Redcliffe Bridge Final Mechanical & Electrical Inspection Report

PREPARED FOR:	Chris Dooley	Bristol City Council
COPY TO:		
PREPARED BY:	Jim Walters	
DATE:	June 2017	
PROJECT NUMBER:	203742	
REVISION NO.:	Rev 2	
APPROVED BY:	K Powell	

This report covers includes the information gathered from the two static inspections and the two trial lifts carried out between May 2016 and January 2017 by CH2MHILL, Radicon Transmissions UK, SSE and members of the Docks maintenance team. It also includes information taken from operation logbook and O&M manual.

The purpose of the report is to assess the condition of the mechanical and electrical items of the bridge installation and to determine what measures are required to extend the asset life for a further 20 years.

Introduction

The Redcliffe Bridge is a rolling bascule type bridge that spans the Redcliffe Back-Prince Street channel which is part of the floating harbour linking the Redcliffe way to the Welshback. The bridge was constructed in 1942 with the major mechanical elements carried out by Thomas Broadbent & Sons of Huddersfield.

In 1996 the bridge underwent a major electrical and control system refit bringing the installation up to the then current industry standards, it is not known if there were any significant modifications to the mechanical elements of the installation.

The bascule bridge is a counterbalanced, single leaf structure of steel construction that spans the 51 foot central opening. The bridge comprises three main plate girders with various bolted and riveted stiffeners, cross beams and members, there are also three large quadrants connected to each main girder. These quadrants support the mass of the bridge as the bridge opens and closes and rolls along dedicated tracks. The two outer quadrants and their respective tracks are toothed, this is to maintain a degree of positional alignment.

Two rack trestles are positioned outboard of the two outer quadrants that provide the support for the pinion track, these are anchored to the concrete structure in the machinery chamber below the bridge deck. Also located in the machinery chamber are the two bridge tail dampers, the electrical cable catenary and the access stairs and platforms for manually operating the bridge.

The small pier bridge nose abutment has a below ground access gallery that houses the three nose bolt mechanisms and an external platform that houses the bridge nose dampers. There are also two below ground chambers on each fixed span abutment that house the operating gear for the vehicle and pedestrian barriers.

Bridge Operation

The operating sequence of the bridge when fully functional is semi-automatic, manual input is required after each sequence of operation to initiate the next stage. From record information it is understood that the following is the sequence for opening the bridge.

Operate the divert switch, this sets the wig-wag lights flashing warning both motorists and pedestrians of a pending bridge operation.

The entry gates from each approach are then closed and when the bridge is clear of pedestrians and motorists the exit gates are closed.

When both sets of gates are closed the nose bolt retract switch is operated.

When the nose bolts are retracted the raise bridge switch is operated, the bridge opens slowly and when clear of the nose pier structure a limit switch is activated and the bridge opening speed is automatically increased (this limit switch also slows the bridge down at the same position of elevation when closing). Limit switches signal when the bridge is nearly open, open, nearly closed and closed.

The lowering sequence is the logical reverse of the opening sequence but the final movement to close the bridge is a manual operation.

It is reported that there was an operational issue during a scheduled maintenance lift a couple of years ago. The bridge was raised without issue but when lowering the side of the bridge nose structure scraped the Northern concrete access chamber on the small pier, the bridge was raised again and lowered this time without issue, the bridge had realigned itself and returned to the correct position. It is understood that the bridge has been operated a number of times since with no reported problems. There are also entries in the operating log book that date back to 2004 that report collisions between the moving structure and the fixed abutments.

Mechanical Equipment

Main drive train

The motive power to drive the bridge is provided by two electric motors, the output drive shaft of each motor connects to a differential gearbox with a common output shaft from the gearbox connecting to the two driving pinions located to the outside of the outer quadrants, via an open gearing arrangement each comprising four pinion and gear wheel sets. There is a sensor fitted to the first drive pinion of this open gearing and is presumed to be a counter used to provide information for the bridge angle.

Each motor drive shaft is fitted with a brake with one motor assembly including a manually operated clutch lever that allows the bridge to be manually operated via a four man chain wheel drive.

Both output shafts from the gearbox are fitted with a brake, there is also an electrically actuated speed change mechanism fitted to the gearbox which includes a manual override hand wheel. The gearbox is lubricated by an electrically driven gear pump drawing oil from the belly sump of the gearbox and spraying the internal spur gears and feeding the shaft bearings.

It is believed that the gearbox has a two speed operation, this function is activated by a limit switch which is assumed to be triggered when the nose structure of the bridge is clear of the nose pier abutment, this signal operates an electric actuator on the gearbox assembly to shift into a higher ratio pinion. Slow speed is engaged for initial raising of the bridge and the final lowering into the closed position.

