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Diagnosis And Handling Of A Coil Failure On A Handheld Metal Detector As An Aviation Security Facility

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Abstract

The Handheld Metal Detector (HMD) is an aviation security (AVSEC) facility used for secondary passenger screening to detect metal objects that may endanger flight safety. On 10 February 2025, the HMD at Security Check Point 2 (SCP 2), Terminal 1A of Soekarno-Hatta International Airport, malfunctioned and could no longer emit electromagnetic waves, rendering it unable to detect metal. This article aims to analyze the cause of the malfunction and document the repair process. The method used was field observation and systematic troubleshooting, consisting of disassembling the unit, inspecting the physical modules, measuring battery voltage, checking the continuity of the power supply line using a digital avometer, and testing the metal-detecting coil. The analysis revealed that the battery and power supply line were functioning normally, while, by elimination, the damage was located in the coil, which no longer produced an electromagnetic field. The repair was carried out by replacing the coil with a component taken from another unused HMD unit, soldering it to the module, and retesting the device. The test results showed that the HMD could turn on normally and successfully detected metal, indicated by the buzzer sound, allowing the device to resume normal operation. This case study emphasizes the importance of preventive maintenance and periodic inspection of aviation security equipment to support smooth AVSEC operations. The findings are limited to a single case, and quantitative coil parameters and a standardized sensitivity test are not reported.

Keywords: Handheld Metal Detector, troubleshooting, aviation security, coil, AVSEC

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Introduction

Aviation safety and security (AVSEC) is a primary aspect that every airport operator is required to uphold, as regulated under the provisions of the International Civil Aviation Organization (ICAO), which have been adopted into the national aviation system (Candra Susanto & Keke, 2019). These provisions require every international airport to implement a layered security screening system for passengers, crew, baggage, and cargo, in order to prevent dangerous

items or materials from entering restricted areas and aircraft. This obligation is specifically set out in ICAO Annex 17 -- Security, which establishes that the safety of passengers, crew, ground personnel, and the general public is the primary objective of every member state in safeguarding international civil aviation from acts of unlawful interference (International Civil Aviation Organization, 2024).

The layered security screening system at airports generally consists of several complementary technological layers, beginning with the Walk-Through Metal Detector (WTMD) as an initial check, X-ray machines for cabin-baggage inspection (Snyder et al., 2000), the Explosive Trace Detector (ETD) for detecting traces of explosive materials (Verkouteren et al., 2014), and body scanners for non-invasive body screening (Accardo & Chaudhry, 2014). The overall effectiveness of the system depends heavily on the performance of each technological layer; research by Skorupski and Uchroński (2018) shows that the performance of an airport security screening system can be improved from a moderate to a high category through better screening-equipment quality and more intensive officer training, while Lee and Jacobson (2011) emphasize that the reliability of equipment at each checkpoint also determines the effectiveness of passenger allocation across the overall layered security system.

The Handheld Metal Detector (HMD) is one of the devices used in the secondary screening layer by Aviation Security (AVSEC) officers after the WTMD, specifically to check areas of a passenger's body indicated as containing metal. In principle, the HMD operates based on the phenomenon of electromagnetic induction: a coil inside the device is energized with electric current to generate an electromagnetic field, and when that field encounters a metal object, an eddy current is induced on the metal's surface, altering the characteristics of the surrounding electromagnetic field (Nation & Jiang, 2017; Han et al., 2024). This change is captured by the coil sensor circuit and processed by a microcontroller, producing a warning signal in the form of a buzzer sound (Guag et al., 2017). The precision of the weak-signal detection circuit in the coil sensor greatly determines the sensitivity and accuracy of metal detection, as demonstrated in research on the design of coil-sensor-based magnetic-signal detection circuits (Xu et al., 2024). Optimization of coil design, including differential winding configuration and inter-coil angle, has also been shown to improve detection sensitivity and reduce common-mode noise in other eddy-current-based sensor applications (Zhang et al., 2025), which is relevant to understanding why the coil is the component that most determines HMD performance.

As an electronic device operated intensively every day at international airport checkpoints, the HMD is prone to performance degradation and component damage. Damage to the HMD directly affects the effectiveness of the passenger security screening procedure, so the reliability of this device needs to

be supported by optimal maintenance and adequate technician competency. The data for this study were collected directly at the Safety and Security Electronic Services Unit of the airport operator (name withheld for double-blind review), where the authors were directly involved in handling real problems in the field as part of the applied learning of a vocational aviation engineering programme. This direct involvement also contributes to the work readiness of vocational education graduates (Lubis, 2021), and alignment between technical learning and integration with industry work systems further strengthens that readiness (Darni et al., 2025).

