

User Manual v1.0

THE ETERNAL STOKER SYSTEM

User Manual

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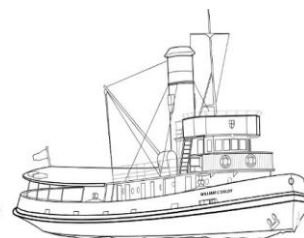
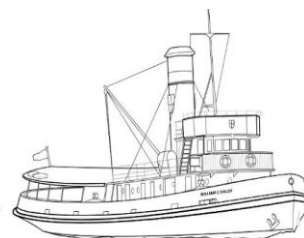


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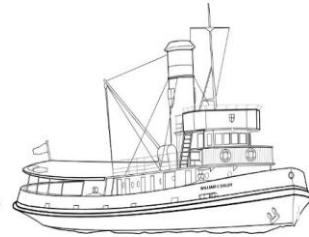


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1. Introduction

1.1 About TESS

The Eternal Stoker System (TESS) is a purpose-built monitoring and management platform for the TST William C Daldy — a 1935 coal-now-wood-fired heritage steam tug based in Auckland, New Zealand. TESS provides the engineering crew with real-time instrument displays, voyage planning tools, and operational record-keeping in a single unified system.

TESS supplements, and never replaces, the vessel's certified gauges and the judgement of the Chief Engineer. All readings displayed by TESS are informational aids only.

1.2 What TESS Does

- Displays live firebox temperatures for all six fireboxes across the aft and forward boilers.
- Shows steam pressure, condenser vacuum, forced draught air pressure, and shaft RPM when sensors are fitted.
- Calculates rate of change on firebox temperatures so stokers can see whether a fire is responding to stoking.
- Records historical temperature data so the engineering team can review a full voyage after the event.
- Provides a bunkering calculator for estimating and recording wood fuel consumption.
- Provides a digital engine room log mirroring the paper form used aboard.
- Manages the crew register with competency ratings and builds voyage rosters with briefing sheets.
- Generates and emails voyage briefing sheets to the crew.

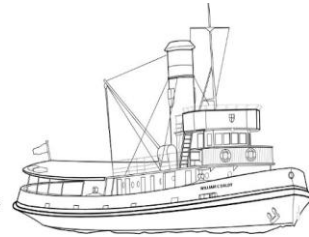
1.3 How TESS is Structured

TESS runs on a Raspberry Pi 5 mounted aboard the vessel. The system has three layers:

- ESP32 microcontroller nodes read sensors and transmit data over wifi to the Pi.
- A Flask server running on the Pi receives, stores, and serves all data.
- HTML dashboards run in any web browser on any device connected to the ship's wifi.

No internet connection is required. All dashboards are accessed by opening a web browser and navigating to the ship's local address. TESS can also be accessed remotely via Tailscale when the Pi is powered on.

Note: *TESS is under active development. Some features shown in this manual may be refined as the system matures through live use aboard the vessel.*



2. Getting Started

2.1 Accessing TESS

Connect your device (phone, tablet, or laptop) to the ship's wifi network. Open any web browser and navigate to:

`http://eternalstoker.local:8080`

The TESS hub page will load showing all available tools. If the address does not resolve, try the Pi's direct IP address instead — this is available from the Chief Engineer.

Note: Remote access from outside the ship's network is available via Tailscale for authorised users.

2.2 The Hub Page

The hub page is your starting point. Without logging in, it shows three watch tiles:

- **Live firebox temperatures for both boilers.** — Boiler Room Watch
- **Telegraph indicators, steam pressure, condenser vacuum, and shaft RPM.** — Engine Room Watch
- **Steam pressure trend and shaft speeds — the skipper's view.** — Bridge Watch

These three dashboards are accessible to everyone — the skipper, stokers, and any crew with a phone or tablet connected to the ship's wifi. No login is required.