The driving pinions are located at the pivot of the bridge and mesh with the racks at high level within the machinery chamber below the deck of the bridge (the elevated rack trestles were not accessible). The rack trestle assembly includes support bracketry at either end for limit switches, these limit switches are believed to be:

- Bridge closed
- Bridge nearly closed
- Slow speed change
- Bridge nearly open
- Bridge open

There is also a set of four manually operated chainwheel assemblies installed to enable the bridge to be raised or lowered in the event of a power failure.

Nose bolts

When the bridge is in the closed position it is retained by three nose bolt assemblies, these nose bolt assemblies are located in the access gallery below the static deck at the nose pier. The gallery is accessed from both sides of the carriageway via a lockable concrete turret type enclosure and short vertical ladder.

All three nose bolt mechanisms are operated by a single electric motor driven worm gearbox via a common line shaft, there is facility to manually operate the nose bolts using a hand wind and chain drive. Each nose bolt comprises a pinion mounted on the line shaft which drives a quadrant gear connected to an independent lay shaft which also drives a lever arm and linkage connected to the nose bolt, the maximum stroke of the nose bolt is in the order of 300mm.

Limit switches are fixed to the steelwork of each nose bolt fabrication to indicate the extended and retracted position of the nose bolt, it was also noticed during the static inspection that proximity switches have been fitted to each of the bridge nose bearings to detect the nose bolt when extended.

All three quadrant gear assemblies were missing their protective guards, it is understood that a permit to enter system is in place with keys to locked gates to prevent inadvertent entry.

Barriers

There are four sets of combined vehicle and pedestrian barriers, two are termed entry gates and two exit gates, the barriers above deck level are robust and in very good condition although may not meet current safety standards, the operating gear is located in a suspended below deck chamber adjacent to each barrier, access is via a removable deck plate. Each gate set is independently driven by an electric motor through a worm gearbox which in turn drives a spur gear that drives a quadrant gear fitted to the pedestrian barrier drive shaft, a second quadrant gear on this shaft meshes with a quadrant gear on the vehicle barrier drive shaft to allow synchronized operation. Limit switches are fitted to indicate when barriers are open and closed.

There is a facility to manually operate the barriers using a hand wheel and chain drive.

Buffers

There are four buffer/damper assemblies, two for the tail of the bridge and two for the nose of the bridge.

The bridge tail buffers are mounted on dedicated concrete structures located within the machinery chamber under the bridge deck, it would appear that the design intention is as over travel protection in the event of control failure or as a cushioning mechanism to slowly bring the bridge movement to the fully open position. Each buffer has a counterweight and pulley arrangement which is assumed to return the piston to the extended position after operation and recharge the housing with the operating media.

The buffer has a right angled mounting plate with the main housing set at approximately 30° to the horizontal, a pair of pulley wheels are mounted on the head cap of the buffer, these are for the counterweight cables. Spaced either side of the buffers there are three large timber blocks or stops fixed to the concrete supporting the quadrant tracks, these are assumed to be aligned to the fully compressed position of the buffers.

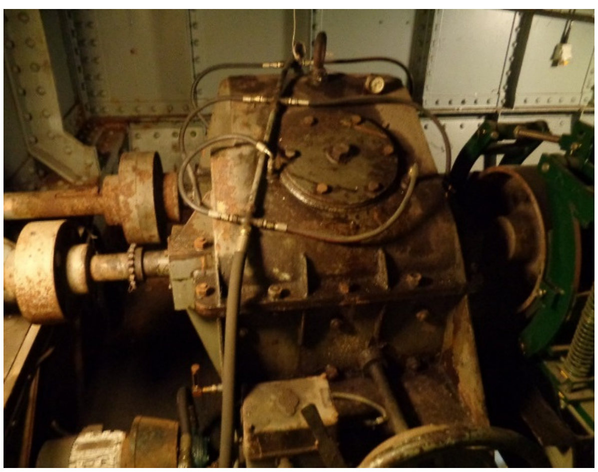
The bridge nose buffers are located in recesses on the nose pier below the nose of the bridge when in the closed position. It is unclear as to the original design intention of the buffers but in this location a cushioning mechanism is more feasible.

The buffers comprise a base mounted vertical housing with an extended piston, a pair of pulley wheels are mounted on the head cap of the buffer and another pair on the concrete structure, these are for the counterweight cables.

Condition

Main drive train

The main drive train is located in the machinery rooms below the main bridge deck but elevated from the machinery chamber, although there is some corrosion to the floor panels and surrounding steelwork structure the main drive train is generally in good condition.



Both sets of brakes visually appear to be in good condition and reportedly operate correctly.

