency.

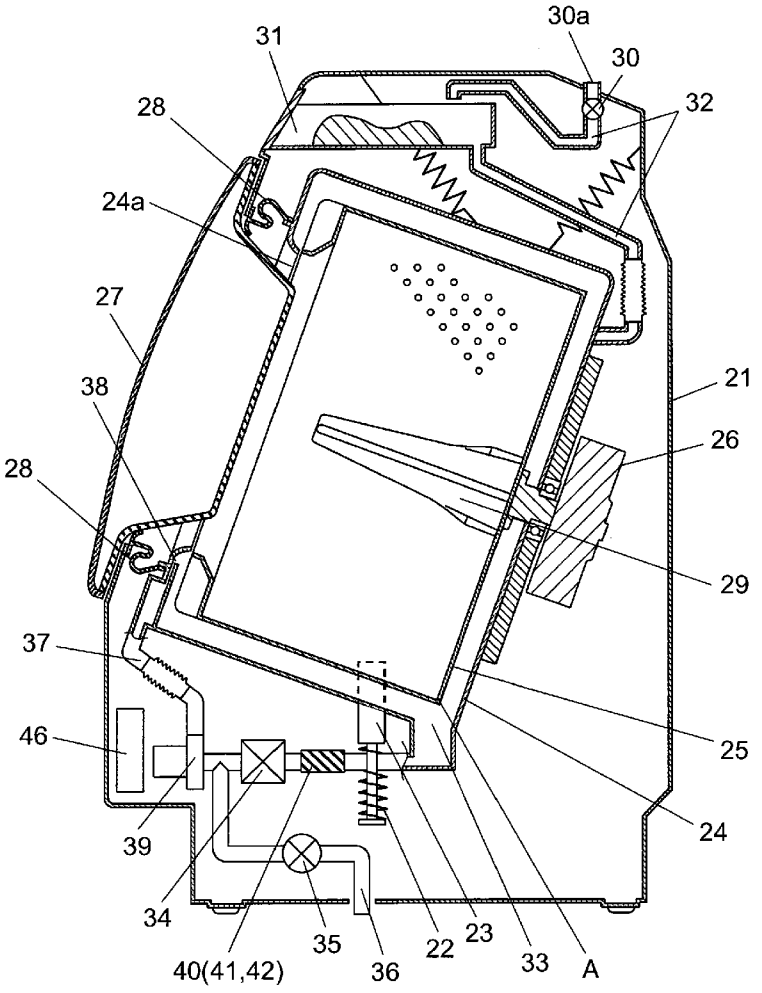

FIG. 1

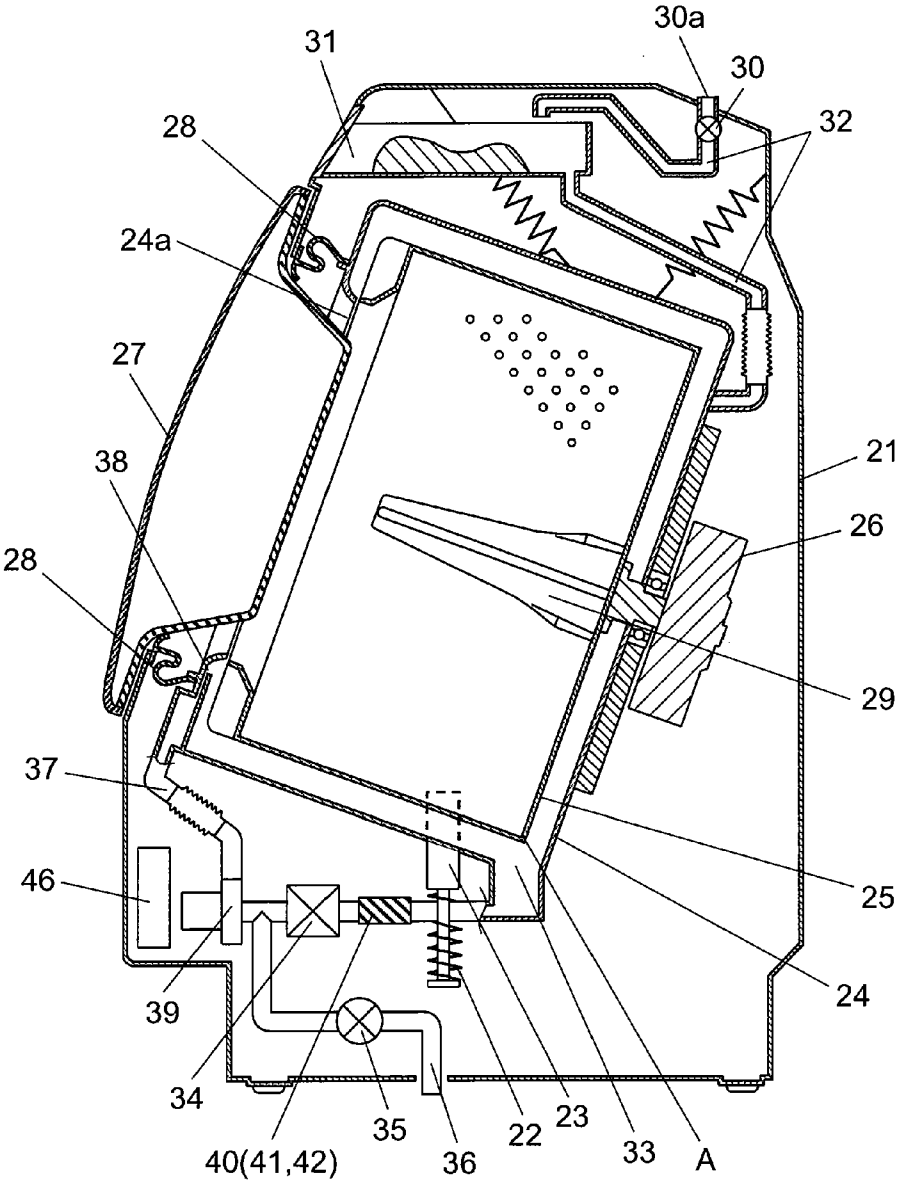
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FIG. 2