Tapping the  lock icon in the top right corner opens the admin login. Once logged in, three additional tiles appear under The Ship's Log section:

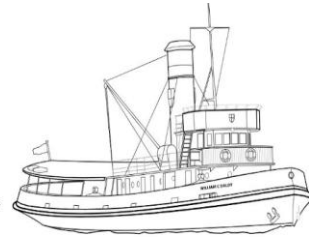
- **Wood fuel estimation and trip recording.** — Bunkering Calculator
- **Crew register and voyage roster builder.** — Voyage Roster
- **Digital engine room log for recording voyage data.** — Engine Room Log

The lock icon changes to a  cog when logged in. Tapping the cog opens the system status drawer — node health, system information, a link to Settings & Admin, and a Log Out button. The drawer also shows which user is currently logged in.

2.3 Admin Login

TESS uses named user accounts. Each admin user has their own username and password. To log in, tap the  lock icon and enter your username and password. Your session persists across page navigations and browser restarts — you will not need to log in again on the same device unless you explicitly log out.

Note: Each device logs in independently. Logging in on your phone does not affect other devices on the network.

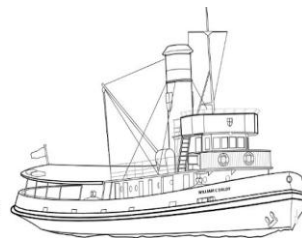


2.4 Demo Mode (SIM)

The Boiler Room Watch and Engine Room Watch pages include a SIM button for demonstration purposes. SIM mode is only available to logged-in admin users — it is not accessible to the public view.

When SIM is active, the gauges display simulated data. The Pi continues recording real sensor data in the background regardless of SIM state.

If a voyage is currently active in the roster when SIM is enabled, TESS will display a confirmation warning before proceeding. Simulated data should never be used for operational decisions during a real sailing.



3. Boiler Room Watch

3.1 Overview

The Boiler Room Watch is the primary instrument panel for the engineering crew. It shows firebox temperatures across both boilers in a gauge format based on the traditional Lobnitz style.

3.2 Overview Page

The overview shows two large gauges — one for the aft boiler and one for the forward boiler. Each gauge displays the average temperature across that boiler's three connected fires. Only fires with live sensor data contribute to the average; unconnected sensors do not drag the reading down.

Tap either boiler gauge to drill down into the individual firebox detail page for that boiler.

3.3 Firebox Detail Page

The drill-down page shows three individual firebox gauges (fires 1, 3, 5 for aft; fires 2, 4, 6 for forward). Below the gauges a temperature trend chart shows the history of all three fires over the configured history window.

Each gauge shows:

- The current temperature in degrees Celsius.
- A colour-coded status label: NORMAL, WARM, HOT, or DANGER based on configured thresholds.
- The assigned stoker role for that fire.
- A TAP FOR RATE prompt.

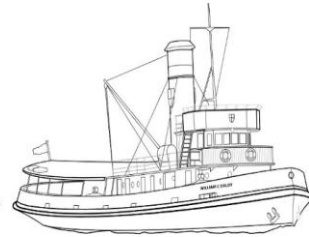
3.4 Rate of Change

Tapping any firebox gauge opens the rate of change panel. This shows how quickly the firebox temperature is rising or falling, expressed in degrees Celsius per minute. The rate is calculated server-side from the last 60 seconds of stored data, so it is meaningful immediately without a warm-up period.

States shown:

- **Temperature climbing strongly — stoking is taking effect.** — RISING FAST
- **Temperature climbing steadily.** — RISING
- **Temperature holding — fire in balance.** — STEADY
- **Temperature dropping — fire may need attention.** — FALLING
- **Temperature dropping quickly — fire needs immediate attention.** — FALLING FAST

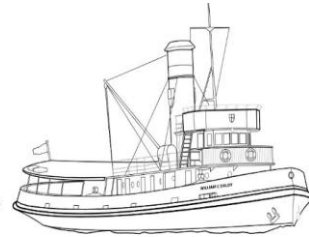
Note: Rate of change thresholds can be adjusted in Settings & Admin > Boiler Watch. For a domestic fireplace, a full scale of $\pm 5\text{--}10^\circ\text{C}/\text{min}$ is recommended. For the Daldy's fireboxes at working temperature, $\pm 25\text{--}50^\circ\text{C}/\text{min}$ is more appropriate.



