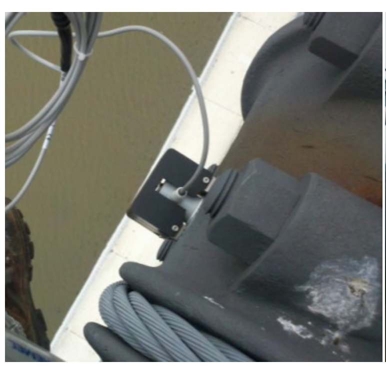
APPENDIX A – ANTHONY WAYNE BRIDGE ACOUSTIC EMISSION MONITORING REPORT (MISTRAS)

Anthony Wayne Bridge
Acoustic Emission Monitoring Report

Location: Toledo, Ohio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3.0 Executive Summary

This report documents the installation, monitoring and current status of the Acoustic Emission Monitoring system installed on the Anthony Bridge Bridge in Toledo, Ohio. The installation of the system was started Monday, June 13, 2011 and was completed on Thursday, July 14, 2011. As of Thursday, July 14, 2011 – the systems and sensors on both the North and South cables have been continuously recording and monitoring the cable. As of September 10, 2011, no potential wire breaks have been recorded.

The primary objectives of this monitoring include:

- Monitoring the main cables of the Anthony Wayne Bridge for a potential wire break(s);
- Provide frequency and location of potential wire break(s);
- Identify any additional areas of interest along each main cable for future inspection;
- Inspection of the AE sensors, strain gauges, and installed

4.0 Structural Health Monitoring Equipment

4.1 Sensor Highway II Smart Remote System

Two (2) Mistras Sensor Highway II (SH-II) AE systems (Figure 1) are installed on the Anthony Wayne Bridge (1 system/main cable) and use the AEwin Sensor Highway Smart Monitor (SHSM) software application package for the collection of AE data. Each system contains (4) 4 channel AE subsystem boards with the capability for simultaneous feature/waveform based AE channels, for a total of 16 AE channels (15 channels installed). The SH-II has been developed for un-attended use in "Asset Integrity Monitoring" management and condition monitoring applications. The Sensor Highway case size is approximately 20" x 16" x 6" deep. The AE Sensor Highway is scalable, allowing for multiple units to be placed near the structures that are being monitored. There is no theoretical limit to the number of overall channels (based on 16 channel separate units) that can be connected in one location.

Figure 1 - AE Monitoring System

4.2 Acoustic Emission Sensors

The sensors used for collection of AE data are the Mistras R0.45I-LP-SC-AST sensors (Figure 2). The "R" designation indicates that the sensor is a "resonant" transducer with a resonant frequency of 45 kHz and peak sensitivity over an operating frequency range of 5-30 kHz with a roll off to either side of the range. This sensor is typically used for AE inspection of suspension/cable-stay structures. The "I" designation indicates that the sensor has a built-in, low power (LP) 12dB preamplifier, which allows the capability to drive long cables without the need for separate preamplifiers. For field applications, the

Figure 2 - AE sensor

sensor and cable are provided with an environmental coating (SC) for protection from the elements. The "AST" designation indicates that the sensor has an integrated Auto Sensor Test (AST) capability. The AST capability allows the sensor to send a pulsing signal to verifying correct coupling between the sensor and the structure by measuring the response. A total of fifteen (15) sensors have been installed on each of the main cables with a spacing of approximately 100 feet between each sensor. The sensors were mounted to the bridge using a 2-part epoxy.

4.3 Two part epoxy

Each of the (30) sensors (15 North, 15 South), were mounted to the surface of the cable band. Each location required preparing each surface for mounting the sensor. This included minor grinding of the cable band surface, cleaning of the surface, and then mounting the sensor with the epoxy. The epoxy used is the Loctite E-20NS two part, 2:1 mixing ratio, cartridge style epoxy system. The epoxy has a 20 minute working time, designed for vertical surfaces (non-sagging), high shear strength and a working temperature range from -65° to +180° F. When cured, the epoxy is colored a light-tan.

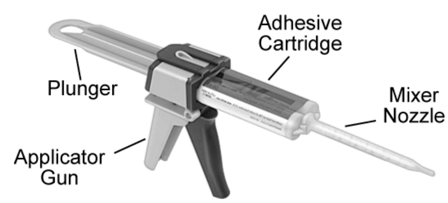

Figure 3 Two part epoxy system

4.4 Remote (Wireless) Communication

For communication, each system contains a Sierra Wireless PinPoint X broadband mobile device (Figure 4). This device is part of the AirLink Intelligent Gateway and Router device that allows control of the device either locally or remotely from any location that has Internet access. The device also includes (4) digital I/O, (4) analog and 2 relay ports. One of the relay ports is currently used to shutdown or reboot each system remotely in the event the operating system hangs or to put the systems in standby mode. Additionally, the systems and data can be accessed directly through the built-in Ethernet 10/100 interface with a laptop.

Figure 4 Airlink PinPoint X broadband mobile device

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5.0 System Location & Setup

Each SH-II system is located at midspan (near Sensor 8) for each main cable (Figure 5). This location was chosen for several reasons: a) Easy access to system for future maintenance and b) access to power (using the navigational lighting power source). As previously mentioned, each main cable is instrumented with fifteen (15) sensors with an approximate spacing of 100 feet. Channels 1 & 15 for both main cables are located below deck and have been mounted directly to the wrapping system using 2-part epoxy.

Once all sensors were mounted, a center punch test was conducted to verify the response of each sensor, system and location detection. The center punch is a standard verification tool for system verification and performance as it induces a known (and repeatable) AE signal into the material.

Final system setup and verification was completed on July 14, 2011 and both systems brought online for the collection of data.

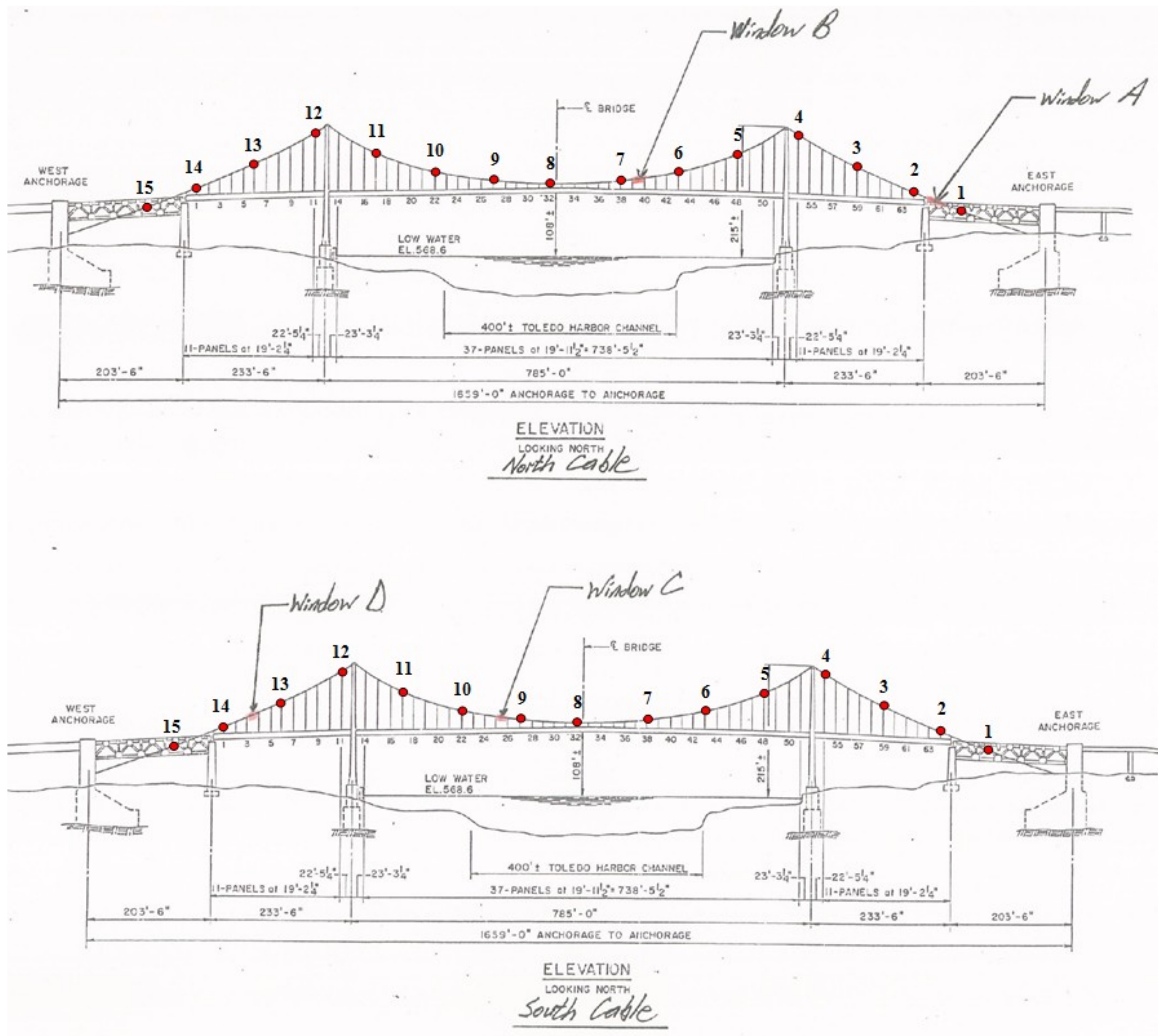


Figure 5 Sensor map location

6.0 Background on Acoustic Emission (AE)

Acoustic Emission (AE) is defined as the rapid release of energy in the form of a transient elastic stress wave generated by an acoustic source that can be detected and recorded by AE instrumentation (Figure 6). AE detects changes in the deformation of the material due to an applied stress that occurs during shifts in operating loads (e.g. increase in loading, hydrostatic, thermal stress, wave motion), overloading conditions or degradation of the material. There are a variety of different AE sources that can be detected in various materials. For suspension, cable-stayed, pre/post-tensioned structures the AE of interest includes those sources that may be a result of crack initiation and/or growth, crack fretting (i.e. rubbing of crack faces as it opens and closes), corrosion, impact and wire breaks. Regardless of the type of source, AE is detected by transducers that are coupled to the material which converts the mechanical energy (e.g. elastic waves) into an electrical signal that is transmitted by transducer cables to the AE data acquisition system (DAQ). Due to the fact that most AE sources are relatively low in amplitude, a pre-amplifier amplifies the voltage of the signal that is recorded as a hit by the DAQ as the wave passes the transducer. The waveform features typically recorded include amplitude, energy, duration, counts, rise time, peak frequency and frequency centroid (Figure 7). These features can then be used during analysis as a tool to help discriminate between the different types of AE sources.

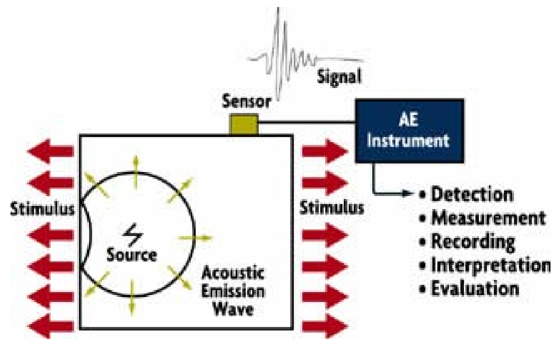


Figure 6 AE monitoring schematic

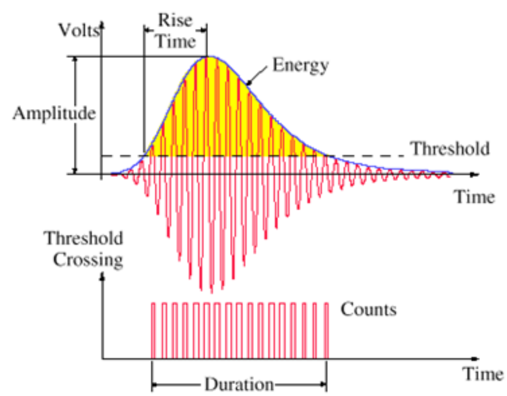


Figure 7 AE waveform features

6.1 Location Algorithm

Each SH-II Smart system is controlled by data acquisition software called AEwin. Built in to the software is a series of different location algorithms. For the Anthony Wayne Bridge, the linear location algorithm is used. To use the algorithm, the location of each sensor (in relation to one another) is entered into the system along with the sensor spacing and the calculated wave velocity along the cable. For linear location, an AE source must be strong enough to propagate through the cable and be detected by a minimum of 2 sensors. Then using the location and wave velocity information, the time difference is calculated and the location of the AE event is displayed (Figure 8).

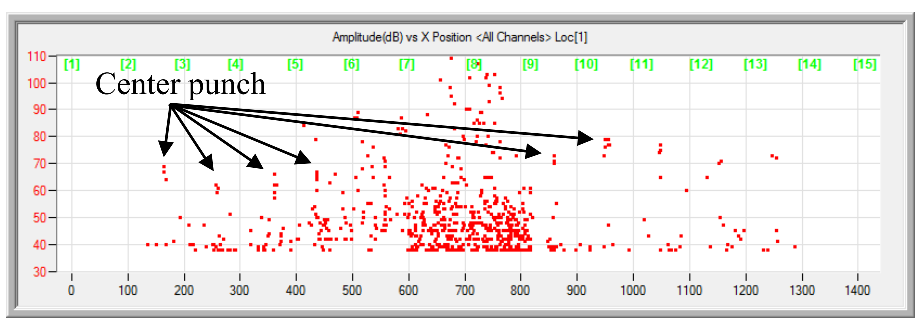


Figure 8 Linear location plot of detected events

Figure 8 is a linear location plot showing the Amplitude of the AE signal and the location of the AE source along the cable. One of the AE sources shown is from the center punch test as personnel walked along the cable and performed the test to verify the system and linear location algorithm were accurately locating. As it can be seen from this graph, the majority of the detected AE activity is occurring in the mid span area between sensors 7, 8 and 9.

6.2 Location Algorithm & Event Classification

In addition to the location algorithm, each system uses a built-in classifier that was specifically developed for wire break detection. In the case of the classifier, a set of (7) user defined AE values is entered in to the algorithm, so that if an AE source is strong enough to be located, the collected parameters, such as the amplitude of the signal, energy of the signal, frequency centroid, etc are compared. For each feature that meets or exceeds the value of the classification, it is assigned a source type. Thus for a wire break, the AE signal would meet or exceed all (7) criterion and would receive a "Source Type" classification of 7.

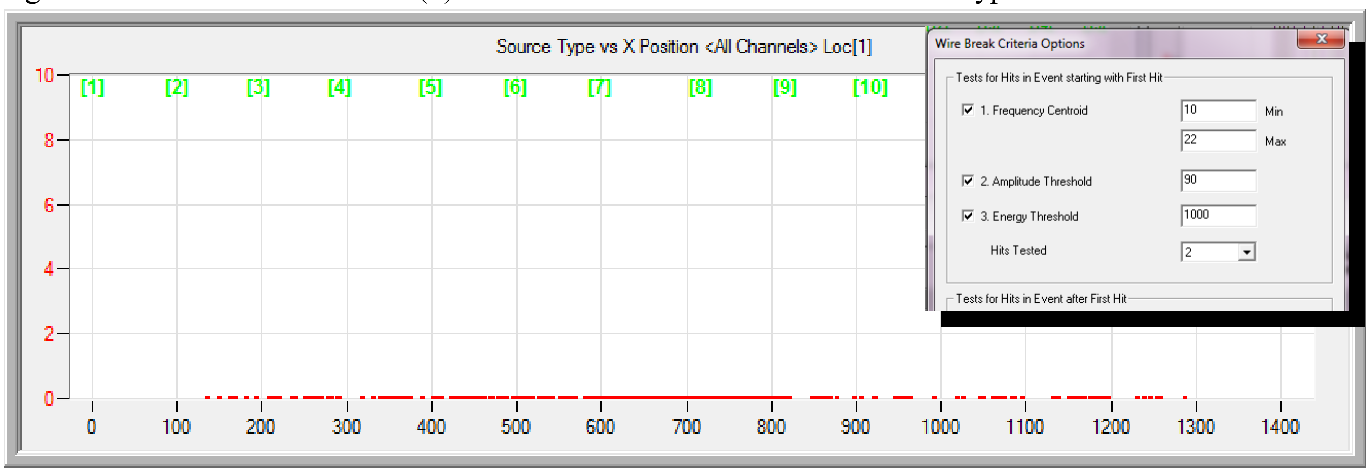


Figure 9 AE Source Type classification vs. Linear Location

Figure 9 (above) shows the classification of each of the located events detected in Figure 8. As it can be seen in Figure 9, all located events have a source classification of 0. This means that none of the AE events have met the criterion for a wire break. Even though no wire breaks have been detected from the above data, the system is still able to identify other areas along the cable that have AE sources strong enough to be detected by a minimum of 2 sensors. Some of this AE activity is related to friction between the cable band and main cable, personnel walking along the cable, etc. This information still provides useful information for trending over time for significant changes. For a wire break, the energy and amplitude of the wire break signal is several orders of magnitude above this type of AE activity.

6.3 Logging into the System

Currently the AE monitoring system is connected via cellular, wireless modem, through the Sierra Wireless PinPointX modem. The modem acts as a gateway through the AirLink platform to provide a consistent connection to remote devices. Similar to DynDNS, the device will automatically update any changes to the IP so that the URL that is used to connect to the device does not change. This allows for an **approved** user to log in to the system remotely to view each of the screens, make changes to the software (if needed), download data, etc. The procedure for logging in to the system remotely uses the Windows based Remote Desktop Connection:

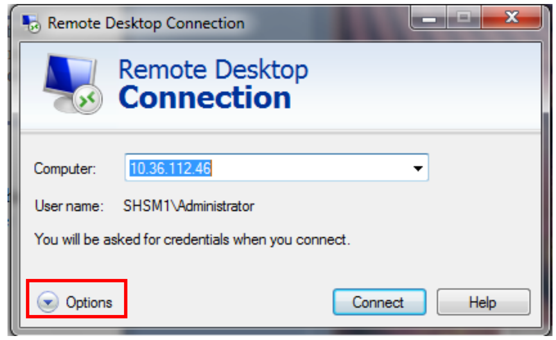


Figure 10 Windows RDC client

1) On the **approved** user(s) computer, go to: Windows Start > All Programs > Accessories > Remote Desktop Connection (Figure 10).
2) In the box labeled 'Computer', enter in the static IP address of the AE system: bridge.somewhere.com
3) If this is the first time connecting to the system, the 'User name' will show "None Specified".
4) Click on the button to "Connect".
5) When the **approved** user(s) computer has successfully connected to the remote system, the user will be prompted for a Username and Password.
   a. Username: <Username>
   b. Password: <password>
6) Once connected, the **approved** user(s) will then have access to the following screen and graphs shown in the next section of this report.
7) For the advanced user(s) that need to retrieve data from the remote AE system, there are a few changes that may need to be made in order to retrieve the data and download to the **approved** user(s) computer before clicking the "Connect" button. To make these changes, click on the drop down arrow for "Options" (Figure 11). Click on the tab for "Local Resources". Under the section 'Local devices and resources", click the button for "More". This will open a new window with other devices and drives available for use in the remote session. In this window, select the checkbox for "Local Disk (C:)". Click 'OK' and then click "Connect". Now when the user logs in to the system, the data can be copied to the **approved** user(s) hard drive. ***Step 7 should ONLY be used by those approved for data retrieval.***

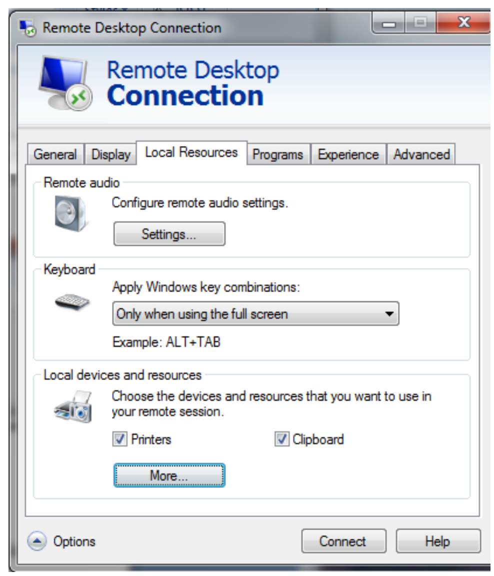


Figure 11 RDC client options

Now that the approved user(s) is connected to the system, the following section discusses the different screens and graphs currently generated by the monitoring system:

6.4 System Settings and Graphs (North cable)

The following information is in regards to the typical graphs used to track the activity and trending of the detected AE hits and events. Each of the graphs is displayed on "screens" or "tabs". Each screen can be viewed by clicking on the appropriate tab at the bottom.

