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The 3 C's of Consideration for COVID-19 Workplace Fever Detection Device Selection: Context, Calibration & Cost

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ABSTRACT

COVID-19 screening protocols have become normal practice for employees entering workplaces around the world. However, workplace screening programs that include temperature detection via infrared thermometers or thermal detection cameras often violate many technical specifications for the correct use of these devices. Therefore, this article aims to provide practical guidance for non-thermal imaging specialists responsible for selecting thermal detection devices for workplace screening protocols. Focusing on three critical points of consideration including: the context of use, calibration of equipment, and cost of purchase and maintenance, readers are presented with a framework to guide their decision-making. This framework not only prioritizes the health and wellbeing of employees by ensuring the context of use is appropriate but balances the cost of calibration, purchasing and additional supporting supplies. Further, the presented framework extends beyond the COVID-19 pandemic and can be easily adapted to implement any new workplace technology.

Key words: Calibration; cost analysis; occupational health & safety (OHS); SARS-CoV-2; thermal detection

INTRODUCTION

Throughout 2020, screening protocols have become the norm when accessing medical centers, using public transit, entering restaurants and shopping centers and other public venues. Governments worldwide have further recommended that workplaces implement COVID-19 screening for any employees or essential visitors entering the work environment. As a result of these recommendations, protocols range from passive self-declarations and self-identification of symptoms to more advanced active screening relying on temperature assessments for fever detection. Although fever is not specific to COVID-19, it is one of the most common presenting symptoms and is considered a method with good sensitivity for detecting illness.[1]

There are various methods of temperature detection, but for workplace screening protocols, practicality and implementation ease are primary influences of tool selection. Infrared thermometers (IRTs) and thermal detection cameras, which require no contact, cause no discomfort and produce instant results, have frequently been adopted, as they have been shown to correlate with core body temperature and are suited for screening large cohorts.[2]

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Currently, the only international standard for IRTs is based on testing procedures in a laboratory environment and require temperatures between 18-24°C, relative humidity between 10-75%, airflow control, and the reduction of all other sources of infrared radiation (*e.g.*, incandescent and halogen lightings) surrounding the assessment site.[3] In the context of workplace temperature screening, many of these controlled criteria are not met. Workplaces may choose a variety of methods to perform screening such as: while the person is sitting within their own vehicle with A/C influencing airflow; while queuing outside the entrance where environmental conditions are impacting the temperature and humidity; or in a main entrance with no ability to control the ambient lighting and illuminance. Despite these concerns, IRTs are currently the only practical temperature measurement strategy for mass screening for global outbreaks and pandemics.[4] Therefore, exploring considerations for device selection within the context of implementation in the workplace warrants further exploration.

This article aims to provide practical guidance for non-thermal imaging specialists, who are now responsible for selecting thermal detection devices used for COVID-19 workplace screening protocols (i.e., joint health and safety representatives, safety coordinators, industrial hygienists, and health promoters). The article focuses on three critical points of consideration, termed the 3-Cs: context of use, calibration of equipment, and cost of purchase and maintenance. The best source of information related to context, calibration and cost is the IRT product datasheet. However, these documents often use unfamiliar terminology alongside technical data that can be difficult to interpret.[4] Therefore, we have presented the findings relative to a sample IRT product datasheet (Figure 1) and guide the reader in how to use these specifications in their decision-making framework.

CONTEXT

When selecting temperature instrumentation for workplace screening purposes, the context of use is the first consideration, which in the framework of this paper refers to the unique, and often dynamic nature of the workplace environment using the device. Infrared thermometers are typically used to measure thermal radiation emitted from the forehead and occasionally the wrist, targeting the skin above the superficial temporal artery and the radial artery, respectively.[5] Unfortunately, peripheral measurement sites have more significant variability and increased susceptibility to environmental conditions, such as radiation, wind velocity, and air temperature and humidity.[1] These conditions affect the IRTs ability to represent an accurate core body temperature in various situations (i.e., outdoor workplace screenings). The majority of recent research

