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# Non-Contact Fever Detection and What you Need to Know

If you are in charge of implementing a noncontact fever monitoring that doesn't require personal protective equipment, you need to know a few things first because more than half of vendors with fever solutions are offering systems that don't work. Fortunately, there is an ISO/IEC standard that does work and you can use a little knowledge of it to get rid of bad vendors. This brief will describe what works and what you should watch out for. The bottom lines:

- Most thermographic cameras will work (accuracy is limited by calibration source)
- The system MUST use a calibration source (no worse than 0.5C accuracy)
- IR forehead scanners have good accuracy but the forehead is not the most reliable area
- The area you scan in MUST be set up properly (indoors, no air blowing nearby, <10 feet)
- Ignore claims about AI, they mean nothing here and do nothing to help with accuracy
- The vendor should know the IEC standard or the science behind it

Below are more details, if you have any questions or concerns, or would like advice on fever detection, please reach out by phone, text or email. We have a non-contact fever detection solution coming in June that addresses all issues, including full automation, lower cost and better accuracy than systems currently on the market.

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**The Standard**

The standard[1] was developed in the wake of the 2003 SARS incident. It requires a properly functioning thermal imaging camera, an accurate calibration box and a controlled area to measure each person's temperature. The camera is the easiest part of the equation. Most (not all) manufacturers provide cameras with enough resolution, uniformity and stability to perform this task[2]. The room has to be at a reasonably comfortable ambient temperature and humidity, with no forced air blowing near any of the parts of the measurement, because it can throw off the measurement enough to miss a fever.

The calibration box, known as a blackbody[3] in the industry, is used to provide a temperature reference and is essential for accurate temperature measurement. Most thermal imaging cameras are really only accurate to within 2C (nearly 4F!), although some vendors are quoting sensitivity as accuracy, which isn't the case. A good camera should have a sensitivity as low as 0.05C. While a nice low sensitivity like that is a good thing, do NOT let that sensitivity fool you, it just describes how clean the image is from pixel-to-pixel, NOT the accuracy, a nice clean image will be off by as much as 2C and still "look" good. The accuracy we can get is completely dependent on the accuracy and stability of the calibration box, because we will be using it like a "standard candle" to correct that 2C accuracy down to the accuracy of the calibration box. If your calibration box is accurate to 0.3C, then the best accuracy is going to be somewhere worse

than 0.3C. There are other components that add to this, but we'll leave this with a recommendation that the quoted system accuracy should be below 0.5C.

For the measurement scene, the blackbody must be in view and the camera must be focused on both the person and blackbody at consistent distances, because there is a focus-effect that is different for every camera - this can add another 0.2C or worse, depending on the optical system.

It is essential to let the person's face warm (or cool) to ambient temperature at least a minute before the scan, longer if they were recently at a much colder or warmer temperature (up to two minutes). Your vendor should be able to provide customized guidance for your site. This is true for any noninvasive temperature method such as a forehead IR scanner.

The person's face and especially inner eye areas must be visible. If they're wearing glasses, they must remove them. The camera you're using must have enough resolution to resolve the inner eye regions; your vendor should set up the measurement area and make sure the boundaries are well-defined. If you repeat the measurement on the same person multiple times in a short period of time, the measurements should be within 0.5F of each other.

Finally, the vendor's equipment should adjust with the ambient temperature, so if you measure someone in a room at 65F, you should get the same results as if you measure that person in a room at 75F. Some vendors will fail that test by a degree or more, meaning their accuracy is a lot worse than they think it is. This is an easy way to weed out vendors that don't know what they're doing and are providing potentially dangerous feedback.

Once you start looking for solutions, you'll see a lot of vendors that don't bother with the blackbody and claim a sub-$20,000 camera can get better than 2C accuracy, which you should be skeptical of. You'll probably also see claims about AI-powered and so on, which should be tossed in the garbage, because AI cannot help with a bad measurement setup and isn't the important part here. You don't need to know all these details, but expect your vendor to know the standard or at least the science behind it and be able to justify how they deviate from it.