6.4.1 Activity Screen (Tab 1 – Figure 12)

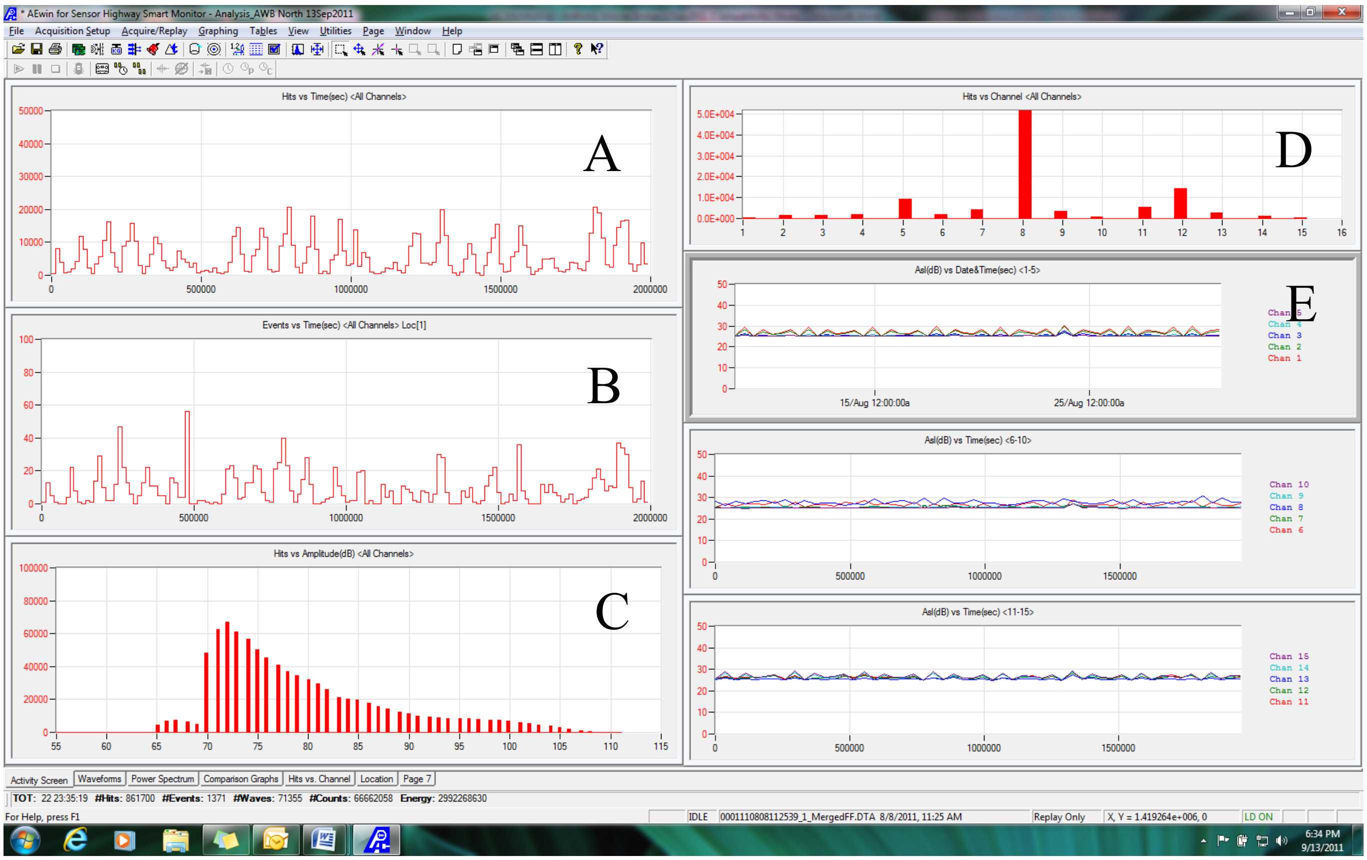


Figure 12 Activity Screen graphs (North cable – 14Aug2011 to 10Sep2011)

A: This is a standard 2D histogram showing the cumulative number of Hits vs. Time recorded by all (15) sensors. The number of detected hits is periodic and corresponds to rush hour traffic in the morning, later afternoon and in to early evening.

B: This graph is a 2D histogram showing the cumulative number of 'Events vs. Time' for all sensors. As previously discussed, in order for the AE activity to be classified as an 'event', the AE source must be detected by a minimum of 2 sensors (i.e. 2 single hits on 2 different sensors was determined to be a single event).

C: Standard 2D histogram showing the cumulative number of AE hits vs. Amplitude level.

D: Standard 2D histogram showing the cumulative number of AE hits vs. Channel. As it can be seen from this graph, Channel 8 has the highest number of recorded AE hits, followed by Sensor 12, 5, 11, 7, 9, 13, etc. Overall, there is a cluster of AE events between sensors 11, 12 and 13.

E: This is 2D histogram (line) showing the Average Signal Level (ASL) vs. Time for channels 1-5. A zoomed in view is shown in Figure 13. The ASL plotted in this graph is time driven and not hit based (i.e. the ASL used in this graph is threshold independent). Thus, every acoustic wave that is detected by each sensor is recorded and averaged. This graph can be used for multiple purposes. The first is to determine the operability of the sensor(s). As can be seen from this graph in Figure 13, the ASL for sensors 1-5 is typically around 25 dB. Secondly, the ASL can be used to established trends. For instance, Channels 1 & 2 appear to be close to an AE source that becomes active between over a 12 hour period (between 7pm on August 14 to 7am on August 15). It is likely that there is a frictional noise source in this area that becomes active due to the expansion and contraction of the bridge, as it is seen for every day.

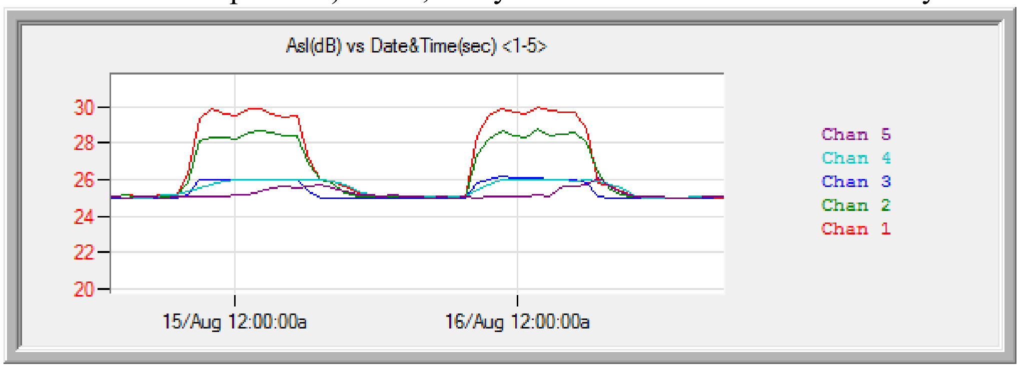


Figure 13 ASL levels for Channels 1-5 over a 24 hour period

6.4.2 Waveforms (Tab 2)

These screens allow for the display of the waveform collected for each hit detected by the individual sensor and that meets the user defined front end filter (i.e. only waveforms of certain amplitude are recorded). This screen is used on a periodic basis to identify potential electrical shorts in the sensor or other noise sources. For instance, Sensor 8 shows a low frequency, continuous waveform and is often indicative of a frictional source. As previously noted, sensor 8 had the highest AE activity. Based on the analysis of the data and waveforms, the AE is primarily due to friction (partial due to corrosion) at the anchorage points to the main bridge beam as shown in the inset of Figure 14.

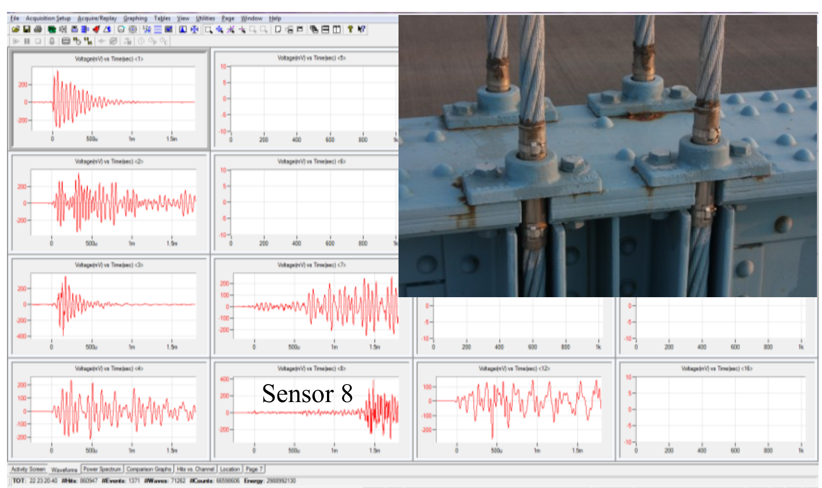


Figure 14 Waveform graph(s) for each channel

6.4.3 Location & Classifier Identification (Tab 3)

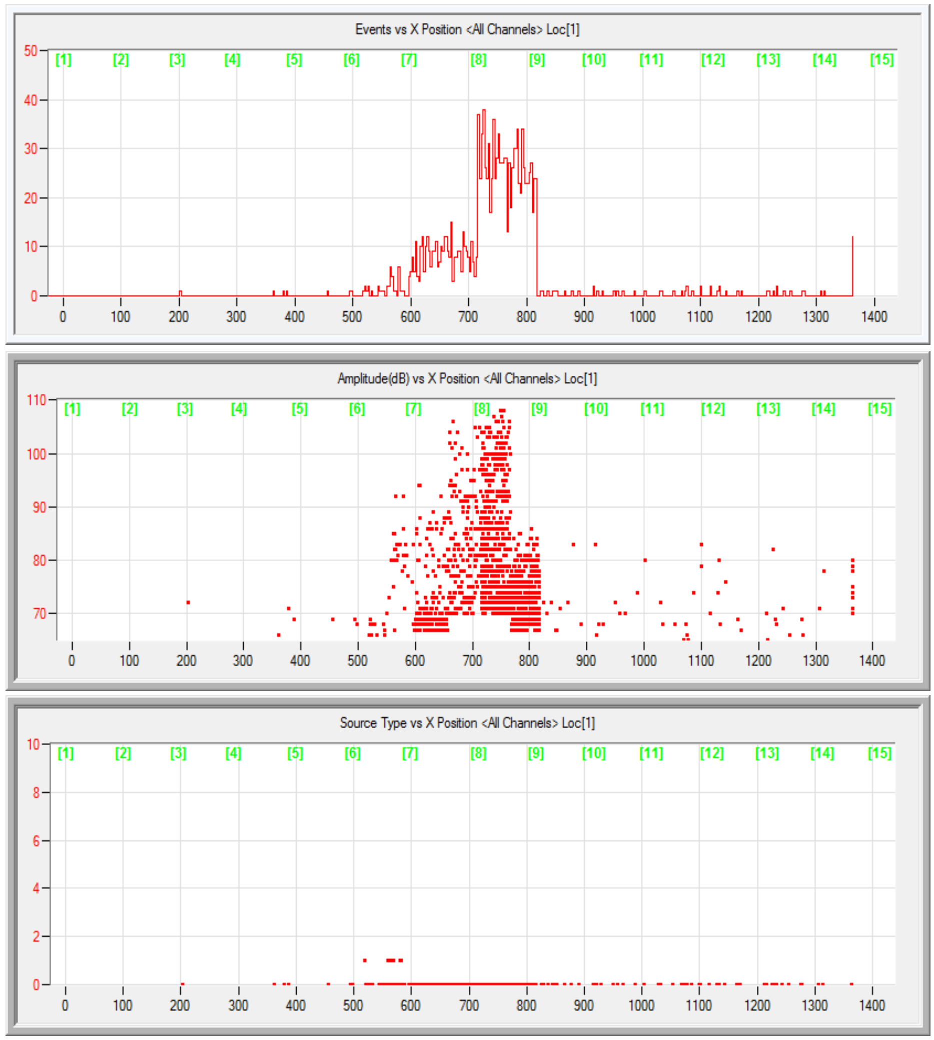


Figure 15 (North): Cum. Events vs. Pos. (top), Amp. of Events vs Pos. (middle), Source Type vs Pos. (bottom)

While different screens are used to compare the data, and identify trends, the main graphs used are shown in Figure 15. These 3 graphs display the (cumulative) number of Events vs. Position (top), the Amplitude of those events for vs Position (middle) and the Source Type of the events vs. Position. The importance of the top graph is that it shows the cumulative number of events over the entire monitoring period, which in this case is was from August 14 to September 10, 2011. This plot helps to identify the areas/panels with the highest amount of detected and located activity. In this case, there is a cluster of activity between sensors 8 & 9 with a smaller amount of activity between 7 & 8 and a small cluster at the midpoint between sensors 14 & 15. To better understand this activity, the middle graph is a point plot that shows the amplitude of each of the events. Again, the trend shows higher amplitude events between sensors 7 to 9 and a cluster between sensors 14 & 15. The third graph is the main graph of concern. As previously discussed, each system uses a classifier for determining whether the located events are closely related to a wire break. In order to be classified as a potential wire break, the event must meet 7 different criteria and would receive a source classification as Source Type equal to 7. Thus when referring to the bottom graph, of the 1371 events recorded, only 10 events (0.007%) of these events (between sensors 6 & 7) were classified as Source Type 1 (related to frequency centroid). The rest of the events had a Source Type=0. So even though no wire breaks have been detected, the AE system shows that certain sections of the cable produce a higher amount of AE activity as compared to others. If potential wire breaks are detected, the Source Type will be in the range of 5 to 7 where a higher value means the detected event is more closely related to a wire break.

6.5 System Settings and Graphs (South cable)

The graphs used for the South cable are the same as the examples of the data for the North cable as shown in Section 6.4. The data in this section covers the period from August 4, to September 6, 2011. Figure 16 shows the same plots of Cumulative Events, Amplitude of Events and Source Type of the Events vs. X Position. Similar to the North cable, the South cable shows the same clustering trend of AE events at the midspan of the main cable betweens sensors 7 & 8 and is approximately 3 times more active than the same section for the North cable. There are additional clusters shown at the middle of sensors 1 & 2 and 14 & 15. For the entire cable a total of 1101 events were located. Of those events, zero events reached a Source Type classification > 0. Thus, no potential wire breaks have been observed.

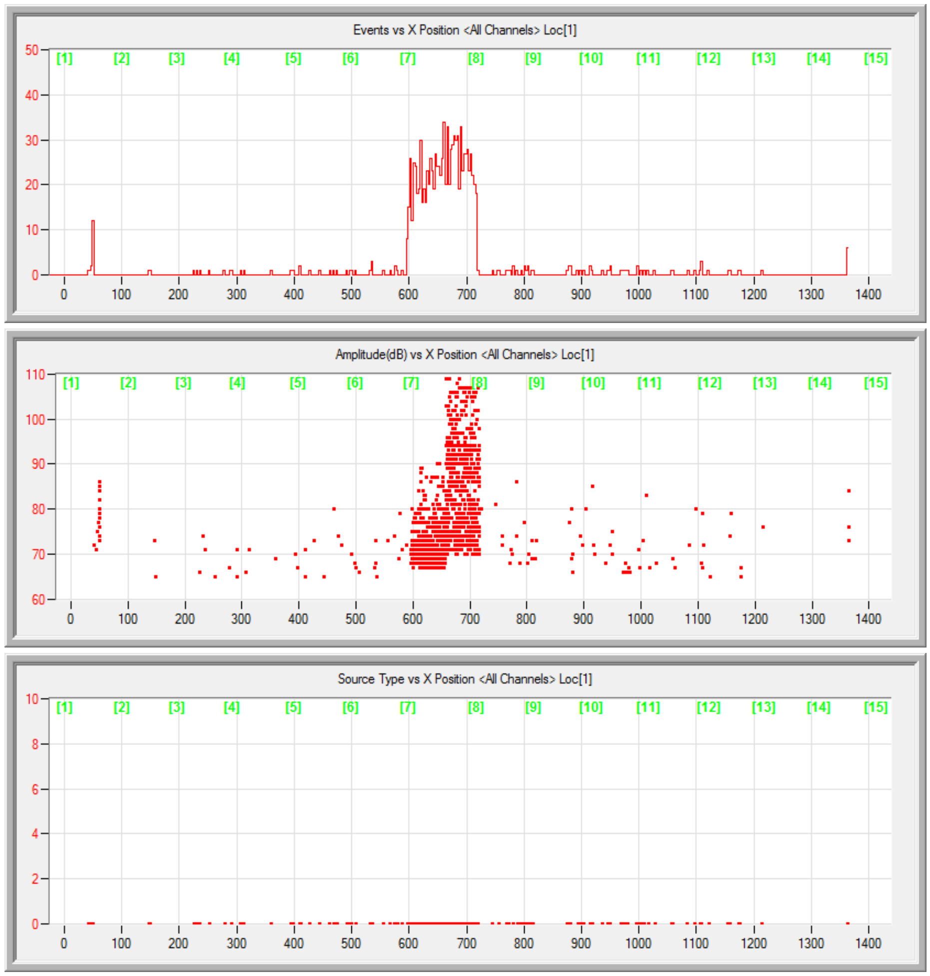


Figure 16 (South): Cum. Events vs. Pos. (top), Amp. of Events vs Pos. (middle), Source Type vs Pos. (bottom)

A review of the remaining graphs shows that the next highest channel (after Channel 8) with AE activity is coming from Channel 3 and is several orders of magnitude higher than the surrounding channels. While only a few events were strong enough to be located in the graphs of Figure 18, the amount of activity coming from channel 3 signifies a very active source in this area of the cable. Thus, this section of the cable would be a good candidate for additional inspection. In the area of Channel 7 & 8, a review of the waveform data again shows a low frequency, continuous type waveform and indicative of a frictional noise source in the area of the sensor.

7.0 Bridge Shutdown – Panels with Potential Corrosion

On Sunday, October 23, 2011, the Anthony Wayne Bridge was closed off to traffic from between 7:30-8:00AM Sunday morning through approximately 6am Monday, October 24, 2011. This date was chosen as it had been preceded by several days on rain and it was the intent of the authorities to try and use the acoustic emission monitoring system (currently monitoring for potential wire breaks) to identify areas of potential corrosion. During this time, the acoustic monitoring system was reconfigured to increase the sensitivity of the system in an attempt to try and locate areas along both cables that may be experiencing or is susceptible to ongoing corrosion activities.

For this installation, there is a limitation in corrosion monitoring in that AE activity will be limited to the local areas in which the sensors are installed. The reason for this limitation is that AE generated by the corrosion process does not produce a signal that is strong enough to reach the next nearest sensor which is approximately 100 feet away. Typically for corrosion monitoring, sensor spacing is less than 5 feet. As such, analysis of the AE data is performed on a channel by channel basis.

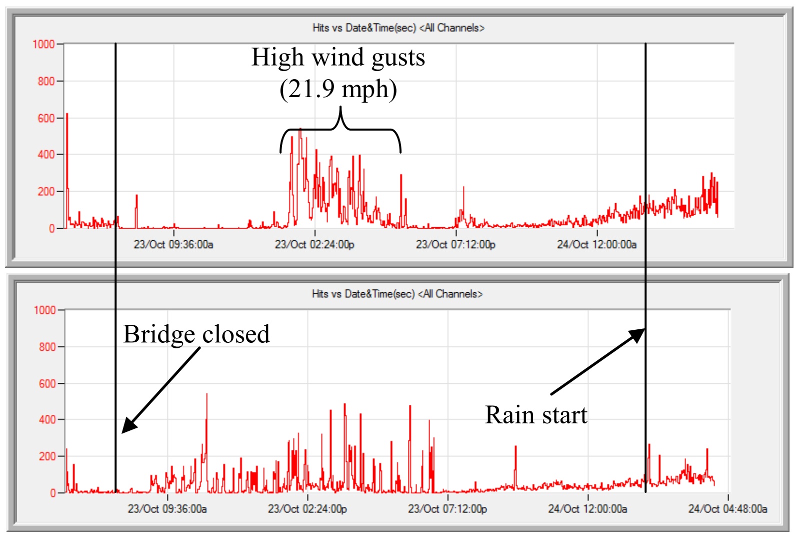


Figure 17 AE hit rate during bridge closure (North-top; South-bottom)

Figure 17 shows the AE hit rate (from all channels) before and during the time when the bridge was closed to traffic for the north and south side of the bridge. In addition to the bridge being shut down, there were 2 distinct periods of changes noted in the data. The first was a period in which wind speed had changed from a calm period to high winds with gusts up to 21.9 mph (SSW-S) for approximately 3.5 hours. The next period occurred in the evening in which the relative humidity rose from 45% to 70% and began increasing until around 4:30am when the next rain band moved through the area. From Figure 17, the overall hit rate dropped once the bridge was fully closed to traffic. However, the hit rate for the South side of the bridge increased around 9am and was sustained throughout the day until around 7pm as compared to the North side of the bridge during this same period. By increasing the sensitivity of the system, and removing the live load from the bridge, it is expected that if there are active corrosion sources in the area, the increase in activity will be due to corrosion. However, due to the increased wind loading during this time period, trying to decouple AE generated just from corrosion and AE generated by bridge movement is extremely difficult. Typically, localized corrosion will produce AE events that are relatively low in amplitude, energy, and duration. Therefore, to better understand the information shown in Figure 17, new graphs are generated to look at specifically at the hits detected by each channel and the makeup of those hits.

Figure 18 shows the channel by channel breakdown for the total number of hits detected for all sensors mounted on the North (Figure 18-top) and South (Figure 18-bottom) side of the bridge. Just looking at the cumulative number of hits for each channel, the north side of the bridge shows more of a distribution of AE hits with the highest channels at 1, 9 and 14. Compared to the south side of the bridge, channels 1 and 13 show the highest amount of AE activity.

However, the data from this 24 hour period includes not only potential corrosion sources, but additional sources from bridge movement due to high winds as well as passing rain showers in the area. Therefore, this information is further broken down to look specifically at the amplitudes of each hit in relation to time. As such, a new set of graphs are generated to better define the recorded information.

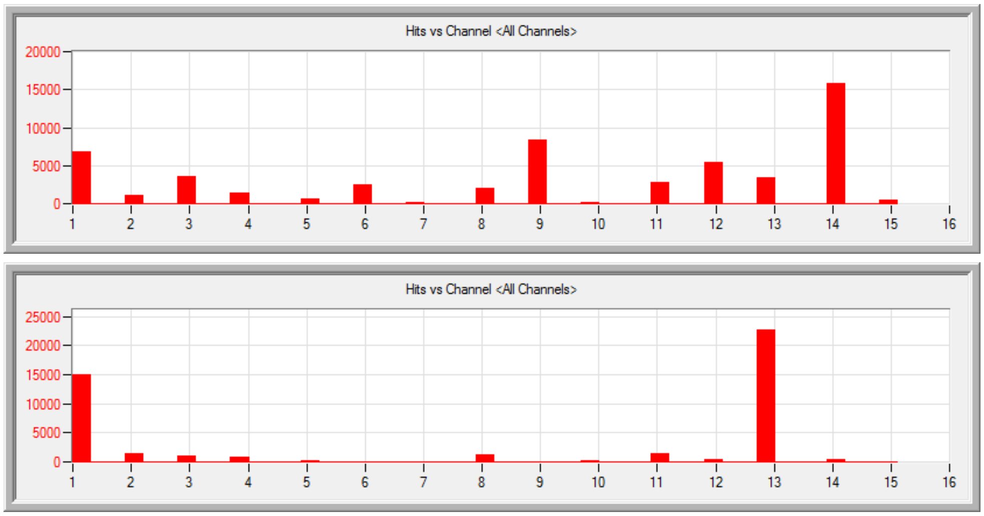


Figure 18 AE hit distribution by channel for North (top) and South (bottom) sides of the bridge.

