

Development of X-ray Inspection System for Saving Labor and Effort

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[Summary]

By using the latest detector and image processing technologies, we developed an X-ray inspection system designed to minimize labor and operational effort. A high-resolution imaging-based inspection algorithm reduces the false detection rate to one-seventh of conventional systems, helping improve yields. High-quality inspection reduces the need for re-inspection and rework, significantly lowering the operational burden on users. In addition, by increasing automatic configuration, we successfully reduced the man-hours required for inspection setup. 1-Pass Product Setup enables faster foreign-object inspection configuration in one test run, minimizing required preparation and more efficient inspection start-up.

1 Introduction

It has been 10 years since Anritsu first developed the XR75 series X-ray inspection systems currently in commercial use¹⁾. Over this period, Anritsu has developed a diverse range of systems to address a broad spectrum of inspection targets and market needs, including systems specialized for sealing checks and those designed primarily for the meat-processing industry.

The regulatory landscape surrounding the food industry has also undergone significant changes over the past decade. The partial amendment to the Food Sanitation Act, promulgated in 2018, made HACCP-based sanitation management mandatory under the Food Sanitation Act in 2021. Furthermore, the transitional period for the positive list system governing food-use utensils and container packaging expired in May 2025, reflecting the steady year-on-year advancement of regulatory frameworks aimed at ensuring food safety. As these regulatory developments illustrate, food safety is a theme of enduring importance that transcends decades, and interest in the topic has been growing in recent years.

At the same time, labor shortages have long been a serious challenge in the food manufacturing industry, and the situation has grown increasingly severe in recent years with the added pressures of rising raw material and labor costs. In this environment, manufacturers must simultaneously maintain rigorous quality control and stable production operations, placing a significant burden on the shop floor. In fact, labor productivity in the food manufacturing industry remains at approximately 60% of the manufacturing sector average, making it one of the lowest-performing industries

in the sector. A key contributing factor is the high degree of dependence on manual labor due to insufficient automation²⁾.

In response to these challenges, Anritsu has developed a system that enables highly accurate inspection with ease, regardless of the operator's skill level.

Advances in X-ray detector performance and the evolution of our proprietary image processing technology have achieved up to about 40% improvement in inspection capability for stainless steel materials, enabling the detection of previously difficult-to-detect contaminants, such as small metallic foreign objects and low-density substances like stones. Significant cost savings in complaint handling are expected by reducing foreign-object contamination complaints. The false detection rate has also been cut to one-seventh that of conventional systems, helping reduce food waste and improving yields. Furthermore, the system still delivers stable inspection quality for foreign objects that were already detectable by conventional systems.

The improved inspection performance has created greater margin for adjusting inspection parameters. Leveraging this advantage, the system is designed to maintain high inspection quality independent of operator skill level by automating the majority of these adjustments. As a result, the system achieves both reduced operational burden on the production floor and improved yields.

Specific features include 1-Pass Product Setup and detection limit configuration for reducing operator workload, as well as improved operability through an enhanced touchscreen interface. This article overviews the system.



Figure 1 External View of X-ray Inspection System

2 Principles of X-ray Inspection

An X-ray inspection system is a device that uses X-rays to non-destructively examine the internal condition of products. Anritsu X-ray inspection systems are used primarily on food and other manufacturing lines to detect foreign-object contamination and product defects in inspected items. These systems are installed inline on food production lines, enabling continuous sequential inspection without interrupting the production flow. The X-ray inspection system is configured so that products under inspection pass through the interior of the unit while X-ray-based inspection is performed.

X-rays are a part of the electromagnetic spectrum known for their high directionality and penetrating power. X-rays emitted from the source pass through the product under inspection and are detected by an X-ray detector on the opposite side. Since the amount of X-rays passing through the product depends on the product internal structure, the intensity of the detected transmitted X-rays is represented as gradations of light and dark, enabling capture of information such as the shape and internal structure of the inspected product. The amount of passing X-rays varies with the type and density of the material. As a result, areas with a foreign object show a clear difference in image contrast, appearing as shadows. The presence or absence of foreign objects is determined based on these contrast variations.