The toothed quadrants and associated toothed tracks are located in the machinery chamber which is at or partially below the water level in the floating harbour and subject to damp and humid conditions. There is also evidence of surface water run-off from the above road deck down the side of the bridge structure, this leads to corrosion which in turn, debris falls down onto the horizontal track which causes an issue with the bridge movement. There is significant corrosion to the interlocking blocks/teeth on the outer quadrants and track, there is also evidence of wear to the leading edges which could promote misalignment.

The elevated drive pinion and rack are located just below the road deck, this is also fully exposed and subject to any potential debris, although not accessible during the inspection this should always be checked prior to any bridge lift.

Nose bolts

The nose bolt assemblies are in the gallery and relatively well protected from the elements, all three mechanisms appear to be in good condition. The nose bolts appear well greased, however the nose bearings are heavily corroded and have a significant amount of temporary packing fitted believed to be to limit the bounce of the bridge when subject to heavy traffic and reduce the resulting noise.

The nose bolts will need to be retracted and the grease removed from the bolt, housing and nose bearing to check for wear on these items.

It was noticed that a hinge on one of the steel access doors to the nose bolt machinery room was broken

Barriers

During the inspections only two of the barrier operating drive mechanisms were accessed, these were on the south side of the bridge structure on the Redcliffe and Welshback approaches.

The existing vehicle/pedestrian barriers/gates although are in good condition are unlikely to meet the current design safety standards and therefore may require replacement.

The barrier operating gear is located in a suspended pit below the road deck and is in very poor condition, surface water, grit and road debris passes through the opening in the deck for the barrier drive shafts and accumulates on the quadrant and spur gears unnoticed. The quadrant gear on the pedestrian barrier drive shaft is so badly corroded that most of the gear teeth are missing, there is trapped water in the support structure and the manually operated chain drive is also seized solid. The limit switch brackets are so corroded it is unlikely that they operate correctly, it is highly unlikely that this particular barrier would operate correctly.

Buffers

The two bridge tail buffers located in the machinery chamber are inoperable, one is stuck in the depressed position and the other stuck in the extended position with the counterweight disconnected.

The two bridge nose buffers are beyond repair, both are severely corroded with their counterweights missing.

Bridge Test Lifts

Two bridge test lifts were carried out, the original scheduled for Sunday 21st August 2016 had to be abandoned when after 10° of rotation the tail section of the bridge clashed with the access support platforms and steelwork on the fixed section of the Redcliffe approach. The bridge was lowered and the decision made to return at a later date when the offending platforms had been removed.

The second bridge test lift was carried out on Sunday 23rd October 2016, this was attended by representatives of the docks operations team, Bristol city council, CH2M, Radicon Transmissions and SSE.

During the first lift significant amounts of water poured out of the kentledge chamber at the bridge tail as the bridge inclination increased, the chamber is fitted with a drainage pipe but this may be blocked. Additionally large amounts of debris fell down from the bridge and support structure that can potentially come to rest on the outer quadrant tracks and the high level drive rack, this could lead to potential misalignment. There was nothing untoward during the first lifting sequence, the operating mechanism was smooth and reliable however upon later investigation of the video recordings on the outer quadrant on the northern side it is clear that the moving structure slides along the rack. It was not evident what the cause for this movement was but could have been a combination of debris on the track and misalignment on the tooth face causing the sliding movement.

During the first lowering sequence a video recording was taken of the outer quadrant on the south side of the bridge structure from the viewing platform, throughout the majority of the bridge travel there were a series of loud popping noises heard. As the bridge lowered the moving structure scraped the concrete structure on the southern abutment. Other than this there were no noticeable incidents and the lowering operation was smooth.

The second lift was also a smooth movement regarding the mechanical operating mechanism with no noticeable incidents (all of the water and most of the debris had occurred during the first lift), however when in the raised position a significant patch of debris/material was witnessed on the outer quadrant to the north side of the structure, this was manually removed and the track cleared. On lowering, the edge of the bridge structure only slightly kissed the concrete structure on the southern abutment.

It is clear that there are some misalignment issues with the bridge structure these are confirmed by the worn concrete nibs on the central reservation and the irregular clearances on the outer floor plates on both sides of the bridge walkway at the nose end of the bridge. It was commented that the bridge has always had an element of misalignment.

Recommendations

The following are the recommendations proposed to bring the asset up to a serviceable standard and enable continued operation into the future.

Main drive train

The general condition of the main drive train is good with no concerns regarding a bridge movement, there are some minor recommendations in the Radicon report, typically replace the existing lubrication oil and correct any minor leaks in the distribution pipework, fit a gasket to the inspection cover and possibly replace the oil seals with split units. The open gearing arrangement on the drive shafts are in good condition and have been regularly greased as have the supporting plummer block bearings, continue with the maintenance regime.