Figure 19 shows the amplitude of each AE hit recorded, channel and time when the AE activity was recorded for the north side of the bridge. It is expected that for active corrosion, AE will be constantly recorded during this time period. As previously observed, channels 1, 9 and 15 had the highest AE hit rate. A review of this graph shows that for a majority of the period in which there was no loading on the bridge (vehicular, or wind), most of the channels are relatively quiet. For clarity, the graphs have been divided into periods that show changes external loading on the bridge. Period 1 shows activity

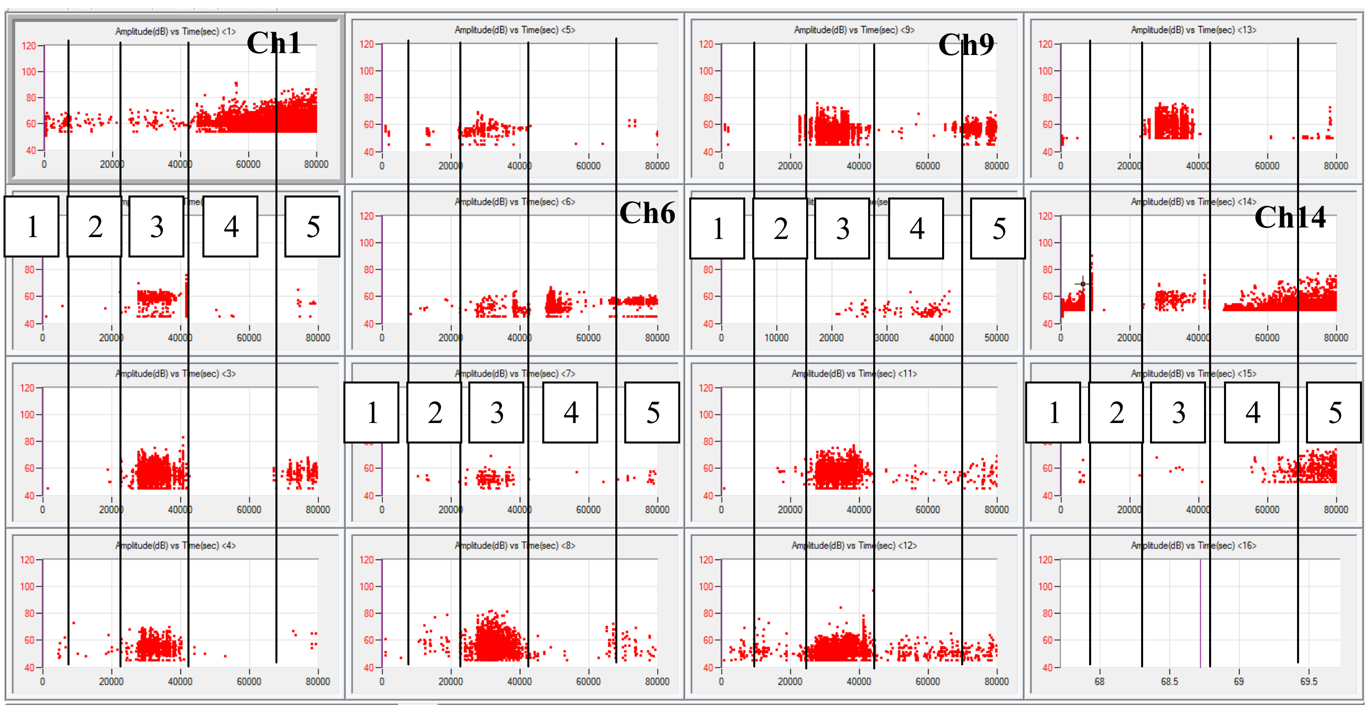


Figure 19 Channel by Channel analysis (Amplitude vs Time) - NORTH

caused by traffic loading on the bridge. Period 2 shows the start of the shutdown of the bridge and during the time when the wind was relatively calm. Period 3 highlights the start of the period when there was a significant increase in the wind with gusts up to 21.0 mph. Period 4 shows the time when the wind decreased to around 5-6 mph (and the start of increasing relatively humidity) and Period 5 shows highlights the time when there was a continuous increase in the relative humidity and start of a period of rain that lasted approximately 3.5-4 hours.

As such, at the beginning of Period 2, right after the bridge was closed to traffic, there is a significant drop in the hit rate for the majority of the channels. However, channels 1, 8, and 12 still continued to detect AE during this time period and closer inspection of the data shows a correlation for potential corrosion in the areas of these sensors. There is then a hit increase for all channels during Period 3 and the high wind loading event. While there is likely to be some AE due to corrosion during Period 3, it is masked by the increase in AE hits due increased wind loading on the bridge. Once the high winds died down in Period 4, again, the majority of the AE channels returned to very little AE activity. It was also during this period that the relative humidity began to increase from around 45% to 70% and then on to 90+% in Period 5 when a new rain event moved through the area. The exceptions at this time were channel 1, which actually began to see a significant increase in AE activity. New activity (minor) was also seen from Channel 6, 10, 11, 12 with medium increases at channels 14 and 15 moving in to Period 5. Typically in corrosion monitoring, it has been observed that corrosion will not typically activate until relative humidity levels reach at least 55% and above. Thus looking at the transition from Period 4 into Period 5, observation in the change of AE activity (minor, medium, major) is may be indicative of areas that are potentially susceptible to corrosion. Based on this transition the following changes and classifications of each channel are given as Channel 1 (major), 6 (medium), 10 (minor), 11 (minor), 12 (medium), 14 (major) and 15(medium).

This same process is then followed for the south side of the bridge (Figure 20). Similar to the north side of the bridge, Channel 1 sees a significant increase in the transition from Period 4 into 5. However, Channel 13 shows a significant amount of AE coming from this location throughout most of the 24 hour period and would be classified as major. The remaining channels for classification would be Channel 3 (medium), 8 (minor), 12 (minor), and 14 (medium).

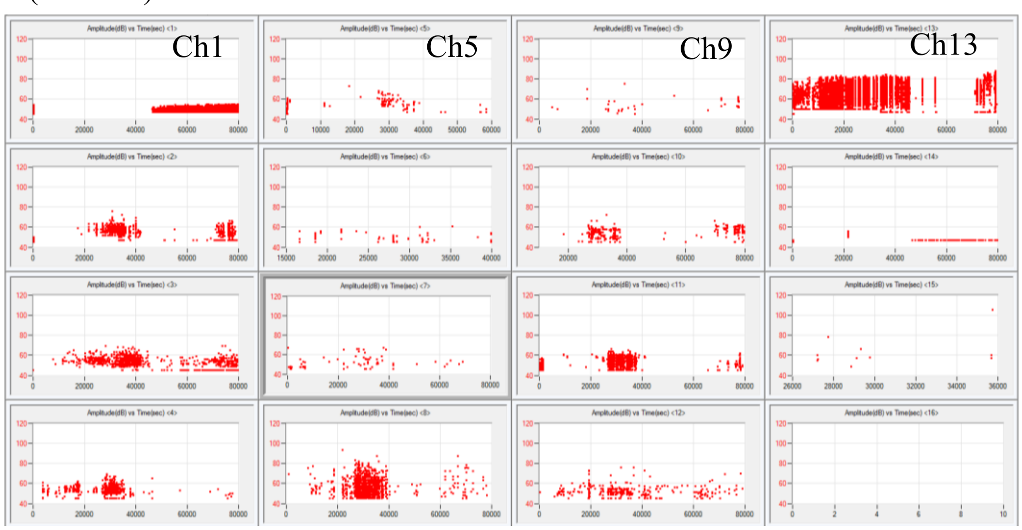


Figure 20 Channel by Channel analysis (Amplitude vs Time) - SOUTH

Based on the channel by channel analysis, potential areas of interest for future inspection of the north side of the bridge (based on AE activity classification) is as follows: – east anchorage near deck level; west anchorage around cable band 1; panel(s) around cable band 43; and panel(s) near cable band 11. On the south side of the bridge, potential areas of interest include: panel(s) around cable band 6; east anchorage; panel(s) around cable band 59; and panel(s) near cable band 11. For simplicity, the areas of interest are marked on Figure 21.

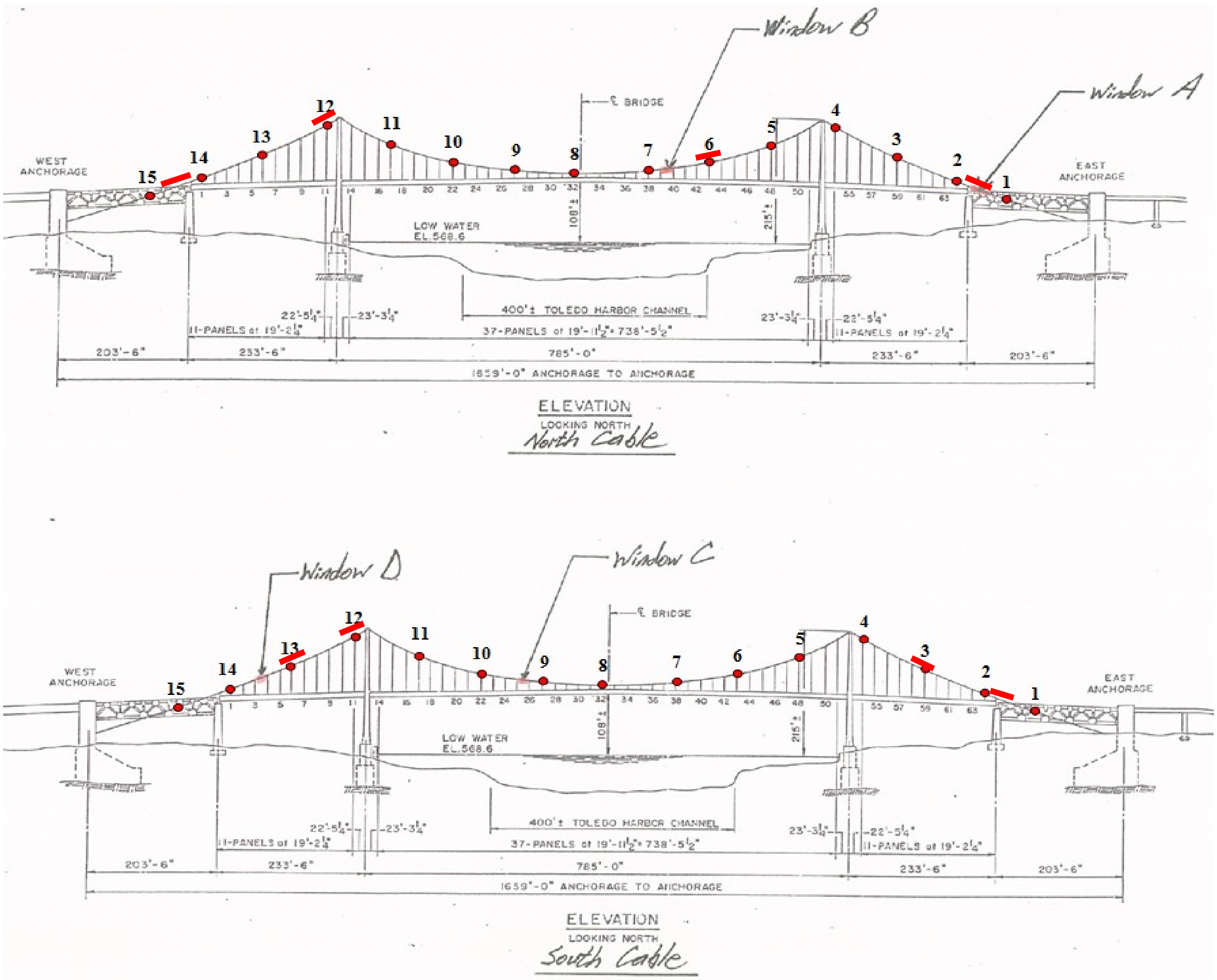


Figure 21 Area of potential interest for future inspection

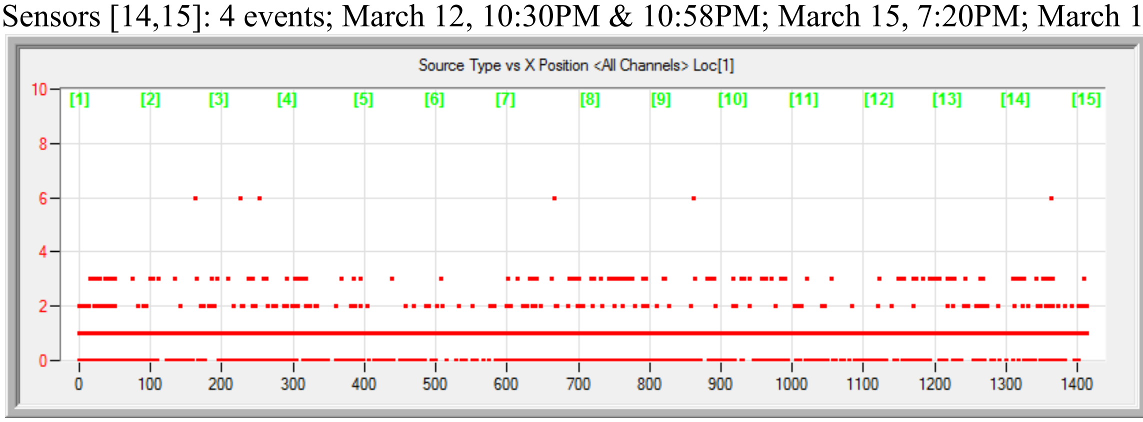
8.0 Monitoring Results: Jan. 2012 thru Apr. 2012

The system is configured to look specifically for potential wire breaks along the main cables on both the North and South side of the bridge. The data and graphs shown cover the data from January 2012 thru April 26th, 2012.

As previously discussed, each system uses a built-in classifier that was specifically developed for wire break detection. In the case of the classifier, a set of (7) user defined AE values is entered in to the algorithm, so that if an AE source is strong enough to be located, the collected parameters, such as the amplitude of the signal, energy of the signal, frequency centroid, etc are compared. For each feature that meets or exceeds the value of the classification, it is assigned a source type. Thus for a wire break, the AE signal would meet or exceed all (7) criterion and would receive a "Source Type" classification of 7.
If the source classification is equal to 0, this means that none of the AE events have met the criterion for a wire break.

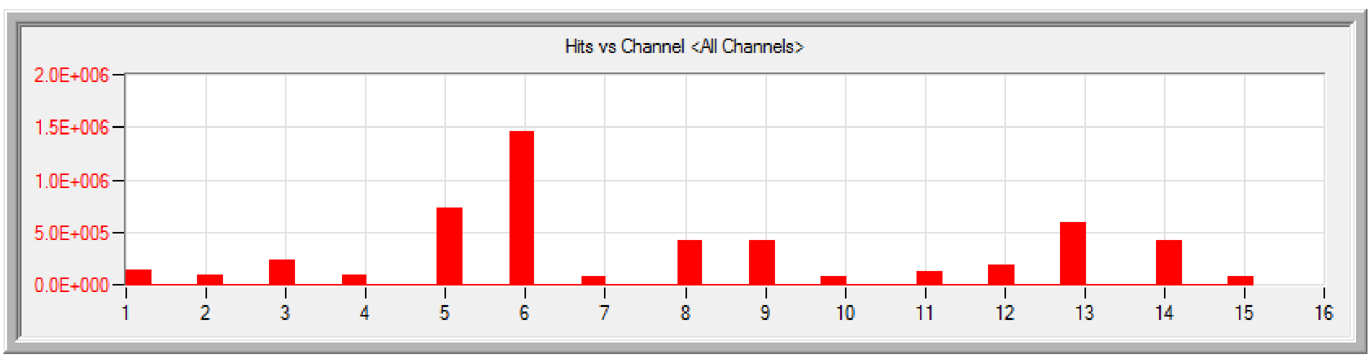
North Cable

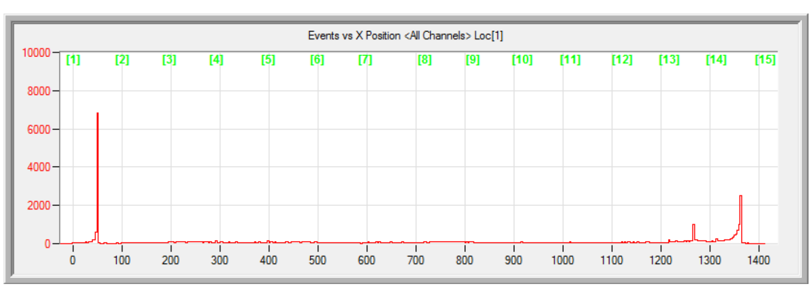
9 events with Source Type 6 classification.
Sensors [2, 3]: 1 event; March 12, 11:08PM
Sensors [3,4]: 2 events; March 15, 7:52PM & 8:09PM
Sensors [7,8]: 1 event; March 15, 10:21PM
Sensors [9,10]: 1 event: March 15, 9:26PM
Sensors [14,15]: 4 events; March 12, 10:30PM & 10:58PM; March 15, 7:20PM; March 18, 3:50AM

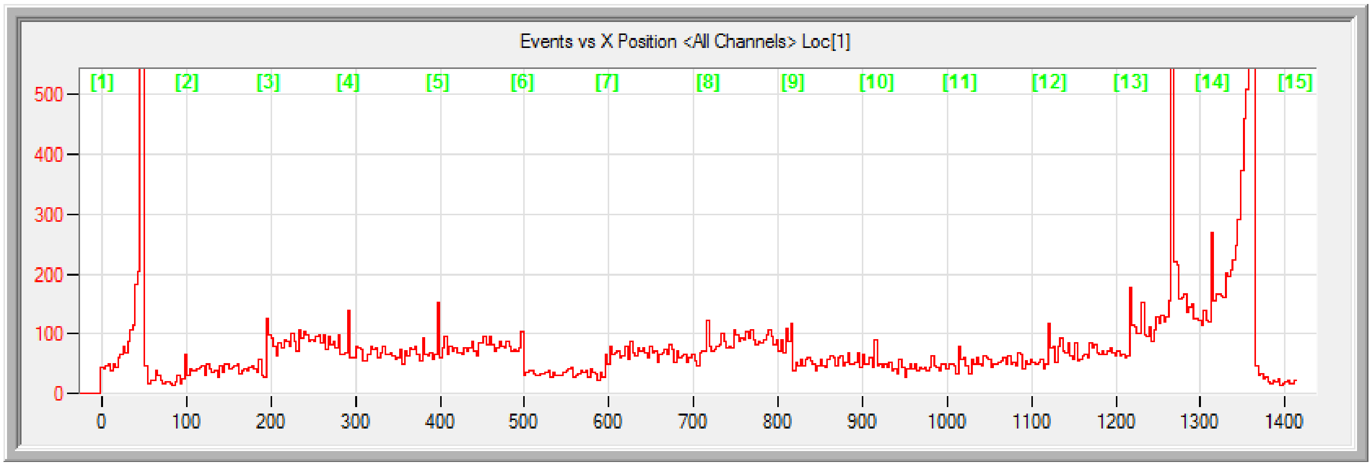


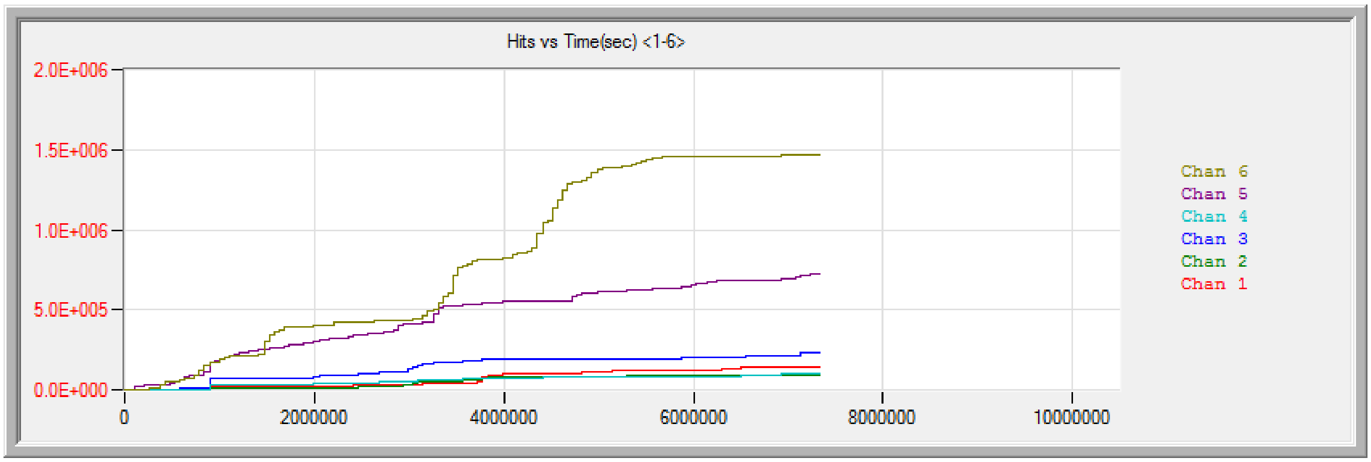

```
ID     SSSSSSSS.mmmuuun  CH  RISE  ENER AMP A-FRQ PCNTS SIG STRNGTH  ABS-ENERGY FREQPP1 FREQPP2 FREQPP3
FREQPP4 C-FRQ P-FRQ
* Gp# 1[14,15] x =    1363.6, y =     0.625, Source Type = 6 dT[     2] Src Amplitude = 92.0
*    3568954.4230477  14   312  1212  92     5     5   7.589E+06   7.586E+06       5       24       36
34    33    40
*    3568954.4230497  15   312  1403  90     5     5   8.787E+06   8.902E+06      17       29       30
24    30    20
* Gp# 1[14,15] x =    1363.6, y =     0.625, Source Type = 6 dT[     8] Src Amplitude = 92.0
*    3570603.2618497  14   394   907  92    18    10   5.674E+06   6.311E+06       8       58       20
14    28    16
*    3570603.2618577  15   388   626  89    15     7   3.941E+06   3.222E+06      11       60       18
11    26    16
* Gp# 1[3,2] x =    163.32, y =     0.625, Source Type = 6 dT[  1992] Src Amplitude = 89.0
```