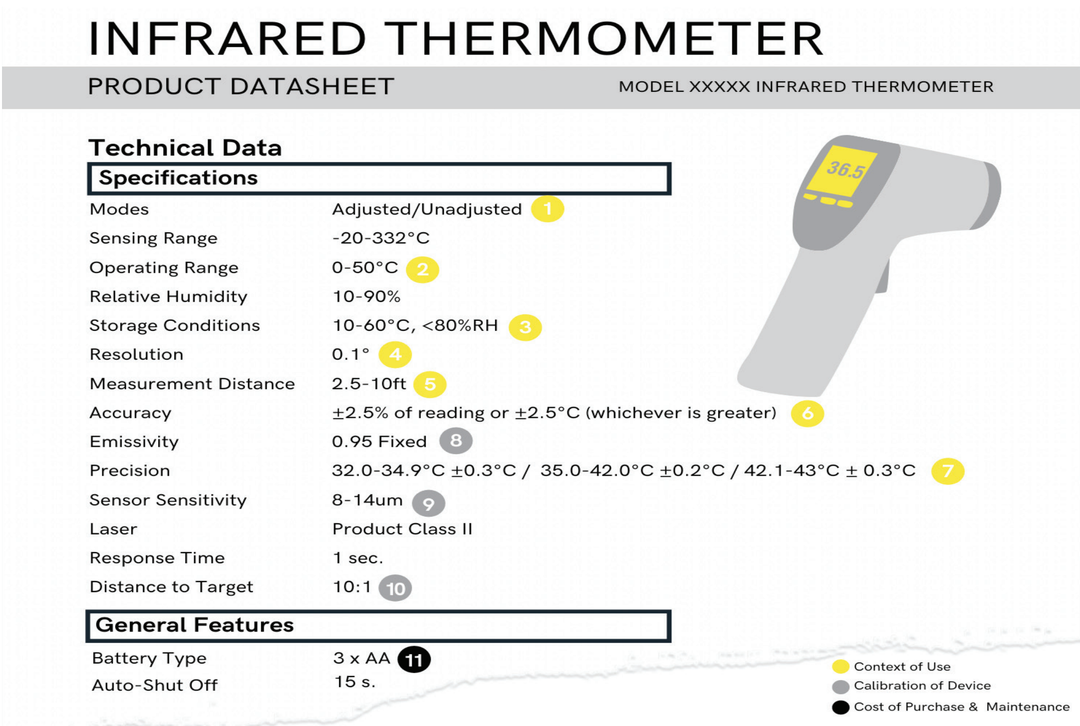

Figure 1: Sample IRT technical datasheet with indicators of context, calibration and cost related features.

assessing the validity and reliability of temporal infrared screening methods for COVID-19 has been conducted in hospital settings, thermoneutral laboratory environments, and within airport environments.[2,5,6] Few studies have addressed the use of IRTs outside of these standardized environments and lack an in-depth evaluation of the effect of hot, cold and fluctuating temperatures on the body and the response time of the skin.[1,2,5,6] Recently, an underestimation of 9.9-11.7°C, measured at the forehead, was detected with an IRT after exposing participants to sub-zero conditions (-5 to -20°C).[7] As screening practices conducted outside or in fluctuating temperatures are likely to be significantly underestimating readings, these should occur indoors in thermoneutral environments.

Another unique consideration in workplaces is the impact of headwear (i.e., hard hats) and cold weather wear (i.e., gloves, toques) worn for thermal comfort or safety requirements. However, the degree to which skin temperature is affected and the duration of time required for the skin to return to normal is dependent on prior environmental exposure.[7] Thus, in addition to controlling environmental conditions to minimize errors, the skin should be provided approximately 2-9 minutes in a neutral temperature environment (18-24°C) to respond.[7,8] The subject also should not have undergone any activity which could affect skin temperature (i.e., exercise).[4,9]

When considering the context of use, seven critical features of the IRT datasheet (Figure 1) help determine the appropriateness of the chosen device. The first consideration ① is the intended use of the device, distinguishing mainly between clinical and industrial use. The critical distinction is that IRTs for human body temperature detection have smaller measurement ranges and have two modes: adjusted and unadjusted, whereas industrial IRTs have only one mode: unadjusted. The adjusted model accommodates the difference between skin temperature and body core temperature using an internal algorithm, whereas unadjusted is the raw temperature reading used in industrial practices and during calibration. Therefore, for workplace temperature screening purposes, a model designed for human body temperature with a narrower sensing range and an adjusted mode feature would be a good starting point for instrument selection.

The next consideration ② is the operating range (also listed as ambient temperature range or operating conditions) which refers to the temperature and humidity in which the device operates optimally. Operating range is of critical consideration for workplace settings where screenings may be occurring in dynamic temperature areas (i.e., drive-by mobile screenings). It is important to note that most devices do not list below zero temperatures in their operational range, and therefore, workplaces may need to accommodate their screening areas. Typical relative humidity ranges are broad at 10-90%. A related consideration is for storage conditions ③, which also refers to temperature and humidity between uses. Workplaces that use trailers or parking lot booths may exceed the limits for storage conditions, and therefore, the devices may be at risk for measurement error.