Estimated cost: £ 5k

The two sets of electro-hydraulic thruster brakes should have an inspectionvisit by the OEM to confirm that the equipment is operating as the original design this should include the manual hand pump system and advise of any rectification works.

Estimated cost: £500

The sensor on the first drive pinion is faulty and needs to be replaced in order for the bridge angle meter to function correctly.

Estimated cost: £300

The main rolling quadrants require some major works to remove any corroded material from the interlocking teeth of the quadrant and track, this should include the removal of the quadrant teeth and making good and repainting. The majority of this work could be undertaken during normal shift working hours however there would be a night time bridge closure required to access the teeth that are currently engaged on the track.

Estimated cost: £ (BCC internal task)

The drive pinions and track were not accessible during the static inspection, these must be checked to be free of any potential obstructions that could jam or misalign the drives.

Estimated cost: £

An alternative method to operate the bridge in the event of an electrical power failure should be investigated, this would require the removal of the four hand operated chainwheels and the drive shaft adapted to mount a hydraulically driven gearbox powered by a portable generator/power unit.

Estimated cost: £ 15k

Nose bolts

The nose bolt drive assemblies are generally in good condition and do not require any remedial works. The nose bolts should be retracted and inspected for damage and wear in conjunction with the pockets on the respective bearing stools on the bridge structure.

Barriers

The vehicle/pedestrian barriers themselves are in good condition and in keeping with the construction of the bridge structure although unlikely to meet the current design safety standards, the below deck operating mechanisms are in a poor state of repair.

Two options are recommended for the vehicle/pedestrian barriers:

- A – Replace both the vehicle and pedestrian gates and the operating mechanism at all four locations with a new gate set tailored solution to suit the existing site layout and constraints. The new gates can be designed to match the style of the existing gates and will operate in the same manner as the existing with the drive mechanism installed above ground.

Estimated cost: £200K.

- B – Replace the existing vehicle and pedestrian gates and the operating mechanism at all four locations with a new vertical lift barrier arrangement to suit the existing site layout and constraints. The new drive mechanism to be installed above ground.

Estimated cost: £85K.

Buffers

The buffers/dampers located at the nose pier of the bridge structure are beyond economic repair, it is unclear whether they would be a functional element of the structure even if they were in an operational condition.

The buffers/dampers at the tail in the machinery chamber should be replaced with new hydraulically operated industrial standard dampers.

Also the three wooden block end stops should be replaced, sized to suit the stroke of the new damper.

Estimated cost: £25,000 (£5,000 per damper plus £5,000 design)

Electrical Equipment

General

The Electric systems associated with the Redcliffe Bridge can be broken down into the following discreet systems, with the year of repair / replacement given in brackets as identified from the operation and maintenance manual.

- Drive systems
  - 2 x 50hp (37kW) Main Drive DC Motors (original 1940’s but overhauled 1993).
  - Gearbox lubrication pump motor (replaced 1996).
  - 4 x brake/retarding motors (replaced 1996).
  - Nose bolt drive motor (replaced 1996).
  - 4 x traffic gate and pedestrian gate motors (replaced 1996).
- Electrical Control System
  - Main control panel Redcliffe side (new 1996).
  - Nose bolt control panel Queens Square side (new 1996).
  - Operator control panel at bridge level control room (new 1996).
  - Field devices such as limit switches and proximity devices (bridge limit switches are original 1940’s but overhauled 1996).
  - Nose bolt limit switches and other control sensors (New 1996).
- Wig Wag lighting system
  - 4 x Wig Wag lights units and columns (circa 1986).
  - Wig Wag Control panel Redcliffe side (circa 1986).
  - Wig Wag Control panel Queen Square side (circa 1986).

- Intake electrical Switchgear (1986)
- Domestic electrical installation consisting of lighting, emergency lighting, and 240/110V small power services. (1996)

This report details the findings of a visual inspection of the electrical systems made on the 23rd October 2016 and a review of the systems obtained from the operation and maintenance manual.

The electrical systems should have a certificate of periodic inspection and testing carried out in accordance with the requirements of BS7671. When this is carried out additional requirements for remedial or replacement works may be identified to those identified in this report.

Parts of the electrical installations on the bridge were installed circa 1986 when the 15th Edition of the IEE Wiring regulations were in force. Other parts of the installation date from 1996 and were installed under the 16th Edition of the wiring regulations (adopted as BS7671). There is no mandatory requirement to upgrade the electrical installations to the current 17th Edition of the Regulations (Inc. Amendment No.3, 2016). It would however be expedient to upgrade to the use of residual current devices on the few socket outlet circuits installed on the bridge electrical installations. The periodic inspection and testing will also ensure the integrity of the wiring in terms of correct insulation resistance, adequacy and continuity of earthing and bonding, and the correct disconnection time of circuits under fault conditions.