3.5 Temperature History

The trend chart at the bottom of the drill-down page shows the last two hours of firebox temperatures by default. The history window is configurable in Settings. When the page loads, TESS fetches historical data directly from the database so the chart is populated immediately — there is no warm-up period.

Gaps in the trend line indicate periods where a sensor was not reporting. This is distinct from a genuine zero temperature reading, which does not occur in a lit firebox.



4. Engine Room Watch

4.1 Overview

The Engine Room Watch page provides the 3rd Engineer and engine operators with a view of the main engine instruments. It displays the Chadburn Synchrostep telegraph indicators for both port and starboard engines, combined steam pressure trend, condenser vacuum, and shaft RPM.

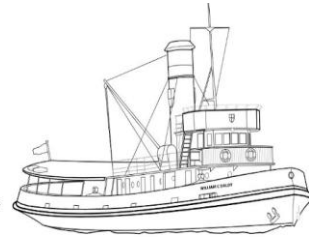
4.2 Telegraph Display

The telegraph display renders the Daldy's Chadburn Synchrostep telegraphs as a graphic overlay. The needle position reflects the current telegraph setting received from the voltage sensor on each telegraph unit. Positions displayed include all AHEAD and ASTERN orders plus Stand By, Stop, and Finished With Engines.

Note: *Telegraph voltage mapping must be calibrated aboard before the telegraph display becomes operational. The physical measurement of all 11 telegraph positions is required.*

4.3 Engine Movements

The Engine Room Log (see Section 6) automatically records telegraph changes between Stand By and Finished With Engines. This provides a timestamped record of all engine orders during a voyage without manual entry.

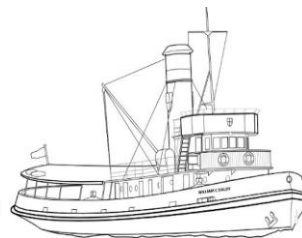


5. Bridge Watch

The Bridge Watch page provides the skipper and deck officers with a simplified instrument view focused on steam pressure and shaft speeds. It shows:

- Combined steam pressure gauge with a 2-minute trend and HOLDING / RISING / FALLING advisory.
- Port and starboard shaft RPM gauges (0–220 RPM).
- Shaft imbalance indicator — green when within 10 RPM, amber within 30 RPM, red beyond.

The Bridge Watch contains no controls. It is a pure read-only display.



6. Engine Room Log

6.1 Purpose

The digital engine room log mirrors the paper form used aboard the William C Daldy. It provides a structured record of each voyage covering gear testing, feedwater and bilge readings, oil levels, engine readings, and crew notes.

6.2 Sections

Voyage Details

Record the cruise name or charter, date, and departure time at the top of the log.

Gear Tested

Eight checkboxes covering: Gauge Glasses, Steering Gear, Whistle, Batteries, Windlass, Capstan, Telephone, and Telegraphs. Tick each item as it is tested during engine room preparation.

Times

Eight timed events: Clock Check, Rock Engines, Standby, Full Away, Anchor Arrive, Anchor Depart, and Finished With Engines. Tap the event name button to stamp the current time. The time can also be manually entered or edited. On desktop browsers, click the button to stamp; on mobile, tap either the button or the time field.

Feedwater Tanks

Record start and finish readings for the Aft Peak and Fore Peak tanks in tonnes. TESS automatically calculates the Used figure (Start minus Finish). Fields accept numerical values only.