The resolution specifications (also listed as display resolution or maximum resolution) ④ of the device also need to be considered. Resolution refers to the data pixels used to create the visual image from the thermal profile. Generally, the more pixels and data points, the more accurate the thermal image will be and allows for an increased distance to the target without losing measurement accuracy. For thermal cameras, this is often expressed in increments of 0.1°C, assuming optimal ambient temperature. In addition to resolution, measurement distance ⑤, which represents the distance between the subject and the device, needs consideration. Distance is significant for jurisdictions where policy requires mandatory physical spacing (typically 2m). The device distance and resolution restrictions may require additional PPE to ensure the safety of the person doing the temperature screening.[10] Datasheets also typically provide measurements of accuracy ⑥, which represents how close a measured value is to its actual value. Typically, when using IRTs for human body temperature, the accuracy is recommended within ±0.3°C (ASTM E 1965-98). Similarly, reliability or precision ⑦ provides a measure of the degree of consistency or the extent to which a measurement yields the same results on repeated trials. Ideally, select a device with a reliability value as close to 0°C as possible (i.e., ±0.1°C) within the fever detection range (i.e., 35-42°C). A few additional features may be listed on product datasheets to provide the buyer/user with further detail, for example, spectral response ⑧, which refers to the wavelength sensitivity of the sensor. Practical temperature measurement using IRTs typically uses wavelengths between 0.7-20, with individual sensors operating within a narrow part of the band.[11]

CALIBRATION

An important aspect of thermal detection device choice is the calibration methodology required to ensure that these devices are correctly aligned in terms of temperature to reduce measurement errors and ensure user confidence.[12] To ensure the accuracy of human body temperature measures, emissivity, wavelength and distance to spot (D:S) ratio can be referenced on the datasheet. Emissivity ⑨ is the ratio of the spectral radiance of a real surface to that of an ideal surface (i.e., how much energy is coming off the object).[11] It is typically agreed upon that skin has an emissivity of 0.98 (references ranges vary from 0.94 to 0.99), and therefore most IRT datasheets will have emissivity reported as this value.[4] The wavelength ⑩ should also be referenced, which for measurements near room temperature should be 8-14 μm because this wavelength band is not as sensitive to humidity.[13] This value is important for calibration because this wavelength of the IRT must be the same as the calibrator. Lastly, the D:S ⑪ is the ratio of the distance to the object and the diameter of the area containing a specific percentage of the total energy pick up by the IRT.[13] This ratio guides the appropriate distance for making practical measurements (e.g., 12:1 means that at 12 inches, the field of view is 1 inch in diameter). The lower the quality of the device, the closer the device needs to be to the measurement surface to improve reliability.

Currently, there are no common practices for IRT device calibration in the field. The following aims to summarize what is known regarding considerations for the calibration process that a workplace may consider when calibrating devices used for mass screening practices. First, calibration should always occur in an environment as close to the datasheet specifications as possible, including attention to optimal environmental temperature and humidity, removing all additional heat sources, controlling for lighting and minimizing air movement.[3] The device should be in this condition for approximately one hour in advance of the calibration to ensure the internal temperature is optimal.[3] The operator should ensure that the device is set to 'normal' body conditions; temperature (37°C) and skin emissivity (0.98). Referencing the device's D:S ratio, mark where a 2-inch spot size is achieved relative to your target (Figure 2).[4] The target refers to the calibration source, which is either a blackbody or a graybody (also called flat-plate infrared calibrator). Blackbody calibration sources are the preferred option for checking the calibration of an IRT sensor and consist of a heated (or cooled) target object whose temperature and emissivity are precisely known.[12] Blackbody calibrators are considered an ideal surface that emits and absorbs electromagnetic radiation with the maximum amount of power possible at a given temperature.[12] Using a partition, the operator then blocks their body heat and completes 3-5 measurements. The average readings from the IRT and the target display are calculated, and then the error is determined by subtracting the device average from the target average.

