KOSCIUSZKO BRIDGE
RF ILLUMINATION/SAFETY, SHOCK HAZARDS INVESTIGATION

FINAL REPORT

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1.0 Scope

The scope of this document is to present the results of investigations conducted at the Kosciuszko Bridge located in Queens, New York relative to induction of Radio Frequency voltages and the consequential potential shock and RF burn effects. These effects are as a result of proximity to AM Radio station transmitter WQEY (1560 kHz).

1.1 Background

A person approaching the bridge structure from beneath via "man-lifts" reported shock like sensations and in some cases arcing and minor burns when coming in contact with the bridge structure during the process of disembarking from the lift. Use of the man-lift is necessary to accomplish various bridge maintenance tasks such as structural inspections and painting. Original speculation that the "electrification" of the bridge was due to 60 Hz faults proved incorrect. Measurements of the frequency of the voltages present produced a result of 1560 kHz corresponding to the carrier frequency of WQEY at a distance of 1 mile on a relative heading from the bridge of 140 degrees true. These results suggested that investigation of the RF induction mechanism was appropriate. Ahern Painting Contractors Inc. of Woodside, NY, retained the author of this report to conduct the indicated investigation. The information contained herein is the result of that effort.

2.0 References


4.) OSHA Regulations (Standards - 29 CFR) - 1910.97 - Nonionizing radiation
3.0 Executive Summary

The concept of "grounding the bridge" to prevent occurrences of electric shock etc. from the incident electric field from the radio station is not possible or practical within the constraints of the intended bridge usage. Moreover, "grounding the bridge" such that all parts of the structure remain at zero volts with respect to earth ground is not desirable. This is because the man-lift may extend to heights approaching 40 meters (120 feet) resulting in voltage being induced on the man-lift in the amount of 80 volts. Contact between the man-lift and anything at zero potential would still involve a difference potential of 80 volts, which is enough to produce the indicated sensations. The optimum solution would be that of preventing any voltage difference from arising in excess of 30 volts between the man-lift platform and the bridge, without regard to the location or height of the lift, without regard to the position with respect to the bridge, and without the need to establish a connection between the bridge and the lift. This is not possible due to the variability of the voltage induced onto the bridge structure by the combination of RF induction into the vertical members on the bridge and the voltage-standing-wave pattern induced on the horizontal sections of the bridge by conduction from the vertical supports.

3.1 Practical Solutions

The following techniques used separately or in combination will result in elimination of the shocks/burns to personnel:

a.) Use automotive type "jumper cables" to connect the man-lift platform to the bridge prior to contacting the bridge with the hand or other body parts. This technique will limit the voltage difference between the man-lift, the person on the man-lift and the bridge to a maximum of approximately 12 volts, which cannot produce any sensation.

b.) Personnel using the man-lift should wear insulating gloves and outer garments to prevent coming into electrical contact with the bridge.

c.) The man-lift platform/bucket, may be modified to utilize an insulating dielectric material such as Fiberglass to provide insulation between persons aboard the man-lift and the man lift structure. (Note: This is the technique used by utility workers when servicing overhead high voltage power lines.)

4.0 Discussion, Observations

Measurements and observations were made during the period of January 14 through January 18, 2002. Additionally, information relating to the location, antenna pattern and field strength at the bridge from the neighboring radio station (WQE W)
were obtained. The writer is indebted to the "Carl T. Jones" Corporation c/o Herman Hurst, for the latter information.

4.1 **Location, Field Strength Information, WQEW (Formerly WQXR) 1560 kHz**

![Map showing the location of WQEW (1560 kHz) and its relationship to Kosciuszko Bridge.](image)

*Figure 1*
Physical Relationship of WQEW (AM 1560 kHz) to Kosciuszko Bridge
It should be noted that the reference to "Radio Towers WEVB" in the approximate center of the map refers to a transmitter that appears to be non-operating as of this writing. No reference to this station could be obtained from the FCC or the website, http://www.radio-locator.com.