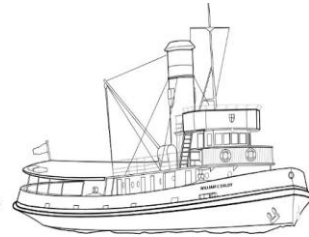
Main Engine Readings

Add rows to the port and starboard engine reading tables as required during the voyage. Tap the TAP button in the Time column to stamp the current time. TESS simultaneously fetches the current combined steam pressure from the live sensor feed and populates the Steam Pressure column automatically. Additional columns cover RPM, LP Vacuum, Engine Bearings, Thrust Block, Shaft Bearings, and Stern Gland.

Note: Steam pressure auto-population requires the pressure transducer sensors to be fitted and reporting. If sensors are not yet installed, the pressure field will remain blank after time stamping.

Engine Movements

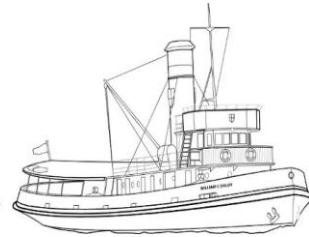
TESS automatically records all telegraph changes between Stand By and Finished With Engines. Each entry shows the time, engine (port or starboard), and the order given. Entries can be manually edited. A SIM Telegraphs button is available for testing the movement recorder without live telegraph sensors.



6.3 Saving and Loading

Tap Save Log at the top or bottom of the page to save the current log to the Pi's database. A confirmation shows the assigned log number. Logs are saved with the cruise name and date for easy retrieval.

Previously saved logs can be viewed from Settings & Admin > Reporting > Engine Room Log Records. Tap the eye icon to open any saved log in a new tab, pre-populated with all recorded data. Logs can also be downloaded as JSON files for archiving.



7. Bunkering Calculator

7.1 Purpose

The Bunkering Calculator estimates wood fuel consumption for a planned voyage and records actual fuel usage against those estimates. This supports planning, purchasing, and post-voyage analysis.

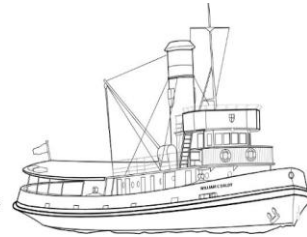
7.2 Using the Calculator

Enter the voyage name, date, and configure the base consumption rate. Add voyage legs with the speed setting and duration for each leg. The calculator estimates total fuel consumption accounting for different consumption rates at different speeds. Warmup and startup fuel can also be configured.

Save the trip to the database using the Save Trip button. A confirmation flash shows the assigned trip number. Saved trips are accessible from Settings & Admin > Reporting > Bunkering Trip Records.

7.3 History and Annual View

The History tab displays all saved trips loaded from the database. The Annual tab provides a yearly summary of fuel consumption across all recorded voyages.



8. Voyage Roster

8.1 Overview

The Voyage Roster module manages the engineering crew register and builds voyage rosters with briefing sheets. It is the primary tool for the person responsible for crew rostering.

8.2 Crew Register

The Crew Register displays all engineering crew with their operational capability indicators. The register is sorted by capability, with the most qualified crew at the top.

Operational Capability Dots

Each crew member shows four coloured dots indicating operational roles:

Dot	Meaning	Qualification Criteria
• Chief	Chief Engineer qualified	Expert on Boilers AND Competent or Expert on Main Engine
• Lead	Lead Stoker capable	Competent or Expert on Stoke Hold
• Engine	Engine operator	Competent or Expert on Main Engine
• Stoker	Can stoke	Aware or better on Stoke Hold

Note: The role label (e.g. Chief Engineer) and the operational dots are independent. Promoting a crew member to Chief Engineer in the register updates their title but does not change their dots. The dots are determined solely by competency ratings. Both must be updated for a crew member to appear fully qualified in the Roster Builder.