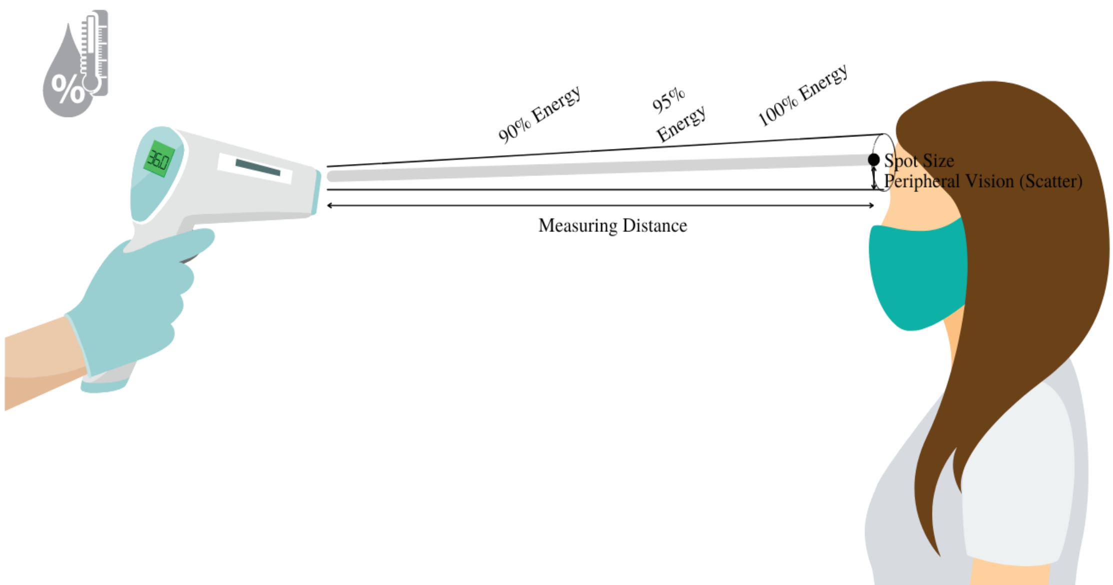

Figure 2: Illustration of IRT testing procedure with reference to distance to spot ratio.

COST

In addition to considering the discussed context of use, and calibration considerations, an economic assessment is also of relevance when implementing a screening program. Economic considerations can include: the direct cost of the purchase price, the cost of consumables (i.e., probe covers and sterilized alcohol wipes), batteries ⑫, cleaning, maintenance and repair and calibration costs charged by the manufacturer/ supplier and replacement costs.[8] With the evolving nature of outbreaks, estimates are further required for the anticipated frequency and duration of use, along with the cost of training and staffing the screening protocol for the duration of the infectious period.

The costs of implementation and ongoing use of thermal detection devices in workplace entrance protocols vary considerably. The unit price of thermal detection devices ranges from $5 CAD ($4.13 USD) to several thousand dollars.[6] Some devices have high recurring costs, including consumables intended for single-use (i.e., alcohol, batteries, probe covers) and point-of-entry (POE) screeners required for equipment operation.[14] Other devices are self-sustaining, featuring automated operation, which reduces the need for person-person contact. Employers must consider these upfront and recurring costs in conjunction with the robustness of each device, the period of intended use, and the number of employees requiring routine screening to select the most appropriate and economical device for their workplace (Table 1).

This analysis presents the comparative costs for three models of thermal detection equipment for one, two, and five-year use in workplaces with ≤20, 21-50, 51-100, and 101-500 employees. This analysis incorporates the initial unit price of the thermal detection device, and where applicable, the estimated costs of consumables, device replacement, and the annual salary for point-of-entry screener personnel. All cost estimates make assumptions specific to screening measures in workplace entrance protocols. Feasibility for use may differ in settings requiring more frequent and variable temperature measurements (i.e., hospitals). However, the framework presented is adaptable for individual workplace use.

The number of annual temperature measurements per workplace category (20, 50, 100, 500+ employees) was estimated using the number of daily temperature measurements per employee, the proportion of full-time (FT) to part-time (PT) employees in each workplace, in addition to the number of working days per week and working weeks per year for FT and PT employees, respectively.[15] For example, a workplace with ≤20 employees would require 4600 annual temperature measurements; assuming a workplace of this size has sixteen (80%) FT employees and four (20%) PT employees. Additionally, compensation estimates account for the annual salary of a POE screener; accounting for the mean hourly wage of POE screeners in Canada, the proportion of POE screeners to workplace facility entrances, the mean working hours per week and working weeks per year for POE screeners, and the rate of expected wage inflation for POE screeners in Canada. The latter estimate may be unreliable due to the current and projected economic implications of the COVID-19 pandemic.