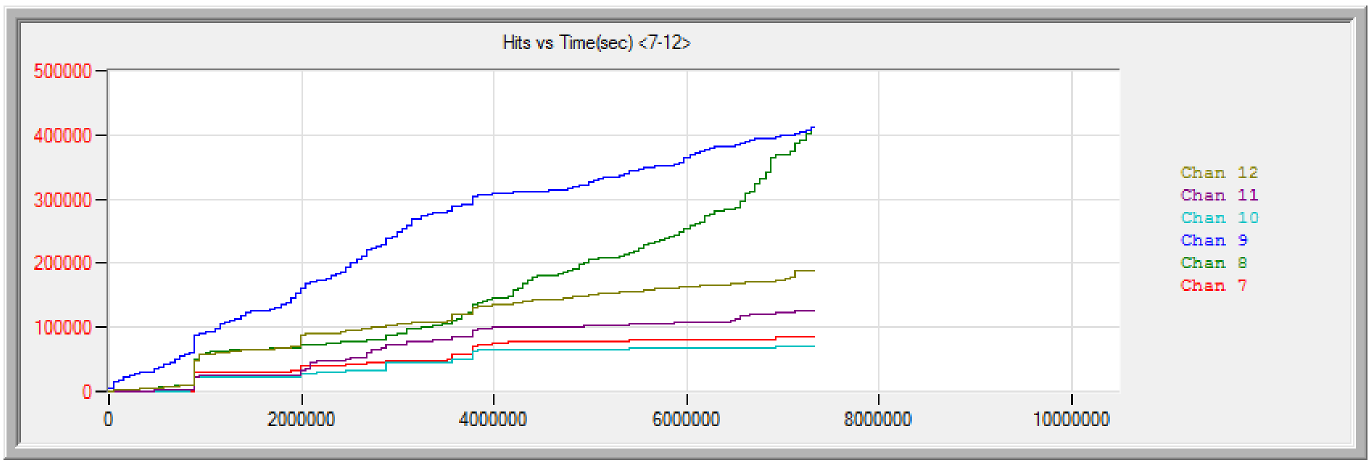
```
*    3571221.0412597   3   574   736  89    14     6   4.624E+06   5.091E+06       0      96       2
2    26    21
*    3571221.0432518   2   488   982  84    21    14   6.164E+06   3.732E+06       0      46      44
10    30    23
* Gp# 1[14,15] x =    1363.6, y =     0.625, Source Type = 6 dT[     2] Src Amplitude = 93.0
*    3816743.5066657  14    26   666  93     3     1   4.183E+06   7.116E+06      52      31      11
7    22     7
*    3816743.5066678  15    24   576  90     2     1   3.611E+06   5.068E+06      60      27       8
5    21     7
* Gp# 1[3,4] x =    226.57, y =     0.625, Source Type = 6 dT[  2249] Src Amplitude = 87.0
*    3818634.5234037   3  9318   982  87     1     4   6.158E+06   2.550E+06      11      73      16
0    28    13
*    3818634.5256522   4  3836  1498  81     1     7   9.387E+06   1.465E+06       3      68      28
1    25    23
* Gp# 1[4,3] x =    252.45, y =     0.625, Source Type = 6 dT[  1108] Src Amplitude = 88.0
*    3819680.3730420   4   100   706  88    20     3   4.441E+06   4.259E+06       1      66      32
1    27    24
*    3819680.3741498   3   322   586  81    10     7   3.693E+06   1.527E+06       2      87       9
2    24    18
* Gp# 1[9,10] x =    861.14, y =     0.625, Source Type = 6 dT[   730] Src Amplitude = 90.0
*    3824297.3232378   9   382  1252  90    13     7   7.851E+06   9.313E+06      26      72       2
0    17    12
*    3824297.3239680  10    82   586  83    10     3   3.692E+06   1.597E+06       1      87       9
2    24    19
* Gp# 1[8,7] x =    667.08, y =     0.625, Source Type = 6 dT[  1318] Src Amplitude = 85.0
*    3827605.0858540   8  1460  1638  85    13    30  10.264E+06   4.337E+06       4      73      19
4    25    21
*    3827605.0871720   7 22996  3292  81     4    67  20.593E+06   5.110E+06       9      89       3
0    20    20
* Gp# 1[14,15] x =    1363.6, y =     0.625, Source Type = 6 dT[     4] Src Amplitude = 88.0
*    4020108.3526438  14  1302   666  88     7     9   4.171E+06   3.840E+06      66      14      12
8    25     5
*    4020108.3526478  15  1458   716  85     6     9   4.494E+06   4.234E+06      82       8       6
4    22     5
```

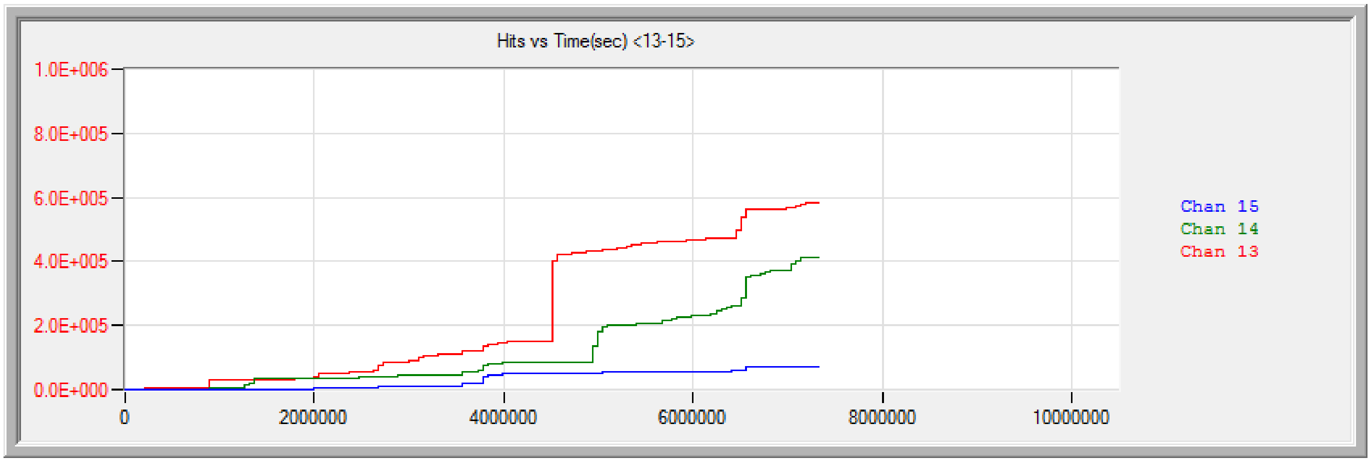


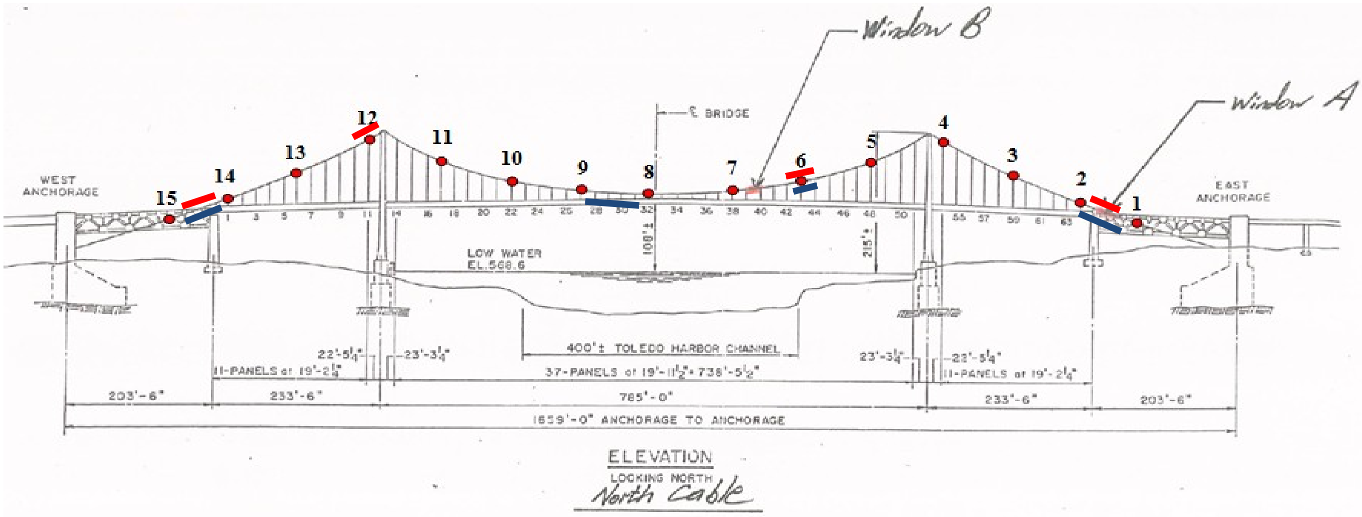


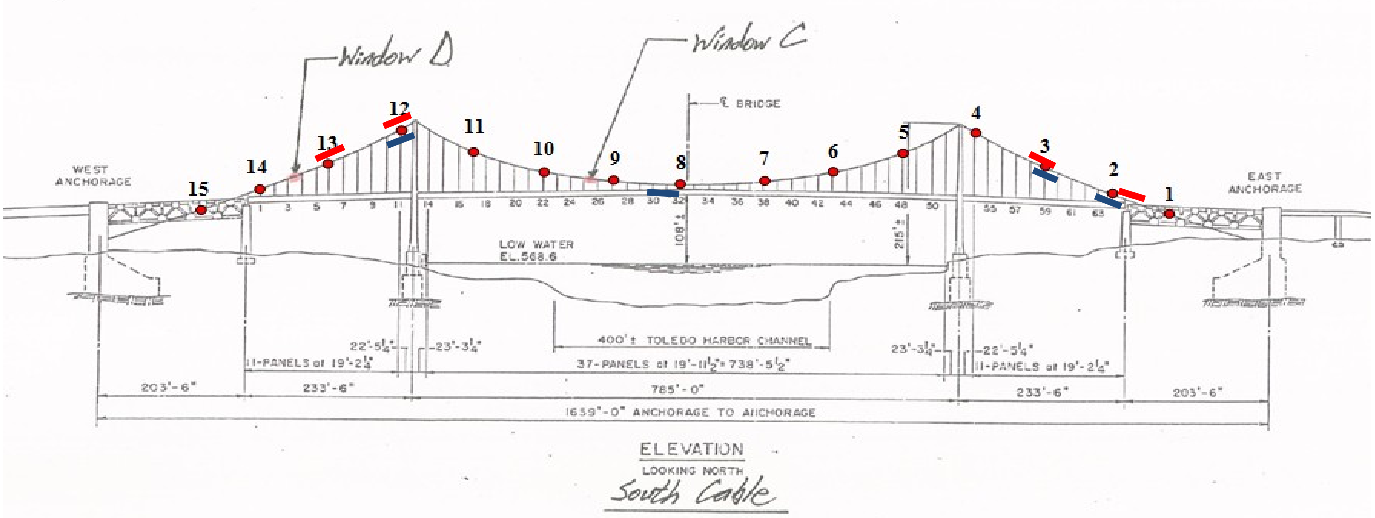

Events vs X Position <All Channels> Loc[1]
[1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15]
500
400
300
200
100
0
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400


Hits vs Time(sec) <1-6>
2.0E+006
1.5E+006
1.0E+006
5.0E+005
0.0E+000
0 2000000 4000000 6000000 8000000 10000000
Chan 6
Chan 5
Chan 4
Chan 3
Chan 2
Chan 1


Hits vs Time(sec) <7-12>
500000
400000
300000
200000
100000
0
0 2000000 4000000 6000000 8000000 10000000
Chan 12
Chan 11
Chan 10
Chan 9
Chan 8
Chan 7


Hits vs Time(sec) <13-15>
1.0E+006
8.0E+005
6.0E+005
4.0E+005
2.0E+005
0.0E+000
0
2000000
4000000
6000000
8000000
10000000
Chan 15
Chan 14
Chan 13





Potential areas of interest: [NORTH] Middle section between sensors 14 & 15, any panel between 8 & 9, panel to the right or left of sensor 6, middle section between 1 & 2. [SOUTH]

9.0 Concluding Discussion/Follow-Up

As of Thursday, July 14, 2011 – the systems and sensors on both the North and South cables have been continuously recording and monitoring the cable. As of September 10, 2011, no potential wire breaks have been recorded. However, there are several sections on both the North and South cable that have an AE signature that is different from the surrounding panels and are potential locations for future inspection. On the North cable, the section of cable between sensors 7, 8 and 9 show a high amount of activity, with higher trending of activity between sensors 8 & 9 (mostly frictional). Additionally, a small cluster between sensors 14 & 15 has been observed. For the south cable, a similar trend of AE activity is located between sensors 7 & 8 and is about 3 times higher than the average observed for the same section on the North cable. Additionally, a small cluster of AE activity was observed between sensors 1 & 2.

Glossary/Key Terms in Acoustic Emission Testing (AET)

Acoustic emission:	Elastic waves generated by the rapid release of energy from sources within a material.
AE event:	A local material change giving rise to acoustic emission.
AE source:	The physical origin of one or more AE events.
AE sensor:	A device containing a transducing element that turns AE wave motion into an electrical voltage.
AE signal:	The electrical signal coming from the transducing element and passing through subsequent signal conditioning equipment (e.g. amplifiers, frequency filters, etc.).
AE channel:	A single AE sensor and the related equipment components for transmitting, conditioning, detecting and measuring the signals that come from it.
AE detection:	Recognition of the presence of a signal (typically accomplished by the signal crossing the detection threshold).
AE hit:	The detection and measurement of an AE signal on a channel.
Signal features:	Measurable characteristics of the AE signal, such as amplitude, AE energy, duration, counts, rise time, etc. that can be stored as part of the AE hit description.
AE amplitude:	The largest voltage peak in the AE signal waveform; customarily expressed in decibels relative to 1 microvolt at the preamplifier input (dBae).
AE signal strength:	The strength of the absolute value of a detected AE signal.
Counts:	The number of times the AE signal crosses the detection threshold. Also known as “ringdown counts” or “threshold crossing counts”.
Duration:	The time from an AE signal’s first threshold crossing to its last.
Risetime:	The time from an AE signal’s first threshold crossing to its peak.
Parametric inputs:	Environmental variables (e.g. load, pressure, temperature, etc.) that can be measured and stored as part of the AE hit description.
Burst emission:	A qualitative description of the discrete signal related to an individual emission event occurring within a material.
Continuous emission:	A qualitative description of the sustained signal level produced by rapidly occurring acoustic emission events.

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Discontinuity: A lack of continuity or cohesion; an intentional or unintentional interruption in the physical structure of a material or component.

Flaw: An imperfection or discontinuity that is detectable by nondestructive testing. A flaw is not necessarily rejectable (see Defect).

Defect: One or more flaws whose aggregate size, shape, orientation, location or properties do not meet specified acceptance criteria. By definition, defects are rejectable.

Indication: Response or evidence of a response in a nondestructive test.

Kaiser effect: The absence of detectable acoustic emission at a fixed sensitivity level, until previously applies stress levels are exceeded.

Felicity effect: (Reverse of the Kaiser effect) The presence of AE at stress levels below the maximum previously experienced.

AE activation: The onset of AE due to the application of a stimulus such as force, pressure, heat, etc.

AE activity: A measure of the emission quantity, usually in the cumulative energy count, event count, ringdown count, or the rates of change of these quantities.

AE intensity: A measure of the size of the emission signals detected, such as the average amplitude, average AE energy or average counts.

Amplitude distribution: A display of the number of AE signals at (or greater than) a particular amplitude, plotted as a function of amplitude.

Attenuation: Loss of amplitude with distance as the wave travels through the test structure.

Noise: Irrelevant indications; signals produced by cause other than AE, or by AE sources that are not relevant to the purpose of the test.

Location: Relating to the use of multiple AE sensors for determining the relative positions of the acoustic emission sources.

Nondestructive testing (NDT): The development and application of technical methods to examine materials or components in ways that do not impair future usefulness and serviceability in order to detect, locate, measure and evaluate flaws; to assess integrity, properties and composition; and to measure geometrical characteristics.

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APPENDIX B – INTERNAL CABLE INSPECTION DATA

Wire Condition Data Sheets

Cable Corrosion Plots

Daily Inspection Reports

Wire Condition Data Sheets

Primary Cable Opening Location PP 3 – PP 4, South

GENERAL COND AFTER UNWRAP [8314-17 ADK]

PP3-4

Anthony Wayne Bridge Main Cable Investigation
Cable Circumference Measurements

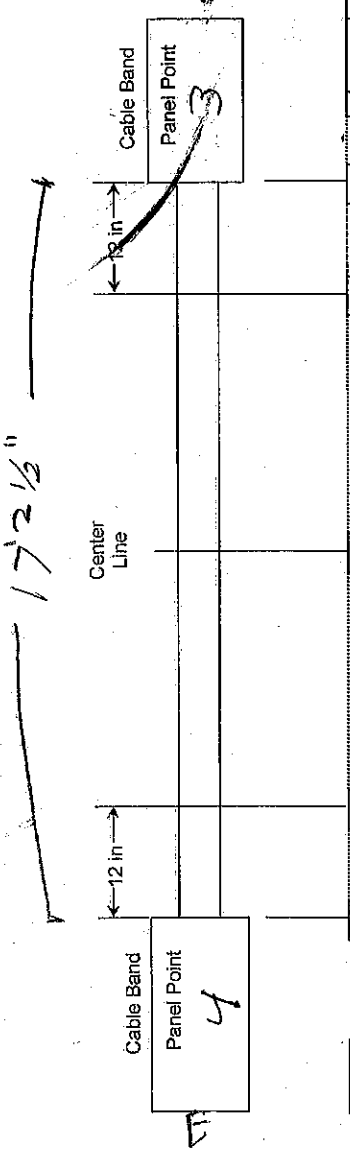
Prepared by: ADK
Date: 11-15-12
No. Wires in cable (N): 8066
Wire Diameter (d): 0.192

Cable: SOUTH
Side:
Panel: 3-4

17'2½" LONG CABLE BAND TO BAND

13⅞" BET. ROPES OUTSIDE

19'2¼" BETWEEN SUSP. ROPES @ 3-4



Before Unwrapping		After Unwrapping		Density	After Compaction		Density	After Rewrapping	
Measured Circum-ference	Calculated Diameter	Measured Circum-ference	Calculated Diameter		Measured Circum-ference	Calculated Diameter		Measured Circum-ference	Calculated Diameter
Ci	Di	C	D	DENS	Cc	Dc	DENSc	Cf	Df
42½"	13.53"	41⅜	13.18"		41½"	13.22"		42 11/16	13.59"
42½"	13.56"	41 11/16	13.28"		42 1/16"	13.40"		43	13.69"
43"	13.7	42⅝	13.59"		43½"	13.85"		44 3/16	14.07"
43 3/16"	13.75	42 7/16	13.52"		42 11/16	13.59"		43 5/8	13.89"
42 13/16"	13.63"	41½"	13.22"		41 9/16	13.23		43 1/8	13.73"

$D_i = C_i/\pi$ $D = C/\pi$ $DENS = Nd^2/D^2$ $D_c = C_c/\pi$ $DENS_c = Nd^2/D_c^2$ $D_f = C_f/\pi$

Temperature	Temperature	Temperature	Temperature
35 ± F	35° ± F	33° ± F	36° ±

11 BANDS SPACED APPROXIMATELY 18"

RAL # 2243

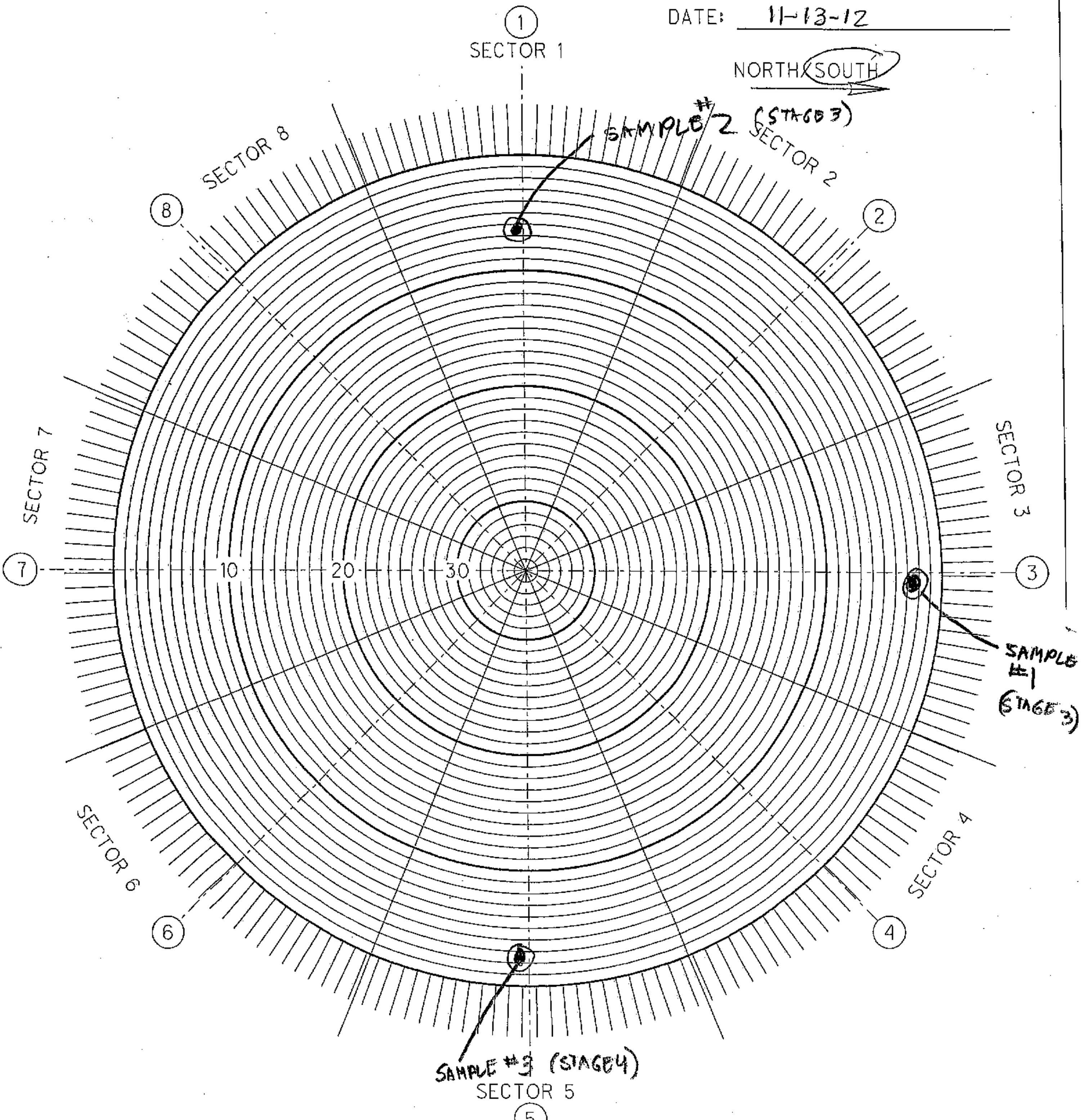
¾" STRAP WIDTH

BRIDGE NAME: ANTHONY WAYNE BRIDGE

PREPARED BY: ADK

DATE: 11-13-12

NORTH/SOUTH



LEGEND

● - BROKEN WIRE NO.