On 10 February 2025, damage was found in the HMD at Security Check Point 2 (SCP 2), Terminal 1A of Soekarno-Hatta International Airport, in which the device could not emit electromagnetic waves and therefore could not be used to detect metal. The literature reviewed above addresses the layered screening system and the principles of eddy-current sensing, but it does not describe the field-level diagnosis and repair of handheld metal detector failures; this study addresses that practical gap through a documented single case. This article aims to (1) systematically analyze the cause of the damage based on the electromagnetic working principle of the HMD, (2) document the handling steps and repair verification carried out, and (3) relate the field findings to the literature on the reliability of aviation security screening systems, so that this study may serve as a reference for troubleshooting practice and the maintenance of similar aviation security equipment in the future.

Research Method

This study uses a descriptive qualitative method with a case study approach, as put forward by Baxter and Jack (2008), which systematically describes the process of identifying the cause and handling the damage of a single unit of equipment under study, as is commonly used in applied, field-practice-based research (Ulfa, 2022). Unlike quantitative research, which emphasizes numerical measurement and hypothesis testing, the case study approach here focuses on tracing the root cause narratively and verifying it through retesting, so that the results can serve as a replicable reference for troubleshooting practice in similar cases. A similar approach has been used in research evaluating airport security technology (Hofer & Wetter, 2012), showing that a descriptive case study is effective for revealing the cause and handling process of a problem in depth for a single unit of study. Data collection techniques were carried out in three ways: direct observation at the incident site, technical measurement using electronic instruments (a digital avometer), and documentation of each stage of the repair process in the form of photographs and field notes.

Data were collected directly at the incident site during the period of 15 January-28 February 2025, at the Safety and Security Electronic Services Unit, Terminal 1A, Soekarno-Hatta International Airport (airport operator name withheld for double-blind review). This unit is responsible for the maintenance of all aviation security electronic facilities in the terminal area, including the WTMD, HMD, X-ray, and other supporting devices at the security checkpoint. The object of this study is one unit of Handheld Metal Detector (HMD) that malfunctioned at Security Check Point 2 (SCP 2) on 10 February 2025.

The tools and materials used in the troubleshooting process included: a screwdriver to open the unit's cover without damaging the casing; a digital avometer as a multifunction measuring instrument to measure battery (DC) voltage, test the continuity of electrical pathways in buzzer mode, and check component resistance; and a soldering iron with solder wire for reconnecting the replacement coil component to the circuit module. The avometer was selected as the primary diagnostic instrument for its ability to perform quick, non-destructive measurements of basic electrical parameters, making it suitable for field troubleshooting without the need for complex laboratory equipment. Because an avometer measures only electrical parameters and not the electromagnetic field itself, the conclusion on the coil rests on the elimination of the power source and wiring and on the absence of a detection response; the coil's electrical parameters are not reported.

The troubleshooting stages were arranged systematically following a diagnostic flow from the power source toward the functional component, namely: (1) opening the HMD cover using a screwdriver to access the internal module; (2) performing a physical inspection of the oscillator module, transmitter coil, and receiver coil to identify visually apparent damage, such as burnt components or detached solder joints; (3) measuring the battery voltage using the avometer to confirm that it met the 9V standard, as an initial step to eliminate the possibility of a power-source fault; (4) checking the continuity of the power supply line from the battery to the module using the avometer's buzzer mode, to ensure no wiring path was broken; (5) checking the coil's performance in generating and detecting an electromagnetic field, as the core component determining the HMD's metal-detection function; and (6) identifying the location of the damage based on the results of these staged inspections using an elimination method (a process of elimination from the most common possible cause toward the most specific). Once the source of the damage was identified, the component was replaced, soldered, and retested on the device as well as on a sample metal material to verify the success of the repair.

Results and Discussion

Object Profile and Scope of the Study

The object of this study is one unit of Handheld Metal Detector (HMD) operating at Security Check Point 2 (SCP 2), Terminal 1A, Soekarno-Hatta International Airport, under the management of the Safety and Security Electronic Services Unit of the airport operator. As the busiest airport in Indonesia, Terminal 1A operates several security checkpoints in parallel with a high daily passenger volume, so every HMD unit is required to remain ready to use throughout operating hours. This condition makes the reliability of every HMD unit an important factor in maintaining a smooth passenger-screening flow without compromising the required security standard.