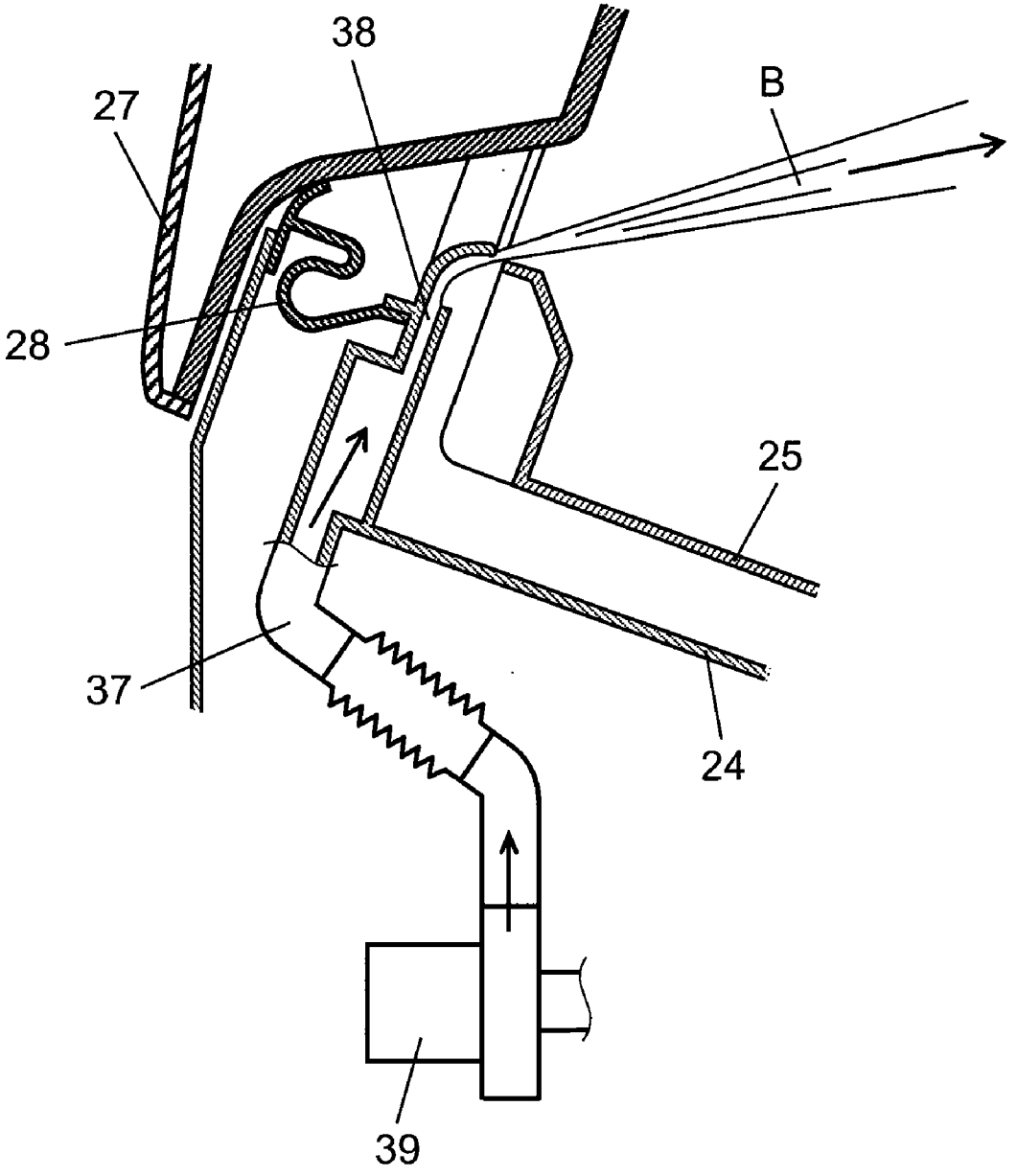

FIG. 3

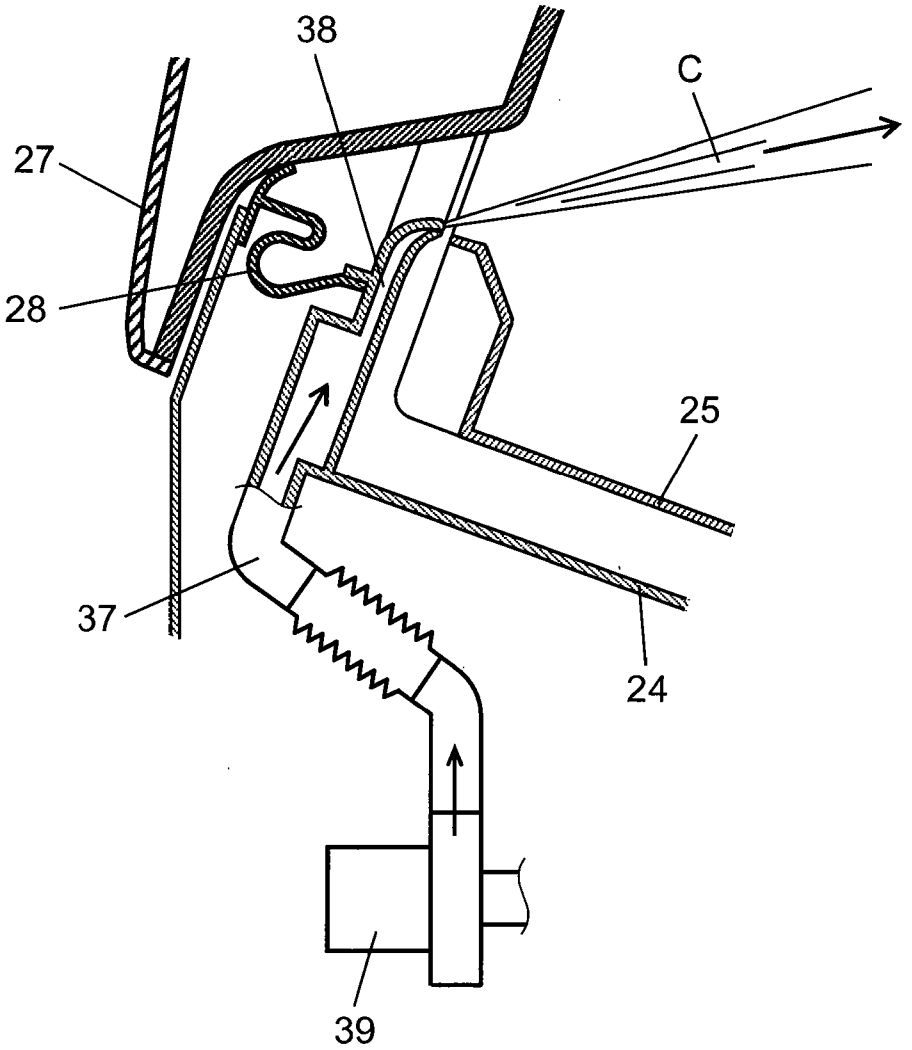

FIG. 4

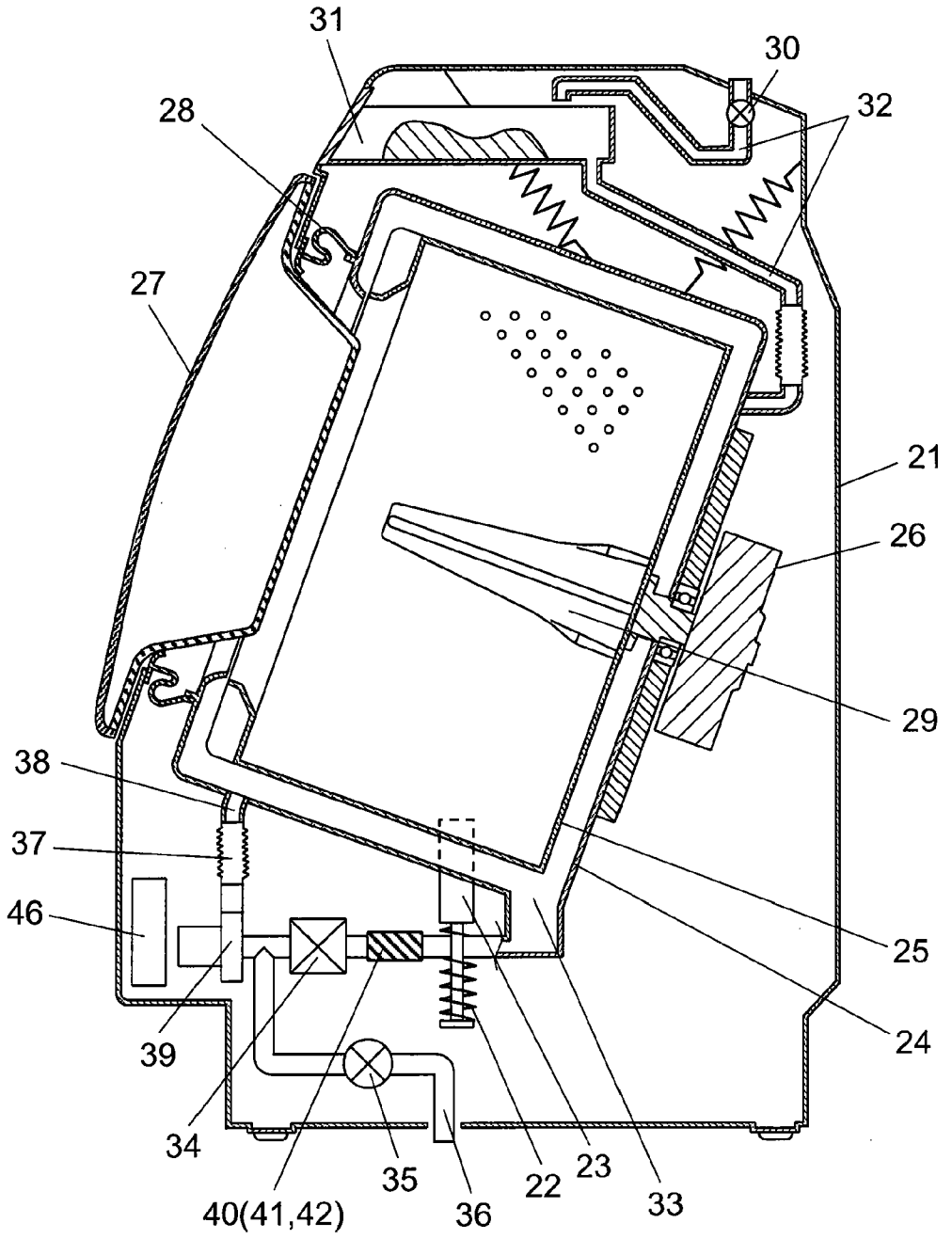

FIG. 5