(1) - WEDGE LOCATION

(●) - SAMPLE FOR TESTING

CABLE CROSS SECTION

SOUTH CABLE, LOOKING EAST

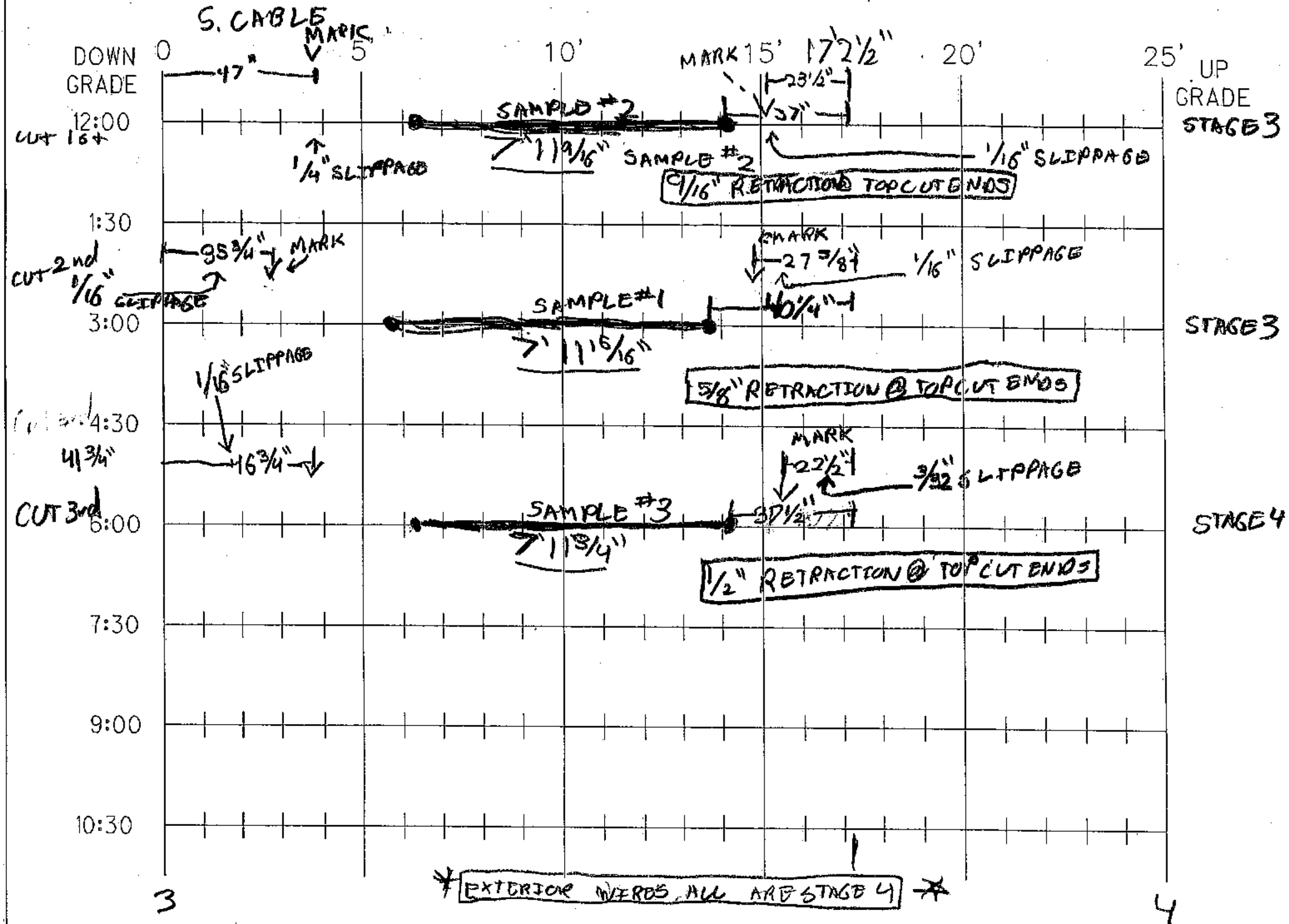
SPAN

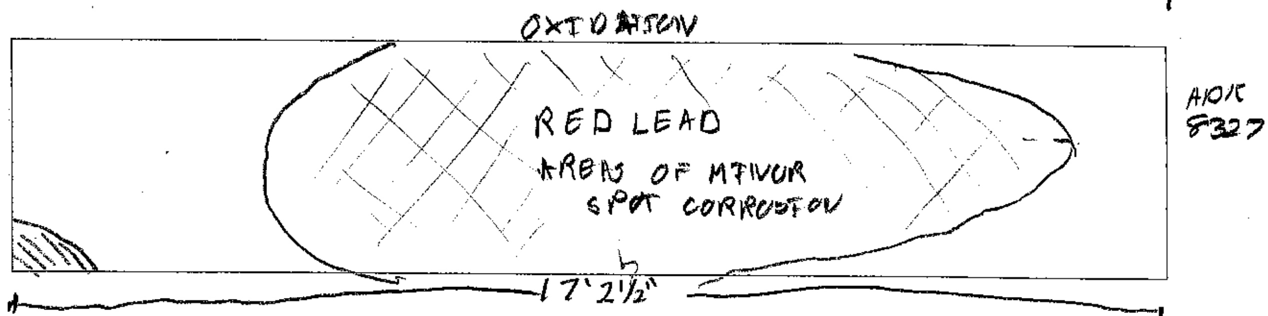
PANEL 3-4

BRIDGE NAME: ANTHONY WAYNE PREPARED BY: ADK

S CABLE ______ SIDE DATE: 11-13/14-2012

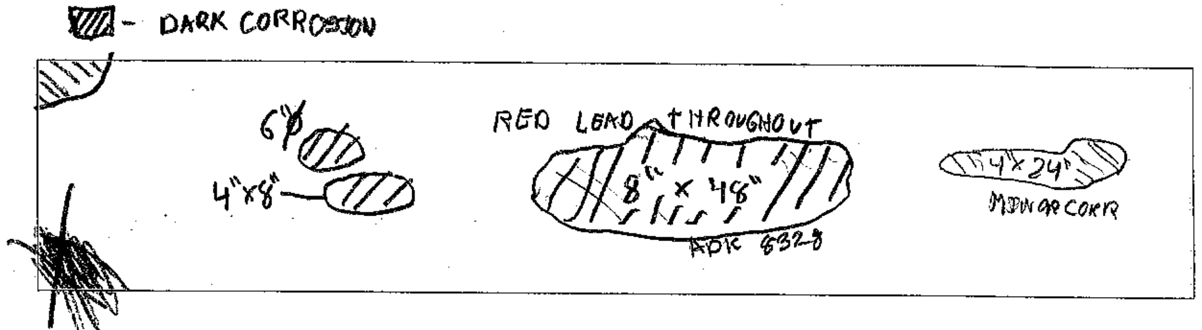
PANEL P3-4 TOTAL LENGTH EXPOSED 17'2½"





TOP OF CABLE EXTERIOR

DARK CORROSION



BOTTOM OF CABLE EXTERIOR

Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

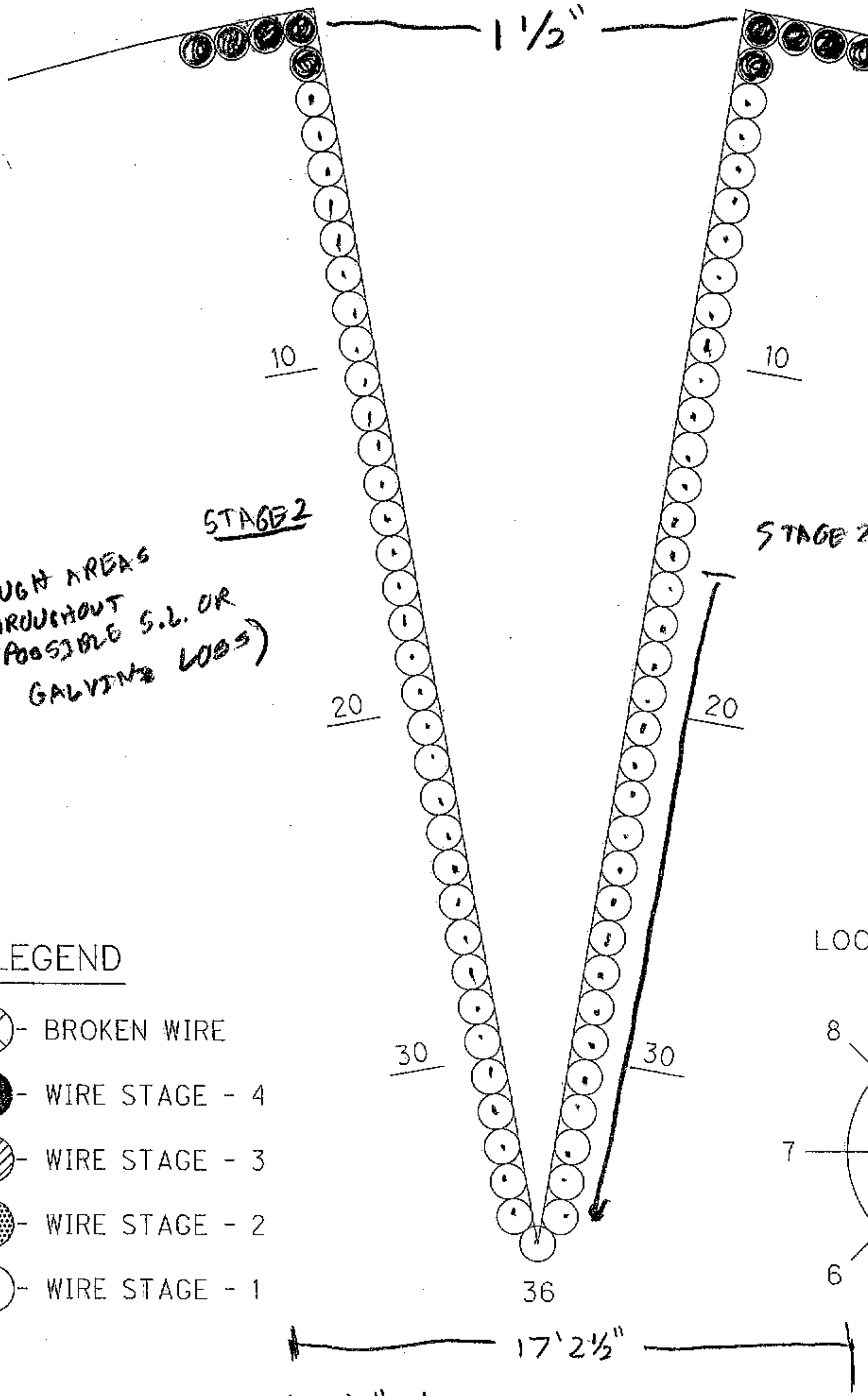
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-13-12

PANEL 3-4

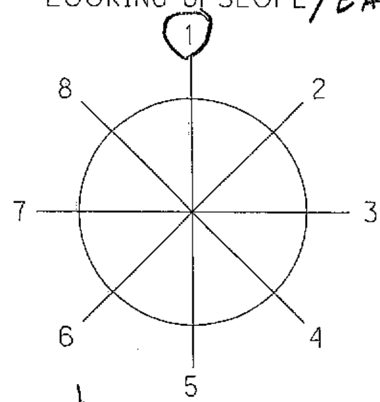
DEPTH OF CABLE INSPECTED 6 3/4"

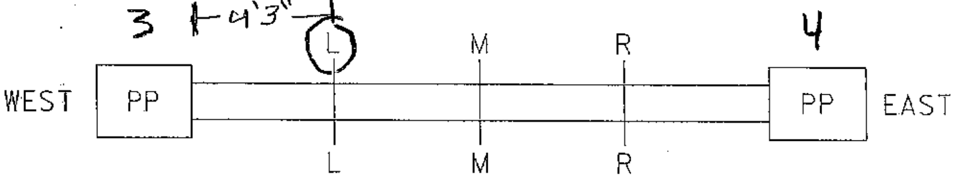


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE/EAST





Total Wires ~~53~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

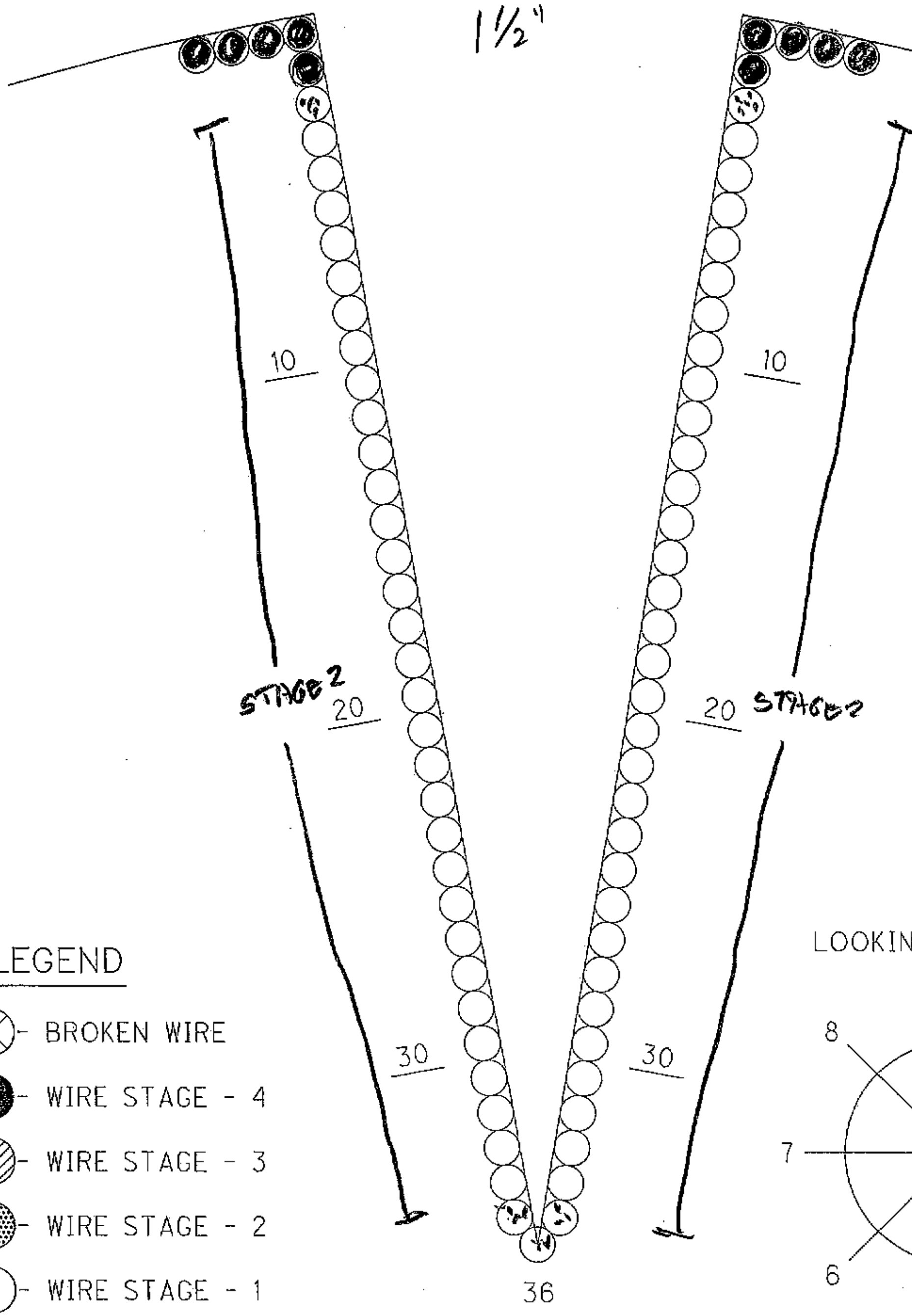
PREPARED BY: ADK

5 CABLE ______ SIDE

DATE: 11-13-12

PANEL 3-4

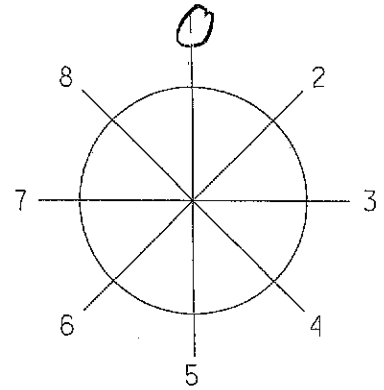
DEPTH OF CABLE INSPECTED 6 3/4"

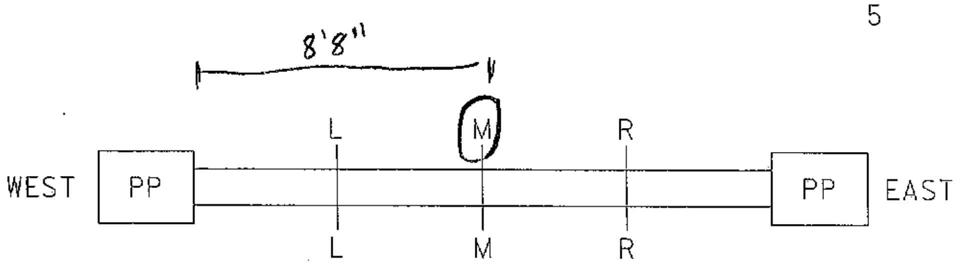


LEGEND

- ⊗ - BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE





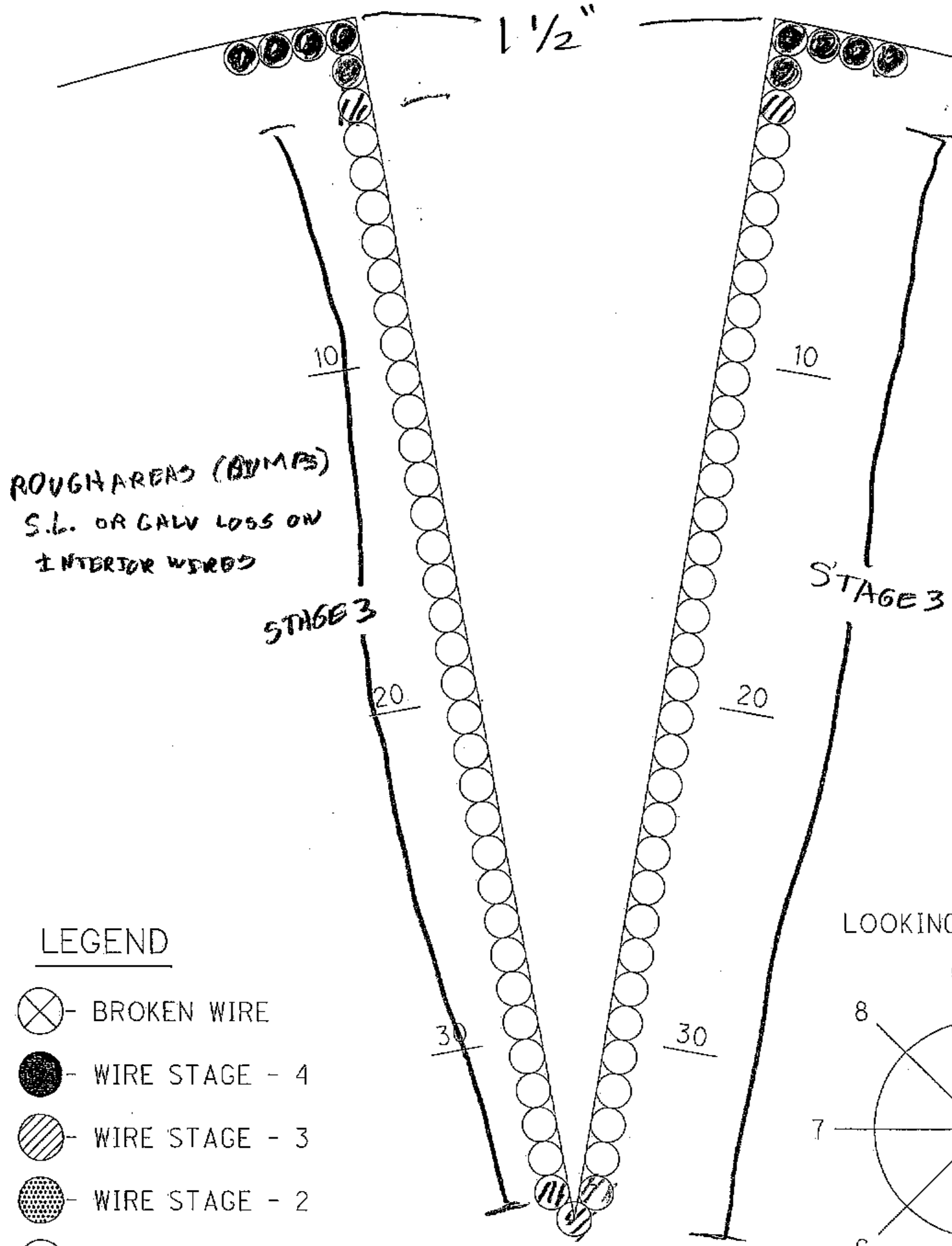
Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE — PREPARED BY: ADK