Working Principle of the Handheld Metal Detector

Functionally, the HMD consists of three main modules: the oscillator module, transmitter coil, and receiver coil. The oscillator module generates an electrical signal of a certain frequency, which is fed to the transmitter coil, creating an electromagnetic field around the coil. When this electromagnetic field encounters a metal object, an eddy current is induced on the metal's surface, producing a secondary magnetic field in the opposite direction, which alters the characteristics of the electromagnetic field captured by the receiver coil (Nation & Jiang, 2017; Han et al., 2024). This relatively weak signal change is then amplified and processed by the microcontroller; the better the amplifier and signal-filter circuit in the coil sensor, the higher the sensitivity and accuracy of the resulting metal detection (Xu et al., 2024). If the microcontroller identifies a signal change exceeding a certain threshold, the buzzer activates as an indicator of the presence of metal (Guag et al., 2017). This principle forms the basis for tracing the damage discussed in this case, because a failure at any stage in the signal generation-detection-processing chain can cause the HMD to malfunction.

Problem Identification

Based on a report from an Aviation Security (AVSEC) officer on 10 February 2025, the HMD on duty at Security Check Point 2 (SCP 2), Terminal 1A, could not be used to emit electromagnetic waves and was therefore unable to detect metal on a passenger's body. This condition had the potential to disrupt the effectiveness of the aviation security screening procedure if not addressed promptly, given that the HMD is a secondary screening layer that cannot be fully replaced by the WTMD alone for checking specific body areas.

Diagnosis and Damage Analysis

Diagnosis was carried out in stages in accordance with the method described above, following the flow from the power source toward the core functional component. The physical inspection showed that the oscillator module, transmitter coil, and receiver coil were installed normally, with no

visible signs of damage such as burnt components. The battery voltage measurement using the avometer showed a result within the standard (9V), and the power-supply-line continuity check using the avometer's buzzer mode showed that the current flow to the module was normal. Consequently, the possibility of damage in the power source and electrical wiring could be eliminated. However, at the coil-inspection stage, it was found that the component could no longer generate an electromagnetic wave despite receiving an appropriate current supply. A summary of the inspection stages is presented in Table 1.

Table 1 HMD Inspection Stages and Results

No.	Inspection Stage	Instrument / method	Result	Remarks
1	Battery condition (avometer)	Digital avometer (DC voltage)	9V, normal	Good
2	Power-supply-line continuity	Digital avometer (continuity, buzzer mode)	Connected	Good
3	HMD coil	Coil performance check (elimination of other causes)	Not emitting electromagnetic wave	Damaged
4	Test after coil replacement	Test on a metal sample	Detects metal, buzzer active	Normal

Table 1 shows that all inspection stages on the power source and electrical wiring -- including the battery voltage measurement and power-supply-line continuity check -- produced normal results, whereas the coil inspection produced an abnormal result because the component could no longer generate an electromagnetic wave. This comparison of results at each stage strengthens the conclusion that the root of the problem originated in the coil component, rather than in the power source or electrical wiring.

Figure 1 presents a flowchart that systematically summarizes the entire diagnostic process, beginning with the visual inspection of components, battery voltage measurement, power-supply-line check, and coil testing, together with the handling step at each decision point, up to the final post-repair verification.

This finding indicates that the root cause of the HMD malfunction lies in the coil, not in the power source or electrical wiring. This is consistent with the working principle of the HMD, which depends entirely on the coil's ability to generate an electromagnetic field and detect the changes caused by eddy currents in metal objects (Nation & Jiang, 2017; Han et al., 2024). Coil failure can be caused by winding wear from intensive use, weakened solder joints, or mechanical damage from repeated impacts during daily operational use, given that the HMD is a handheld device more susceptible to physical stress than fixed-mounted security equipment. These are possible contributing factors only; no physical evidence confirming which of them applied in this case is reported (see the limitations in the Discussion).