Providing an accurate assumption regarding the cost of, and need for, device repairs and calibrations is challenging, as the fees for these services are not widely accessible on manufacturer websites. Therefore, this cost analysis excludes repairs and calibration. Further, if faced with failure or malfunctioning, it is assumed that device replacement may be more economical than absorbing the costs of device inspection, diagnostics and repair, particularly for units with short warranty periods. Accordingly, the five-year summative costs include a one-time device replacement.

Based on the presented assumptions, the non-contact thermal radiation camera was the cheapest device by a considerable margin, with an estimated five-year cost of CAD 13720.00 (USD 11328.33); an amount over thirty times less expensive than the mean five-year cost for the other two thermal detection devices examined (Table 2).

It is important to note that the cost-benefit associated with the automated operation of the thermal radiation camera may be negligible in workplaces that hire POE screeners to conduct additional, self-reported symptom screening. Nonetheless, some workplaces have adopted remote self-screening measures to reduce on-site contact between employees. The differential cost remains in favour of the thermal radiation camera, irrespective of the need for a POE screener. The non-contact infrared laser was slightly less expensive than the infrared contact device, despite its higher initial purchase price. These findings are notable because the initial purchase price of the devices examined was inconsequential in the long-term compared to the ongoing costs of use (i.e., consumables and screener salaries). Costing equations to approximate implementation cost for workplace temperature screening using an IRT or thermal imaging camera are presented for 1-year, 2-years, and 5-years (Figure 3).

1-Year Cost ($)

$$= (initial\ unit\ purchase\ cost\ \times \#\ of\ units) + ATSS + ABB + AAW$$

2-Year Cost ($)

$$= (initial\ unit\ purchase\ cost\ \times \#\ of\ units) + (ATSS \times 2) + ABB + AAW$$

5-Year Cost ($)

$$= (initial\ unit\ purchase\ cost\ \times \#\ of\ units) + (ATSS \times 5) + ABB + AAW + (unit\ replacement\ cost \times \#\ of\ units)$$

Where:

ATSS – Annual Temperature Screener Salary

$$= hourly\ wage \times \frac{hours}{week} \times \frac{weeks}{year} \times \#\ of\ screeners\ required$$

ABB – Annual Box(s) of Batteries

$$= \left[ATR \div \left(\frac{\#\ of\ alcohol\ wipes/box}{alcohol\ wipes\ per\ reading}\right)\right] \times price/box\ of\ alcohol\ wipes$$

AAW – Annual Alcohol Wipes

$$= \left[\left(\frac{ATR}{3000}\right) \div \left(\frac{baterries/box}{batteries/thermal\ detection\ unit}\right)\right] \times price/box\ of\ alcohol\ wipes$$

Note: assuming 3000 uses per battery

ATR – Annual Temperature Readings

$$= \frac{\frac{readings}{person}}{day} \times \left[\left(\#\ of\ FT \times \frac{days}{week} \times \frac{weeks}{year}\right) + \left(\#\ of\ PT \times \frac{days}{week} \times \frac{weeks}{year}\right)\right]$$

Note: *FT*: full-time, *PT*: part-time

Figure 3: Costing equations to approximate implementation cost for workplace temperature screening using an infrared thermometer (IRT) or thermal imaging camera for 1-year, 2-years, and 5 years.

Table 1: Assumptions used in the costing table with ≤20†, 21-50‡, 51-100§, and 101-500 employees.

Method used for temperature screening measurement	Contact/IR sensing — ear	Contact/IR sensing — forehead	Non-contact/IR sensing laser — forehead	Non-contact/ Thermal radiation camera
Temperature measurements per year	Proportion of full-time employees (0.8) x 1 temperature measurement per day x 5 days per week x 50 weeks per year			
	Proportion of part-time employees (0.2) x 1 temperature measurement per day x 3 days per week x 50 weeks per year			
Number of units purchased	One per facility entrance († ‡ § 1; ¶ 2)			
Consumables	Batteries and alcohol wipes		Batteries	None
Point-of-entry screener salary per year	† ‡ § $19.98 (CAD) per hour x 40 hours per week x 50 weeks per year x 1 screener x 2.0% inflation per year † ‡ § $16.50 (USD) per hour x 40 hours per week x 50 weeks per year x 1 screener x 2.0% inflation per year ¶ $19.98 (CAD) per hour x 40 hours per week x 50 weeks per year x 2 screeners x 2.0% inflation per year ¶ $16.50 (USD) per hour x 40 hours per week x 50 weeks per year x 2 screeners x 2.0% inflation per year			-
Alcohol wipes	One per temperature reading		-	-
Battery life	3000 uses per AAA battery			-
Replacement	One replacement device per 5-year period			

Table 2: Comparative cost (CAD and USD) of using selected examples of thermal detection equipment for workplace entrance protocols for 1 year, 2 years and 5 years at companies with ≤20†, 21-50‡, 51-100§, and 101-500¶ employees.