S CABLE ______ SIDE — DATE: 11-13-12

PANEL 3-4PP

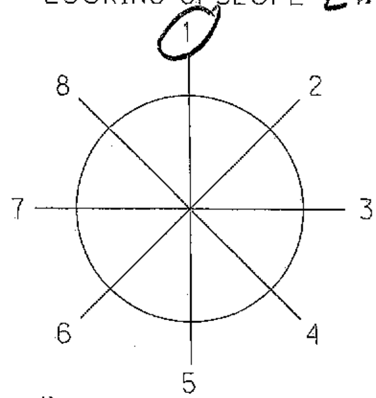
DEPTH OF CABLE INSPECTED 6 5/8"

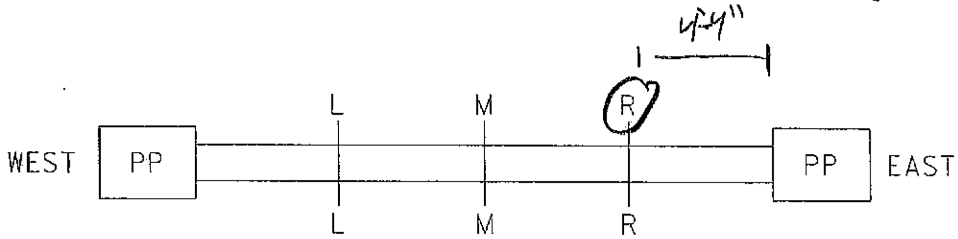


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE EAST





Total Wires 55 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

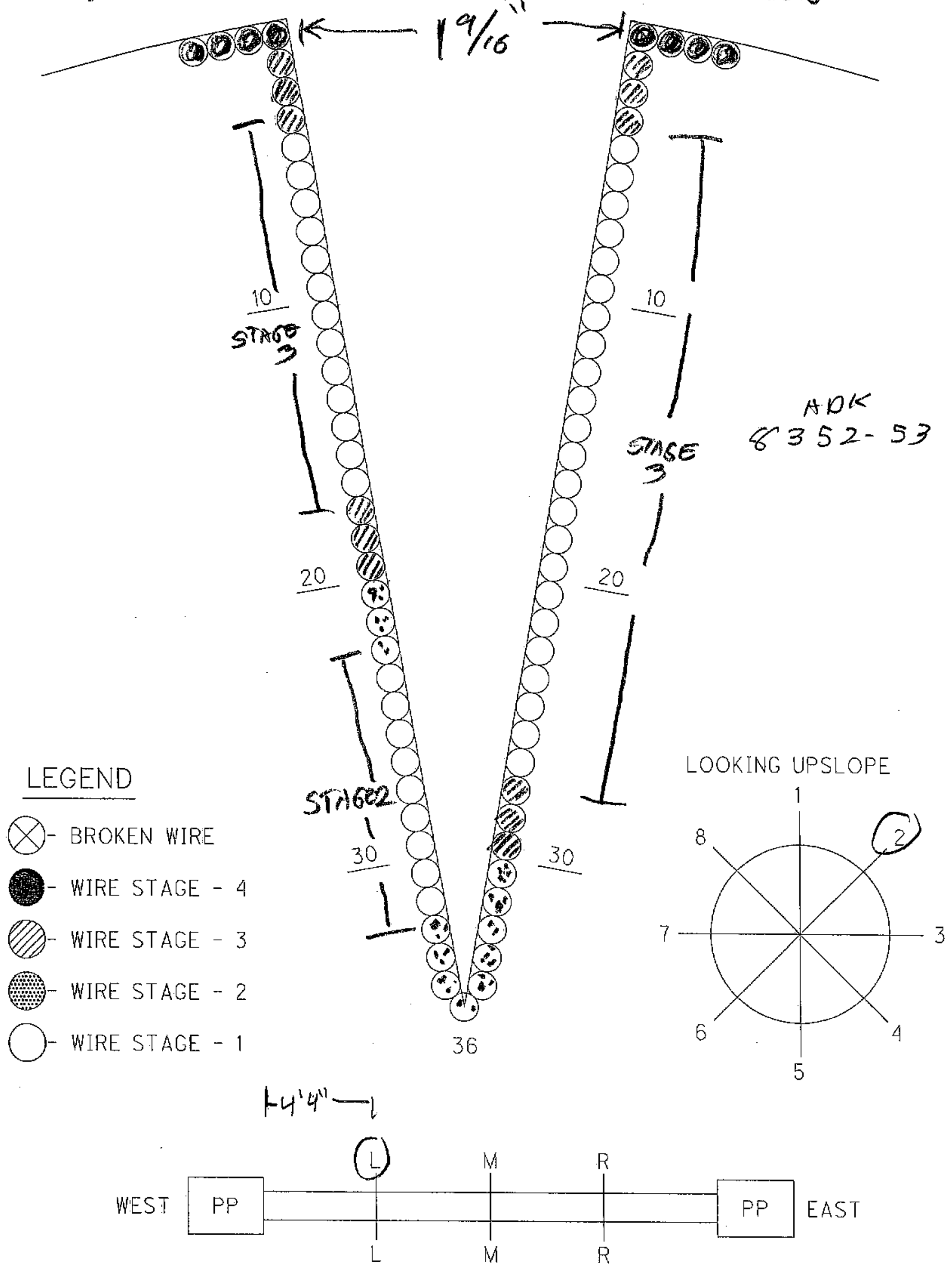
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-13-12

PANEL 3-4

DEPTH OF CABLE INSPECTED 7" FULL PENETRATION



Total Wires ~~53~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

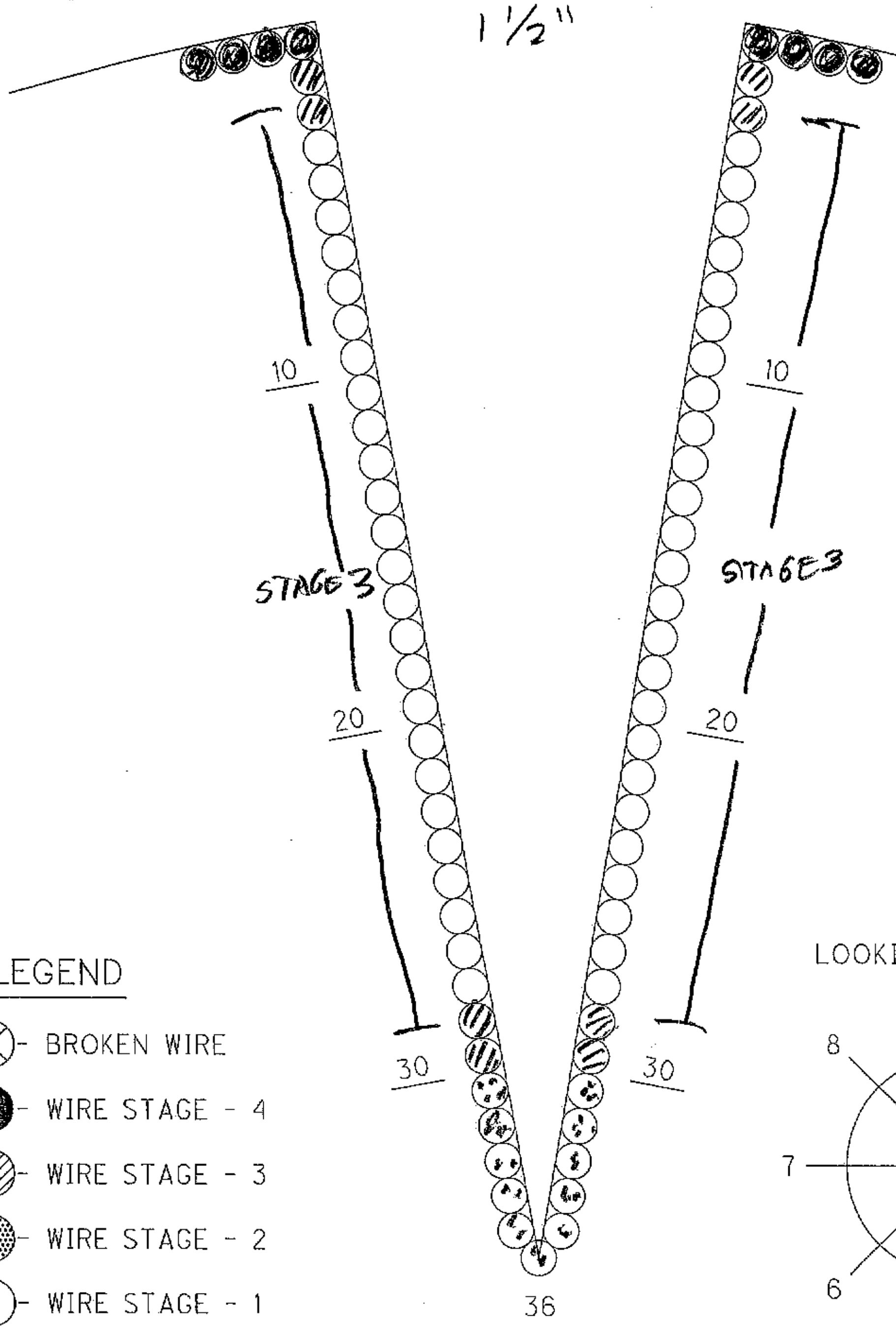
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-13-12

PANEL P 3-4

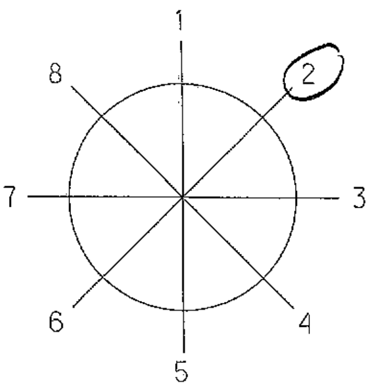
DEPTH OF CABLE INSPECTED 7" FULL DEPTH (ALL THE WAY TO OTHER WEDGES

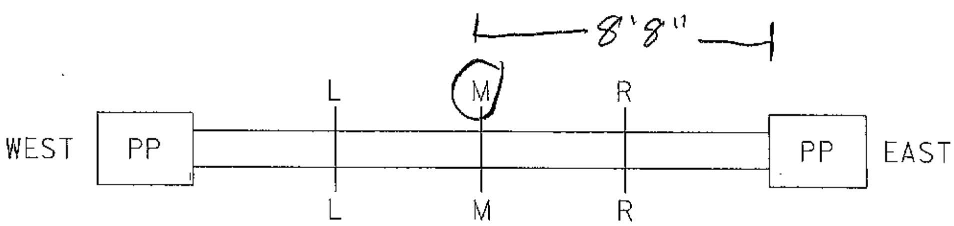


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE





Total Wires 55 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

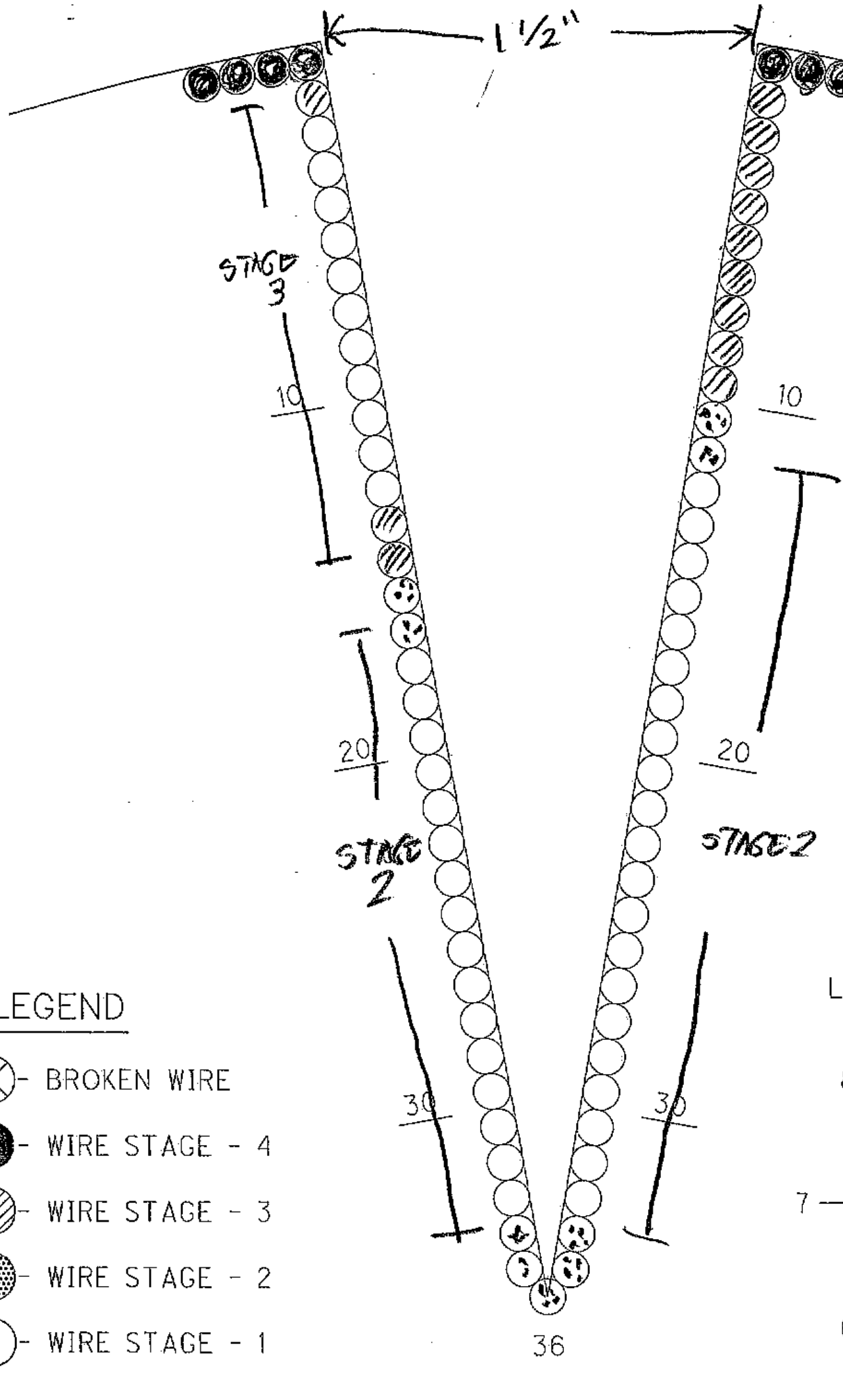
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-13-12

PANEL 3 + 4

DEPTH OF CABLE INSPECTED 7" ALL WAY THROUGH

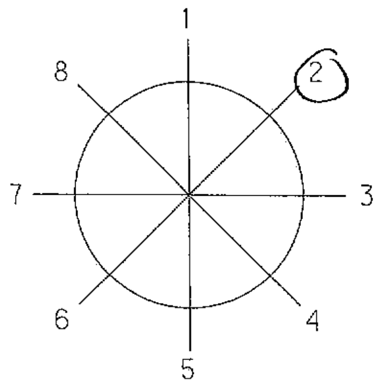


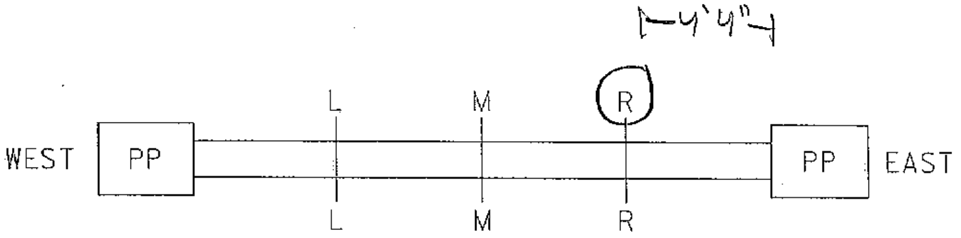
ADK
8349-51

LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE EAST





Total Wires 55 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

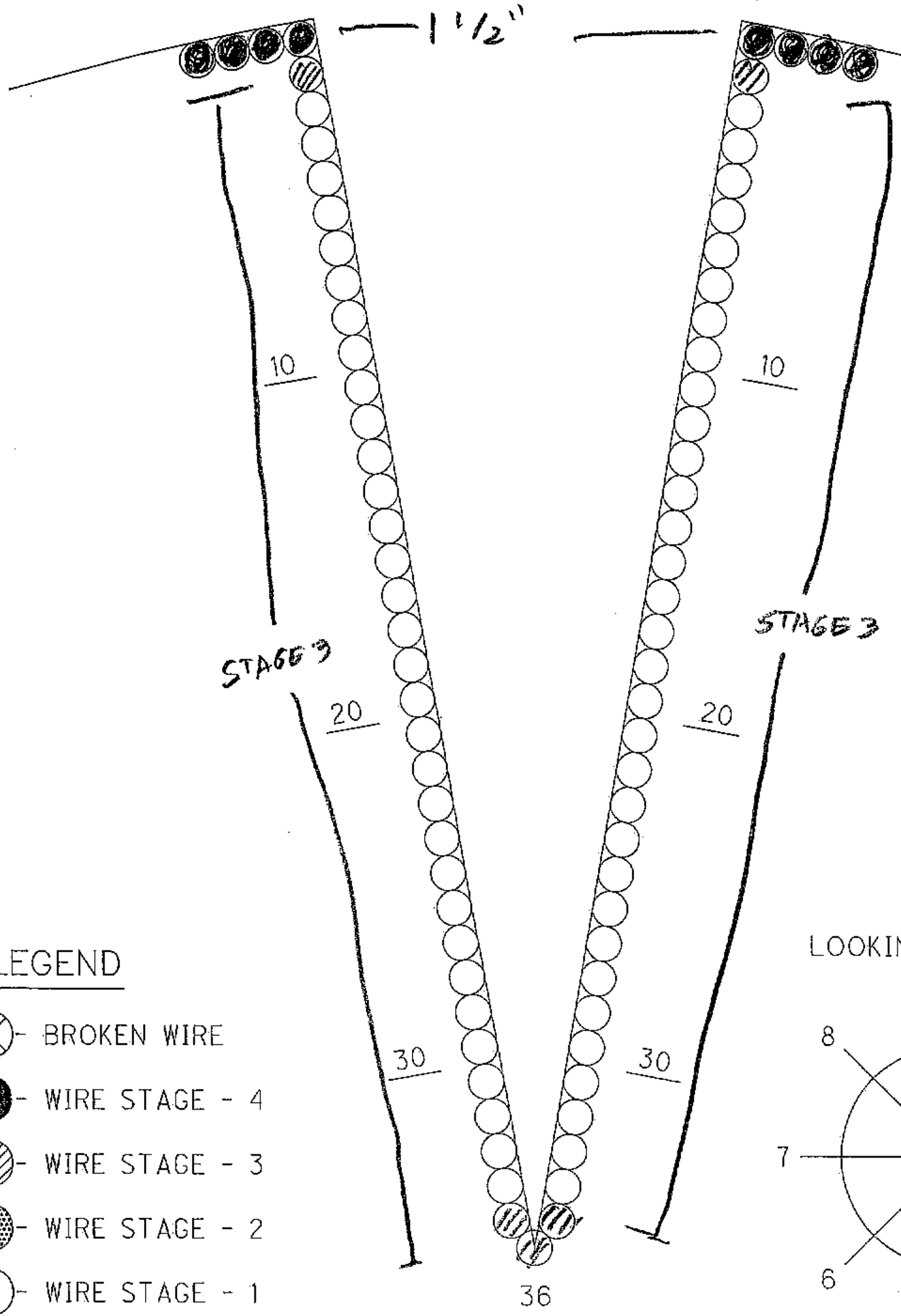
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-13-12