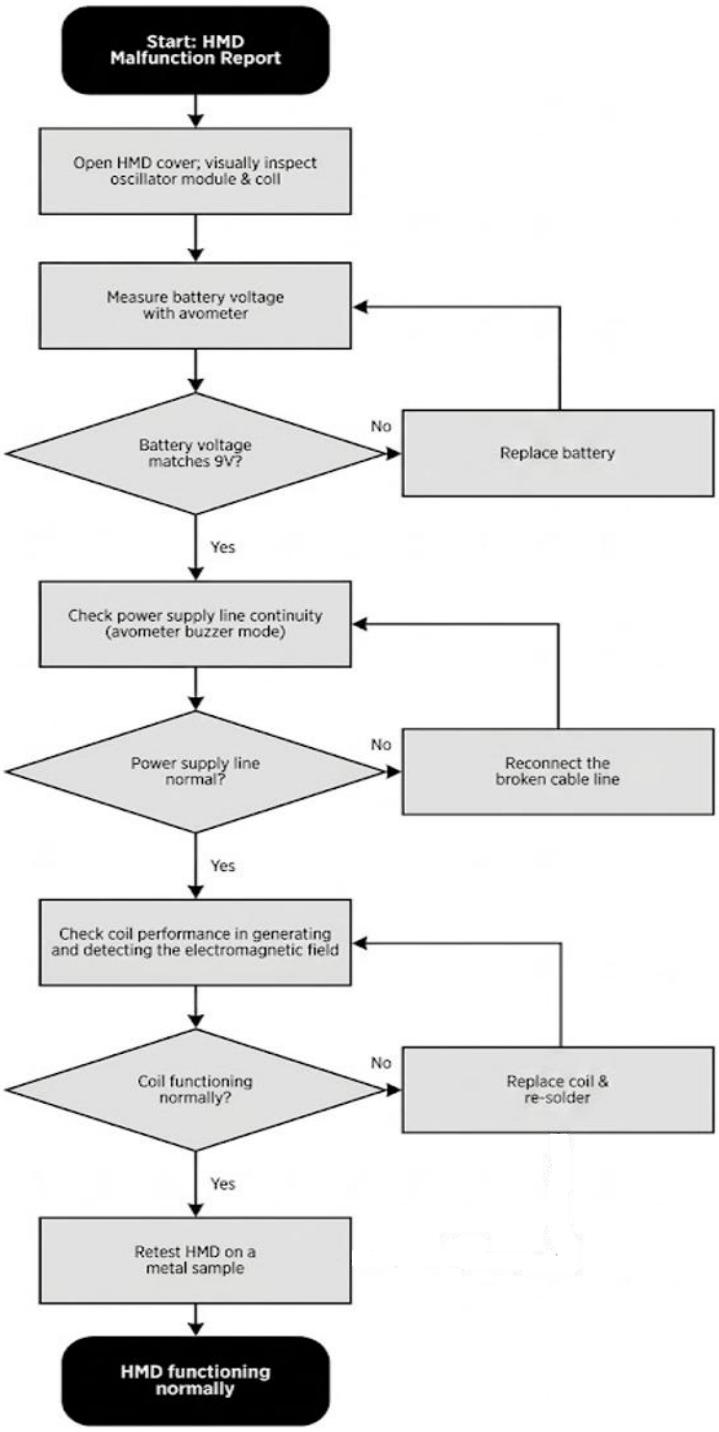


Figure 1 Flowchart of the HMD Damage Diagnosis and Handling Process (Source: Processed by the Authors, 2025)

Handling and Repair Verification

The repair was carried out by replacing the damaged coil with a coil component taken from another unused HMD unit (cannibalized), which was then soldered onto the device's module. After the soldering process was completed, a test was conducted to confirm that the device could power on normally, followed by a detection test on a metal material. The test results

showed that the HMD could emit electromagnetic waves and successfully detected metal, indicated by the buzzer sound, so the device was confirmed to be functioning normally again and could be returned to duty at SCP 2. The compatibility of the donor coil with the original unit, and the detection sensitivity relative to a standard test piece, were not documented in this study; verification against the manufacturer's procedure is recommended before a repair using a component from another unit is regarded as permanent.

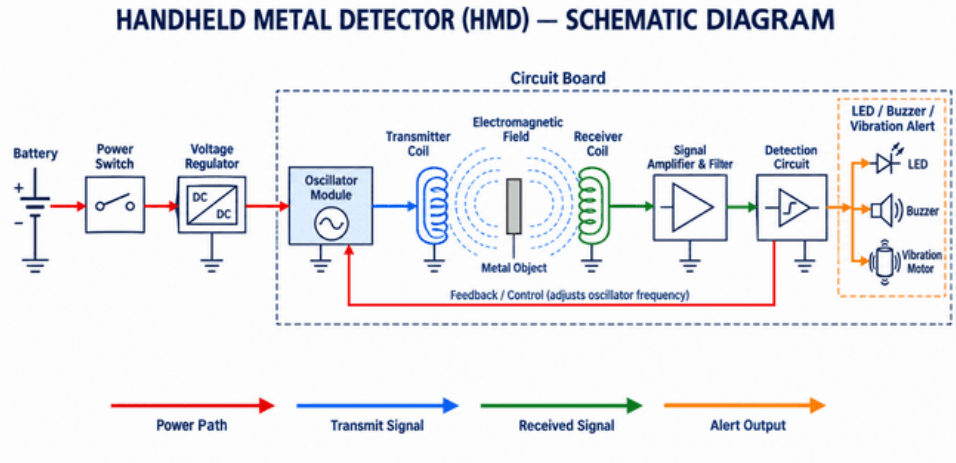


Figure 2 Conceptual Illustration of the Handheld Metal Detector (HMD) in Aviation Security Screening