DNO Intake Electrical Switchgear
There are two incoming Distribution Network Operator’s (DNO) power supply cutouts to the bridge.
Both the Redcliffe and the Queens Square cutouts, were replaced in 1993 along with the incoming cables which are of PVC insulated type. These appear to be in excellent condition and no work is envisaged to this switchgear or cabling.

Bridge Electrical Switchgear
The Bridge mains intake and distribution switchgear at the Redcliffe side consists of an incoming metalclad 200A Switchfuse by MEM and a GEC mini-form 415V switch-fuse panel for the sub main distribution. This equipment was installed circa 1986. Subject to satisfactory testing and inspection in accordance with BS7671 it’s use could continue but we recommend replacement within 5 years and for costing purposes this has been included.
The mains distribution panel on the Queens square side was installed in 1996, is in reasonable condition. Subject to satisfactory testing and inspection in accordance with BS7671 it can be considered suitable for continued use.

There are three final distribution panels located around the bridge DB1, DB2 and DB3. These panels were installed in around 1996. Distribution panels DB1 and DB2 are located in the main switchroom and are in reasonable condition as the environment is dry, however (DB3) located in the main bridge basement is now suffering external corrosion due to the damp environment. It is recommended that DB3 is replaced and relocated in the main switchroom with the 4 electrical circuits serving lighting and sump pump extended accordingly.

Power Distribution Cabling
The electrical cabling associated with the low voltage sub-distribution is mainly of PVC sheathed /armoured type installed in 1996 is in good condition and can be retained subject to testing.
The cable containment is generally galvanised steel cable tray except for some steel trunking and conduit in the switchrooms. This is generally in good condition and is suitable for continued use. Some small sections

of cable tray in the Queens square basement are showing corrosion and need to be cut out and replaced, however this is localised in nature.
The lighting and small power wiring is carried out in PVC cables drawn into galvanised steel conduit and this is generally in good condition without sign of corrosion.
Despite the good general visual condition all wiring this should be periodically tested and inspected in accordance with BS7671.

Lighting and Emergency Lighting Installation
The lighting installation was installed in 1996.
Operator cabins, staircases, switch rooms, nose bolt room, workshop, have corrosion resistant fluorescent luminaires and these are in good external condition. Approximately 30% of these luminaires have emergency lighting packs and these may require replacing or new emergency packs fitted due to battery degradation.
A number of Thorn 2D compact style fluorescent fittings are found in some rooms e.g. gate gear rooms, and these should be replaced. There are a number of self-contained 8W emergency non-maintained emergency luminaires installed in various areas which should be replaced due to age.
At basement level on the Redcliffe pier there are 150W and 70W SON floodlights, which are of poor to average condition externally, with some showing corrosion due to the damp environment. The lighting levels in this area are considered below current standards and should be improved by approximately 50% of the installed light capacity. It is proposed that all these luminaires are replaced as required and additional units provided.
In the Redcliffe Pier basement, the emergency lights are of the self-contained halogen floodlight type. These are showing signs of corrosion and due to their age should be replaced.

<u>Bridge Operating Machinery (Electrical) Drive System</u>
Main Drive motors
The Bridge raising and lowering action is powered by two 50hp (37kW) DC electric motors driving through a differential gearbox which in turn drives two rack and pinions, one on either side of the bridge platform. Each motor is rated to lift / lower the bridge independently of the other, however in normal operation both motors operate together and should ideally share the mechanical load. The differential gearbox does allow each motor input shaft to operate at different speeds and the load share will be dependent on the set up of the two DC motor controllers located in the main control panel.
The DC motors, which date to the original bridge construction in the 1940’s, were refurbished in 1993, and although the extent of the refurbishment is not known, it is likely that this may have included bearing replacement, rewiring the armature and field windings and dressing the armature.
The motors are still operable and recent successful test lifts have been carried out on 23rd October 2016. The motor power and current were monitored during raise and lower operations, the summary of main findings are as follows:-

	Bridge Raise @ full speed Max (kWe)	Bridge Raise @ creep speed end of travel Max (kWe)	Bridge Lowering @ full speed Max (kWe)	Bridge Lowering @ creep speed end of travel Max (kWe)
Motor 1	16	22.5	17	18
Motor 2	11	2.5	11	2
Total Bridge Elec Load (kWe)	27	25	28	20

From these results it can be seen that the total electrical load on the bridge with both motors operating does not exceed the individual rating of a single motor rating of 50HP or 37kW, hence either motor should be capable of lifting the bridge with a healthy margin. However more importantly, is the starting torque of the motors and test lifts with single motor operation are recommended during bridge recommissioning.