In X-ray inspection, the detector is a critical component directly involved in output of inspection images, and its

performance is directly linked to the accuracy of inspection results. An X-ray detector consists of a scintillator, a photodiode array, and a readout circuit, which detect X-rays as follows. First, X-rays incident on the detector are absorbed by the scintillator. Electrons in the scintillator are excited by the absorbed energy and transition to a higher energy state. As the electrons subsequently return to their ground state, they emit visible light corresponding to the energy difference. Visible light converted from X-rays in this manner can then be detected by the photodiode array. This visible light is then converted into electrical charge by the photodiodes and accumulated in internal capacitors. Finally, the accumulated charge is sequentially read by the readout circuit, enabling X-ray detection and outputting differences in intensity as an image.

The method of detecting X-rays by first converting them into visible light using a scintillator and subsequently converting that light into electrical charge is called the indirect conversion method. This approach is the predominant technology for X-ray detectors used in X-ray inspection systems, owing to factors such as the availability of materials. However, since this method involves two conversion stages, signal loss occurs during the process, which tends to reduce the clarity of the output image. To achieve higher sensitivity and improved stability in X-ray inspection systems, careful selection of components such as the scintillator, as well as optimized system design are critical, and these technical considerations determine the direction of system development.

3 Boosting Production Efficiency with High-Speed Image Processing

We have successfully developed an X-ray inspection system capable of performing inspections using low-noise, high-resolution images by the comprehensive redesign of the X-ray detector's scintillator, photodiode array, readout circuit, and X-ray optical system. Use of higher-definition images enables identification of minute foreign objects that were previously difficult to detect. In practice, verification of detection performance at a conveyor speed of 40 m/min for a specific food product confirmed that while the conventional model can detect stainless steel wire down to $\phi 0.6$ mm, the XR76 can detect stainless steel wire down to $\phi 0.2$ mm.

At the same time, challenges exist in achieving higher

resolution in X-ray detectors. As the pixel count increases, the volume of image data grows larger, resulting in an increased computational load for image processing. Consequently, processing time is extended, making it more difficult to complete foreign-object determination while the product is passing through the system. One approach to this challenge is to increase the system length to secure additional processing time. However, this results in a larger overall system footprint, requiring greater installation space. Furthermore, as the conveyor speed of the product under inspection increases, the volume of image data to be processed grows accordingly, imposing increasingly stringent constraints on processing time.

The conventional XR75 series intentionally reduces acquired data size to lighten the processing load when the conveyor speed exceeds 40 m/min before inspection is performed. While this approach enables inspection at high conveyor speeds without extending the machine length, it causes image compression that significantly reduces foreign-object detection accuracy compared to a lower conveyor speed.

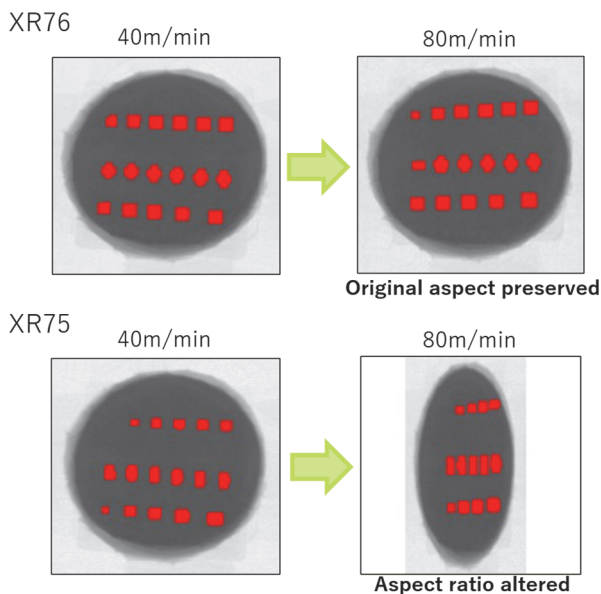


Figure 2 Image Comparison

In contrast, the XR76 achieves high-speed processing of high-pixel-count images by improvements to both the software and the foreign-object detection algorithm, as well as to the enhanced X-ray detector. This enables inspection without image compression even under high-speed inspection conditions, achieving stable foreign-object inspection using high-quality images on high-speed production lines.