A quick side-note on close-in forehead temperature scanners. In general, the forehead is not as good as the inner eye areas, because the forehead varies more during the day. You can check this yourself with thermal camera images taken twice a day of the same person. These short-range forehead scanners are usually a single pixel and can be calibrated below 0.5C, so unlike thermographic cameras they can be used without a calibration source. However, these aren't as accurate due to that entire area being averaged into that single pixel.

Ultimately, none of the non-contact and skin contact (e.g. temporal artery scanner) methods are as reliable as the properly-administered clinical methods (e.g. clinical oral probes). The bottom line: if the non-contact method is set up properly, it is possible to get close enough to do actionable fever detection but your vendor has to know how to do it.

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**Footnotes:**

1. "IEC 80601 Part 2-59: Particular requirements for the basic safety and essential performance of screening thermographs for human febrile temperature screening" IEC 80601-2-59:2017, https://www.iso.org/standard/69346.html
2. Camera should have sensitivity around 0.05C (up to 0.2C) and accuracy of ±2C or 2%. Resolution depends on distance to target and how narrow the lens focus area is, but most cameras would need at least 160x120 pixels to work up to 2 feet away and need at least 320x240 to work up to 4 feet away from the person's face.
3. A perfect IR calibration box reflects no light, emitting only thermal light, and black means nonreflective, hence, a good calibration box is a "blackbody" in the thermal wavelengths.
4. Celsius into Fahrenheit, multiply by 9/5 and add 32. There's no way around it, you'll probably have to do this at least once when looking at what a vendor gives you.
5. "Best practices for standardized performance testing of infrared thermographs intended for fever screening", DOI: 10.1371/journal.pone.0203302, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0203302

**Examples of Bad Claims**

- Claiming 0.3C accuracy without a reference (blackbody)
    - Usually when a value below 2C is quoted, they're really referring to their relative sensitivity, which means, if you point it at a perfectly uniform temperature surface, how different might two adjacent pixels be? 0.3C sensitivity is actually pretty bad and images will look noisy. Real-life accuracy for the vast majority of sensors is rarely better than ±2C, while real-life sensitivity is often 0.05C or lower.
- Claiming AI will somehow solve for missing data
    - These seem to be out-of-the box object detectors for finding the face, which is not the hard problem here and does nothing to improve accuracy.
- "We've got FDA 510(k) premarket approval"
    - All 510(k) thermography filings are for ***relative*** temperature differences for things like blood flow abnormalities, ***NOT*** accurate temperatures. Furthermore, 510(k) is a relatively lenient and easy bar to clear for class II medical devices and only indicates the device in question is "as safe and as effective as a legally marketed device". Not whether it'll work. Be wary of vendors resting on this claim.
- Not specifying an operating range and accuracy across that range
    - The accuracy will be dependent on operating within the range the vendor has validated their equipment across, and in many cases they simply aren't doing this. The accuracy might also vary a little across this range, with worse accuracy at lower ambient temperatures. If they don't know what this means, be wary.
- Requiring non-cancellable and pay-in-advance orders
    - Coronavirus price-gouging, hoarding and advance-fee fraud is becoming common. These are scary times and you want to help your employees stay safe. Resist the temptation, only unscrupulous vendors would force product on their customers.

    - Check https://www.justice.gov/coronavirus for more information on coronavirus scammers.
- Claiming you can scan a crowd or from more than 5 feet away
    - It is possible, with sufficient resolution or a longer-distance lens, to scan people at distance, but most systems don't have the resolution to do this effectively.
    - For example, one vendor is promoting a camera with 320 pixels but a 90 degree field of view lens. At this very large field of view, the pixels will be so large you will not be able to scan someone (accurately enough to detect fever) from further than a foot and a half away from the camera. Their literature claims you can scan multiple people at a time in what looks like a large lobby or food court.
- Claiming you can scan someone instantly
    - Thermal cameras have a fairly long exposure window, and if someone is moving, the pixels of interest will smear with cooler pixels, falsely reducing the temperature measured.