It is noted that the electrical power drawn is weighted in a ratio of 60/40 towards Motor 1 during the main lifting operation and a ratio of 90/10 towards Motor 1 during the creep operation at the end of the bridge travel. It is recommended that the reasons for this are investigated during re-commissioning and may be simply due to the setup of the DC motor controllers.

The bridge drive motors were built in the 1940’s and of old DC technology, it is still currently possible to get these types of motors rewound/refurbished by specialists in the field.
If the brief was to bring the Bridge back into full time operation with regular daily lifting and say a design life of 25-30 years then now would be an appropriate time to consider replacing the motors and the associated control system with modern AC induction motors and AC inverter drive control system. Considering that the bridge is not going to be regularly used and there are duty / standby drive motors then this major reconstruction is not proposed at this juncture.
The recommendation for the main drive motors is for an ‘insitu’ inspection and electrical testing by a specialist motor refurbisher, such as Rotamec Engineering solutions. The inspections would involve electrical winding insulation tests, armature / brush gear inspection, removal of non-drive end bearing cap to inspect and check lubrication / check for corrosion and a general internal inspection where accessible. For budget purposes a provisional cost included in the summary.

2 x Holding brake motors and 2 x retarding brake motors
These motors look to be in excellent visual condition they are of a sealed type and requires only electrical testing.

1 x Nosebolt motor
This motor is externally corroded due to the damp environment and should be cleaned and repainted. It has an in-built in clutch release at the non-drive end which should be inspected and tested. Electrical testing is required.

Gearbox lubrication pump motor.
This motor is of aluminum construction is heavily corroded; the aluminum cooling fins have all but disappeared. This should be replaced.

External Anti-Condensation heaters adjacent to motors
These were operational at the time of inspection, but they are poorly fixed and do not have guards to prevent contact with high temperature surface. The wiring is carried out in 230V unarmoured cable which has no mechanical protection and the circuit is not protected by an RCD. The domestic type BS1363 socket outlet is not appropriate for the environment. It is recommended to replace the anti-condensation heater on each motor, upgrade the wiring and fit an industrial socket outlet to BS EN 60309.

Wig Wag traffic control
The Wig Wag system dates to around 1986. There should be four Wig Wag lighting units mounted on columns, one located on each carriage way at both ends of the bridge. One of the Wig Wags units and it’s mounting column have been removed. The three remaining Wig Wag are mounted on heavily corroded columns. The Wig Wag system is not currently functional and due to the age of the system it is recommended for complete replacement including controls.

Traffic and Pedestrian Gates Electrical Systems

The electrical systems associated with the traffic and pedestrian gates are located in four pits located under road/pavement level. One of these pits were surveyed on the 23 January, but it is understood that the condition of all equipment is all similar. The system is not operational.

The electrical equipment in each pit consists of an electric drive motor and end of travel limit switches mounted on the geared gate drive system. The motor and drive is controlled from the main bridge control system with gate position signalled by the limit switches.

The motor inspected was heavily corroded, the limit switch mountings were corroded away and the limit switches were loose and not functional.

As the whole gate system is considered for a complete replacement (see mechanical section of this report) this will also need to include the electrical systems to suit the new technology employed.

Main Control System

The main bridge control system which was updated and replaced in 1996 consists of the following main elements:-

- Operator control panel
- Redcliffe Pier control panel
- Queens Square Pier control panel
- Remote relay panels collecting remote signals e.g. ‘Trolex’ Relay Panel’s
- Digital sensors
- Nose bolts position limit switches
- Bridge position limit switches (refurb 1993)*

In general terms electrical/electronic control systems typically achieve a design life of around 15 to 20 years, but with increased maintenance and management can often extend beyond this. The issues that determine the end of useful and economical life is primarily that of obsolescence, caused by new / improved technology resulting in lack of legacy support for spare parts and also a general increase in failure rates of the discrete components forming the control system. On this basis the Bridge control system at around 20 years age could be considered for replacement. If a decision was made to replace the control system this should also be made with consideration to the age of the main DC drive motors which were built in the 1940’s. The motor drives and electrical system as a whole would be replaced with modern AC motors, AC inverter motor drives and a programmable logic controller (PLC) based control system.

However the bridge control system has proven reliable, with failures being related only to the newer limit switches employed at the nose bolts (a number of references in the Operation log). Also the fact that the operation of the bridge does not have high criticality and is only operated a few times per year give the basis for extending the life of the systems rather than replacement at this juncture.

Many of the components used in the control panel and field devices are no longer manufactured as direct replacements. A brief check on the ‘Trolex’ relays and the AC/DC thyristor drives for the DC motors indicate these items are no longer manufactured. If there is any failure and spares are not available then more extensive repair would be required taking longer to implement e.g. subsystem replacement of a suite of relays or rewiring to suit an alternative manufacturer’s equipment would be required. However due to low criticality of operations this could be an acceptable situation to Bristol City Council.