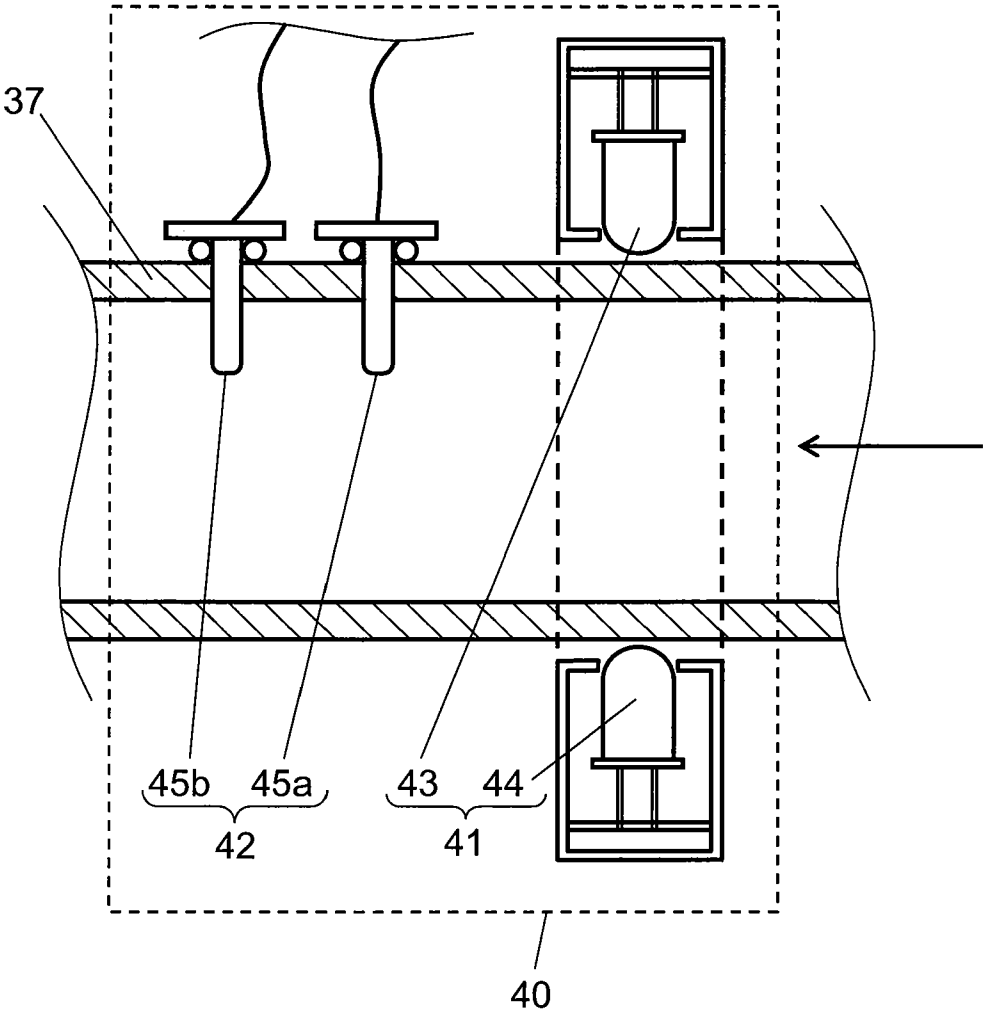

FIG. 6

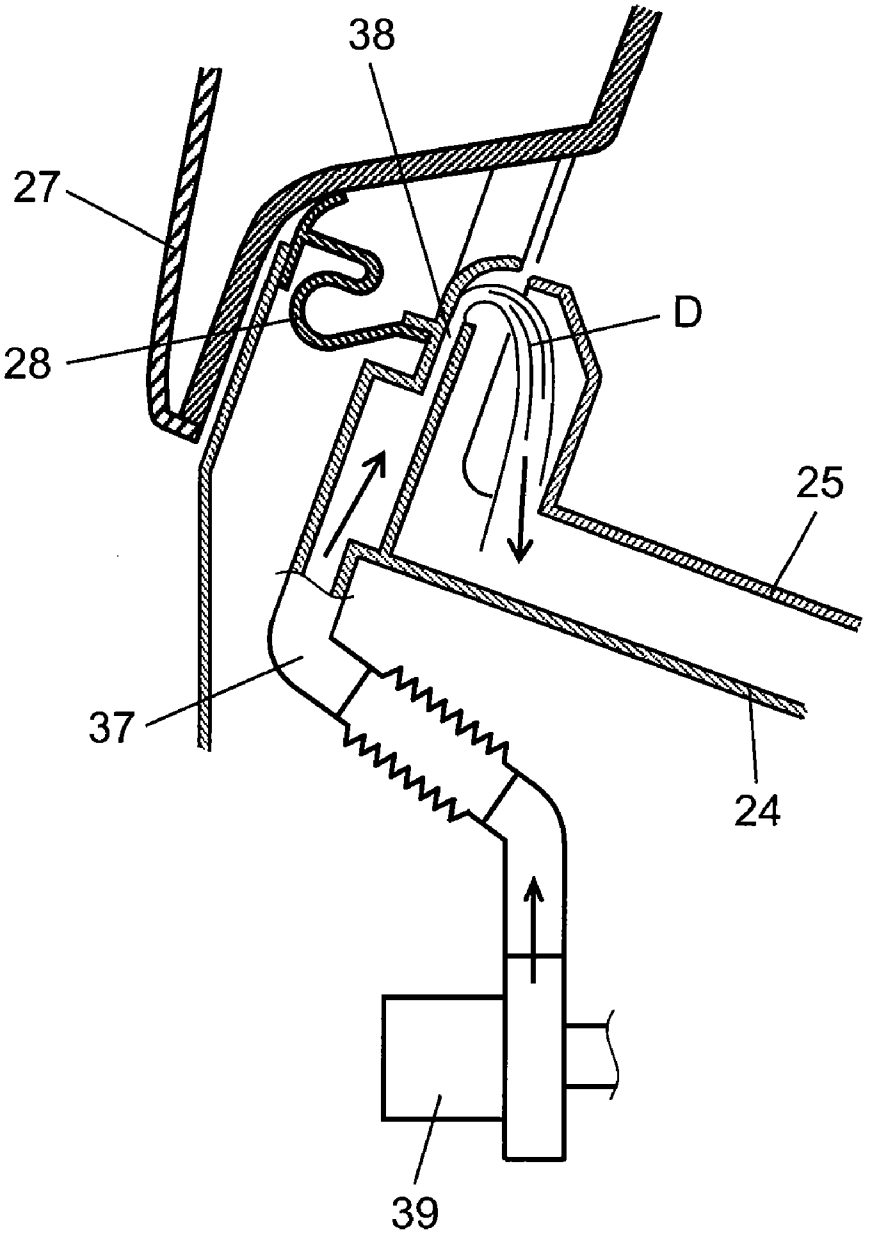

FIG. 7

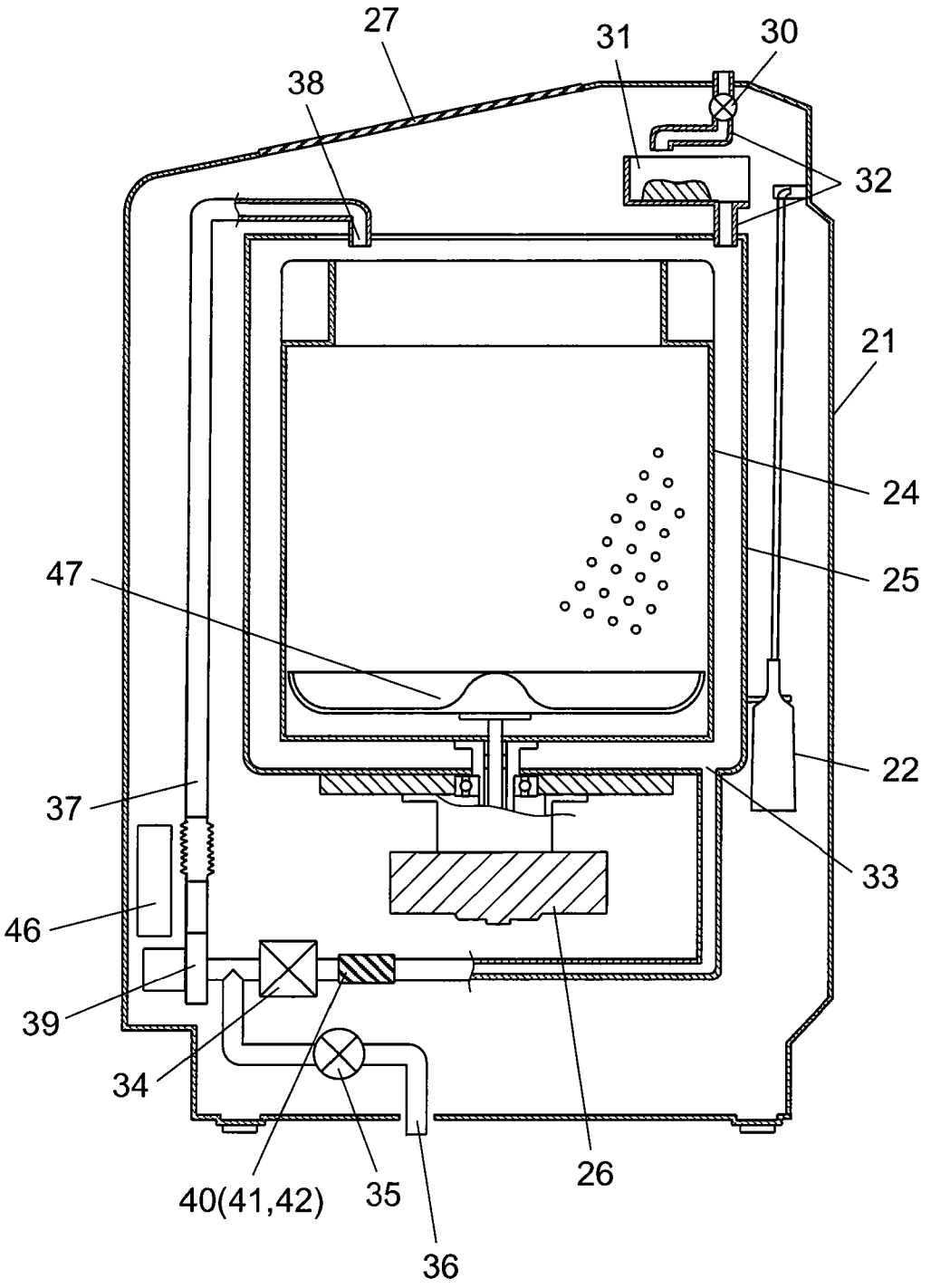

FIG. 8

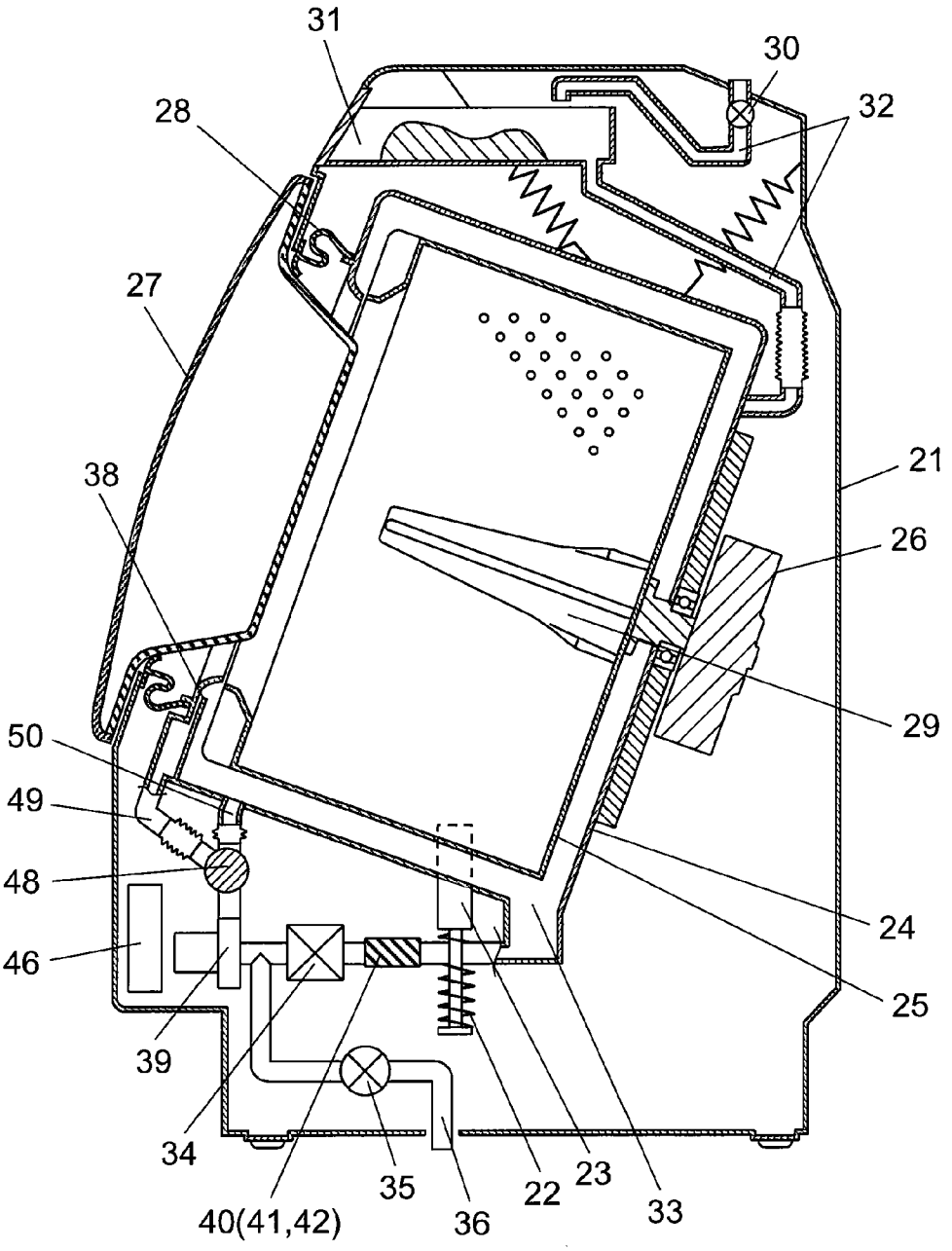