**Specs You Should Require**

- Thermal camera with ***sensitivity*** lower than 0.15C and:
    - if using a blackbody reference source, camera accuracy no worse than ±3C
    - if NOT using a blackbody, camera accuracy better than 0.7C (these are very expensive and uncommon)
- Blackbody with better than 0.2C uniformity and better than 0.5C accuracy and better than 0.2C stability (less is better)
    - The emissivity of the blackbody should be known to the vendor, ask them! Expect at least 0.95, ideally 0.98, but it is not essential that it be exactly 0.98.
- Resolution of at least 160x120 pixels for up to 2 feet and 320x240 for up to 4 feet distance from face with a moderate field of view lens OR a very narrow field of view lens may be acceptable with lower resolution or longer distances provided your vendor lays out specific distance guidelines
- Overall body temperature measurement better than ±1C (overall system accuracy)
    - ±1C is sufficient to detect a 100.4F temperature
    - Claims of lower accuracy such as 0.7C or lower are simply not realistic
    - Vendors are quoting accuracy only for surface temperature accuracy, which is NOT the same as overall body temperature accuracy. For a rule of thumb, add 0.5C to any quoted accuracy if they don't specify different accuracies for body temperature and system accuracy.

**Example error budget**

Assume you have a 0.05C sensitivity camera with 2% accuracy (this is relevant for the reference correction, for which we'll assume at most a 3C difference, or 0.06C offset correction uncertainty), a 0.1C accurate blackbody with 0.01C stability, 98% emissivity and 0.05C uniformity. What is the total system performance?

These components only contribute 0.14C to the error budget, and we could call this the "system accuracy" - it sounds good but we're not done. There's an error we haven't talked about

yet, which is that due to the physiologic-to-ambient correction. Assume this is 0.6C when ambient temperature is above 20C (68F) and as high as 1C when ambient temperature is as low as 15C (59F). The actual value is dependent on how the vendor got their correction (we'll go easy and assume 0.6C). If they only validated it between 18C and 22C, be wary of trusting it outside that range. There is a further error for a distance-dependent (an effect of the focus setting and depth of field) reduction if the person is standing further from the system. This depends on the optics and every camera will be different, but here we'll assume this error is another 0.2C. Double that if your vendor doesn't give you an exact distance (within a few inches) for the blackbody distance (so we'll assume 0.4C). Total core body temperature error is 0.74C, within our specifications for detecting 100.4F fevers. For comparison, a typical forehead IR scanner likely has a system accuracy of 0.5C, but adding in the physiologic correction plus the variability in the forehead region and it is unlikely their actual core body temperature accuracy is better than 1C. This is good enough to detect most fevers but at a cost of false positives.

However, we need to be aware that very few vendors are going to come even close. Blackbodies with better than 0.5C overall performance are hard to make and expensive. They do exist, but expect to spend several thousand dollars. More likely, expect a greater source of error from the blackbody than that given above, due to lower-spec system and due to deviations from real-world conditions. The camera is much easier to come by, many thermography cameras are sufficient for this purpose. The worst source of error is likely to be the physiologic correction (and some vendors might be ignoring ambient temperature). The easiest way to tell if your vendor is ignoring ambient is to test their system in a 68F room and again in a 77F room (or rooms with any 9 degree difference). Measure at least 3 people 3 times each in both conditions, making sure each person waits in the room for at least 2 minutes to normalize to that temperature. That average difference should be less than 0.5C. It's also possible the vendor is using a "regression to the mean" smoothing algorithm (e.g. smoothing the value the system gives with an average, e.g. 98.6F), but this is harder to detect even with comparison to oral thermometry - oral thermometry is unlikely to reveal anything is wrong with one of those systems because most of your sample of people will have core body temperatures close to 98.6F. A box reporting 98.6F every time will appear remarkably accurate when compared to oral thermometry/