REF LIGHTS

User Manual

(Wireless Version)

Contents

Part 1: General Operation

This part of the document provides information to get you set up and running the wireless or the cabled version of Ref Lights at a competition using either the cable-connected or the wireless system.

Part 2: Wireless Operation deals exclusively with the wireless system, gives an overview of how the devices communicate with each other and provides some help with troubleshooting.

General Description

Ref Lights is an easy-to-use system designed to signal referees' decisions in powerlifting or weightlifting events. White 'Good-lift' and red 'No-lift' lights are displayed on a video screen attached to a laptop/PC. The system comprises three ref boxes (for the Left, Centre and Right Referees), a controller box and an HTML file containing a JavaScript program that presents the lights and a countdown clock in a standard browser running on a Windows based PC or laptop. A video monitor or TV will also be needed to display the lights in a location visible to the lifters, officials and the audience.

Pushbuttons on the ref boxes send signals to the controller box either wirelessly or through cables. The controller box sends these signals to the computer through a standard USB port.

You can purchase the wireless version or send me an email if you would like a copy of my guidelines for making your own cable-connected version.

DIY Cable-connected Ref Lights system
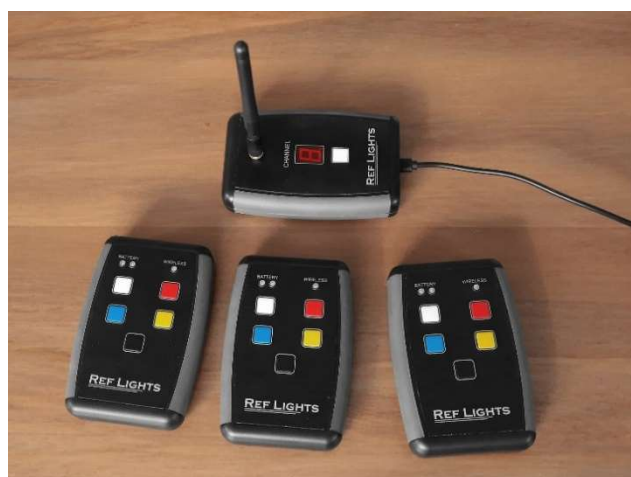
Wireless Ref Lights system

Ref Lights also has an on-screen countdown clock that can be used to show the time remaining for the current lifter to commence their lift. You can also use it to count down time remaining in session breaks during a competition. Smaller timers are also provided to help lifters and the competition timekeeper by displaying the time remaining for lifters to submit their next attempts to the desk.

The computer software is in a JavaScript/HTML file that runs in a Chrome, Firefox or Microsoft Edge web browser. The code is therefore accessible to the user and can be customised by someone with knowledge of JavaScript.

Always use the latest version of the HTML file, which is available for download on the web page: https://weighttraining.nz/ref-lights. Please report any bugs you find in the program so I can fix them promptly.

For powerlifting, Ref Lights can display the coloured infraction cards used by the International Powerlifting Federation (IPF). When the system is run in IPF mode, the cards appear below each 'no-lift' light. The ref boxes have white, red, blue and yellow buttons for use in this mode. When not in IPF mode, only the red and white buttons are used to signal decisions.

A small green spot appears in place of each light when a referee makes their decision. Once all three decisions have been signalled, the three lights will appear. The spots provide confirmation to the referees that the system has received their button presses. They also show when a ref may have forgotten to press their decision button, or when a button may have been pressed by accident.

Ref Lights is optimized to run on a screen with a 16:9 aspect ratio and a resolution of 1920 x 1080 pixels.

As well as the referees' pushbuttons, keys on the computer keyboard can also be used for certain functions as explained in the Lights Operation section of this document. See also: Summary of Keyboard Functions

Components

Essential items:

- Three referee boxes and a controller box ('Ref Lights')
- The Ref Lights HTML file
- Laptop/PC running Windows 10 (or higher) with keyboard, mouse and an available USB port
- An up-to-date version of the Chrome, Firefox or Microsoft Edge browser installed on the PC
- Driver program for the controller box
- A suitable external display screen, TV or projector

Although you can run Ref Lights on-line from the internet in your computer's browser, it's highly recommended that you download the HTML file to your computer or a USB memory stick and run it 'off-line'.

Optional:

- The supporting files in the compressed package **ref-lights.zip**
- Sound system to amplify the countdown timer warning buzzers.

The compressed file package contains sample warning buzzer sound files for the countdown timer, a sample banner file and a sample file for a customised lights shape. Users can replace any of these files with their own but must use the same file names. A banner file is used to display a static image on the screen, for example, a club logo before the competition starts or during session breaks. Two different banner files can be loaded and displayed at different times.

Setting Up for the First Time

Installing the Files on the PC/Laptop

Open your browser, go to the Downloads section of the Ref Lights web page https://weighttraining.nz/ref-lights and download the HTML file (**ref-lights.html**) and the zipped file package (**ref-lights.zip**). The files in the zip package are:

- **warning.mp3**   (lift countdown warning buzzer sound)
- **timeout.mp3**   (lift countdown time expired buzzer sound)
- **banner.jpg**   (the sample banner file)
- **custom.png**   (the sample customized lights file)

Extract the files in the zip to a folder in your file system (or a USB stick). *Make sure the extracted files are put in the same location as the HTML file*.

The only essential file is **ref-lights.html**. (Optionally, you can run Ref Lights online from https://weighttraining.nz/ref-lights/ref-lights.html without having to download any files.)

Installing the Driver Program on the PC/Laptop

When you plug the controller into a given computer for the first time, a driver program may need to be installed on the computer. Make sure you have an internet connection at this time so the computer can check for driver updates. Once the driver has installed (you should see a message), unplug the controller and plug it in again. You may also need to restart the PC before the driver will work.

Relaying to an External Monitor

Several methods can be used to relay the screen displayed on the PC/Laptop to an external screen for viewing by the lifters, referees and the audience. Only two will be mentioned here, each with its own pros and cons.:

- Video monitor or TV connected to the PC/Laptop by an HDMI cable and used with the second screen function available on most modern PCs or laptops.
- Running Ref Lights in a Chrome browser and using Google's Chromecast technology to relay the screen to an external TV which either has an inbuilt Chrome casting function, or a Google Chromecast dongle plugged into one of its HDMI inputs.

Direct connection between the PC/Laptop and the external monitor via an HDMI cable has the advantage of not being reliant on the Internet and a local WiFi network for use and being able to drive more than one external monitor by using an HDMI splitter. The only disadvantage is that it requires sometimes quite lengthy HDMI cable(s) for interconnecting the devices. In my experience, this is the most used and a well-proven method of driving external monitors at lifting meets. The procedure for enabling and configuring a second screen can differ between computers, so you may need to consult your PC/Laptop documentation to find out how to do it.

