APPENDIX A

HARMONIC DISTORTION: CAUSES AND EFFECTS

Although a complete power quality survey is beyond the scope of the normal infrared inspection, the load data for thermal problems during your survey will indicate whether harmonic distortion exists in the circuit supplying the defective component.

Harmonics are currents of voltages with frequencies that are integer multiples of the fundamental power frequency. For example, if the fundamental frequency is 60 Hz, then the second harmonic is 120 Hz, the third is 180 Hz, etc. [1]

Harmonics are created by non-linear loads that draw current in abrupt pulses rather than in a smooth sinusoidal manner. These pulses cause distorted current wave shapes which in turn cause harmonic currents to flow back into other parts of the power system.[2]

The problem is evident when you look at the current or voltage waveform. Normal 60 cycle power appears on the oscilloscope as a near sine wave (see Figure 1).[3] When harmonics are present, the waveform is distorted. These waves are described as non-sinusoidal (see Figure 2).[4]

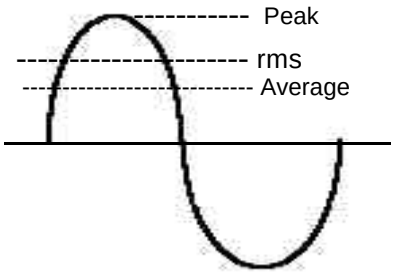

Figure 1

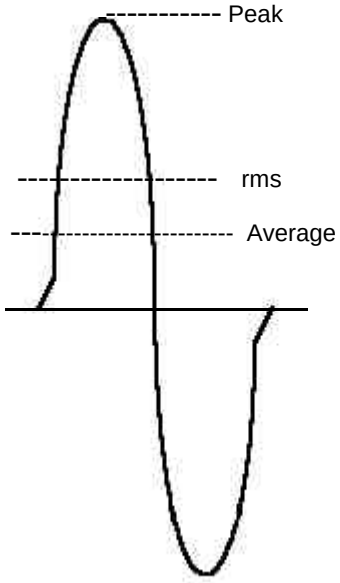

Figure 2

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[1] "In Tune With Power Harmonics," John Fluke Manufacturing Co., Inc., p. 5.

[2] Ibid.

[3] David C. Griffith, "Harmonics in Power Distribution Systems," AIPE Facilities, July/August 1993, p. 58.

[4] Ibid.

The voltage and current waveforms are no longer simply related; hence the term non-linear.[5] The ratio of the peak current to the RMS current, called the crest factor, is also indicative of the power quality, as shown below.

$$\text{Crest Factor} = \frac{\text{Peak Current}}{\text{rms Current}} \qquad \text{Form Factor} = \frac{\text{rms Current}}{\text{Average Current}}$$

Crest Factor for Sine Wave = 1.41 for Typical Non-Linear Load = 2 to 3

Form Factor for Sine Wave = 1.1 for Typical Non-Linear Load = 1.5 to 5

The following are typical non-linear loads which cause harmonic distortion:

- Computers, especially PCs
- Computer Terminals and Work Stations
- Computer Peripherals and Modems
- Word Processors
- Copy Machines
- Facsimile
- Teletype
- Telephone PBX
- Heat Pumps and Air Conditioners
- Adjustble Speed Drives
- Rectifiers
- Fluorescent Lights (including electronic ballasts)
- Arc Furnaces[6]

Current distortion can cause these problems:

- Improper calibration of overload devices and meters
- Low power factor resulting in possible surcharge
- Reduced electrical system capacity
- Excess neutral current - three-phase, four-wire systems
- Overheating and failure of components, transformers and circuits
- Overvoltage of system components - ASD and PF capacitors
- Voltage distortion[7]

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[5] "In Tune With Power Harmonics," John Fluke Manufacturing Co., Inc., p. 5

[6] David C. Griffith, "Harmonics in Power Distribution Systems," AIPE Facilities, July/August 1993, p. 55

[7] Ibid., p. 59

The effects of voltage distortion can be:

- Metering and relaying errors.
- Unnecessary computer shutdown.
- Reduced power interruption tolerances.
- Increased heating - motors, transformers, and switchgear.
- Timing errors - multiple zero crossings.[8]

Although harmonics are not always the primary cause of themal problems, the effect of harmonic distortion should always be considered when correcting thermal problems found from the infrared inspection.

If the customer does not have sufficient electrical training, an electrical consultant knowledgeable in harmonics should be called in to properly analyze the power quality and effect the proper solution.

[8] David C. Griffith, "Harmonics in Power Distribution Systems," AIPE Facilities, July/August 1993, p. 55