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FIG. 9

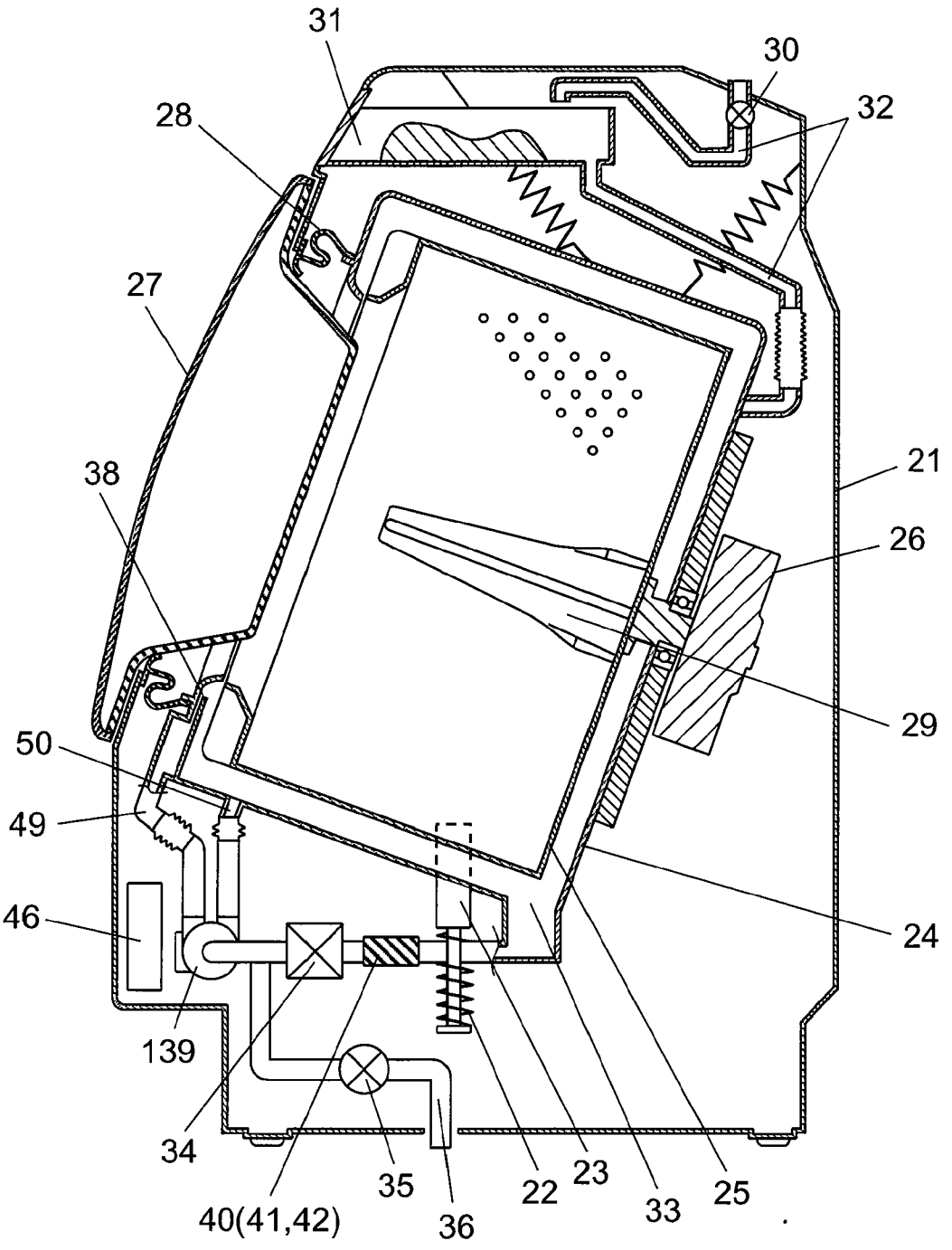
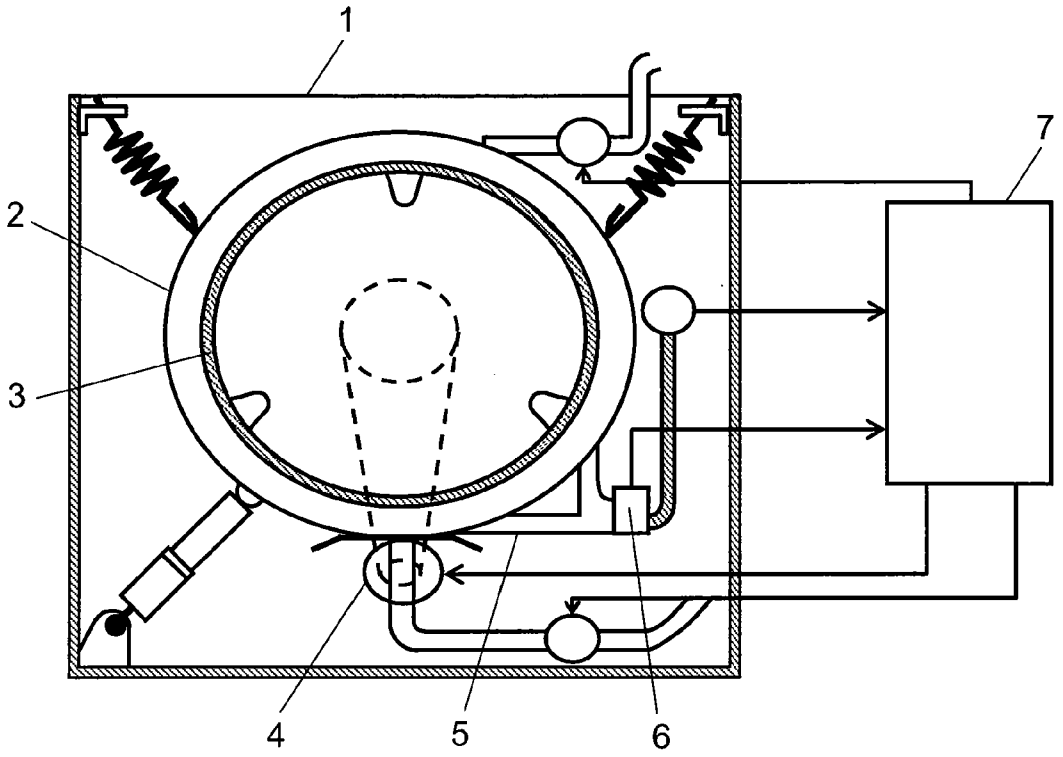