Alternatively, the fewer cables on the floor around where heavy weights are being lifted – the better, and Chromecast has the advantage of not requiring an HDMI cable connected between the PC/laptop and the external monitor. However, it does require access to a reliable, local WiFi network with internet access at the site. Chromecast dongles are inexpensive and readily available so, if the TV doesn't have an inbuilt Chrome cast function, purchasing one shouldn't be a problem.

To the best of my knowledge, casting is also limited to one device at a time, so if you want more than one external monitor, you're going to have to get the HDMI cables out to interconnect them!

Finally, an issue has been reported with attempting to Chrome cast Ref Lights in some situations. Hopefully this has been resolved in version 4.3.4 of the HTML file. Feedback on any problems experienced with Chrome casting would be greatly appreciated.

At the Start of Every Use

- <u>For the wireless version:</u> Make sure the supplied antenna is fully screwed into the socket on top of the controller, the USB lead and plug are not damaged and the batteries in the ref boxes have been charged with the supplied charger.
  <u>For the cabled version:</u> Plug each of the ref box cables into one of the sockets on the controller and, if provided, use the screw rings to secure the plugs. The box with the BLACK button is intended for the Centre Ref.
- Plug the controller into a USB port on the computer.
- <u>On the wireless controller,</u> check that the channel indicator lights up and shows a number from 1 to 6. <u>On the cabled controller,</u> use the small inspection hole located at one end to confirm that the red LED inside is lit.

Open the browser and navigate to Ref Lights (either via the online link, or the ref-lights.html file that you downloaded). Bookmarking the location is handy!

The browser should now display a message indicating that a Ref Lights controller has been detected and (for the wireless version) it may also display the firmware version installed in the controller.

Immediately under that message you should see the prompt:

Press LEFT referee's WHITE button …

If, instead, you see this message:

**Ref Lights requires an up-to-date Chrome, Firefox or Microsoft Edge browser.
Referee lights controller not found**

either you're using an incompatible browser, or the PC isn't communicating properly with the lights controller. Check that you're using an up-to-date version of Chrome, Firefox or Edge, that the USB cable is plugged in firmly and then reload the page (**Ctrl+F5**). If these don't solve the problem, there may be a fault with the controller or the USB cable.

Powering on the Referee Boxes (required only for Wireless Version)

Switch a ref box on and wait a few seconds for it to boot up. Once the blue WIRELESS LED has stopped flashing it means the ref box has searched for and found which channel the controller is using and is ready to use.

While a ref box is powered on, the two BATTERY LEDs continually indicate the state of the battery as follows:

- Green LED flashes about once every seven seconds: The battery is good.
- Green and red LEDs flash alternately: The battery is partly discharged and should be charged at the end of the current day's use.
- Red LED flashes rapidly: The battery must be recharged, and the ref box functions have been disabled.

(Some models have an amber-green LED in place of the green one.)

Switch on the other ref boxes and check that they behave in a similar way. With the HTML page, the controller and the three ref boxes now all communicating with one another, you're ready to consider how you want to configure Ref Lights to operate. Don't switch more than one ref box on at a time as this may a clash of wireless signals.

Don't forget to switch the ref boxes off after use!

Configuring the Options

You must now tell Ref Lights in which position each of the ref boxes will be located.

At the prompt:

Press LEFT referee's WHITE button …

Press the white button on the box to be used by the Left Ref for this session. You'll then see the prompt:

Press RIGHT referee's RED button

Press the red button on the Right Ref's box. The system now knows which box will be used in each position and displays the "Configuration Selection" screen, where you select the various configuration options you want to use for the session. The on-screen descriptions of each option are mostly self-explanatory, but note the following:

The black buttons on the ref boxes are the 'Clear' buttons. They're used to clear green spots or lights from the screen.

In addition to the clear function, you can select an option that allows the Centre Ref's black button to also function as the start button for a 1-minute lift countdown. With this option selected, priority is given to the button's "clear" function when one or more spots, or the lights, are showing on the screen.

Saving configuration selections as your favourite is covered in a later section.

Assuming you're not going to save a favourite configuration at this point, click on the "Use this configuration" button. The screen will then clear and the browser will switch to full-screen mode, ready for you to start using the lights.

Lights Operation

Once you've clicked "Use this configuration" and the browser is in full-screen mode, operating the lights is simple:

- Each ref presses a button to signal their decision on a lift (WHITE, RED, BLUE or YELLOW when configured for IPF mode, otherwise WHITE or RED). As each ref makes their decision a green spot will appear on screen in the corresponding position. Once all three refs have signalled their decisions, any time showing on the lift countdown clock (see later) will automatically clear and the lights will show. You can also choose to have a short delay before the lights appear.
- Right up until when the lights appear, any ref can press another button to change their decision.
- A *Side* Ref's BLACK button clears a spot showing for that ref only. (Effectively cancelling their decision or clearing an accidental key press.)
- The *Centre* Ref's BLACK button clears *all spots or lights* on the screen. They can also be cleared from the keyboard.

Keyboard

A large countdown clock in the centre of the screen can be used to indicate the time within which the current lifter must commence their lift, or to time a session break. Countdowns can be set in 1-minute increments.

Keys used to operate the countdown clock:

- **Numeric keys:** These start a countdown for the corresponding number of minutes. So, pressing **1** starts a 1-min countdown. A *Lift* countdown can be set for between 1 and 5 mins. *Lift* countdowns are automatically cleared from the screen once all three refs have pressed a decision button.

  Countdowns of 10 to 30 minutes can be set for timing longer periods, such as *session breaks.* For example, press **2** immediately followed by **0** to start a 20-minute countdown. Unlike a shorter *lift* countdown, the *session break* countdown clock is unaffected by pressing buttons on the ref boxes.
- **Zero:** Pressing the zero key cancels the current *lift* or *session* countdown – unless it was immediately preceded by a **1**, **2** or **3** key press to start a 10-, 20- or 30-minute *session* countdown.
- **Spacebar:** This pauses/resumes a *lift* countdown. The clock display turns grey when paused. In typical operation, the timekeeper would pause the clock when a lifter commences their lift, leaving the time at which the lift commenced visible for the referees and timekeeper until the lights appear. You can't pause a *session break* clock – it continues until it times out or until **0** is pressed.
- **+ and – keys:** These keys add or subtract a minute on the fly while a *lift* countdown is in progress. They're primarily intended for quickly correcting errors made by the timekeeper.