Operator Control panel

The operator control panel is in good condition internally and externally with all switches and indicators reported as functioning.

On the assumption that complete control system replacement is not a preferred option, then the following is recommended to extend the operation of the electrical systems by 5 to 10 years.

- Carry out periodic testing and inspection of electrical wiring installations.
- Review spares holdings and identify other components that may be obsolete; check and source adequate spares.
- A number of 110V joint boxes (at least two seen) around the installation are corroded and need replacement.
- Treat and prevent further corrosion to the ‘Trolex’ relay panels.
- Replace bridge angle sensor.
- The main flexible travelling cable systems (allows the bridge leaf rotation) are likely to require replacement, (50% of cables were replaced in 1993 and by definition the others must be older and possibly original 1940’s).
- Replace the joint boxes on the flexible cabling system both ends. These are original units, have unsealed covers protecting the terminals (terminations could not be inspected on the day of the survey but should be inspected for condition). If the terminations are in good condition then provision of gaskets to the joint box lids and treatment of any corrosion may be acceptable.
- In the main control panel (Saftronics) power section, to improve safety, provide internal IP2X perspex shielding over the exposed low voltage terminals, contactor terminals etc.
- Replace anti-condensation heaters which are showing signs of blackening.
- Provide mechanical protection and support to the sensor cabling at the nose bolts and bridge angle sensors at the main gearbox.
- Inspect the main bridge travel limit switches and ensure no degradation to electrical contacts, confirm bearings and seals are serviceable. Ensure the latching mechanisms are not damaged and engage correctly. Clean and rewire locally.

Miscellaneous works
To enable the repainting of the bridge works it may be necessary to remove, release and protect electrical equipment and a budget cost is allowed in the Summary for this.

Recommissioning
On conclusion of all testing inspection and repairs it is recommended that the bridge electrical and mechanical system undergoes a full recommissioning programme. This would include the following works:-

- A series of bridge operations with each main motor drive operating independently and both operating together.
- Balance the AC/DC electrical motor drives.
- Check all safety interlocks.
- Check all operational interlocks.
- Check operation of all sensors to specification.
- Check operation of brakes.

Summary of Proposed Electrical Works

Item	Action Proposed	Provisional Budget Costs £k	Comment
DNO switchgear /cutout	None	0	
Bridge Electrical Installation	Periodic inspection and testing of wiring installations.	8	Includes budget for minor corrective works, replacement of DB3.
Bridge mains switchgear	Replacement of 1986 equipment	3	Depending on tests may be suitable for 5 to 10 years
Lighting & Emergency Lighting	Replace emergency units and upgrade lighting levels in Basement	8	Requires scaffolding.
Small Power 230V	Replace outlets with RCD protected units. In motor room replace domestic sockets with Industrial socket outlet feeding anti-condensation heater.	1	
Bridge Control System	Periodic inspection and testing of wiring installations. Provide IP barriers in main Control Panel power section. Replace anti-condensation heaters in panels. Repair/protect relay panels	5	
Sensors and limit switches	Service or replace. Improve wiring on nose bolts	3	Scaffold access is required to access bridge end of travel limit switches
Main DC Drive motors	Arrange (insitu) inspection and test of windings, brushgear, armature, bearings and internals as far as possible Clean carbon dust. Prepare report.	1	Further works may result depending on outcome of inspections. Full motor refurbishment is around £5k per motor plus removal, transport and re-install. (not included here).
Anti-condensation heaters for motors.	Replace with anti-condensation heater and fit with safety guard, plus rewire locally	1	
Gearbox lube oil pump motor	Replace motor and test.	1	

Nosebolt motor	Clean and repaint. Test.	.5	
Brake motors	Electrical testing. Brake function test (see mech section).	-	
Flexible travelling cabling and junction boxes for bridge rotation	Check condition in detail and replace as necessary.	5	Complete replacement is dependent of further investigations
Wig Wag system	Complete replacement of Wig Wag heads, columns, wiring and controls.	20	
Gate / Barriers	Electrical works associated with replacement	5	
Bridge Control system	Major recommissioning of control system after all works carried out; with full functional testing of all interlocks and operation of bridge drive motors in operating individually and together.	10	
Bridge Repairs e.g. repainting	Provisional sum for temporary removal and replacement of cabling etc.	10	

Structural Assessment

The structure was inspected using roped access techniques 18 June 2015 and an interpretive principle inspection report was produced dated 16 September 2015.