The bridge is on a heading relative to the WQEW transmitter of 320 degrees true (140 degrees true, bridge to transmitter) at a distance of 1 mile. The measured field strength at the bridge location is 2.15 volts/meter. This information is obtained from the daytime antenna pattern used by WQEW. The transmitter output power is 50,000 watts AM. The antenna pattern is shown as Figure 2.
Figure 2
Daytime Antenna Pattern, WQEW AM (formerly WQXR)
4.2 Concept of RF Induction, Electrical Height

The consequence of the presence of a vertically polarized electric field at 1560 kHz at the bridge location is that any vertical conductor will have voltage induced upon it equal to the field strength in volts/meter X the actual height of the conductor in meters. This relationship applies so long as the conductor in question is shorter than \( \frac{1}{4} \) wavelength at the frequency of interest. This is an approximate relationship whose accuracy improves as the conductor length becomes shorter. In this case, \( \frac{1}{4} \) wavelength = approximately 50 meters (150 feet). Wavelength is determined from the following relationship:

\[
\lambda \text{ (Meters)} = \frac{300,000,000}{\text{frequency in Hz}}.
\]

For WQEWS then, we have:
\[
\lambda = \frac{300,000,000}{1,560,000} = 192.307 \text{ meters.}
\]
\[
\lambda/2 = 96.1535 \text{ meters.}
\]
\[
\lambda/4 = 49.32675 \text{ meters.}
\]

For the purposes of these discussions, 100 meters and 50 meters will be used to approximate the \( \frac{1}{2} \) and \( \frac{1}{4} \) wavelengths associated with WQEWS's signal.

“Electrical Height” is the factor for a given antenna that relates voltage induced to incident field strength. In the case of short monopoles (such as the TWA-tran-lift) electrical height is simply equal to the physical height in meters. (See reference (1.) section 32) The concept of electrical height is illustrated below as Figure 3.

```
Any Vertical Conductor

\[
V = hE
\]
\[
(h < 1/4 \text{ wavelength})
\]
\[
\text{Wavelength} = \frac{300}{(\text{Frequency MHz})}
\]
\[
\text{Meters}
\]
\[
\text{WQEWS wavelength} = 197 \text{ Meters}
\]

Earth Ground

Figure 3 – Concept of Electrical Height
```
It may be seen as an example that a man-lift extended to 120 feet (approximately 40 meters) will have Eh volts induced or \(2.15 \times 40 = 86\) volts with respect to earth ground potential. Similarly, voltage will be induced onto the vertical members of the bridge. Inspection of the bridge revealed that the horizontal span contacts the two center towers at each side of the river in the approximate middle of the bridge. The concrete piers supporting the remaining spans (11 on each side) are not in RF electrical contact with the center span. It was therefore concluded that the sketch shown as Figure 4 depicts the electrical model of the bridge and vertical conducting supports.

\[
\text{Volts (RF)} \quad 50\text{V (est.)} \quad 120\text{V (est.)}
\]

![Connected Bridge Parts](image)

Figure 4
Electrical Bridge equivalent conductors with resulting induced standing wave pattern (upper sketch)

It should be noted that the depiction of 120 volts at the center of the bridge is an estimate based upon the height of the center towers. Contact with the center towers will result in a "Standing Wave" pattern of voltage induced on the horizontal span radiating from each of the towers. This effect will result in alternating voltage maximums and minimums spaced one half wavelength from each other (100 meters). At the location of the minimums, the current in the bridge will be at a maximum while the voltage is at a minimum. At the voltage maximum locations, just the opposite is the case (minimum current, maximum voltage). It should be noted here that induction in voltage directly into the horizontal portions of the bridge from the incident field is a second order effect due to the vertical polarization of the incident field. The main source of excitation of the horizontal
portion of the bridge is as a result of contact with the center towers that are being driven by the field.

4.3 Measurements

Voltage measurements were made near the base of the Queens side center tower. The main purpose of the measurements was to obtain data relating to RF voltages present at the base of the tower with respect to earth ground as well as measurements made at a location part way up the center tower (approximately 20 meters from ground level) between the man-lift platform and the tower.

Figure 5
4.3.1 Measurement Instrument(s)

The RF voltage measurements were made using a Simpson Model 260 series 5 volt-ohm-meter. This instrument was selected over the more modern digital meters because of its total lack of active electronics that may be upset by the strong RF signals present. A schematic of this meter is shown as Figure 6 for reference.