Keys used for other functions:

- **Backspace**, **Delete** or **End:** (Clear keys) Pressing any of these keys allows the timekeeper to clear all spots or lights from the screen in the same manner as the BLACK button on the Centre Referee's box.

- **B and Shift+B:** (Banners) These toggle the display of a banner image (for example, to show a club logo before a competition or during session breaks).

  A banner can only be displayed in full-screen mode and with no *lift* countdown in progress. The banner is dimmed if a *session break* timer is running to make the countdown easier to read.

  To use your own banner, replace the sample banner file with a JPG file with the name **banner.jpg**. The image will fill the full height of the screen, regardless of its width. Press **B** to display this banner.

You can use a second banner, with the file name **shift-banner.jpg**. Press **Shift+B** to display this banner. Only one banner can be displayed at a time! Pressing either **B** or **Shift+B** hides whichever banner is currently being displayed.

- **H:** (History) This shows a summary of the 15 most recent decisions made since Ref Lights was last started. You can toggle the history on and off only in full-screen mode while no spots or lights are showing. The details displayed for each decision are: Date and time of decision, colours of left, centre and right lights/cards and the time remaining on the lift countdown clock when the lights appeared.
  Any banner or clock running will be temporarily hidden while the history is displayed.

- **Esc:** The escape key exits full-screen mode and returns to the configuration menu.

Additional Notes

- Unlike some referee lights systems, Ref Lights will accept lift decisions at any time while the browser is in full-screen mode and the lights are not already showing. There is no action required to signal when the system should start recognizing referee button presses.

- **'Ref decisions pending':** This message appears on the screen if all three refs fail to signal a decision within 8 seconds of each other or if, say, a ref box malfunctions, and the system can't record that referee's decision. The message will clear once the controller box has received a decision from all three refs.
  If the message arises from a referee accidentally pressing a button at some random time, either that ref or the Centre Ref should clear it with their BLACK button, or the timekeeper can do so using the **Backspace**, **Delete** or **End** key.

  It's important to clear this message from the screen well before the next lift commences. This avoids any decisions that may still be held in the system from the previous lift from being counted for the next lift! This is a consequence of using a system that will accept ref button presses at any time throughout a session.

- **Lift countdown warnings:** At a time specified in the options, the *lift* countdown clock turns orange, and a buzzer sounds to warn that time is running out. The clock turns red, and another buzzer sounds when time expires. If not cleared beforehand, the clock automatically clears shortly after timing out.

- **Light shape:** Round or square lights can be selected in the options. It's also possible to use an image file to customise the shape of the lights or cause a silhouette or 'watermark' to appear in them. This feature was incorporated following a request from a user! Instructions for creating and using a custom file are in a separate pdf on the web site. The zip file package also contains a sample custom image file.

- **Centre Ref starts lift countdown:** This option allows the Centre Referee to use their BLACK Clear button to also start a *lift* countdown after calling 'Bar loaded.'

  When this option is enabled, the BLACK button functions as usual to clear any spots or lights showing but, if no spots or lights are showing, it starts a **1-minute** *lift* countdown clock. For *lift* countdowns longer than a minute, or for corrections to the time, the keyboard must be used. Pressing the BLACK button again once the timer is running will just restart the 1-minute clock.

- **Lift submission countdowns:** An option allows **1-minute** timers to be displayed at the bottom of the screen to show the time remaining for lifters to submit their next attempt to the desk. When enabled, the timers run automatically: As soon as the decision lights appear for a lift, a 1-minute submission countdown clock appears at bottom-centre screen. On expiry, the clock display turns red and clears from the screen shortly afterwards. If a lifter completes their lift before the previous lifter's submission timer has cleared, the first clock display shifts to the right and a new one starts in the centre for the current lifter. Up to three timers can display concurrently - corresponding to the three most recent lifts.

Changing Options During a Session

Press the **Esc** key to exit full-screen mode and return to the configuration screens. Any countdown clocks will continue to run, but lights will be cleared when exiting full-screen mode.

Saving a Favourite Configuration

If you run Ref Lights *offline* you can save your favourite configuration in a file. With a favourite configuration file in place, the next time you load/reload the Ref Lights HTML file, you'll get the choice of using your favourite configuration or selecting a new one. The file must have the name **ref-lights.config** and must be in the same location as all your other Ref Lights files.

Here's how to create the file:

1. On the "Configuration Selection" screen, select the options you want to save as your favourites.
2. *There's a note at the bottom of the screen reminding you of the location and name the file must have.*
3. Click the "Save as favourite" button and, depending on your browser's Download settings, you'll either be able to choose a location and file name in a 'Save As' dialogue box, or the file may just be written directly to your browser's Download location.
4. If a 'Save As' dialogue box opens, make sure you select the correct location and file name before you save it.
   If no dialogue box appears, you'll have to look for the file in your browser's Download folder and move it to the correct location.

It's the same procedure if you're replacing an existing favourite configuration, except that Windows will remind you that you're about to replace a file.

The favourite configuration feature is not available when you run Ref Lights *online*. However, if your browser has cookies enabled, it stores your *online* configuration in a cookie. If the cookie is there next time you run Ref Lights *online* with the same browser and machine, the "Configuration Selection" screen will show with your last-used options already selected.

Summary of Referee Button Functions

Button Colour	Function
White	Signals a Good Lift.
Red	Signals 'No Lift'. **In IPF mode:** Signals 'No Lift' due to a red-carded infraction of IPF rules.
Blue	**In IPF mode only:** Signals 'No Lift' due to a blue-carded infraction of IPF rules.
Yellow	**In IPF mode only:** Signals 'No Lift' due to a yellow-carded infraction of IPF rules.
Black (Centre Ref)	Immediately clears the lights or any placeholder green spots showing on the screen. (Same function as the **Delete**, **Backspace** or **End** keys on the keyboard.) **With option selected:** The button can also start a 1-minute lift countdown clock. (No lights or green spots must be showing on the screen when using this function.)
Black (Side Ref)	Clears only that referee's placeholder green spot from the screen.