PANEL P 3-4

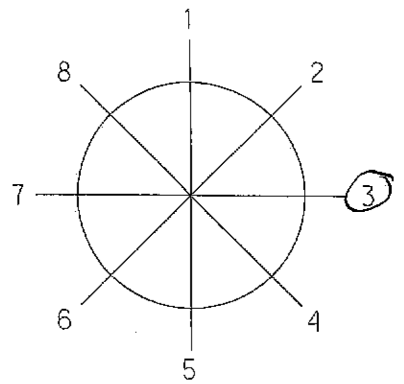
DEPTH OF CABLE INSPECTED 7 1/2" ALL WAY THROUGH

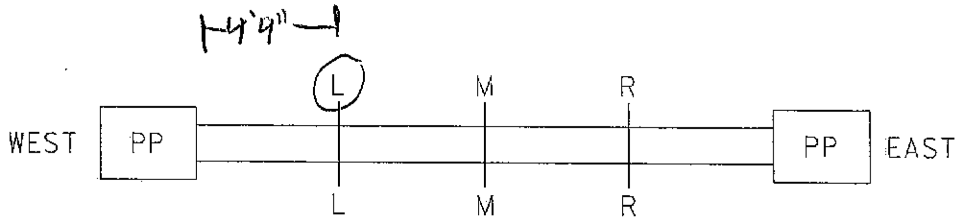


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE EAST





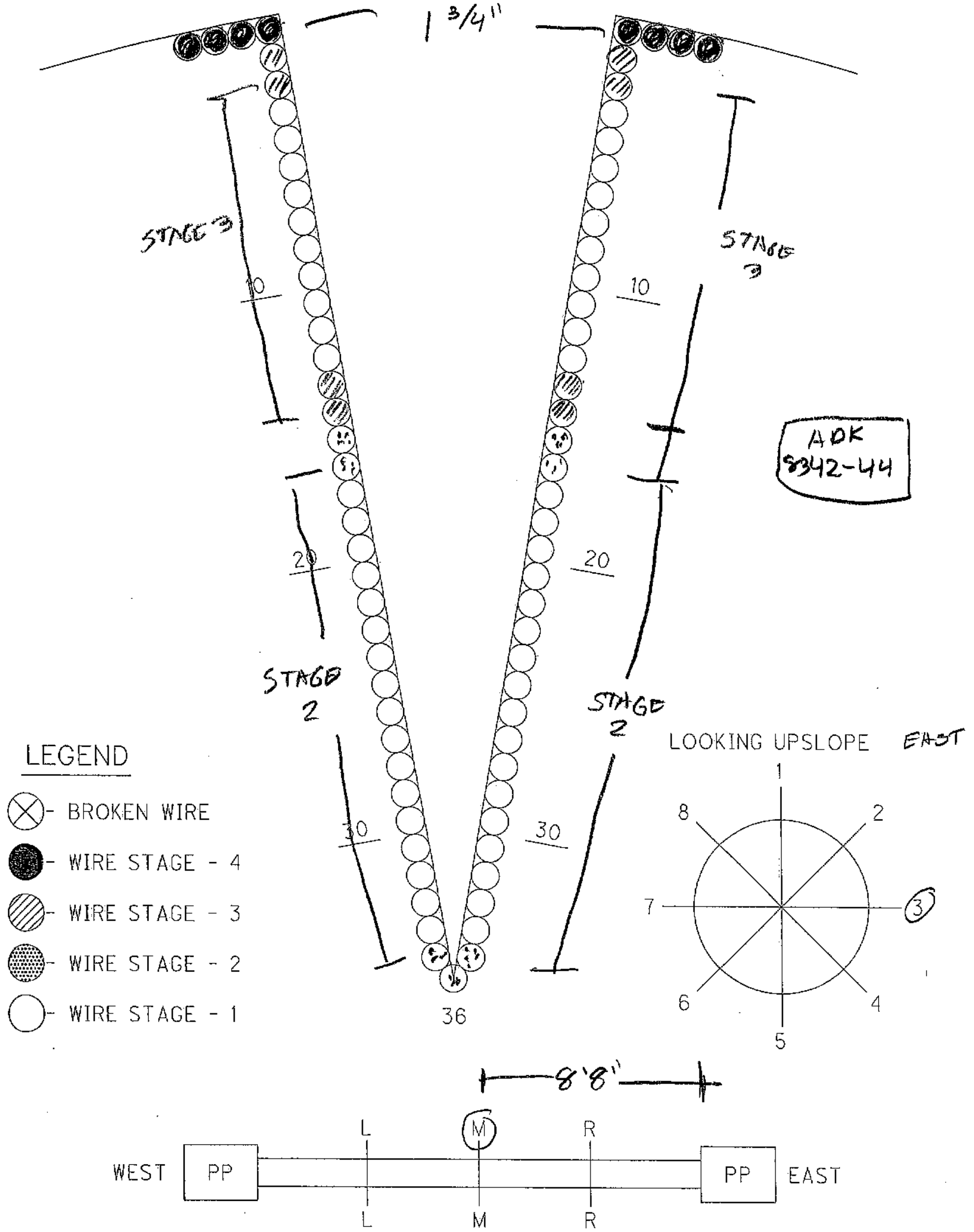
Total Wires 55 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE PREPARED BY: ADK

S CABLE ______ SIDE DATE: 11-13-12

PANEL 3-4

DEPTH OF CABLE INSPECTED 7 3/4" ALL WAY THROUGH



Total Wires ~~53~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

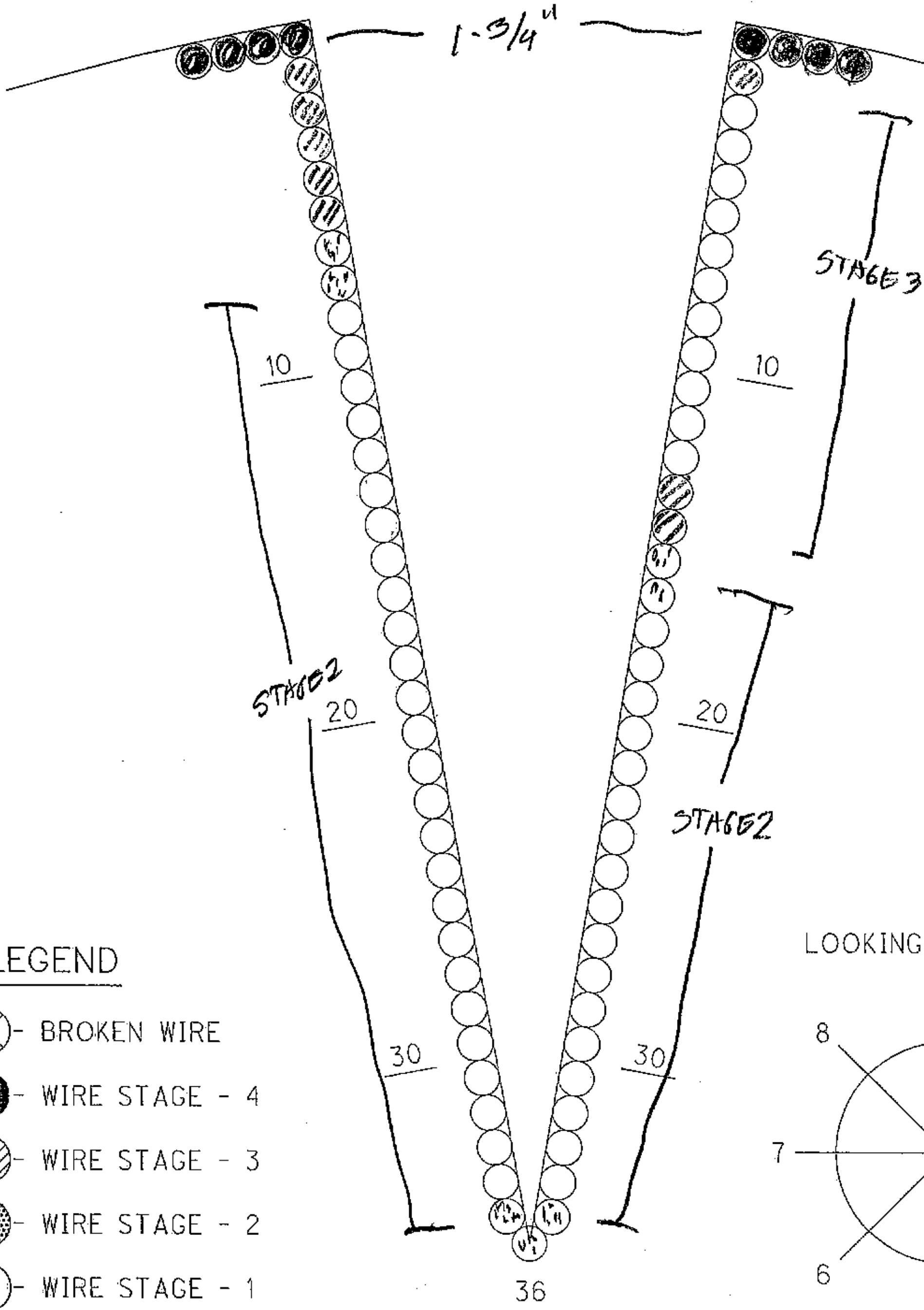
PREPARED BY: NOK

S CABLE ______ SIDE

DATE: 11-13-12

PANEL 3-4

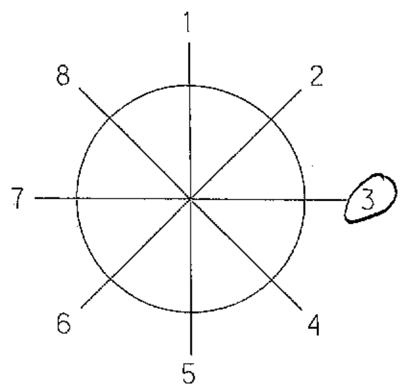
DEPTH OF CABLE INSPECTED 8" ALL WAY THROU

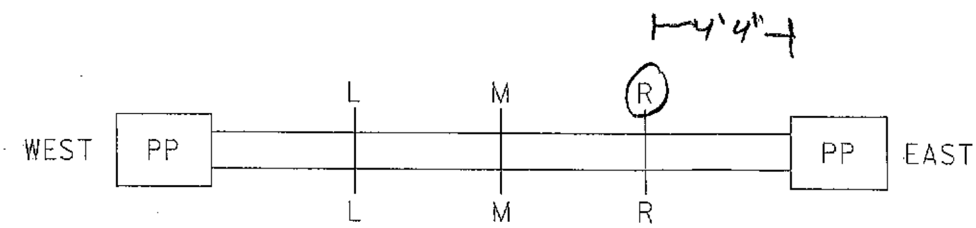


LEGEND

- ⊗ - BROKEN WIRE
- ● - WIRE STAGE - 4
- ▨ - WIRE STAGE - 3
- ◍ - WIRE STAGE - 2
- ○ - WIRE STAGE - 1

LOOKING UPSLOPE EAST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

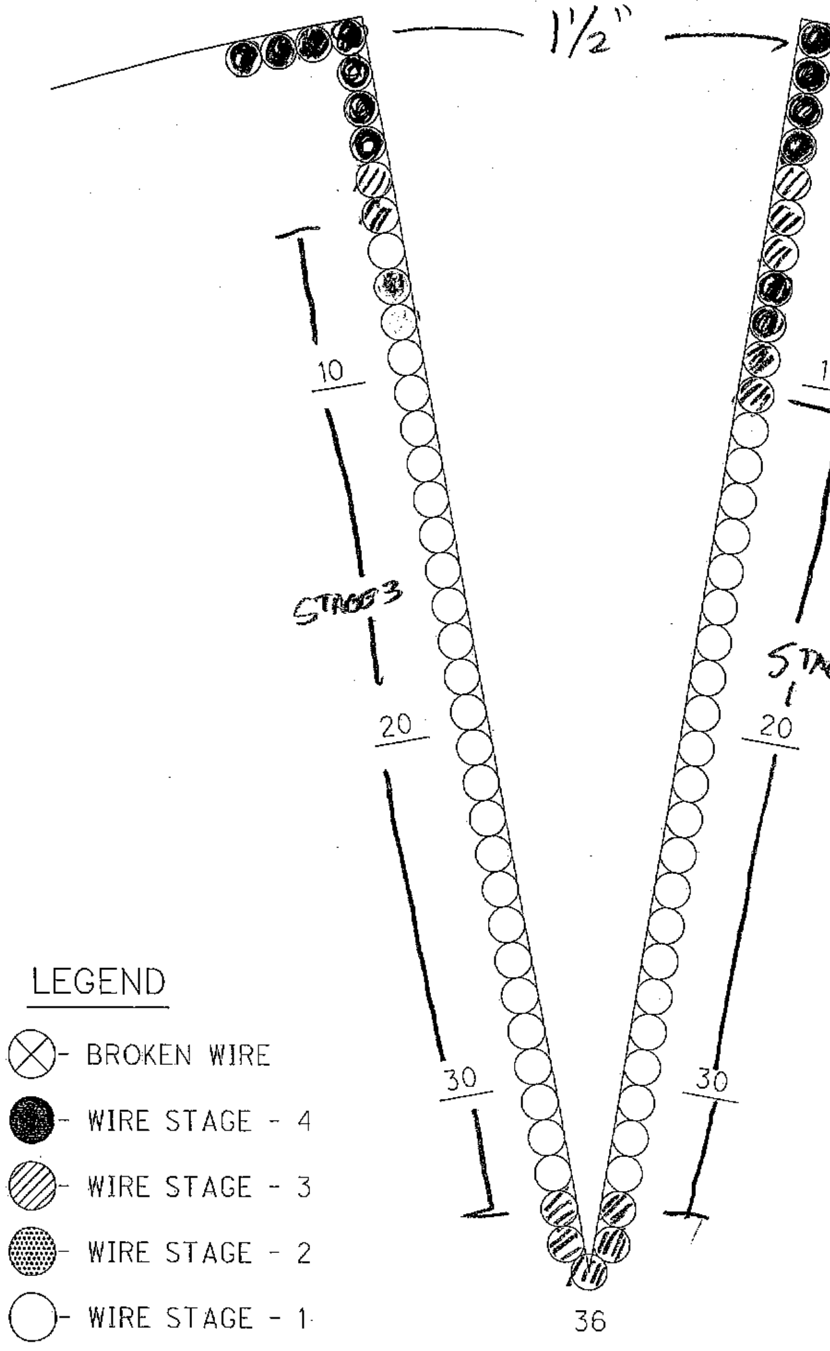
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-13-12

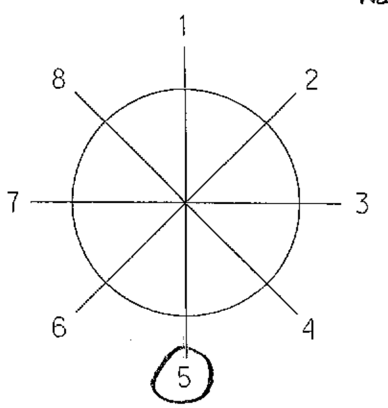
PANEL 3-4

DEPTH OF CABLE INSPECTED 7"

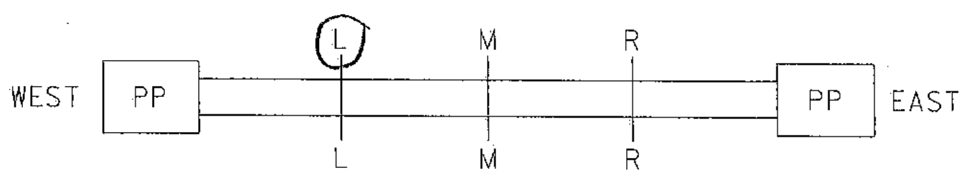


ADK 8334 - CORRODED WIRE SPLICE

LOOKING UPSLOPE EAST



4'4"



Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

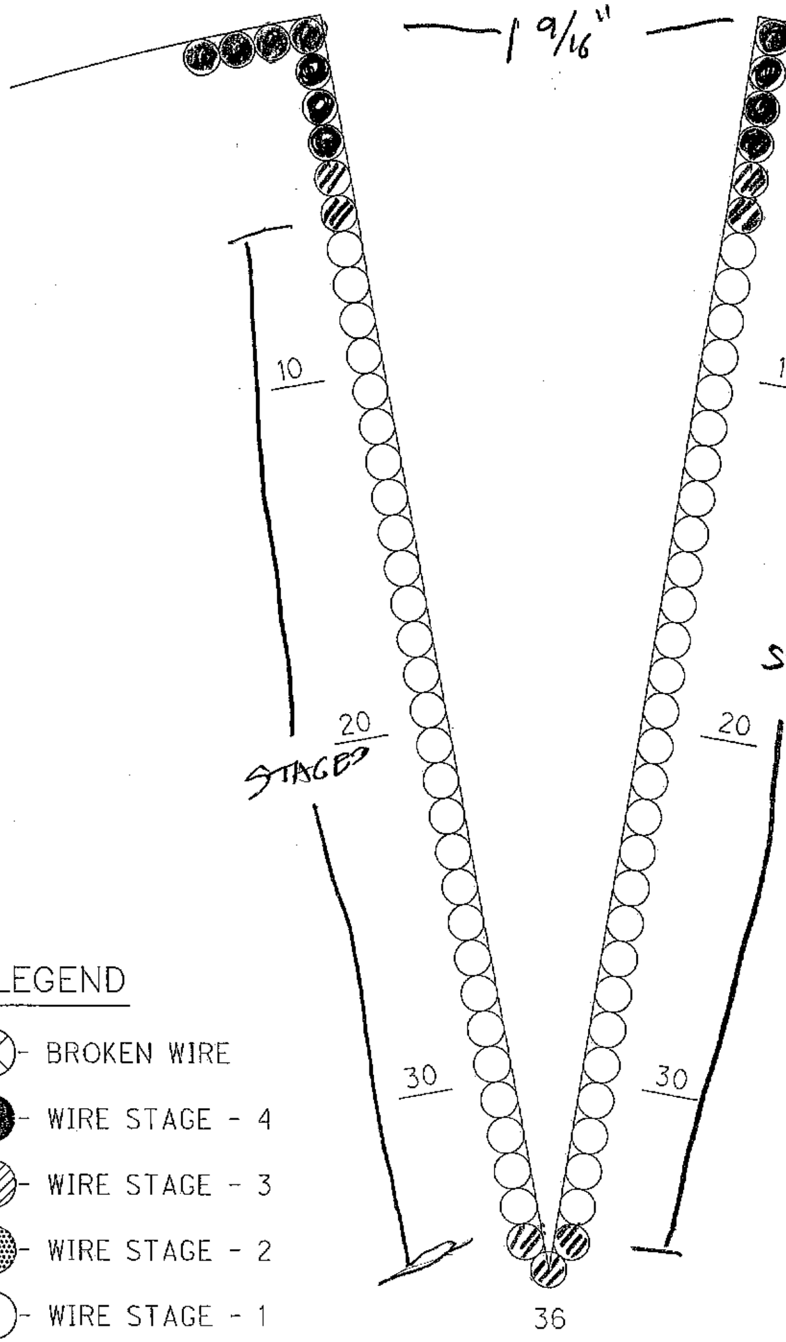
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-13-12

PANEL 3-4

DEPTH OF CABLE INSPECTED 7 1/4"

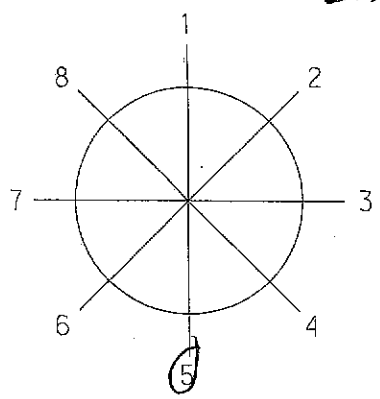


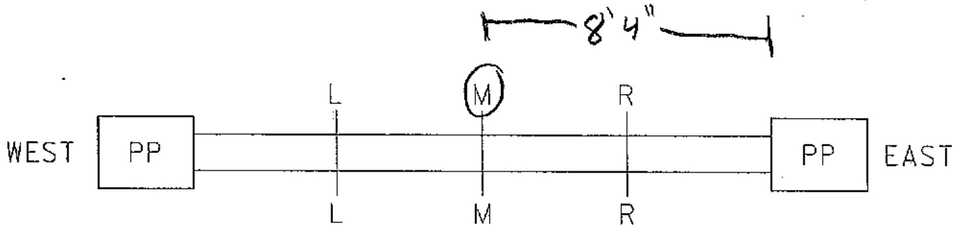
STAGE 3s HAVE SIGN. CORR

LEGEND

- ⊗ - BROKEN WIRE
- ● - WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- ○ - WIRE STAGE - 1

LOOKING UPSLOPE EAST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

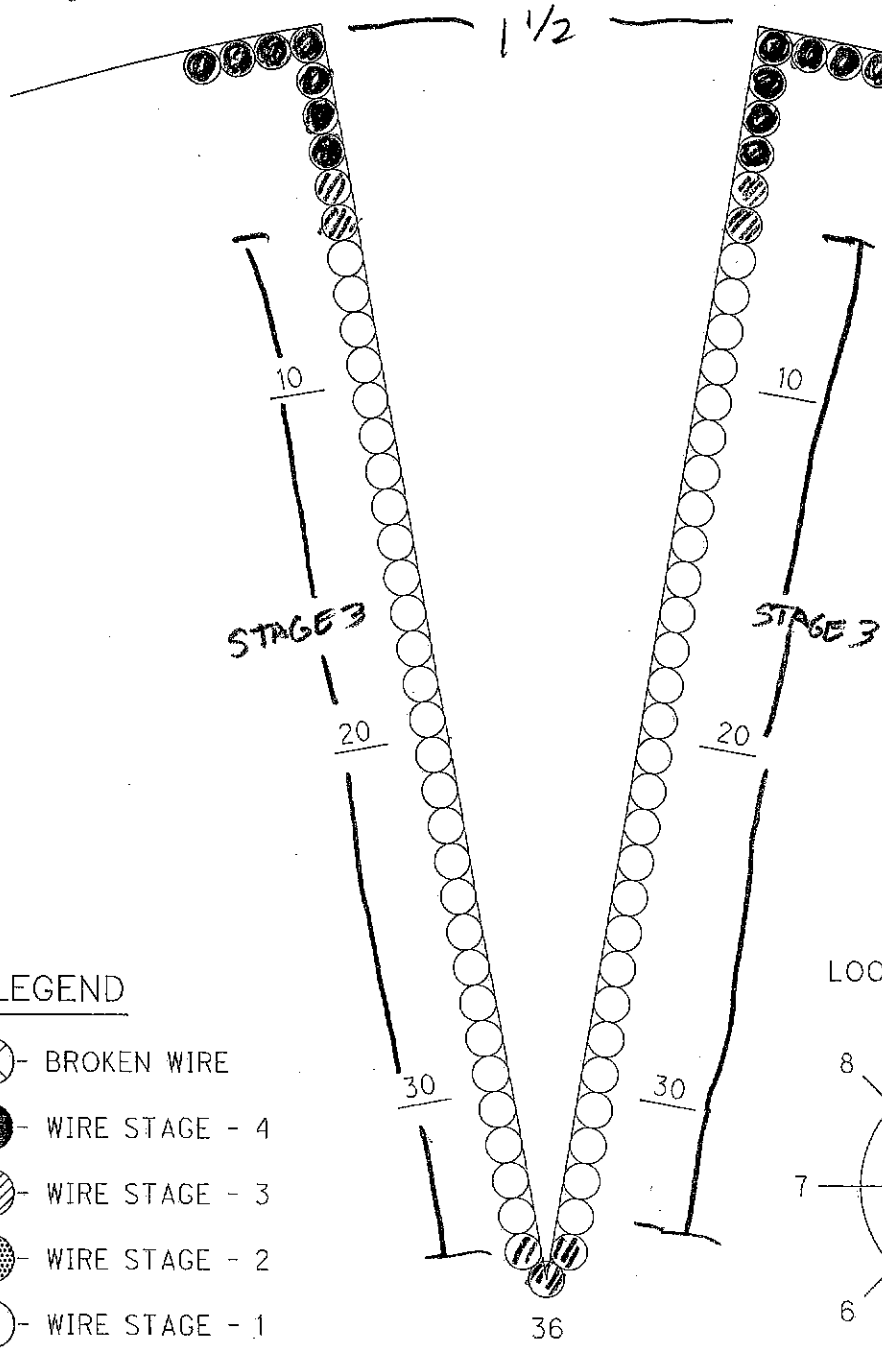
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-13-12