The overall condition of the superstructure bridge was considered in good condition, the 3 deck spans. There was some cracking in the concrete encasing the steel beams on the two approach spans. There was concern about the two trestles which support the rack that provides the reaction of the pinion wheel which causes the bridge to lift and the steel frame supporting the central part of the Redcliffe approach span and further assessment of these parts of the structure were advised. A review of the assessment and strengthening works undertaken by Cas Hayward in 1988 was undertaken as part of the principle inspection and concluded the structure remained suitable for normal traffic loading. Paint testing during the principle inspection found lead levels in the paint that will require complying with working with lead regulations and arising from abrasion of the paint will have to be disposed as hazardous waste

Following the Principle inspection report an assessment of the trestle steelwork supporting the opening rack and the pier support for the Redcliffe span, both in the main pier. The reason for the assessment was considerable corrosion to the steel work which was considered to have deteriorated further since the works by Cas Hayward in 1998. Taking into account the significant loss of section of some members it was still considered robust to support the applied loads. However, it is important that the steelwork is restored to original dimensions. The estimate to correct these defects is £108,000

The inspection of the machine room has shown extensive failure of the paint with at least surface rusting. The whole area requires to be stripped back to bare metal and repainted. Some of the rivets may require to be replaced with tension control bolts. It was not possible to make an accurate assessment of the numbers due to the paint and rust flakes around the edges. The estimate for repainting the machine room is £133,000

The kentledge weight tank has not been inspected internally, during the test lifts large volumes of water drained out of the tanks. It is possible that the protective paint system has failed and there is corrosion of the steelwork forming the kentledge weight tank. If left this corrosion will lead to significant loss of section and failure resulting in the weights falling out. During the first lift there were pops and bangs heard which may have been the kentledge weights moving in the tank as the bridge was lowered. The estimate for the ballast tank to remove weights, prepare and repaint with some repairs is £313,000

The gate operating mechanism is housed in a recess in the deck with a steel floor which is corroded over the entire area on both sides. No estimate has been made about any section loss and therefore whether it is safe to support any weight. It is advised that no one enters these chambers until the stability of the floor plate has been assessed. It is difficult to estimate cost of replacing the floor plate because the method of access is the more significant cost but could be £100 000 – £200 000

There is significant wear on the nose landing bearings and these will need to be refurbished or replaced. Estimated cost of refurbishing the bearings is £40 000

The joint on the Redcliff pier requires replacing as one section is missing. The estimated cost of replacing the joint is £50 000

If major refurbishment works are being undertaken, then a total repaint would be beneficial and this would be approximately £0.5m

Conclusion

Overall the main operation of the bridge is satisfactory but there are serious deficiencies in ancillary equipment which prevents opening the bridge solely from the control panel.

Mechanical

There were no concerns with the main drive train, some servicing of the lubrication of the differential is required, replace oil seals and gaskets and repair leaks in distribution pipework. The open gearing is in good condition and well lubricated. It is suggested that an alternative to manual operation is used in the event of a power failure by installing an alternative drive powered by a portable power pack. The vehicle pedestrian barriers are non-functional and the operating mechanism needs to be fully replaced and it is considered they are unlikely to meet current standards. None of the buffers or dampers at the nose landing or tail end in the machinery chamber are functional and require replacing.

Electrical

The electrical installation wiring requires testing in accordance with BS 7671, subject to satisfactory testing the switchgear will be satisfactory for a further 5 years when it should be replaced. Final distribution Pane DB3 has external corrosion to the damp environment and should be replaced and relocated. The main drive motors were found to be satisfactory but the extent of refurbishment in 1996 is unknown and a full inspection and testing by a specialist motor refurbished is recommended. The various ancillary motors need testing and the gearbox lubrication pump motor requires replacing. The external anti condensation heaters and supply wiring require replacing. The wig wag traffic control lights are non-functional and require complete replacement including controls replacing. The main control system has proven reliable but is beyond what is typically achieved as a design life and many of its components are obsolete. Due to the low criticality of operations the longer duration required to carry out more extensive repair is likely to be acceptable. The section of the report on the electrical equipment contains a full set of recommendations to extend the life of the main control equipment

Structural

There are no structural deficiencies that require immediate attention but there are works required to retain structural stability in the longer term. Sections of the rack trestle support and trestle supporting the Redcliffe span have significant corrosion and loss of section which requires replacing. The internal condition of the kentledge tank is unknown and requires emptying, inspecting, carrying out any necessary repairs and repainting. Repairs to the drainage system, refurbishment of replacement of the nose bearings and replacement of the Redcliff pier joint are required

Estimate of Mechanical works	£246 k
Estimated cost of Electrical works	£82 k
Estimated cost of structural works	£1 344 k
Sub Total	£1 672 k
Sum for contractor's welfare supervision site management overheads and profit -20%	£334 k
Sub Total	£2M
Contingency – 20% Additional work 10% Additional constraints 5% Delays 5%	£400k
Grand total	£2.4m