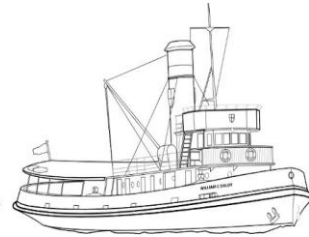
Searching the Register

The live search filters the crew list as you type. You can search by name, role, or capability keyword:

- "chief" or "chief engineer" — shows Chief Engineer qualified crew.
- "lead" or "lead stoker" — shows Lead Stoker capable crew.
- "engine" or "engineer" — shows engine operators.
- "stoker" — shows all crew capable of stoking.
- "expert" — shows all crew with any Expert rating.

Not Current Crew

Crew who are not currently active are hidden by default. Toggle Show not current to include them. Their cards appear greyed out and their dots are dimmed. Not-current crew do not appear in roster assignment dropdowns.



Adding and Editing Crew

Tap + Add Crew to add a new crew member. Complete the name, email address, primary role, secondary role, and all 12 competency ratings (Expert / Competent / Aware / Training). Tap any crew card to open their detail panel, then tap Edit to modify their record. All changes are saved to the Pi database automatically.

Changing Current Status

Tap a crew card, then tap Change Status in the detail panel. Choose Current or Not Current. The change is saved immediately.

8.3 Roster Builder

The Roster Builder constructs a voyage roster and generates a printable briefing sheet.

Voyage Details

Enter the voyage name (e.g. the charter name), sailing date, sailing time, duration, and passenger count. The engineers on board and stokers on board times are pre-filled from the roster settings and can be adjusted for each voyage.

Light-Up Crew

When a sailing date is set, the three light-up day fields automatically populate with the three days prior to sailing (Wednesday, Thursday, Friday for a Saturday sailing). Assign up to three crew members per light-up day from the dropdown. TESS prevents the same person being assigned twice on the same day.

Note: *Light-up crew and sailing crew are separate pools. A crew member can appear in both.*

Sailing Crew Assignment

Assign crew to each of the seven standard roles: Chief Engineer, 2nd Engineer, 3rd Engineer, Lead Stoker A Shift, Lead Stoker B Shift, Stoker A Shift, and Stoker B Shift. TESS flags any assignment where the crew member's competency does not meet the minimum for that role.

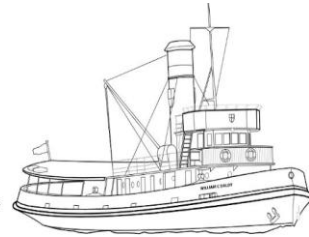
For longer sailings, tap + Add Extra Crew to add additional role slots from a list of options. Extra roles can be removed with the × button. TESS prevents the same person being assigned to two roles simultaneously.

Crew Notes

Add any briefing notes for the crew. These appear prominently in both the briefing sheet and the crew email.

8.4 Saving and Viewing Voyages

Tap Save Voyage to save the roster to the Pi database. Saved voyages appear on the Saved Voyages tab where they can be viewed, edited, or deleted.



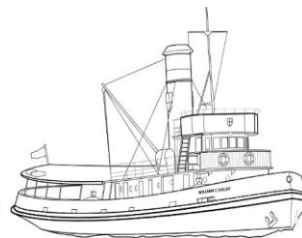
8.5 Briefing Sheet and Crew Email

The briefing sheet is a clean white document formatted for printing or sending as a PDF attachment.

To generate and send a crew briefing:

1. Tap Save PDF to open the briefing sheet preview and the print dialog. Choose Save as PDF.
2. Tap Send to Crew to open your email client. Your email address appears in the To: field. All assigned crew with email addresses in the register are added to BCC automatically. The email body contains the voyage details and the notes section. Attach the saved PDF.
3. Send the email.

Note: Crew email addresses are managed in the Crew Register. Open any crew member's detail panel and tap Edit to add or update their email address.



9. Settings & Admin

Access Settings & Admin by tapping the ⚙ cog on the hub page (admin login required), then Open Settings & Admin. The page has six tabs.