Summary of Keyboard Functions

Key(s)	Function – General
S	Starts simulation when HTML page is first loaded or reloaded in the browser. There must be no Ref Lights controller plugged into the computer.
Esc	Exits full-screen mode, returning user to the Configuration screen.
1, 2, 3, 4, 5	Starts the lift countdown clock for the corresponding number of minutes.
0, 1, 2, 3, 4, 5, 6, 7, 8, 9	Start a session break countdown of 10 to 30min when pressed straight after **1**, **2** or **3**.
0	Clears a currently running countdown clock.
+	Adds 1 minute to a lift countdown clock while it's running, to a maximum of 4:59s.
-	Subtracts 1 minute from a lift countdown clock while running, to a minimum of 1s.
spacebar	Pauses a running lift countdown clock. Resumes a paused lift countdown clock.
Delete, Backspace, End	Use any of these keys to clear any green spots or lights that are showing on the screen.
H	Toggles display of the 15 most recent lift decisions on or off.
B	Turns on display of the banner.jpg file. Turns off display of either banner file.
Shift+B	Turns on display of the shift-banner.jpg file. Turns off display of either banner file.

Simulation Mode

Starting from version 4.0 of the HTML file, you can simulate the operation of Ref Lights without needing the referee boxes and controller – a handy feature for learning how to use Ref Lights. Keys take the place of the buttons on the three ref boxes as indicated in the photo.
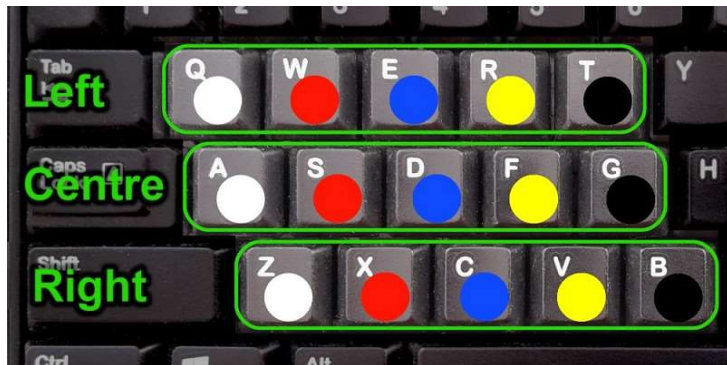
To run Ref Lights in Simulation mode:

- Make sure no controller is plugged in.
- Open the HTML file in your browser.
- When **Referee lights controller not found** appears, press the **S** key.

You'll see on-screen prompts to remind you which key represents each ref's pushbutton.

In all other respects Ref Lights will behave exactly as when using ref boxes and a controller.

Ref Lights remains in Simulation mode until you exit from or reload the HTML file.

| Keys	Function in Simulation Mode
Q, W E, R, T	Act, respectively, as the Left Ref's White, Red, Blue, Yellow and Black buttons.
A, S, D, F, G	Act, respectively, as the Centre Ref's White, Red, Blue, Yellow and Black buttons.
Z, X, C, V, B	Act, respectively, as the Right Ref's White, Red, Blue, Yellow and Black buttons.

Sample Screenshots
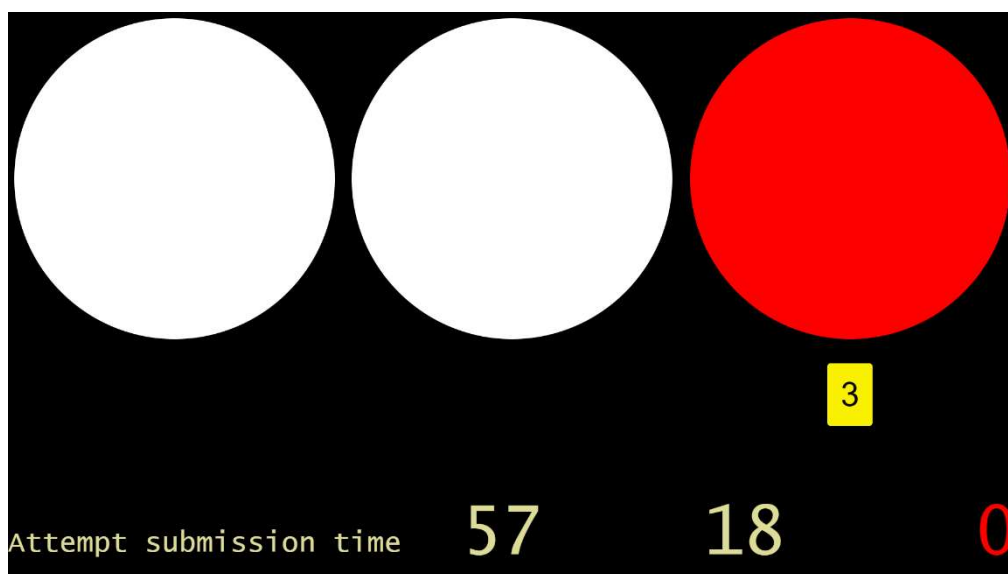
This indicates a good lift (two-to-one majority). IPF cards are in use and the Right Ref gave the lift a yellow card. The lights appeared just 3s ago, so the lifter has 57s to submit their next attempt, the previous lifter has 18s to have submitted their next attempt and the attempt submission time for the lifter before that has expired.

The timekeeper paused the lift countdown (clock grey) at 44s when the current lifter commenced their lift. The Centre and Right Ref's have signalled decisions, but the clock won't clear and the lights won't show, until the Left Ref also signals a decision. The previous lifter has 18 seconds left to submit their next attempt to the desk.
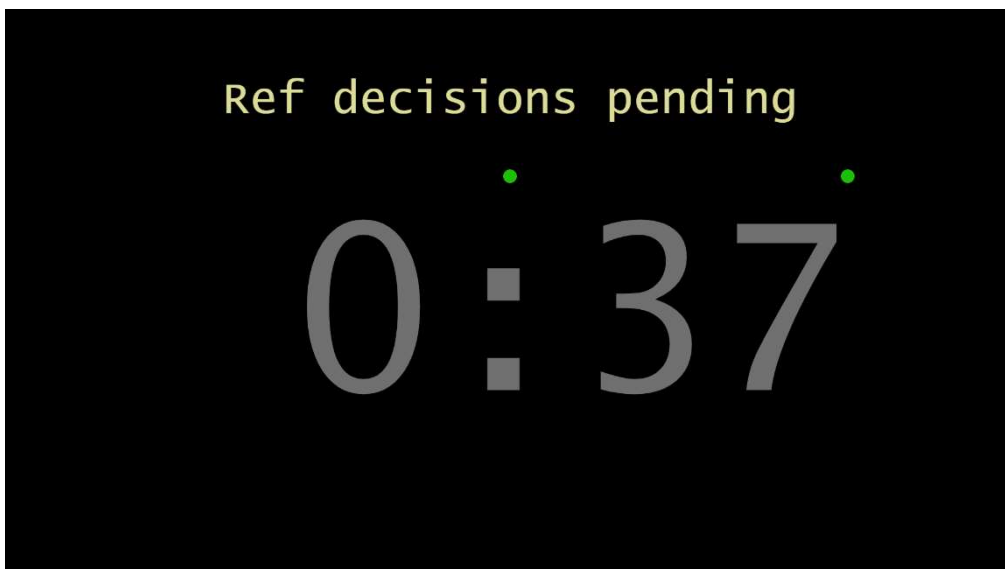

Two refs made decisions, but the Left Ref's box was turned off and the delay caused the warning to show. It's important to clear this before the next lift because, for example, if the Left Ref is first to signal a decision for that lift, the system will have decisions for all three positions and *the lights will show a mix of decisions for that and the previous lift*.