FIG. 10 Prior Art



WASHING MACHINE

TECHNICAL FIELD

[0001] The present invention relates to a washing machine which controls its operation according to the condition of washing water.

BACKGROUND ART

[0002] A conventional washing machine of this type is disclosed in Japanese Patent Unexamined Publication No. H4-240485 (Patent Literature 1). FIG. **10** is a sectional view of the washing machine disclosed in Patent Literature 1. The machine includes cabinet **1**, outer tank **2**, inner tank **3**, drive motor **4**, circulation tube **5**, turbidity sensor **6**, and controller **7**. Cabinet **1** includes outer tank **2**.

[0003] Outer tank **2** includes inner tank **3**, which has a bottomed cylindrical shape. Inner tank **3** accommodates laundry such as clothes, and rotates around a horizontal axis. Drive motor **4** rotates inner tank **3**. Turbidity sensor **6**, which detects the turbidity of the washing water, is located at some midpoint in circulation tube **5**. Circulation tube **5**, which allows the washing water to circulate, is located outside outer tank **2**.

[0004] The rotation of inner tank **3** allows the washing water to circulate through circulation tube **5**, thereby preventing detergent and stains from accumulating at the bottom of outer tank **2**. The rotation of inner tank **3** also makes the concentration of the washing water uniform between outer tank **2** and circulation tube **5**. As a result, turbidity sensor **6** can detect the degree of contamination of the uniformly concentrated washing water from the degree of its turbidity. Controller **7** determines the degree of contamination of the laundry based on the detected degree of contamination of the washing water. When the laundry is not heavily dirty, controller **7** selects a short wash time to optimize its length.

[0005] As described above, in the conventional washing machine, the rotation of inner tank **3** allows washing water to circulate through circulation tube **5**. It is therefore necessary to rotate inner tank **3** at high speed enough to circulate the washing water. Inner tank **3** also functions as an agitating portion for agitating laundry. The laundry is washed by being raised and dropped repeatedly by the rotation of inner tank **3**. This washing method is referred to as beat wash. Inner tank **3** has an optimum speed of rotation for beat wash. When inner tank **3** rotates at a higher speed than the optimum speed, the laundry is stuck to the rotating inner surface of inner tank **3**. In this situation, beat wash is impossible to be performed, thereby reducing the washing efficiency of the washing machine. In the conventional washing machine, inner tank **3** is rotated at the optimum speed for beat wash so as to maintain the washing efficiency. It is therefore impossible, at the optimum speed of rotation, to circulate a sufficient amount of washing water through circulation tube **5**. As a result, it takes time to make the concentration of the washing water uniform between outer tank **2** and circulation tube **5**. This causes turbidity sensor **6** to have low detection accuracy.

SUMMARY OF THE INVENTION

[0006] The present invention provides a washing machine, which can detect the degree of contamination of washing water with high accuracy while maintaining its washing efficiency.

[0007] The washing machine of the present invention includes a cabinet, an outer tank held in the cabinet, an inner tank rotatably mounted in the outer tank so as to accommodate the laundry, and an agitating portion for agitating the laundry. The washing machine further includes a circulation tube, a circulation pump, and a controller. The circulation tube draws washing water kept in the outer tank and returns it to the outer tank. The circulation pump is located at some midpoint in the circulation tube so as to circulate the washing water. The controller controls the operation of the agitating portion and the circulation pump. The washing machine further includes, at some midpoint in the circulation tube, a washing water-condition detector for detecting the condition of the washing water.

[0008] This structure ensures the amount of washing water circulating through the washing water-condition detector, without depending on the operation of the agitating portion. Thus, the washing machine can detect the degree of contamination of the washing water with high accuracy while maintaining its washing efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a sectional view of an example of a washing machine according to a first exemplary embodiment of the present invention.

[0010] FIG. **2** is a sectional view of an example of a discharge port of the washing machine according to the first exemplary embodiment.

[0011] FIG. **3** is a sectional view of another example of the discharge port of the washing machine according to the first exemplary embodiment.

[0012] FIG. **4** is a sectional view of another example of the washing machine according to the first exemplary embodiment.

[0013] FIG. **5** is a sectional view of a washing water-condition detector of the washing machine according to the first exemplary embodiment.

[0014] FIG. **6** is a sectional view showing another operation of the discharge port according to the washing machine according to the first exemplary embodiment.

[0015] FIG. **7** is a sectional view of another example of the washing machine according to the first exemplary embodiment.

[0016] FIG. **8** is a sectional view of another example of the washing machine according to the first exemplary embodiment.

[0017] FIG. **9** is a sectional view of another example of the washing machine according to the first exemplary embodiment.

[0018] FIG. **10** is a sectional view of a conventional washing machine.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Exemplary Embodiment

[0019] FIG. **1** is a sectional view of an example of a washing machine according to a first exemplary embodiment of the present invention. Cabinet **21** includes outer tank **24** supported by spring **22**, attenuator **23**, and other members. Outer tank **24** includes inner tank **25** rotatably mounted therein. Drive motor **26**, which rotates inner tank **25**, is located on the rear surface of outer tank **24** (the right side in FIG. **1**). This washing machine is a drum type washing machine where the

axis of rotation of inner tank **25** is either horizontal or inclined upwardly toward the front (the left side in FIG. **1**). Cabinet **21** further includes door **27** to open and close front opening **24***a* of outer tank **24**. Cabinet **21** and door **27** are sealed with water-seal packing **28**. Inner tank **25** has a cylindrical inner surface, which is provided with a plurality of projections **29**. Projections **29** raise the laundry when inner tank **25** is rotated at low speed.

[0020] Cabinet **21** further includes, at its top, feed valve **30** and detergent inlet **31**. Fed valve **30** has feed-water inlet **30***a*, which is connected to one end of a feed-water hose (not shown). Detergent inlet **31** keeps detergent put by the user before washing. Cabinet **21** further includes feed-water tube **32** and drainage tube **36**. Feed-water tube **32** connects feed valve **30** and detergent inlet **31**, and also connects detergent inlet **31** and outer tank **24**. The other end of the feed-water hose is connected to the water service pipe.

[0021] Outer tank **24** has water intake opening **33** at its lowermost part. Water intake opening **33** is connected to drainage tube **36** via drain filter **34** and drain valve **35**. Drainage tube **36** allows washing water to be discharged to the outside of washing machine. The washing machine further includes circulation tube **37**, which is divided into two parts: one leads to water intake opening **33** and the other leads to drain valve **35**. Circulation tube **37** returns the washing water exhausted from water intake opening **33** to outer tank **24**. Circulation tube **37** has discharge port **38**, which is communicated with outer tank **24**. Discharge port **38** allows the washing water to be injected into inner tank **25**. The tubes extending between water intake opening **33** and discharge port **38** are referred to as circulation tube **37**. The washing machine further includes, at two positions in circulation tube **37**, circulation pump **39** and washing water-condition detector **40**. Circulation pump **39** circulates washing water through circulation tube **37**. Washing water-condition detector **40** detects the condition of the washing water. As described above, circulation tube **37** is divided into two parts: one leads to water intake opening **33** and the other leads to drain valve **35**. Alternatively, circulation tube **37** may be communicated with a water intake opening (not shown) of drainage tube **36** different from water intake opening **33**.