Figure 2 presents a conceptual illustration of the Handheld Metal Detector (HMD), showing the physical form of the device and the position of its main components, namely the coil and the oscillator module, as a visual complement to the explanation of the HMD's working principle described in the previous section.

Comparison with Other Security Screening Technologies

The HMD is one of several complementary layers of aviation security screening, alongside X-ray inspection of cabin baggage (Snyder et al., 2000), explosive trace detection (Verkouteren et al., 2014), and body scanners (Accardo & Chaudhry, 2014). Compared with these, the HMD offers low operating cost, high portability, and fast response, but its performance depends on the physical condition of the coil, which is susceptible to mechanical damage from intensive handheld use. Because the effectiveness of the layered system depends on the reliability of each layer (Skorupski & Uchroński, 2018; Lee & Jacobson, 2011), the availability of a functioning HMD at each checkpoint matters for the overall screening flow.

Importance of Preventive Maintenance and Technician Competency

This case study shows that damage to aviation security equipment can originate from a single component worn by routine use rather than from a

systemic failure. Technician competency in diagnosing and handling such damage influences equipment downtime, in line with the link between officer training and screening-system effectiveness reported by Skorupski and Uchroński (2018). Errors or negligence in diagnosing and documenting troubleshooting are among the human-error factors contributing to aviation incidents (Olaganathan, 2024). Scheduled preventive maintenance has been reported to improve reliability and extend the mean time between failures compared with reactive handling alone (Al-Duais et al., 2022). Strengthening preventive maintenance should therefore be accompanied by strengthening technician competency.

Discussion

This case shows that damage to aviation security equipment such as the HMD can occur even when the power source and electrical wiring are in good condition, so staged diagnosis of each functional component remains necessary to ensure the accurate identification of the root cause. The elimination approach used -- checking the power source, electrical wiring, and then the sensor component in sequence -- proved effective in isolating the root cause in this case and may serve as a reference diagnostic sequence for similar HMD failures, subject to validation on further cases. Given that the HMD is part of the AVSEC system, which must meet operational standards in accordance with ICAO regulations (Candra Susanto & Keke, 2019), the reliability of this equipment needs to be maintained through preventive maintenance and periodic inspection, rather than only reactive handling after damage occurs. Implementing a routine maintenance schedule, recording equipment damage history, and providing spare coil components can be further steps to reduce the risk of operational disruption to passenger security screening in the future.

This study has several limitations. First, it covers a single unit and a single failure event, so the findings cannot be generalized. Second, the diagnosis of the coil rests on the elimination of the power source and wiring and on the absence of a detection response; quantitative coil parameters (for example resistance or inductance), a comparison with a healthy coil, and physical evidence of the failure mechanism are not reported. Third, the repair used a coil from another unused HMD unit, and its compatibility, calibration, and sensitivity verification against a standard test piece, as well as the repair duration and downtime, are not documented. Future studies should record these parameters, include more cases, and compare the findings with the failure and maintenance histories of other HMD units.

Conclusion

Damage to the Handheld Metal Detector (HMD) at Security Check Point 2, Terminal 1A, Soekarno-Hatta International Airport was traced to the coil, which no longer generated an electromagnetic field, while the battery and power supply line were in normal condition. The staged diagnosis, which followed the HMD's working flow from the power source and electrical wiring to the sensor component, isolated the fault to the coil by elimination. Replacing the coil and retesting restored the HMD's metal-detection function, indicated by the buzzer response. These findings are limited to a single case and to the parameters recorded in this study. The case indicates that the reliability of the HMD as one layer of the AVSEC screening system depends on the condition of its coil, which is susceptible to intensive handheld use, so periodic preventive maintenance and strengthening of maintenance personnel's technical competency are needed.

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AI Declaration

The author acknowledges the use of artificial intelligence (AI) tools in supporting the preparation of this manuscript. The author remains fully responsible for the accuracy, originality, and integrity of the research and its findings.

Disclosure statement

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