Most recent decisions:
Date	Time			Result
14 Nov	10:32:53	🟨🟨		0:10
14 Nov	10:31:44	⬜⬜⬜		0:34
14 Nov	10:30:19	🟦🟦🟦		0:42
14 Nov	10:29:13	⬜⬜⬜		0:38
14 Nov	10:28:23	🟥⬜⬜		0:41
14 Nov	10:26:59	⬜⬜⬜		0:33
14 Nov	10:25:30	⬜⬜⬜		0:17
14 Nov	10:23:46	⬜⬜⬜		0:46
14 Nov	10:21:22	🟥🟥🟥		0:35
14 Nov	10:19:58	⬜🟨⬜		0:39
14 Nov	10:19:12	⬜⬜⬜		0:42
14 Nov	10:18:07	⬜⬜⬜		0:28
14 Nov	10:16:48	⬜⬜⬜		0:41
14 Nov	10:14:51	🟥🟥🟥		0:03
14 Nov	10:13:19	🟥🟥🟥		0:32

Attempt submission time   29   0

History has been toggled on to review the 15 most recent lifts.

A banner image has been toggled on. Because the session break countdown is also being displayed, the banner is dimmed to make the clock easier to read.
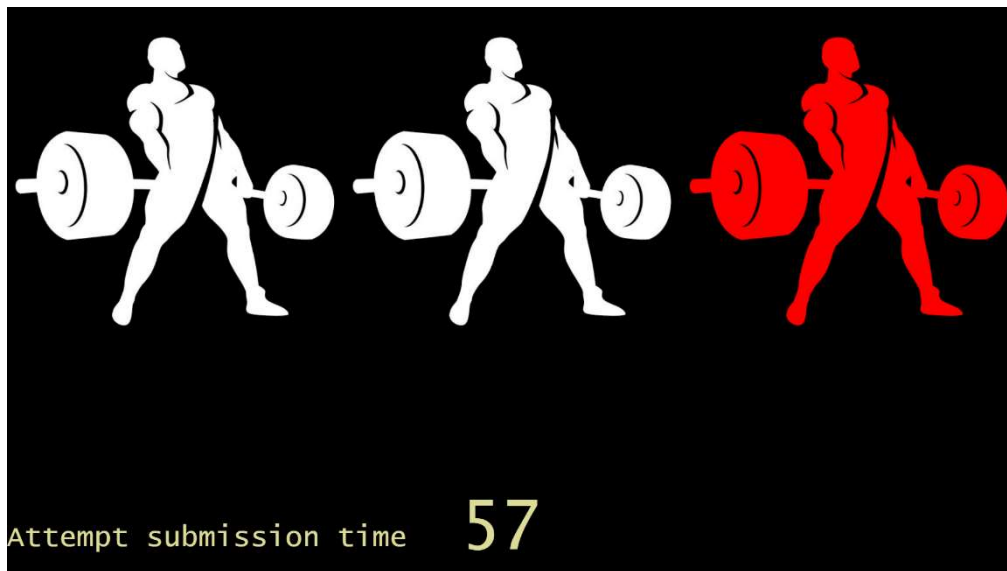
Here are two examples of a custom image file being used to change the lights' appearance.

On the left, the outline of the lights has been completely changed; while a watermark effect has been created in the lower example.
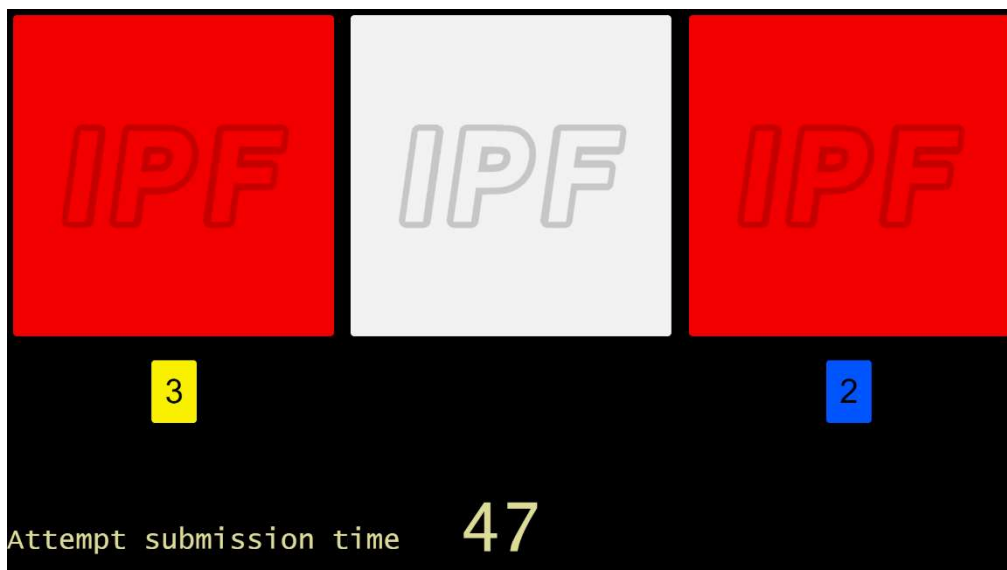
Part 2: Wireless Operation

The information in this part applies from version 19 controller and ref box firmware installed in devices sold after November 2022, although most of it also applies to earlier versions. Version 19 introduced power-saving on the ref boxes, providing improved battery life and a greater usable distance between controller and ref boxes.

Two-way Wireless Communication

A wireless transceiver in the controller and each referee box is used to both send and receive signals.

The system has six channels, numbered 1 to 6. The channel in use shows on the controller's red LED display and is manually selected using the white button beneath the display. The controller always starts up on the channel that was in use when it was last powered down. Try using a different channel if you suspect radio interference is causing trouble at a site.

Synchronising Ref Boxes to the Controller Channel

Always power the controller on *before* the ref boxes.