Figure 2 shows test pieces placed on a ham sample and

conveyed through the X-ray inspection system. The foreign objects, from top to bottom, are stainless steel (SUS) balls, SUS wire, and ceramic balls. Using the conventional XR75 at a conveyor speed of 80 m/min, the image is compressed in the conveyor direction, and the number of detected SUS balls decreases from five to four. In contrast, the new XR76 exhibits no image compression even at a conveyor speed of 80 m/min, and detects all six SUS balls at high-speed conveying without any drop in detection accuracy. The system is capable of high-sensitivity inspection on production lines with high conveyor speeds, contributing to improved production efficiency and fewer customer complaints.

4 Cutting Labor and Saving Effort by Automation and Improved Operability

4.1 Cutting Operator Dependency at Inspection Setup

In line with recent trends toward labor reduction, the system incorporates many features designed to minimize operator dependency, enabling even users unfamiliar with X-ray inspection systems to configure foreign-object inspection settings with ease.

As shown in Figure 3, conventional inspection systems require several preparatory steps before foreign-object inspection can start, including determining the X-ray output level, feeding uncontaminated products (OK products) about ten times, and fine-tuning parameters to reduce false detections. These tasks are cumbersome, and many aspects, including the degree of parameter adjustment, depend heavily on user operation.

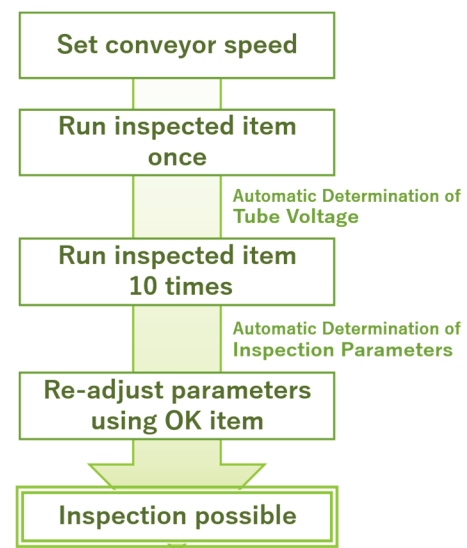


Figure 3 Preparations Before Starting Inspection

The improved inspection stability of the XR76 resulting from fewer false detections through enhanced sensitivity creates a greater margin in configuring inspection parameters, supporting more automated settings. The system has several dedicated features (Table 1) to minimize operator-dependent factors and allow anyone to begin inspection with ease.

Table 1 Comparison of Inspection Modes

	Conventional: Sensitivity- Focused	Detection Limit Setting Mode: Balance	1-Pass Product Setup
Screen Transitions	12	12	5
Tube Voltage Setting	Yes	Yes	No
Passing Test Product	10 times recommended	10 times recommended	Once
Readjusting Detection Parameters	Comparable to conventional models	Few adjustments	Unnecessary
Performance	Maximum device sensitivity	Sensitivity $\geq$ conventional model	Foreign-object inspection only*

* Requires confirmation that it meets management sensitivity requirements

4.1.1 Fewer Parameter Adjustments

To reduce false positives, it is typically necessary to register a product variant using actual inspection targets and then re-adjust the inspection parameters accordingly. At this stage, applying parameters with sufficient margins can reduce false detections caused by variations in the shape, condition, and overlap of the inspection targets. However, this makes it more difficult to discriminate between the inspection target and foreign objects, resulting in lower detection accuracy. Current practice requires accumulated experience and domain expertise in order to fine-tune the parameters appropriately to achieve accurate inspection while suppressing false detections.