9.1 Boiler Watch Settings

Configures the rate of change gauges:

- Rate Gauge Full Scale — maximum °C/min shown on the needle. Reduce for slow or cold fires.
- Rate Window — seconds of history used to calculate rate. Shorter = more reactive.
- Alert Threshold — °C/min at which RISING/FALLING state triggers.
- History Window — how many minutes of data to load on the trend chart.

All settings are saved to the Pi and apply immediately across all devices.

9.2 Reporting

The Reporting tab provides:

- Fire Temperature Report — generate a temperature chart and summary table for any date range and selection of fires. Download as CSV or Excel for further analysis. Print or save as PDF.
- Bunkering Trip Records — view, download, or delete saved bunkering calculator trips.
- Engine Room Log Records — view, download, or delete saved engine room logs.
- Crew Register Export / Import — export the crew register to CSV for editing in Excel; import a CSV to merge changes back in.

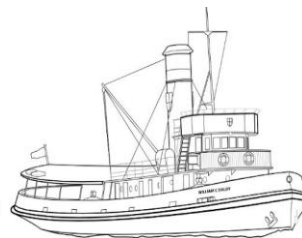
9.3 Database

The Database tab shows system health:

- ESP32 Node Health — live status of each sensor node with last-seen timestamp.
- Database Health — readings count, database size, disk usage, server uptime.
- Data Housekeeping — delete sensor readings older than a chosen number of days. Trip and log records are never affected.

9.4 Voyage Roster Settings

- Engineers on board — default hours before sailing for engineers. Currently 2 hours.
- Stokers on board — default hours before sailing for stokers. Currently 3 hours.
- Show not-current crew in dropdowns — toggle to include not-current crew in roster assignment dropdowns.
- Your email address — the To: address used when sending crew briefing emails.



9.5 Help

The Help tab provides quick access to the in-app help guide and a download link for the full TESS user manual PDF. The manual can be updated by replacing the PDF file on the Pi — see Section 12 for details.

9.6 Security

The Security tab manages admin user accounts and passwords.

Change Your Password

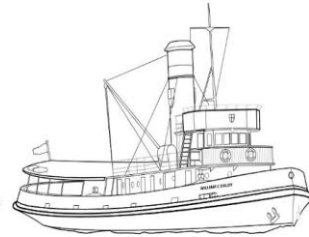
Enter your current password, a new password, and confirm the new password. The new password must be at least 6 characters. Only your own password is changed — other user accounts are not affected.

User Management

The user list shows all admin accounts with their username and role. The primary owner account cannot be deleted. All other accounts can be deleted or have their password reset.

To add a new user, enter a username and password in the Add New User form and tap Add User. New users have full admin access — they can access all dashboards, settings, roster, log, and calculator.

Note: *The primary owner account is identified in the user list. If this account's password is forgotten, the emergency reset procedure in Section 12 will restore it.*



10. Fire Data Reporting

TESS stores every sensor reading in a SQLite database on the Pi. This data can be retrieved and analysed for any past date range using the Fire Temperature Report in Settings & Admin > Reporting.

10.1 Generating a Report

4. Open Settings & Admin from the hub page.
5. Tap the Reporting tab.
6. Set the From and To date and time for the period of interest.
7. Select which fires to include (all six are selected by default).
8. Tap Generate Report.

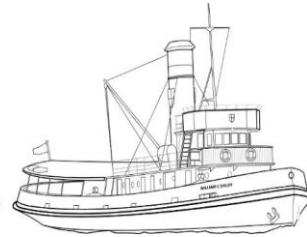
10.2 Reading the Report

The chart shows temperature over time with one coloured line per fire. The summary table below shows minimum, maximum, and average temperature for each fire, plus the total reading count. The date and time range and total readings are shown below the table.

10.3 Exporting Data

Two export formats are available:

- CSV — a comma-separated file with a timestamp column and one column per fire. Opens directly in Excel, Numbers, or any spreadsheet application. Suitable for custom analysis and charting.
- Excel — a formatted .xlsx file with two sheets: Fire Data (full timestamped readings) and Summary (min/max/average per fire). Timestamps are formatted as proper Excel datetime values.