The ref boxes must use the same channel as the controller. When you switch on a ref box it sends a signal out on each channel in turn, starting from channel 1, until it hits the channel that the controller is listening on and receives a response back from the controller. The blue Wireless LED on the ref box flashes once for each channel it tries. So if the controller is powered up and on channel 3, the Wireless LED flashes three times before discovering the controller. Once the LED stops flashing the ref box is ready to use.

Changing the channel during a session may cause a delay in responding to a button press, while the box searches for the new channel. The delay only occurs with the first button press on each box following the channel change. The delay may be up to about three seconds and the Wireless LED will flash while the channels are being searched. See also *Power Saving Mode*.

At start-up, and during use in general, a communication problem between the controller and a ref box is indicated by a continuous flashing of the box's Wireless LED . A few flashes after a button press are normal behaviour; non-stop flashing is a sign that something's wrong. When this happens try: (1) pressing a button, or (2) re-booting the ref box. Either of these actions will force the box to search all the channels for the controller. For more help with problems, refer to the sections: *Factors Affecting Wireless Reception* **and** *Troubleshooting*.

Overview of The Wireless Protocol

A high-level understanding of how the controller and ref boxes communicate and knowing how to 'read' the LEDs may help you to identify and resolve a communications issue.

The Communication LEDs

Two LEDs signal communication events:

- The blue Wireless LED on a ref box, and
- The decimal point on the controller's channel display.

Generally, these LEDs flash once each time the device *sends* a wireless message: For example, when you press a ref box button, the box sends a 'button pressed' message to the controller and its Wireless LED flashes. The decimal point on the controller also flashes a fraction of a second later. This shows that the controller received and understood the "Button pressed" message and sent back an acknowledgement message to the ref box.

Message Resending

Ref boxes are programmed to send a 'button pressed' message up to three times when they don't receive an acknowledgement. If, after three tries, an acknowledgement still hasn't been received, the message is sent again over each of the other channels. So if the controller channel was changed without the ref box's knowledge, it takes a little longer before the controller finally sees the button-press message and can acknowledge it. Once an acknowledgement has been received, the ref box is on the new channel, and everything is back to normal again.

Finally, if a ref box still hasn't received an acknowledgement after sending the message over all six channels, it will stop trying and its Wireless LED starts flashing continuously to indicate that it's lost contact with the controller. This happens, for example, if the controller has been unplugged from the USB.

Try the following to see this sequence play out:

- Plug the controller into a USB, switch on a ref box and wait for it to find the controller channel.
- Now unplug the controller and watch the Wireless LED on the box when you press a button.

You should see the Wireless LED flash rapidly three times (once for each try) then pause briefly before flashing a further five times while it tries each of the other channels. After receiving no acknowledgement from the controller, it gives up and the LED starts flashing continuously.

Time Sharing and Clock Syncing

Messages between ref boxes and controller are sent on a time-sharing basis. Time is divided into a repeating sequence of four slots – each of the four slots being allocated for use exclusively by one of the four devices: (controller plus three ref boxes). So if two refs happened to press buttons at the same moment, their boxes would each have to wait for their next allocated time slot before sending a 'button pressed' message. This ensures that messages are not sent at the same time or so close that they overlap and are not understood by the receiving device.

The 4-slot time sequence repeats every 250ms (¼ second). So the delay between when a ref presses a button and when the box is allowed to send the message varies between about zero and 250ms, depending on when, in the time-slot cycle, the button happens to be pressed. It takes a little extra time for the message to be transmitted, received and interpreted by the controller and for the controller to pass the message on to the PC. A further short delay will usually be involved as explained in the next section: *Power Saving Mode*. The combined effect of all these factors is an overall delay of less than half a second, which is barely noticeable.

Time sharing requires the 'clocks' used by each device to be in sync. To keep the ref box clocks in sync with the controller, the controller sends them a time synchronising message every 70 seconds. When they receive this, they set their clocks back to zero, so the clocks never have much time to drift too far apart before being reset back to zero again. If you keep an eye on the decimal point on the controller display, you'll see it flash each time a sync message is sent.

Apart from regular sync messages sent every 70 seconds, when the controller detects that a ref box has just been started up, it sends a special 'ad hoc' sync message to that box. So, rather than potentially having to wait up to 70s after a ref box is switched on before it receives its first regular sync message and can start communicating correctly, it's synchronized and can be used as soon as it receives the ad hoc sync message.

So, in summary, there are six main message types that Ref Lights uses for communication:

- 'Hello controller': Sent by a ref box when it's searching to find the controller channel.
- 'Hello ref box': Sent by the controller in response to the Hello controller message.
- 'Ad hoc sync': Sent by the controller to sync a ref box clock shortly after it's powered on.
- 'Regular sync': Sent by the controller every 70s to keep the ref boxes in sync.
- 'Button pressed': Sent by ref boxes to tell the controller that a Ref has pressed a button.
- 'Button press ack': Send by the controller to acknowledge receipt of a 'button pressed' message.

Power Saving Mode

Because the system only needs to send short messages, very occasionally, the wireless transceivers spend most of the time doing nothing. The wireless protocol design was changed in firmware version 19 – the main change being to keep the ref box transceivers asleep for much of the time to save power. Not surprisingly, while they're asleep they can't transmit or receive signals! This has some advantages and minor disadvantages.

On the plus side:

- The short times that the transceiver is awake made it practicable to use a wireless mode that, although drawing more current from the battery when awake, actually reduces the average current that the boxes use. This gives approximately 50% longer battery life between charges.
- In most situations, the useable distance between controller and ref boxes will be greater than it was with earlier versions.

The minuses are:

- It takes slightly longer to respond to a button press – because of the extra time required to wake up the transceiver before the messages can be exchanged.
- While the ref box transceivers are asleep, they'll miss any wireless messages sent to them. In particular, a message that the controller sends when it's about to change channel won't be seen (unless it happens to be sent when a box's transceiver is awake.

The last point explains why, following a channel change, the next ref box button press may not be acted on for up to about 3 seconds: the ref box is caught by surprise by the change of channel and must go searching for the new channel in use.

> The one-time delay caused by a channel change probably won't be too concerning for most users. However, the delay can be minimised by only incrementing the channel by one step: Press the channel button on the controller *once* and give the new channel a try before deciding whether you need to move to the next one.