![Figure 6: Overall Schematic, Simpson Volt-Ohm-Milliammeter, 260 Series 1 & Series 5](image)

It was observed however that initial attempts to use the meter in the "AC" voltage mode proved unreliable. Previously, the meter had been checked to determine its frequency response with respect to 60 Hz and found to be within 1 dB accurate at 1.5 MHz with respect to its response at 60 Hz. However, this comparison was made using a 1-volt RMS reference signal at each frequency. At the bridge site, it became apparent that readings of 50 – 100 volts were required. The meter exhibited an effect such that for ranges above 10 volts full scale, the meter read the same value regardless of the setting of the range switch. An examination of the Figure 6 schematic of the meter provides a clue as to the likely problem. Resistors R13 and R9 (upper right corner of the schematic) have values of 1 and 3.75 M\(\Omega\) respectively. These resistors are switched in series with the input leads when making measurements on the 50 and 250-volt full-scale positions respectively. Because of the high value of these resistors, it is likely that their predominant...
impedance characteristics at 1.5 MHz are those of capacitors as opposed to resistors. Notice that a capacitor having an impedance equal to $3.75 \, \text{Megaohms}$ at 1.5 MHz will have a value of $2.82 \times 10^{-14}$ farads or 0.03 picofarads. Typical leaded resistors exhibit capacitance of about 1.5 picofarads which means that the impedance of the two resistors associated with the high range AC settings was dominated by their self-capacitance as opposed to their resistance. Since both resistors would exhibit the same self-capacitance and since the reactance of 1.5 pF is 70.7 kOhms at 1.5 MHz, the similar readings on the high ranges are accounted for.

4.3.2 Simpson Meter RF Adapter

An RF detector circuit was constructed to be used ahead of the Simpson VOM to permit measurements using the DC voltage ranges on the meter that were proportional to the RF voltage being measured. This circuit was constructed to mitigate the problems associated with the use of the meter on the AC voltage ranges.

![Diagram](image)

**Figure 7**

RF Voltage to DC converter adapter

This circuit was used with good results on all voltage ranges (DC) of the Simpson VOM.

4.3.3 Measurement Connections

Measurements made at the tower base with respect to earth ground were performed using the setup shown as Figure 8.
Figure 8
RF voltage measurement setup

The RF adapter board is seen connected directly to the meter input. Note, the light bulb was used to determine if there was enough RF current to illuminate the bulb (15 watts) and there wasn't. (See later discussions about theoretical maximum available power)
### 4.3.4 Measurement Results

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<td>Condensation on tower and ground 0800 hrs</td>
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<td>Ground</td>
<td>Tower connected wire @ 20M</td>
<td>10 volts</td>
<td>Series Resonating capacitor connected between ground and tower wire (see text)</td>
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4.3.4.1 Discussion of Measurement Results

The original objective of "grounding the bridge" was concentrated on during the measurement activities. Toward that end, ideas relating to "tuning" conductors connected to the bridge in an attempt to reduce the voltage induced were tried. Principal amongst these ideas was the circuit shown as Figure 9, which was used for measurements 4 and 6 as depicted in Table I.

![Figure 9](image)

"Series Resonant" shunt loading of tower scheme

The concept here was that since the "tower wire" was electrically short (<λ/4) its equivalent circuit was a distributed inductor. The idea came to add a variable capacitor between the lower end of the tower wire and ground as depicted in the figure with the attempt to create a series resonant circuit at 1560 kHz and thereby "load" the tower with this circuit and reduce the voltage at the upper elevations of the tower with respect to ground. Indication of resonance was a "peaking" of the voltage across the variable capacitor as it was adjusted. This occurred as expected however, the benefit was unknown to minimal as measurements between the lift and the bridge exhibited only minor variations probably due to the fact that the voltage induced on the lift was unaffected by the tuned circuit. Hence a voltage difference between the lift platform and the bridge still remained even though the tower voltage with respect to ground may have reduced.
Measurements 1 and 2 were at first confusing as to the variability with time. However, the observation that the morning measurement was made with the bridge and surroundings covered with condensation from the morning fog of the day suggested that the overall RF loading of the bridge was being affected by moisture. As the day wore on, the sun came out around 9 AM and by noon, everything was dry. During that time, the voltage between the tower base and ground was monitored and found to gradually rise to a peak level of around 10 volts.

5.0 Safety Concerns

Safety of the workers both on and approaching the bridge is of course of paramount concern. There are several properties of the RF illumination of the bridge and support equipment that need consideration. The overview is working in, around, under and on top of the bridge may be considered safe by utilizing a few simple procedures. This section deals with those issues.