[0022] FIG. **2** is a sectional view of an example of discharge port **38** of circulation tube **37** of the washing machine according to the present exemplary embodiment. Discharge port **38** located between outer and inner tanks **24** and **25** allows washing water to be injected into inner tank **25** through between outer and inner tanks **24** and **25** as shown in "B" in FIG. **2**. Discharge port **38** may alternatively be located at an exposed portion of outer tank **24** as shown in the sectional view of FIG. **3** so that washing water can be injected into inner tank **25** as shown in "C" in FIG. **3**. Discharge port **38** may alternatively be located between outer and inner tank **24** and **25** as shown in the sectional view of FIG. **4**. In this case, the washing water is injected not into inner tank **25**, but between outer and inner tank **24** and **25**.

[0023] FIG. **5** is a sectional view of washing water-condition detector **40**. Detector **40** is composed of optical sensor **41** and electrode sensor **42**. Optical sensor **41** detects the turbidity of washing water, and electrode sensor **42** detects the electrical conductivity of the washing water. Optical sensor **41** is composed of light-emitting element **43** and light-receiving element **44**. Light-emitting element **43** can be, e.g., an LED, and light-receiving element **44** can be, e.g., a phototransistor. Light-emitting element **43** and light-receiving element **44** are located substantially horizontally and with circulation tube **37** therebetween. Electrode sensor **42** is composed of a pair of electrodes **45***a* and **45***b* on one side of the side wall of circulation tube **37**.

[0024] The washing machine further includes c **46**, which controls the operations of drive motor **26**, feed valve **30**, drain valve **35**, circulation pump **39**, and other components. Controller **46** further receives the output of washing water-condition detector **40**, and performs calculation to detect the degree of contamination of washing water.

[0025] The following is a description of the operation of the washing machine of the present exemplary embodiment. The user opens door **27**, loads laundry such as clothes into inner tank **25**, and closes door **27**. The user then presses the start button to start the operation of the washing machine. When the operation is started, controller **46** drives drive motor **26** to estimate the weight of the clothes from the load of drive motor **26**. Controller **46** displays a necessary amount of detergent on a display unit (not shown) according to the estimated amount of clothes. The user then pulls out detergent inlet **31**, pours the displayed amount of detergent, and pushes back detergent inlet **31**.

[0026] When a predetermined time has passed, controller **46** opens feed valve **30** to feed water from the water service pipe (not shown). The water is supplied into outer tank **24** through feed-water tube **32**. After passing through detergent inlet **31** containing detergent, the water is supplied to outer tank **24** as detergent-containing washing water.

[0027] Controller **46** drives drive motor **26** to rotate inner tank **25** as soon as the water starts to be fed. When the washing water (water) reaches a predetermined amount, feed valve **30** is closed. Inner tank **25**, on the other hand, continues to be rotated. Along with the rotation of inner tank **25**, the clothes are repeatedly raised to the top of inner tank **25** by three projections **29** on the inner surface of inner tank **25** and are dropped off the inner surface. This beat wash accelerates the cleaning of the laundry. The beat wash has an optimum speed of rotation: too high or too low a speed will reduce the washing efficiency.

[0028] When the clothes are washed for a predetermined time, controller **46** opens drain valve **35**. The washing water is discharged from drainage tube **36** to the outside of the washing machine. Next, controller **46** performs a spin-drying step by rotating inner tank **25** at high speed to remove water from the laundry. Controller **46** then stops inner tank **25**, opens feed valve **30** to feed water to a predetermined feed-water level, and performs a spin-drying step by rotating inner tank **25** again. After performing the spin-drying step and the spin-drying step about two times, controller **46** performs another spin-drying step. As a result, the washing process is completed.

[0029] The following is a description of the operation of washing water-condition detector **40**. Optical sensor **41** detects the turbidity of the washing water. The portion of circulation tube **37** that is sandwiched between light-emitting element **43** and light-receiving element **44** is made of a resin having light transmission properties. This allows light-receiving element **44** to receive the light that has been emitted from light-emitting element **43** and then passed through the washing water in circulation tube **37**. Light-receiving element **44** outputs a signal according to the strength of the received light. Controller **46**, which is composed, e.g., of a microcomputer, receives the signal, converts it into a voltage, and outputs the voltage. Light which passes through the washing water

attenuates according to the degree of turbidity of the washing water. When, for example, light-receiving element **44** receives a small amount of light, this means that the degree of turbidity of the washing water is high. In other words, the washing water is contaminated. When, on the other hand, light-receiving element **44** receives a large amount of light, this means that the degree of turbidity of the washing water is low. Thus, the degree of turbidity of the washing water is quantitatively detected from the amount of light received by light-receiving element **44**. The stains in the laundry dissolve in the washing water and make the washing water turbid. Therefore, when the degree of turbidity of washing water is high, the laundry is estimated to contain a large amount of stains.

[0030] Electrode sensor **42** measures the electrical conductivity of washing water. This measurement can be performed for example as follows. An RC oscillation circuit is composed of the impedance of the washing water between electrodes **45***a* and **45***b*, and a capacitor of a control circuit (not shown). Controller **46** outputs a change in the impedance of the washing water as a change in the frequency, and then converts the change in the frequency into a voltage value. When the laundry contains a large amount of sweat and other stains, the electrolyte composition of the sweat and other stains dissolve in the washing water. As a result, the washing water has a high electrical conductivity. For this reason, the amount of sweat and other stains in the laundry can be estimated by quantitatively detecting the electrical conductivity of the washing water.

[0031] As described above, the degree of contamination of laundry such as clothes is estimated by optical sensor **41** and electrode sensor **42**. More specifically, the degree of contamination is estimated by detecting the change with time of the outputs of optical sensor **41** and electrode sensor **42**, and then calculating the difference between the outputs in a certain period. The degree of contamination can alternatively be estimated by combining the outputs of optical sensor **41** and electrode sensor **42**. The estimated degree of contamination of the laundry is used to control the washing step and the spin-drying step. When the laundry is not heavily dirty, the washing step is shortened, or a smaller amount of water is used in the washing step and the spin-drying step. This can save water, electric power, and operating time.

[0032] The degree of turbidity of the washing water may also be changed by the detergent contained in the washing water. The electrical conductivity of the washing water may be increased by a component of the detergent in the washing water. Therefore, washing water-condition detector **40** can detect the type and the amount of the detergent, for example, immediately after water is supplied into outer tank **24**. Thus, washing water-condition detector **40** can detect not only the degree of contamination of washing water. Detector **40** can also detect the type and the amount of the detergent in the washing water based on the degree of turbidity and the electrical conductivity of the washing water.

[0033] To increase the correlation between the detection result of washing water-condition detector **40** and the amount of stains on the clothes, it is necessary to have a unique determination algorithm. The algorithm can be, for example, the absolute value, the change rate, or other factors of a detection value. In the present exemplary embodiment, washing water-condition detector **40** is located in circulation tube **37**. This prevents optical sensor **41** and electrode sensor **42** from being smeared with stains or affected by the agitating of the washing water. Therefore, any determination algorithm other than the above-described ones can contribute to an improvement in the detection accuracy. For example, the degree of contamination of washing water can be used as the degree of contamination of laundry. In this case, the operating time and the amount of water to be supplied in the wash and spin-drying steps are controlled based on the degree of contamination of the washing water.

[0034] Washing water-condition detector **40** is composed of optical sensor **41** and electrode sensor **42** in the above-described washing machine. Detector **40** can alternatively be composed of either one of sensors **41** and **42** to detect the degree of contamination of washing water. The turbidity and the electrical conductivity of washing water can alternatively be measured by a sensor other than sensors **41** and **42**.

[0035] Light-receiving element **44** of optical sensor **41** is preferably shielded from external light. If, however, optical sensor **41** is an infrared sensor, it is unnecessary to shield light-receiving element **44**, thereby simplifying the structure.

[0036] The washing water circulating through circulation tube **37** contains bubbles and sand particles. Bubbles, which are lighter than water, gather at the top of circulation tube **37**. Sand particles, which are heavier than water, gather at the bottom of circulation tube **37**. For this reason, the detection accuracy can be improved by locating light-emitting element **43** and light-receiving element **44** substantially horizontally on both sides around the center of circulation tube **37**. Alternatively, however, the degree of turbidity of washing water can be detected by locating elements **43** and **44** vertically, diagonally, or horizontally on one side of circulation tube **37**.

[0037] Similarly, electrodes **45***a* and **45***b* of electrode sensor **42** can be located around the perpendicular center of circulation tube **37**. In this case, electrodes **45***a* and **45***b* are not severely affected by bubbles and can detect the electrical conductivity with high accuracy. Alternatively, the electrical conductivity of the washing water can be detected by locating electrodes **45***a* and **45***b* either vertically or diagonally on both sides of circulation tube **37**.