The XR76 “Detection Limit Setting Mode: Balance” function cuts the number of manual parameter re-adjustments required after automatic configuration by applying parameter settings with sufficient margins that minimize false detections. However, under normal circumstances, such a configuration approach would contribute to lower inspection accuracy. However, advances in high-resolution detectors and image processing technology can capture the presence of foreign items with greater clarity to achieve inspection accuracy equal to or exceeding that obtained through fine-tuned

adjustments on conventional machines. Furthermore, the XR76 system displays a One-Touch Adjustment button on the parameter re-adjustment screen. Whereas it was previously necessary to manually re-adjust multiple parameters individually, pressing this button allows simultaneous re-adjustment of multiple parameters, enabling any operator to commence inspection with settings that have sufficient margins.

4.1.2 Simplified Inspection Setup

In conventional inspection machines, parameters such as noise reduction values used to detect foreign objects are determined by passing the product to be inspected through the system about ten times while the product X-ray images are analyzed internally using multi-faceted image processing algorithms to extract product characteristics.

In contrast, the new 1-Pass Product Setup, which is limited to use for detecting foreign objects, automatically configures parameters to minimize false detections by passing an inspection target through the system just once. Since inspection accuracy is affected by the inspection target characteristics, separate verification that the required control sensitivity is satisfied remains necessary. However, in addition to detection limit adjustment, no X-ray output configuration is required, and since nearly all settings can be configured automatically with a single pass of the inspection target, preparations can be completed with minimum necessary effort.

4.2 Improved Operability

Since smartphones have become an indispensable part of everyday life, the design of any user interface (UI) must consider the operational feel and functionality of smartphones that users are accustomed to. The XR76 achieves operability and touch sensitivity comparable to that of smartphones by overhauling both the touchscreen panel integrated into the display and the associated software. Specifically, intuitive gesture-based operations are now supported, including scroll functionality via swiping and pinch-in/pinch-out zooming of X-ray transmission images, providing users with a more comfortable and accessible operating environment.

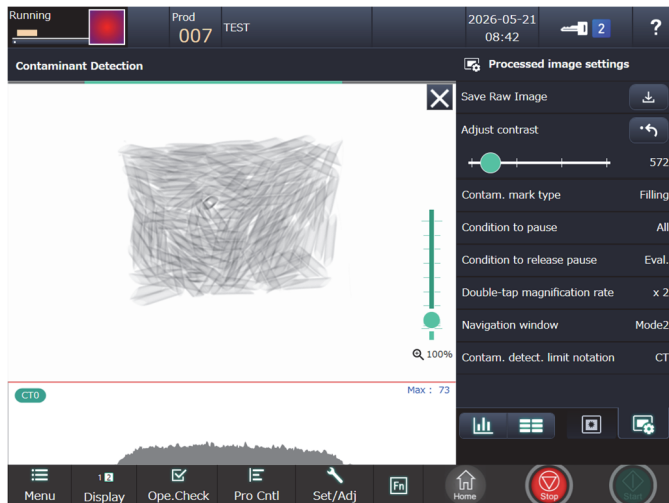


Figure 4 Configuration Screen for X-ray Transmission Image Parameters at Inspection Interface

Figure 4 shows the screen on the inspection display for configuring transmission image conditions. Efficient adjustment of display settings is achieved with the fewest taps by consolidating the most frequently used parameters for transmission image verification at a single screen. Furthermore, minimizing screen transitions and structuring the interface helps users access the desired settings without becoming disoriented by navigation changes. At the same time, the fundamental operational framework, including button layout, inherits the UI of existing systems, ensuring that users are not required to relearn operating procedures from scratch. This allows users who have previously operated conventional machines to transition to the new system with ease.

4.3 Long-Life Design with Less Maintenance

Optimized internal airflow through advanced thermal design, along with technology to extend the X-ray tank service life via low-power operation, which are both inherited from previous developments, are carried over into the XR76 series. Three primary components contribute to extended service life: the X-ray detector, X-ray source, and specially sealed heat dissipation unit.

Using high-sensitivity X-ray detectors reduces the output of the X-ray tank, successfully minimizing wear on both the X-ray tank and the X-ray detector. A cooler-free, specially sealed enclosure developed using fluid dynamics simulation reduces power consumption. Furthermore, the failure rate of key electrical components is also reduced by the structural design preventing ingress of outside air.