11. Troubleshooting

11.1 Dashboard Not Loading

If the TESS hub page does not load in your browser:

9. Confirm your device is connected to the ship's wifi network.
10. Check the Pi is powered on. The Pi has a small green activity LED visible on the board.
11. Try the direct IP address instead of the hostname. The current IP address is available from the Chief Engineer.
12. If no other devices can reach the system, the Flask server may need restarting. This requires SSH access to the Pi (contact the system administrator).

11.2 Sensors Showing Zero or Not Reporting

When a firebox gauge shows 0°C or a sensor appears offline, follow this procedure:

13. Check the Settings cog on the hub page. The Node Health panel shows which ESP32 nodes are reporting and when they were last seen.
14. On the Boiler Room Watch drill-down page, check whether adjacent fires on the same boiler are reporting normally. If some fires report and others do not, the issue is likely with a specific sensor connection.
15. Locate the ESP32 sensor box for the affected boiler. Check that the USB power cable is securely connected and the box shows a power indicator light.
16. Check that the thermocouple wires are firmly secured in the green terminal block connectors on the MAX31855 amplifier boards. Use a small screwdriver to tighten the terminal screws if necessary.
17. If the node shows as offline in the health panel but the hardware appears powered, the ESP32 may have lost its wifi connection. A power cycle (disconnect and reconnect the USB power) will cause it to reconnect automatically.

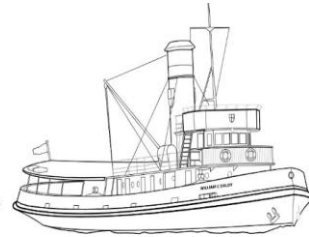
Note: A gap in the temperature trend chart indicates a period where the sensor was not reporting. This is distinct from a genuine cold reading and does not affect stored data from other sensors.

11.3 SIM Mode Stuck On

If the dashboards show simulated data and the SIM button cannot be found, refresh the page in your browser (pull down to refresh on mobile, or press F5 on desktop). This resets the page state and returns to live data mode.

11.4 Email Not Opening

The Send to Crew button uses your device's default email application. If no email app is configured on the device, the button will appear to do nothing. Configure a default email application on the device, or open the email manually and copy the crew addresses from the briefing sheet.



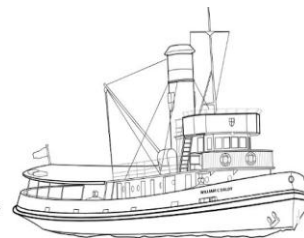
11.5 Settings Not Saving

If settings changes do not persist after the Saved ✓ confirmation disappears, the Pi may not be reachable. Check node health from the hub page cog. If the server is offline, settings will revert to defaults on the next page load. Contact the system administrator to restart the Flask server.

11.6 Forgotten Admin Password

If an admin password has been forgotten, any other admin user can reset it from Settings & Admin → Security → User Management by tapping the reset button next to the affected user.

If the primary owner password is forgotten and no other admin accounts exist, the emergency reset procedure must be used. This requires SSH access to the Pi — see Section 12.5 for the reset command.



12. Technical Reference

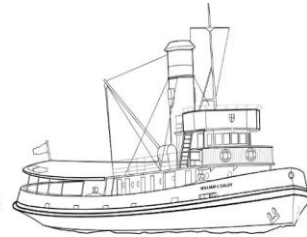
This section is intended for the system administrator and technical crew responsible for maintaining TESS.