[0038] When circulation pump **39** is driven, the washing water kept in outer tank **24** is drawn into water intake opening **33**, passes through washing water-condition detector **40** and drain filter **34**, and is injected through discharge port **38** into inner tank **25**. The washing water removes stains from the laundry, and then is again drawn into water intake opening **33**. The washing water kept in outer tank **24** is circulated in this manner to make the concentration of contamination of the washing water more uniform. In other words, the degree of contamination of the washing water detected by washing water-condition detector **40** becomes substantially the same as that of the washing water in outer tank **24**. Thus, the provision of washing water-condition detector **40** in circulation tube **37** allows the quick and accurate detection of the degree of contamination of the washing water. In short, the degree of contamination can be detected in the early stages of washing. Furthermore, injecting the circulated washing water onto clothes allows the clothes to be dampened immediately after the washing step is started. The mechanical force of the washing water injecting onto the clothes further improves the washing efficiency.

[0039] With the above-described structure, the washing water is forcibly circulated by circulation pump **39** regardless of the rotation of inner tank **25**, which is the agitating portion for agitating clothes. Therefore, the washing water can be well circulated even when inner tank **25** is rotated at low

speed. In addition, it is possible to set arbitrary conditions that are not affected by the operation of the agitating portion, such as the amount and timing of circulation of the washing water. This can improve the accuracy of detecting the degree of contamination of the washing water, without affecting the washing effect. It is also possible to circulate a larger amount of washing water to prevent washing water-condition detector **40** from being smeared with stains.

[0040] Circulation pump **39** is also driven in a spin-drying step to circulate less-stained washing water through washing water-condition detector **40**. The less-stained washing water removes the detergent and stains from washing water-condition detector **40** deposited in the washing step. Thus, washing water-condition detector **40** is prevented from deterioration in the performance.

[0041] Circulation tube **37** has only one discharge port **38** below outer tank **24** in the above description. Alternatively, two or more discharge ports **38** may be provided by dividing circulation tube **37**. In this case, the washing water can be injected into inner tank **25** at the same time through these discharge ports **38**. Alternatively, washing water may be injected through one of these discharge ports **38** that is formed between outer and inner tanks **24** and **25**.

[0042] Circulation pump **39** is intermittently operated in the wash and rinsing steps. When circulation pump **39** is in operation, bubbles and stain particles are circulated together with the washing water. Therefore, the degree of contamination is high, causing large variations in the detection value. To provide stable and accurate detection, washing water-condition detector **40** detects the condition of the washing water while circulation pump **39** is in the stopped state. This improves the accuracy of estimating the degree of contamination. The detection value is not stabilized immediately after circulation pump **39** is stopped due to the influence of bubbles and other causes. Therefore, the detection is performed when a predetermined time has passed after having stopped circulation pump **39**. Alternatively, it is possible to use, as the detection value, a value obtained when the variation width of the detected turbidity becomes equal to or lower than a predetermined value, thereby providing high detection accuracy. Alternatively, a plurality of detection values may be averaged to remove errors, thereby further improving the detection accuracy. Alternatively, washing water-condition detector **40** may perform measurement at, for example, one second intervals, and may use only necessary information.

[0043] Similar to optical sensor **41**, electrode sensor **42** can perform calculation while circulation pump **39** is in the stopped state, thereby providing high detection accuracy. The detection of turbidity by optical sensor **41** and the detection of electrical conductivity by electrode sensor **42** may be performed either at the same time, or separately according to their characteristics. When the accuracy is sufficient, the degree of contamination of washing water may be detected while circulation pump **39** is in operation to estimate the degree of contamination of the laundry.

[0044] As described above, the circulation of the washing water through circulation tube **37** is performed not by rotating inner tank **25** as the agitating portion, but by driving circulation pump **39**. This allows the circulation of the washing water to be stopped without stopping the operation of the agitating portion. As a result, high detection accuracy can be obtained while maintaining the washing effect. The speed of rotation of circulation pump **39** can be changed with the progress of a wash or rinsing step so as to achieve high detection accuracy while considering the penetration of the washing water into the clothes or the degree of bubbling.

[0045] The rotation of inner tank **25** as the agitating portion, which stirs the washing water in outer tank **24**, can affect the detection of washing water-condition detector **40**, possibly causing detector errors. The detection errors, however, can be reduced by synchronizing the operations of circulation pump **39** and drive motor **26** (the rotation of inner tank **25**). In this case, controller **46** synchronizes the driving and stopping of circulation pump **39**, and the driving and stopping drive motor **26**. Drive motor **26** is driven in the forward direction (hereinafter, normal rotation) and the backward direction (hereinafter, reverse rotation). As a result, washing water-condition detector **40** performs detection under certain conditions. For example, controller **46** alternately repeats driving circulation pump **39** for one minute and then stopping it for one minute. The two minutes is referred to as one step. Controller **46** normally rotates drive motor **26** for 30 seconds, and then reversely rotates for 30 seconds. Controller **46** performs this operation twice in one step, thereby synchronizing the operations of circulation pump **39** and drive motor **26**. The above-described way of taking synchronization is one example; the drive time and the stop time are not necessarily equal, or the normal rotation time and the reverse rotation time are not necessarily equal. The speed of rotation of circulation pump **39** may be changed along the way. The way of taking synchronization may be changed during washing step.

[0046] Assume that controller **46** stops the rotation of inner tank **25** by stopping drive motor **26** when a predetermined time has passed after having stopped circulation pump **39**. In this case, both circulation pump **39** and drive motor **26** go into a stopped state. Washing water-condition detector **40** performs detections at or around this moment so as to reduce measurement errors. The effect can be obtained by stopping drive motor **26** only for a short while between normal rotation and reverse rotation.

[0047] Discharge port **38** of circulation tube **37** is provided such that washing water is injected into inner tank **25** from between outer and inner tanks **24** and **25** as shown in FIG. **2**. As a result, the circulating washing water hits the laundry such as clothes to dampen it quickly, thereby improving the washing efficiency of the washing machine.

[0048] When circulation pump **39** is rotated at or above a predetermined speed, the washing water is injected into inner tank **25** and is circulated through outer and inner tanks **24** and **25** as shown in "B" in FIG. **2**. When, on the other hand, circulation pump **39** is rotated at a speed lower than the predetermined speed, the washing water is circulated through outer tank **24** as shown in "D" in FIG. **6**. Thus, controlling the speed of rotation of circulation pump **39** allows switching between the following two conditions according to the need. In one of the conditions, the washing water does not directly go into inner tank **25**. In the other condition, the washing water is injected into both inside and outside inner tank **25**. The following is a description of improving the accuracy of detection of washing water-condition detector **40**.

[0049] As soon as the washing machine is started, feed valve **30** is opened to feed water, and the detergent in detergent inlet **31** is fed into outer tank **24** together with the water. If circulation pump **39** is rotated at or above the predetermined speed at the feed water step, washing water with a high detergent concentration is injected from discharge port **38** into inner tank **25**. If the washing water with the high detergent concentration is absorbed in the clothes, the washing

water in outer tank **24** has a low detergent concentration. The washing water immediately after water feed is started contains detergent only. Washing water-condition detector **40** can detect the washing water in this condition to determine whether the detergent is powder or liquid. The detection result can be used as the initial value of the washing water before starting a washing step. If, however, a large amount of the washing water in this condition is injected into inner tank **25**, it is impossible to determine the type of the detergent or to use the detection result as the initial value of the washing water. For this reason, while water is being fed immediately after a washing step is started, circulation pump **39** is rotated at a speed lower than the predetermined speed. By doing so, the washing water is not injected into inner tank **25** through discharge port **38**, but is dropped to the bottom of outer tank **24**. This allows the determination of the type of the detergent, and improves the accuracy of detecting the initial condition of the washing water before starting a washing step. Assume that the circulation of the washing water by circulation pump **39** is stopped to prevent the washing water from being injected against the clothes. In this case, the washing water kept in washing water-condition detector **40** and the washing water kept in outer tank **24** are not made uniform, thereby providing low detection accuracy. To avoid this happening, as described above, the washing water is dropped from discharge port **38** to the bottom of outer tank **24** and is circulated within outer tank **24** to accelerate the dissolution of the detergent. This makes the concentration of the washing water uniform. Later, in the middle of the washing step, the washing water can be injected against the laundry to improve the washing effect and to accelerate the dissolution of stains on the laundry into the washing water. As a result, the amount of stains can be estimated in the early stages. Thus, controlling the speed of rotation of circulation pump **39** provides a highly accurate determination of contamination using single circulation pump **39** and circulation tube **37**.