5.1 Roadway (bridge surface) concerns

Vehicles, people and other equipment located on the roadway surface of the bridge will be illuminated by the incident Electromagnetic Field just as the remainder of the bridge structure. The important concept to recognize is that the bridge surface will arrive at a certain RF voltage potential as a result of this illumination. Whatever that potential might be, all persons, vehicles etc. will also arrive at that same potential. This means that there are no significant potential differences to be encountered at any given location on the bridge. This is much analogous to the "bird on the wire" concept. The bird landing on a high voltage transmission line, experiences no difficulties so long as all of his body contacts only that one wire. In other words, the bird experiences no potential voltage differences across any part(s) of his body so long as he doesn't contact the neighboring wire. He and the wire may well be at an AC potential of several thousand volts with respect to earth ground but since neither the wire or the bird are in contact with the earth, no current flows and no damage is done. The bridge situation is similar and analogous to the bird situation. Whether the bridge potential with respect to earth is zero or 1000 volts is not important so long as all who are in contact with a particular part of the bridge can only contact the bridge and other items/people in the same location.
They will all be at the same voltage and therefore not experience any adverse affects. This is an important consideration for possible accident scenes on the bridge as well with regard to ignition sources for split fuel etc. It should be noted however, that should a situation arise in which a large crane were to be erected on the bridge roadway, voltages will be induced into the crane structure just as they are in the man-lift and precautions should be taken to avoid contact with the crane cable etc. as already discussed.

5.2 Bridge Inspection Devices (ref: “Snoopers and Travelers”)

These are devices that attach to either the surface of the bridge or the underneath area of the bridge allowing inspection activity to take place while moving along the length of the spans. Since these devices will arrive at whatever the electrical potential is at their particular location, the same assurances apply as for the roadway safety issues. If we assume that the typical dimensions for these devices are such that there are no protrusions from the bridge point of contact that exceed 20 feet, the maximum possible induced voltage will be of the order of 18 volts. This is not a shock hazard and therefore would not require the “jumper cable” type grounding associated with the man-lift.

5.3 Chain Link Platform

This is a horizontally installed “platform” made from chain link material attached directly underneath the bridge structure for the purposes of supporting the painters as they paint the underside of the bridge. The maximum induced voltage here is approximately 10 volts, which is again not a safety issue. No reports of shocks to workers already on this platform have been made.

5.4 RF Exposure Hazard

The following is an excerpt from the OSHA regulations:

OSHA Regulations (Standards - 29 CFR) - 1910.97 - Nonionizing radiation.
Power density: 10 mW/cm.² for periods of 0.1-hour or more.
Energy density: 1 mW-hr/cm.² (milliwatt hour per square centimeter) during any 0.1-hour period.

The units are given in power density (milliwatts per square centimeter). The power density associated with WQE at the bridge is calculated as follows:

Power density = $E^2/Z$ watts per square meter where:

E = Electric Field strength in volts/meter
Z = Impedance of free space = 120π ohms or 377 ohms
Solving for power density we have $(2.15)^2/377 = 0.012$ watts/square meter.
Or $1.2 \times 10^{-6}$ watts per square centimeter.
This level is approximately 1000 times smaller than any of the recommended safe standards for human exposure.

6.0 Conclusions

1.) There is significant RF voltage induced into the man-lift vs. bridge arrangement such that direct contact by people between the bridge and the lift parts will create a shock or possibly a burn.

2.) Mitigation of item (1.) is achieved by attaching a conductor (14 AWG or larger) between the man-lift platform and the bridge structure prior to contact with the bridge.

3.) There is no practical solution to “grounding” in the conventional sense due to the nature of RF energy creating voltage gradients across conductive members of the bridge.

7.0 Recommendations

1.) Permanently attach “jumper cable” type conductors no longer than 20 feet in length to the platforms of the man-lifts to be used. The outboard end of this cable can be a jumper cable style clip, which will provide the needed insulation during the process of connecting it to the bridge.

2.) Install a placard on all man-lifts to be used at the bridge site warning of the need to make the indicated connection prior to any personal contact with the bridge.

3.) Issue a memo to any potential contractors working on or around the bridge as to the presence of this phenomena and advise them to take the indicated precautions.

8.0 Acknowledgements

The writer is indebted to the following people for their assistance in this investigation:

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