12.1 System Architecture

Component	Description
Raspberry Pi 5	Main server. Runs Flask web server and SQLite database. Hostname: eternalstoker.local
Flask	Python web framework serving dashboards and API endpoints on port 8080
SQLite	Embedded database storing all sensor readings, trips, logs, crew, and settings
ESP32 DevKit	Microcontroller nodes. One per boiler. Reads sensors and posts data to Pi over wifi
MAX31855	Thermocouple amplifier boards. One per firebox. SPI interface to ESP32
XGZP6847A	Pressure sensor for forced draught air. I2C interface to ESP32
Tailscale	VPN for remote access to the Pi from outside the ship's network

12.2 Sensor Configuration

Sensor / Signal	ESP32 Pin
CLK (shared, all MAX31855)	GPIO 18
DO (shared, all MAX31855)	GPIO 19
CS — Fire 1	GPIO 5
CS — Fire 2	GPIO 4
CS — Fire 3	GPIO 2
CS — Fire 4	GPIO 15
CS — Fire 5	GPIO 13
CS — Fire 6	GPIO 12
SDA (XGZP6847A pressure)	GPIO 21
SCL (XGZP6847A pressure)	GPIO 22



12.3 API Endpoints

The Flask server exposes the following key endpoints:

Endpoint	Purpose
GET /api/latest	Current reading for all sensors
POST /api/ingest	ESP32 nodes post sensor readings here
GET /api/history/<sensor>	Historical readings for one sensor (supports date range)
GET /api/rate/<sensor>	Server-side rate of change calculation
GET /api/health	Server health and node last-seen timestamps
GET /api/admin/stats	Database statistics and disk usage
POST /api/admin/prune	Delete readings older than N days
GET/POST /api/trips	Bunkering trip and voyage roster records
GET/POST /api/logs	Engine room log records
GET/POST /api/crew	Crew register
POST /api/crew/merge	Merge-import crew from CSV
GET/POST /api/uiconfig	Persisted UI settings (rate scale, on-board times, etc.)

12.4 Database

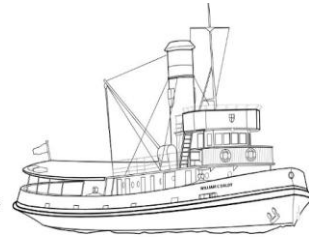
The SQLite database is located at /home/daldy/eternal_stoker/data/eternal_stoker.db. It contains the following tables:

Table	Contents
readings	All sensor readings with timestamp, sensor key, and value
latest	Current value cache for each sensor
trips	Bunkering calculator trips and voyage rosters (JSON payload)
er_logs	Engine room log records (JSON payload)
crew	Crew register (single JSON blob)
uiconfig	Key-value store for persisted UI settings

12.5 Starting the Server

If the Flask server needs to be started manually after a Pi reboot:

```
ssh daldy@eternalstoker.local
cd /home/daldy/eternal_stoker && python3 server.py
```



Note: A systemd service to start Flask automatically on boot is planned for a future release.

12.6 Emergency Password Reset

If the primary owner password has been forgotten and no other admin accounts are available, SSH into the Pi and run the reset script:

```
python3 /home/daldy/eternal_stoker/reset_password.py
```

This resets the primary owner account password to the default. Log in immediately afterwards and change the password via Settings & Admin → Security.

Note: The reset default password is documented separately and held by the system administrator. It is intentionally not published in this manual.

12.7 Sensor Key Reference

Sensor Key	Description
fire_1	Aft boiler — Fire 1 (Stbd stoker)
fire_2	Fwd boiler — Fire 2 (Port stoker)
fire_3	Aft boiler — Fire 3 (Stbd stoker)
fire_4	Fwd boiler — Fire 4 (Port stoker)
fire_5	Aft boiler — Fire 5 (Stbd stoker)
fire_6	Fwd boiler — Fire 6 (Port stoker)
steam_aft	Aft boiler steam pressure (psi)
steam_fwd	Fwd boiler steam pressure (psi)
air	Forced draught air pressure (psi)
vacuum	Condenser vacuum (inHg)
rpm_port	Port shaft RPM
rpm_stbd	Starboard shaft RPM



13. Document History

Version	Date	Author	Changes
1.0	June 2026	Scott Laurenson	Initial release — proof of concept system.

End of Document