Factors Affecting Wireless Reception

Factors include:

- Obstructions that absorb or deflect radio frequency energy in the path and surroundings between ref boxes and the controller. Examples: walls, large metal objects, referee's body!
- Unintentional or deliberate man-made RFI (radio frequency interference).
  Examples: nearby electrical/electronic equipment, communications/remote-control equipment or (more rarely) someone deliberately using wireless equipment to cause interference.
- Wireless signals out-of-range: The ref box and controller are too far apart for reliable message reception. All systems with version 19 firmware have been tested to work reliably at a controller-to-Ref-box distance of approximately 20 - 25 metres, but this may be reduced at some sites.

Be mindful of these factors when deciding where to place the controller. Major obstructions won't usually be an issue in the immediate area of the lifting platform and the competition desk (on which the controller is usually set up) but don't put the controller close to computers, sound systems, stage lighting controls, etc., or large metal objects. Keep it well above the floor, with the folding antenna pointed upwards and, if possible, visible to the referees.

It's wise to test the lights system before a competition/session begins – if possible, with the people who are going to use it.

If one ref box is causing a problem, check how it's being using.

- Wrapping a hand over the top-right corner of the box by the Wireless LED may degrade wireless performance as the transceiver's antenna is located directly behind the LED.
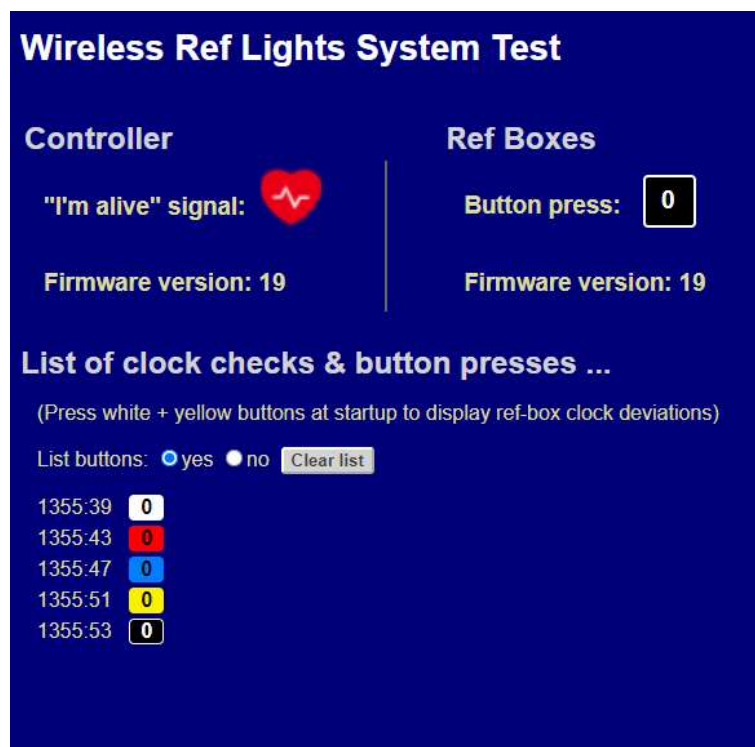
- Don't hold the box right against your body or other objects. (e.g. between your thighs, under a metal chair or in your pocket.) If that's not the cause, try swapping the boxes around then reload the ref-lights.html page on the browser (**Ctrl+F5**). If the problem moves to the new position of the box, the problem is most likely related to the box itself rather than where and how it was used. Finally, it may help if the affected box is used by the referee who's seated closest to the controller.

If RFI is disrupting wireless communication, even after having taken the precautions in this section and trying all the channels, there's nothing more you can do. Occasional short bursts of interference are tolerable but if it's persistent you're going to have to resort to using flags.

Online Testing Utility

https://weighttraining.nz/ref-lights/wireless-test.html

You can use the utility at the above address to confirm that the controller is communicating correctly with the computer and that the ref boxes are communicating correctly with the controller. For all but the earliest Ref Lights systems it can also show you how closely a ref box's clock is tracking the controller's. The firmware versions in the controller and the ref boxes may also be displayed.

The controller needs to be plugged into the PC for the checks. As usual, you need to be using an up-to-date Chrome, Firefox or Microsoft Edge browser.

Controller-to-PC Check

Go to the address of the utility in your browser. If it's detected the wireless Ref Lights controller you should see an "I'm alive" icon flashing. This is a signal sent to the computer every two seconds to help some browsers more quickly discover the controller. Most controllers will also report their firmware version.

If the PC doesn't find the controller, the problem may be the USB connection or the controller.

Ref Box-to-PC Check

With the controller detected, you can power up one or more ref boxes and check whether the messages are getting through to the PC when you press a button.

Each ref box is identified by a number: 0, 1 or 2. A system has one box with each number. When you press a button, the button colour and the box number should show briefly on the screen. If you've chosen to list them, you'll also see a time stamp beside each button press as in the photo.

Ref boxes made after Oct 2022 send their firmware version to the controller and the utility will display this information if a ref box is powered on while the controller is running.

The next section explains how to check how well the clock in a ref box is tracking the controller clock.

Clock Calibration

The clock that controls the timing of operations in each ref box was calibrated when the box was built. This procedure stores a unique adjustment in the non-volatile memory of each ref box to keep its clock more closely tracking the clock in the controller. However, the long-term drift of some ref box clocks, or extremes of

temperature may eventually cause a deterioration in the box's operation than can be rectified by recalibration. Ref boxes have been designed to make it very easy for users to recalibrate them.

> If the reliability of a ref box starts to deteriorate, it's a good idea to check the clocks in all three of them.

Checking a Ref Box's Clock

This check shows you how far out of sync with the controller a ref box's clock is drifting.

You can only check *one box at a time,* so make sure the other boxes are switched off during a check.

1. With the controller plugged into a USB port on the computer, open the browser and go to the online testing utility described on the previous page: https://weighttraining.nz/ref-lights/wireless-test.html.
2. Keep the on-screen test page visible throughout the check, with no other windows open in front of it.
3. Hold down both the WHITE and YELLOW buttons on the box that you want to check while you switch it on. Don't release the buttons until the Wireless LED flashes, indicating the box has started searching for the controller channel.
4. Sometime within about a minute the message "First check is in 70s" should appear in the list, alongside a timestamp. This appears when the ref box receives its first regular sync after being powered on.

   If the message doesn't appear, you may not have held the buttons down firmly enough. Switch the box off, Click the "Clear list" button on the screen and try again.

5. When the next sync is sent, you'll see the time discrepancy between the controller and ref box clocks. This shows how many milliseconds behind (-) or ahead (+) the ref box's clock drifted relative to the controller's over the preceding 70-second regular sync'ing cycle.
6. Leave the box and utility running for a decent amount of time (say, 15min or more) to get a good sample of time discrepancies. The running average of the discrepancies is also shown in brackets.