Method used for temperature screening measurement	**Contact/IR sensing – ear and forehead**		**Non-contact/IR sensing laser – forehead**		**Non-contact/Thermal radiation camera**	
	CAD	USD	CAD	USD	CAD	USD
Model selected for costing	10092		FLIR TG54		Provix PRT-7MFTD – PC20	
Purchase cost	45.17	37.30	185.00	152.75	3430.00	2832.08
Price of consumable items (per item)						
Battery life (# readings)	3000		3000		--	
Sanitizing (alcohol wipes)	0.04		--		--	
Warranty	30 days		3 years		--	
Annual cost of consumable and ongoing costs calculated with the assumptions stated in Table 1.						
Initial purchase cost (Year 1 only)	†‡§45.17 ¶90.34	†‡§37.30 ¶74.59	†‡§185.00 ¶370.00	†‡§152.75 ¶305.50	†‡§3430.00 ¶6860.00	†‡§2832.08 ¶5664.16
Screener salary for year 1 (+ 2.0% increase for years 2-5)	†‡§39960.00 ¶79920.00	†‡§32994.17 ¶65988.35	†‡§39960.00 ¶79920.00	†‡§32994.17 ¶65988.35	--	
Batteries	†‡§13.00 ¶48.00	†‡§10.73 ¶39.63	†‡§13.00 ¶60.00	†‡§10.73 ¶49.54	--	
Alcohol	†184.00 ‡460.00 §920.00 ¶4600.00	†151.93 ‡379.81 §759.63 ¶3798.13	--		--	
Replacement cost (year 5 only)	†‡§45.17 ¶90.34	†‡§37.30 ¶74.59	†‡§185.00 ¶370.00	†‡§152.75 ¶305.50	†‡§3430.00 ¶6860.00	†‡§2832.08 ¶5664.16
Total 1-year cost	†40202.17 ‡40478.17 §40938.17 ¶84658.34	†33194.13 ‡33422.02 §33801.83 ¶69900.70	†‡§40158.00 ¶80350.00	†‡§33157.66 ‡66343.39	†‡§3430.00 ¶6860.00	†‡§2832.08 ‡5664.16
Total 2-year cost	**†80961.37 ‡81237.37 §81697.37 ¶212691.79**	**†66848.18 ‡67076.07 §67455.88 ¶175615.36**	**†‡§80917.20 ¶208383.45**	**†‡§66811.71 ¶172058.05**	**†‡§3430.00 ¶6860.00**	**†‡§2832.08 ¶5664.16**
Total 5-year cost	**†208240.79 ‡208516.79 §208976.79 ¶420735.57**	**†171940.26 ‡172168.14 §172547.96 ¶347392.95**	**†‡§208336.45 ¶416706.89**	**†‡§172019.24 ¶344066.54**	**†‡§6860.00 ¶13720.00**	**†‡§5664.16 ¶11328.33**

CONCLUSION

With the continued implementation and development of temperature devices for mass surveying people prior to entering an area, this work aimed to add to the practical implementation research by presenting a short decision-making framework for selecting temperature measurement equipment for workplace entrance screening protocols.[4,9] The first consideration addressed the context of use. It highlighted seven key features (mode, operating range, storage conditions, resolution, measurement distance, accuracy and precision (i.e., reliability)) to determine device appropriateness and distinguished the need for what corresponding values have been deemed acceptable. The second consideration focused on calibration (emissivity, sensor sensitivity, and distance to target ratio) and the importance of ensuring that these devices are correctly selected to reduce measurement errors and ensure user confidence. Lastly, consideration for the cost of purchasing, use and maintenance was presented with a long-term outlook (5-years) to achieve a balance between affordability and device longevity. This outline not only prioritizes the health and wellbeing of employees by ensuring the context of use is appropriate but balances the cost of calibration, purchasing and supporting supplies to ensure long-term sustainability for the organization. This framework extends beyond the COVID-19 pandemic and is easily adaptable for implementing any new workplace technology, such as audiometers, dosimeters or heat stress monitors.

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