[0050] When the washing water is circulated only within outer tank **24**, it is preferable that no washing water is injected into inner tank **25**. In this case, it does not matter even if the washing water splashes or runs down along the outer wall surface of inner tank **25** and gets into inner tank **25** through the holes or gaps of inner tank **25**. The detection accuracy can be improved at least by reducing the amount of washing water to be injected into inner tank **25**. In other words, the detection accuracy can be improved at least by preventing the washing water from entering inner tank **25** and by circulating the washing water within outer tank **24**. Thus, the detection accuracy can be improved not only when the washing water is not at all injected into inner tank **25**. The detection accuracy can also be improved, even if part of the washing water is injected into inner tank **25**, by injecting other part of the washing water between outer and inner tanks **24** and **25** so as to be circulated within outer tank **24**.

[0051] It is not just immediately after water feed is started that the effect is achieved when the washing water is not injected into inner tank **25** or when the washing water is injected into both inside and outside inner tank **25**. For example, when a washing step is started and the detergent creates a lot of bubbles, the bubbles can be increased by injecting the washing water into inner tank **25**. The bubbling, on the other hand, can be suppressed by stopping the washing water from being injected into inner tank **25**. This prevents a decrease in the detection accuracy due to the bubbles. As described above, controlling the speed of rotation of circulation pump **39** can switch the injection of the washing water without installing additional components.

[0052] The water fed through feed-water tube **32** is supplied between outer and inner tanks **24** and **25**. Washing water-condition detector **40** is located lower than the lowermost portion in inner tank **25** as shown in "A" in FIG. **1**. Therefore, the fed water reaches washing water-condition detector **40** before entering inner tank **25**.

[0053] In a rinsing step, the water fed through feed-water tube **32** reaches washing water-condition detector **40** without coming into contact with the laundry such as clothes containing stains and detergent. Washing water-condition detector **40** detects water not containing stains or detergent, and therefore, it is possible to detect aging of detector **4** from the stains deposited thereon. The detection result can be used to correct measurement results, thereby maintaining the detection accuracy according to aging.

[0054] When water is fed in a washing step, the water fed through feed-water tube **32** does not enter inner tank **25**, but reaches washing water-condition detector **40** as washing water containing the detergent put in detergent inlet **31**. This prevents the detergent from being stuck or adhered to clothes. As a result, the washing water that has reached washing water-condition detector **40** does not contain the stains from the clothes, but contains only the detergent dissolved therein. Detecting this condition can improve the accuracy of determining whether the detergent is powder or liquid. This improves the accuracy of the initial value of the washing water in a washing step, thereby improving the accuracy of detecting the degree of contamination of the washing water. This result can be used to achieve efficient washing when the laundry is not heavily dirty. For example, the user can select a short wash time or reduce the amount of water to be fed.

[0055] As more and more water is fed, more and more washing water containing the detergent enters inner tank **25**. Feed-water tube **32** allows the washing water to be fed into between outer and inner tanks **24** and **25**. This causes a smaller amount of detergent to be stuck or adhered to the clothes than in the case of feeding water directly into inner tank **25**. In addition, even after water is fed into inner tank **25**, the accuracy of the initial value of the washing water is high in a washing step.

[0056] Driving circulation pump **39** can accelerate the dissolution of the detergent and the dampening of the clothes with the washing water. The detergent-containing washing water reaches washing water-condition detector **40** before circulation pump **39** is driven. As a result, the initial condition of the washing water can be detected with high accuracy before the detergent creates bubbles.

[0057] It would be preferable to start to rotate inner tank **25** as the agitating portion in the early stages to improve the washing efficiency of the washing machine. Starting to rotate inner tank **25** in the early stages, however, would cause the washing water to create bubbles, which may deteriorate the detection accuracy of washing water-condition detector **40**. To avoid this, the detergent-containing washing water is made to reach washing water-condition detector **40** before starting to rotate inner tank **25**. As a result, the initial condition of the washing water can be detected with high accuracy before the washing water creates bubbles.

[0058] The rotation of inner tank **25** as the agitating portion, on the other hand, stirs the washing water kept in outer tank **24**, making the washing water create bubbles. Washing water-condition detector **40**, however, is located at some midpoint in

circulation tube **37** that is away from water intake opening **33**, thereby being prevented from facing inner tank **25**. This prevents the rotation of inner tank **25** from affecting the detection of washing water-condition detector **40**. Instead of being in some midpoint diagonal to inner tank **25** as shown in FIG. **1**, washing water-condition detector **40** can be prevented from facing inner tank **25** by providing a partition wall between inner tank **25** and washing water-condition detector **40**.

[0059] In the above-described drum type washing machine, inner tank **25** has a substantially horizontal axis of rotation. A similar effect can be obtained in a different type of washing machine (pulsator washing machine) as shown in the sectional view of FIG. **7**. In FIG. **7**, like components are labeled with like reference numerals with respect to FIGS. **1** to **6**. In the washing machine in FIG. **7**, inner tank **25** has a vertical axis of rotation. Inner tank **25** has agitator **47** as an agitating portion at its bottom surface. Feed-water tube **32** allows water to be fed between outer and inner tanks **24** and **25**. In the case where water is fed through feed-water tube **32** directly into inner tank **25**, circulation pump **39** can circulate washing water through circulation tube **37**, and washing water-condition detector **40** can detect the condition of the washing water. Note that washer-dryers provide the same effect during washing as this washing machine.

[0060] FIG. **8** is a sectional view of another example of the washing machine according to the first exemplary embodiment. This washing machine differs from the above-described washing machine in that circulation tube **37** includes switching valve **48**, and that circulation tube **37** is divided into inner tank circulation tube **49** and outer tank circulation tube **50**. In the washing machine of FIG. **8**, switching valve **48** switches between tubes **49** and **50**. Immediately after water feed is started, outer tank circulation tube **50** is selected to prevent the washing water form directly entering inner tank **25**. In this case, it is possible to accurately detect the initial condition of the washing water which contains only detergent dissolved therein. Furthermore, it is unnecessary to reduce the amount of the circulating washing water by reducing the speed of rotation of circulation pump **39**. Thus, the washing efficiency improves with increasing speed of dissolving the detergent into the washing water. This balances the detection accuracy of washing water-condition detector **40** with the washing efficiency of the washing machine.

[0061] The washing machine shown in FIG. **8** includes switching valve **48**. Another example of the washing machine shown in the sectional view of FIG. **9** includes circulation pump **139**. Circulation pump **139** switches between output tubes depending on whether it is in the normal rotation or the reverse rotation. Circulation pump **139** switches between tubes **49** and **50** to feed the washing water through it, thereby providing the same effect as using switching valve **48**.

INDUSTRIAL APPLICABILITY

[0062] As described hereinbefore, the washing machine of the present invention detects the degree of contamination of washing water with high accuracy, thereby performing control according to the degree of contamination. This washing machine can be applied to other types of washing machines to wash something other than clothes.

REFERENCE MARKS IN THE DRAWINGS

[0063] **21** Cabinet
[0064] **24** Outer tank
[0065] **25** Inner tank
[0066] **27** Door
[0067] **30** Fed valve
[0068] **30***a* Feed-water inlet
[0069] **31** Detergent inlet
[0070] **32** Feed-water tube
[0071] **33** Opening
[0072] **34** Drain filter
[0073] **35** Drain valve
[0074] **36** Drainage tube
[0075] **37** Circulation tube
[0076] **39** Circulation pump
[0077] **40** Washing water-condition detector
[0078] **41** Optical sensor
[0079] **42** Electrode sensor
[0080] **43** Light-emitting element
[0081] **44** Light-receiving element
[0082] **45***a*,**45***b* Electrodes
[0083] **46** Controller
[0084] **47** Agitator
[0085] **48** Switching valve
[0086] **49** Inner tank circulation tube
[0087] **50** Outer tank circulation tube

1. A washing machine comprising;
a cabinet;
an outer tank held in the cabinet;
an inner tank rotatably mounted in the outer tank, the inner tank accommodating laundry;
an agitating portion for agitating the laundry;
a circulation tube for drawing washing water kept in the outer tank and returning the washing water to the inside of the outer tank;
a circulation pump located at some midpoint in the circulation tube, the circulation pump circulating the washing water; and
a controller for controlling operations of the agitating portion and the circulation pump, wherein
the washing machine further includes, at some midpoint in the circulation tube, a washing water-condition detector for detecting a condition of the washing water.

2. The washing machine of claim **1**, wherein
the controller operates the circulation pump intermittently during a washing step; and
the washing water-condition detector detects a condition of the washing water when the circulation pump is stopped.

3. The washing machine of claim **1**, wherein
the circulation tube allows the washing water to be injected into the inner tank.

4. The washing machine of claim **1**, wherein
the controller synchronizes operations of the agitating portion and the circulation pump.

5. The washing machine of claim **1**, wherein
the controller stops the operation of the agitating portion when a predetermined time has passed after having stopped the circulation pump.

6. The washing machine of claim **1**, wherein the controller drives the circulation pump during a rinsing step.

7. The washing machine of claim **1**, wherein
the agitating portion is the inner tank, and the laundry is stirred by rotation of the inner tank.

8. The washing machine of claim **1**, further comprising:
an agitator rotatably mounted on an inner bottom of the inner tank, wherein
the agitating portion is the agitator, and
the laundry is stirred by rotation of the agitator.

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