Discrepancies of ± 7ms or less are fine and are shown in green. Discrepancies greater than ±7ms are in red. If the running average is more than about ±10ms it's probably a good idea to recalibrate the box.

Recalibrating Ref Boxes

This is very easy to do, and all three boxes can be calibrated at the same time in less than 15 minutes.

Follow these steps in order:

1. Have the controller and the ref boxes close at hand, and the batteries fully charged when calibrating boxes. If the batteries are not well charged, calibration will be disabled and the red battery LED will flash.
2. Power up the controller and leave it to run for a few minutes.
3. With the ref boxes switched off, press and hold the channel button on the controller. The display goes blank and, after about 5 seconds (10 for earlier versions), it will show a 'c'. Release the button and the display will start flashing, meaning the controller is in calibrate mode.
4. Switch on a ref box. After searching for the controller channel as usual, all three LEDs on the box will flash simultaneously three times, indicating that it's ready to be calibrated.
5. Switch on any other boxes that you want to calibrate and wait for the three LEDs on them to flash.
6. Initiate calibration by pressing the channel button on the controller. The display changes to a steady 'C' and the blue wireless LED on each ref box will start flashing. Calibration is underway and takes 12 minutes. Don't touch anything until calibration is complete – when the channel display changes back to a flashing 'c' and the wireless LEDs stop flashing.
7. If a box was successfully calibrated, its amber or green battery LED will light. The red LED will light if an error occurred. Switch off the boxes and unplug the controller.

If all was successful, power everything up again and see if the problem has resolved.

If calibration fails on all three ref boxes after a second attempt, the controller will need to be serviced. If only one box fails calibration, the box will be at fault.

Troubleshooting

If something isn't working correctly, using the *Online Testing Utility* will quickly determine whether the PC is detecting the controller, whether the controller is receiving button presses from each ref box, and whether any of the ref box buttons are not working.

The following table lists some problems with their possible causes.

Description of Problem	Possible Causes
PC/USB	
The Wireless LEDs on *all* the ref boxes indicate that the boxes are finding the controller channel when they're powered up, but the PC doesn't recognise any button presses.	• USB plug not firmly pushed in, faulty USB cable or plug • Try rebooting the PC. If the controller is plugged into a USB hub, try plugging it directly into a port on the PC. • If the Online Testing Utility shows everything is fine but the Ref Lights HTML file is not working, the file may be corrupt: Download it again from the web site.
Controller	
Controller appears to be dead.	• Faulty USB cable/plug or USB plug not fully pushed in • Faulty controller
Controller appears to be dead but PC sounds a USB device notification when plugging in the controller.	• Channel button shorting in controller membrane panel
Display not working correctly and *none* of the ref boxes can find the controller (Wireless LEDs flash non-stop).	• Faulty controller
The channel displays and can be changed, but *none* of the ref boxes can find the controller. (Wireless LEDs flash non-stop).	• Antenna not firmly screwed in • Faulty controller
Channel display shows three bars (*Ξ*) when the controller is powered up.	• Faulty controller transceiver
None of the ref boxes work correctly unless they're only a short distance from the controller.	• Faulty controller transceiver • Strong radio frequency interference (RFI): Confirm by trying in a different location, or at a 'quiet' time (e.g. late at night).
System works normally except channel display is not lit or segments are missing.	• LED display is faulty or not fitting properly in its socket
System works normally except the channel can't be changed.	• Faulty channel button in controller membrane panel
Ref box	
A ref box appears to be dead.	• Battery terminals not making good contact: Check that they're clean, not corroded and that the battery is firmly in place. • Dead battery: Swap with the battery of a working ref box to confirm. Replace rather than re-charge a completely dead battery. • Faulty power switch on the box • Faulty ref box
A ref box works for a few seconds then becomes unreliable until it receives the next sync message from the controller.	• Ref box needs calibrating. See *Recalibrating Ref Boxes*.
When powered on, *one* ref box fails to find the controller. (Wireless LED flashes non-stop).	• Faulty ref box

Description of Problem	Possible Causes
One ref box only works correctly when it's a short distance from the controller.	• Faulty ref box transceiver
The Wireless LED is lit continuously when a ref box is powered up.	• Faulty ref box transceiver
A ref box works fine when only a short distance from the controller but deteriorates when they're further apart	• Faulty ref box transceiver
System works normally except that it doesn't react to one or more buttons on a ref box	• Faulty button(s) in ref box membrane panel
A ref box works normally except that one or more of the LEDs don't work.	• Faulty LED(s) in ref box membrane panel

If you suspect a component is faulty, contact me to discuss the symptoms in more detail. In general, if an item needs to be returned for repair, I will ask you to return all four boxes, so they can be more thoroughly tested together as a system and so the latest firmware version can be uploaded to them.

Faulty items will be repaired or replaced free of charge (excluding shipping) if the fault occurs within 12 months of purchase, provided the fault isn't the result of mistreatment, battery being inserted the wrong way around, or use of incorrect battery type.

IMPORTANT: Using Lithium-Ion Batteries

Each referee box is powered by a single lithium-ion battery.

- Use only type 14500 rechargeable 3.7v lithium-ion batteries in the boxes. Although these are similar in size to standard AA cells, they have a higher voltage and can deliver much higher currents.
- Insert batteries with the correct polarity. Incorrect polarity may permanently damage the box's electronics.
- Charge the batteries only with a current- and voltage-controlled charger specifically designed for use with type 14500 Li-ion batteries.
- Li-ion batteries are in common use but can overheat, catch fire and have been known to explode if used incorrectly. The ref boxes are low-current devices. Nevertheless, follow these tips for safety and optimum battery life:
    - When not in the ref boxes, store the batteries so that they can't short or come into contact with conducting material. (For example, store them in separate plastic bags.)
    - Follow the instructions supplied with the charger. It requires a USB power input.
    - Don't over-charge a battery or charge one that has been left to run flat. A very flat battery can overheat when being charged and its life will be shortened. The supplied charger is designed to minimise the risks but play it safe: Don't let the batteries run completely flat! Always switch the ref boxes off after use, store them so the switch won't accidentally be turned on, and recharge the batteries when the LEDs show that it's time to do so.
    - When the boxes haven't been used for a prolonged period, it's recommended you check the battery status now and then. About once every three or four months should be fine.
    - Never short or physically damage a battery or use one that's damaged or swollen. A swollen battery may leak and permanently damage the electronics in a ref box.
    - Check with your local body regarding disposal of batteries or hazardous waste.