These technologies have achieved an XR76 design service

life of 30,000 hours, creating a system with low replacement frequency due to end-of-life or failure, reduced running costs, and compatibility with labor-saving operations. As a demonstrated track record, the XR75 series X-ray tank and X-ray detector service life using this technology has been extended to more than 2.5 times that of preceding series. Since this figure includes units replaced before end-of-life as part of preventive maintenance, the actual service life is estimated to be even longer.

5 Main Specifications

Figure 5 shows the XR76 dimensional drawings, and Table 2 lists the main specifications.

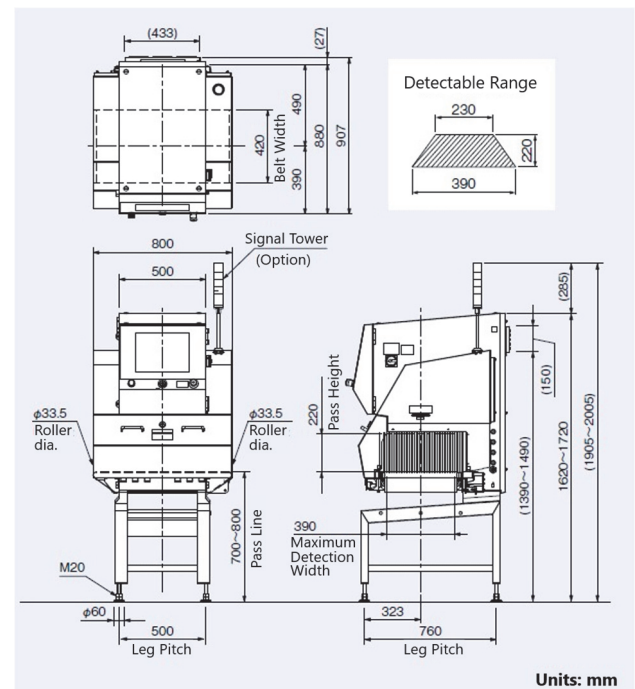


Figure 5 External Dimensions

6 Conclusions

Amid growing public concern over food safety, food processing facilities are facing an increasingly serious array of challenges, including labor shortages and rising material and labor costs. To address these challenges, we developed a new X-ray inspection machine with a focus on personnel reduction and labor savings. Significant labor savings are anticipated through fewer customer complaints and re-inspections by enabling high-sensitivity, low false-detection inspection using the latest X-ray detector and image processing technologies. For customers in high-mix production, features such as 1-Pass Product Setup greatly reduce the

configuration effort required to detect foreign objects, thereby cutting the operator burden and facilitating both personnel reduction and labor savings.

This XR76 model is designed for personnel reduction and labor savings on the production floor while simultaneously ensuring food quality and delivering safe and reliable food products to consumers. Anritsu is continuing to develop inspection machines that bring operational ease and peace of mind to production environments through enhanced inspection efficiency, thereby helping build a sustainable society.

References

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- 2) Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan, "Vision for Overcoming Labor Shortages in the Food Manufacturing Industry," 2019, p. 8 (in Japanese).

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Table 2 Main Specifications

Model	KXS7622AVCTV	KXS7634AVCTV
X-ray Output	Tube Voltage 30 to 80 kV, Tube Current 0.4 to 3.3 mA, 100 W max.	
Safety	1.0 μSv/h max. X-ray leakage prevention by safety device	
Display	15-inch capacitance-type LCD with touch panel	
Detection Area	240 mm max. width, 120 mm max. height	390 mm max. width, 220 mm max height
Belt Width	270 mm	420 mm
Preset memory	200 or 999 products (switchable)	
Conveyor Speed/ Performance	10 to 60 m/min, 5 kg max.	10 to 60 m/min, 5 kg max.
	61 to 90 m/min, 2 kg max.	
Power requirements	100 to 240 Vac, Single Phase, 50/60 Hz, 700 VA max., ±10% permissible power fluctuation	
Mass	230 kg	290 kg
Environmental conditions	Temperature 0° to 35°C, Humidity 30% to 85% (no condensation)	
Protection class	IP66-equivalent	
Exterior	Stainless Steel (SUS304)	

Publicly available