PANEL 3-4

DEPTH OF CABLE INSPECTED 7"



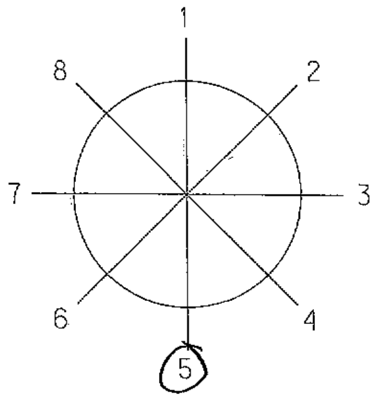
ALL STAGE 3s HAVE SPOT CORROSION

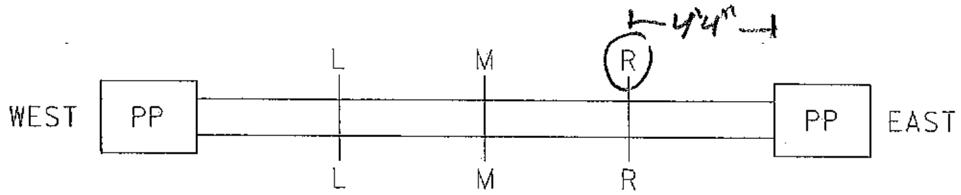
ADK 8345-47

LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE EAST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

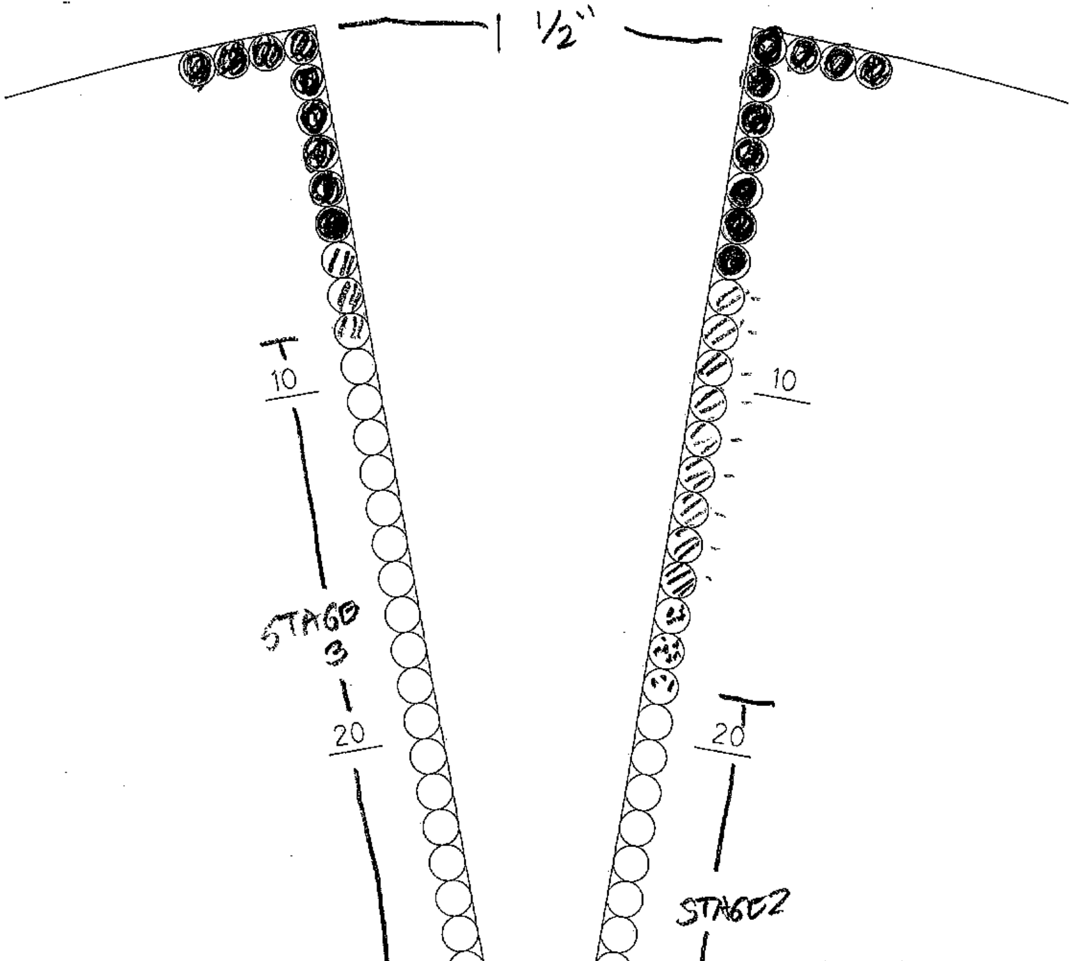
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-13-12

PANEL 3-4

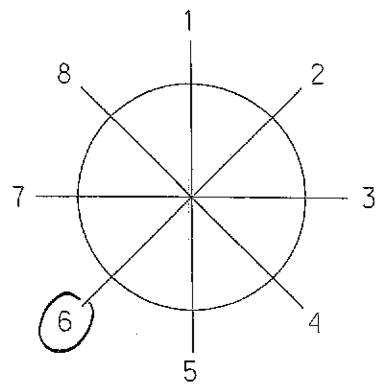
DEPTH OF CABLE INSPECTED ~~6 1/2"~~ NEARLY FULL

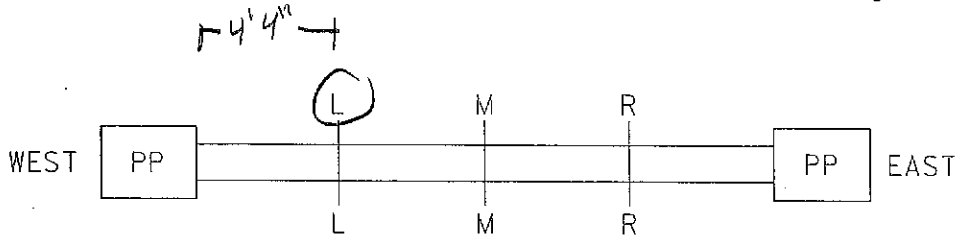


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE EAST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

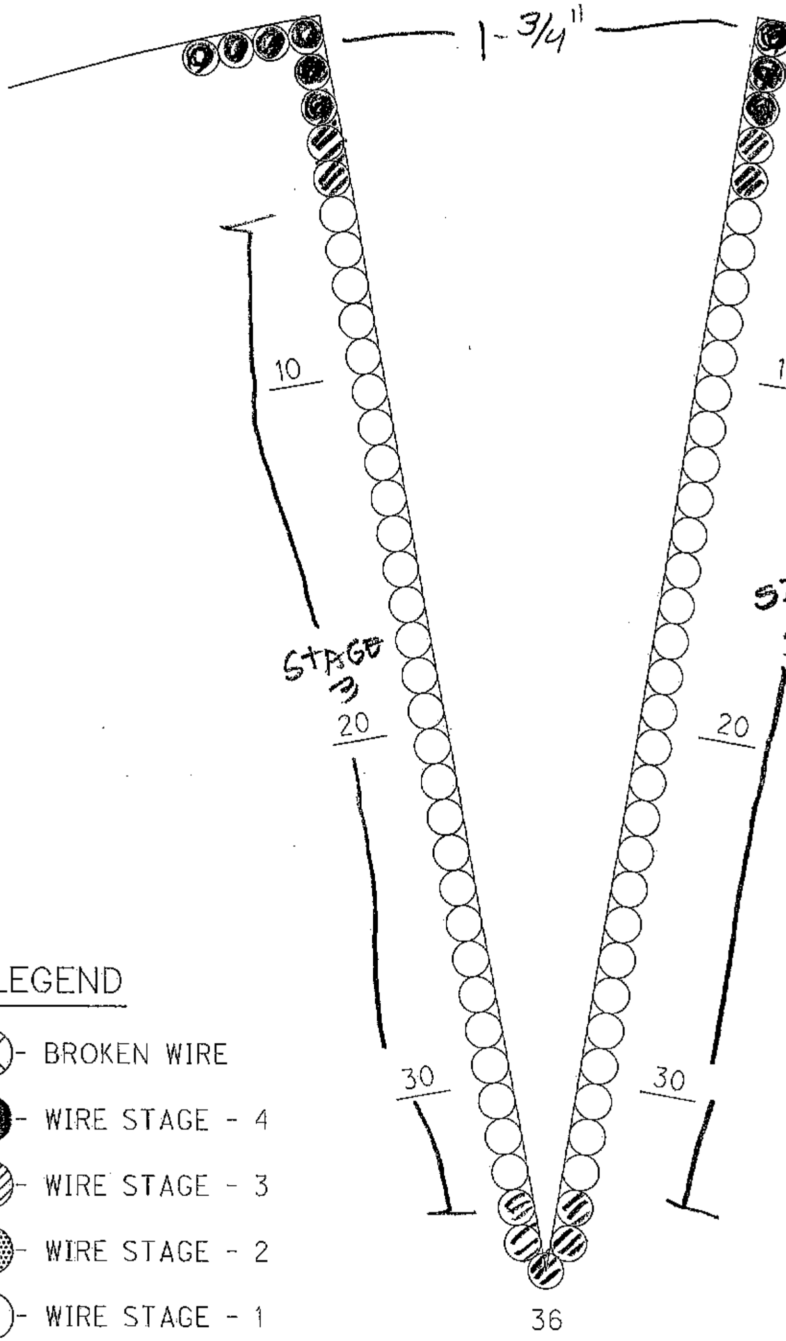
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-13-12

PANEL 3-4

DEPTH OF CABLE INSPECTED 7"

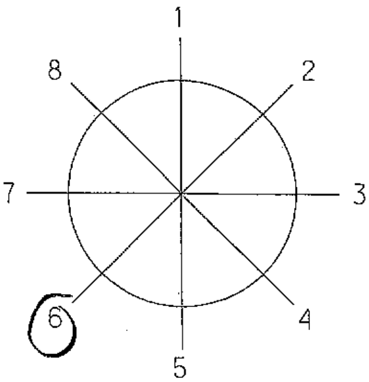


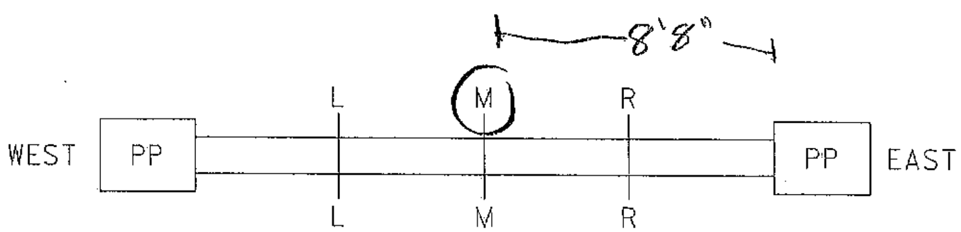
RAL# 2226
LOOKING IN WEDGE

LEGEND

- ⊗ - BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE





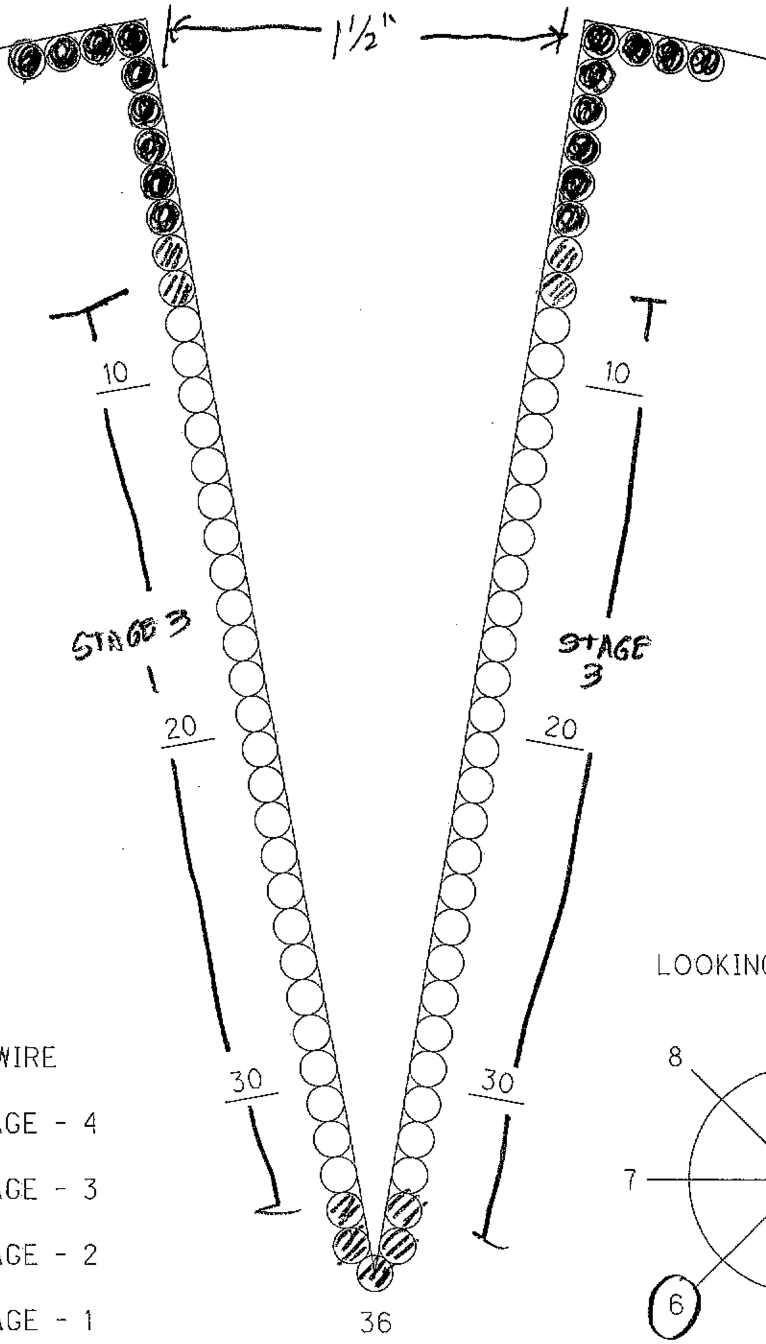
Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE PREPARED BY: ADK

S CABLE ______ SIDE DATE: 11-13-12

PANEL 3-4

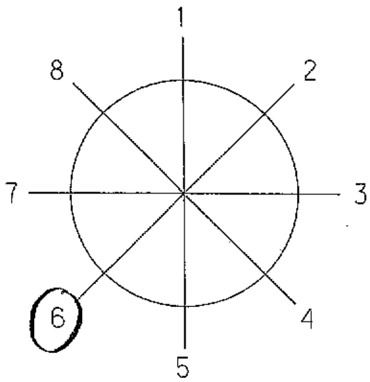
DEPTH OF CABLE INSPECTED 7 1/2" FULL PENETRATION

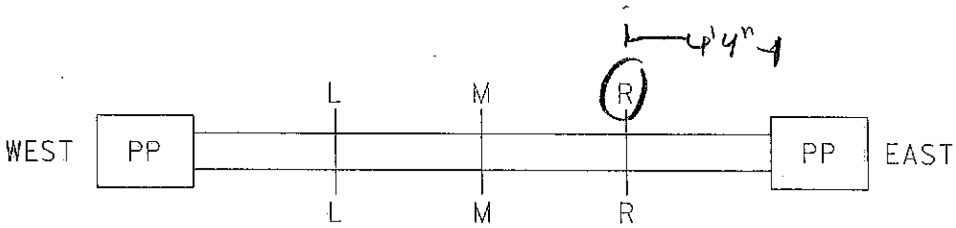


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

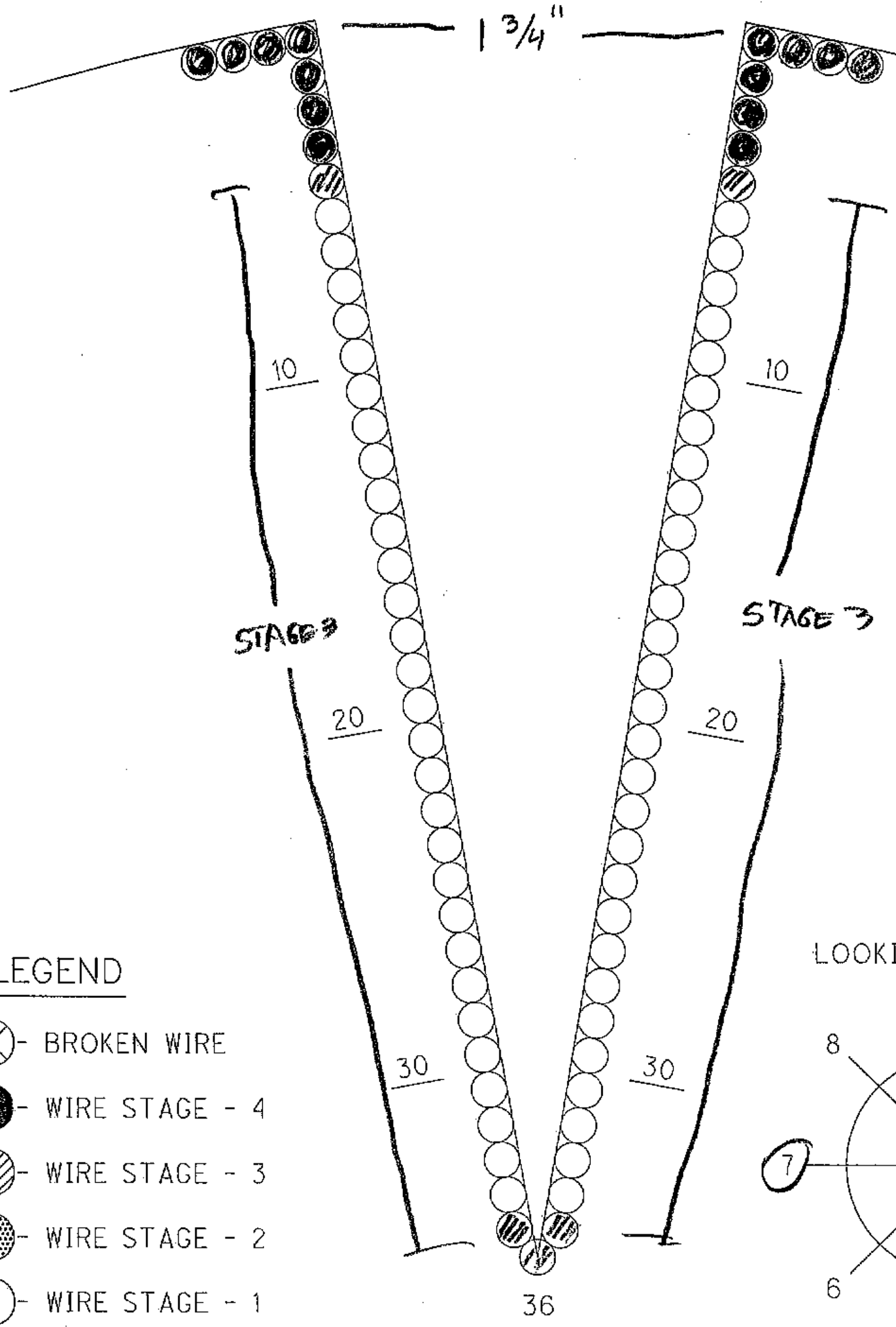
PREPARED BY: ADK

5 CABLE ______ SIDE

DATE: 11-13-12

PANEL 3-4

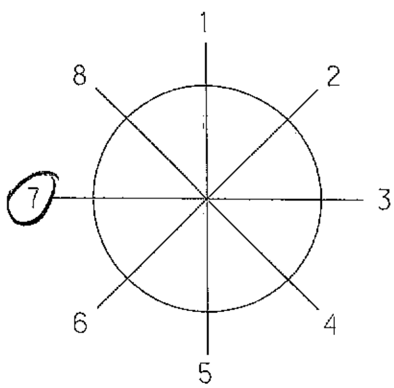
DEPTH OF CABLE INSPECTED 7 3/4" ALL WAY THROUGH

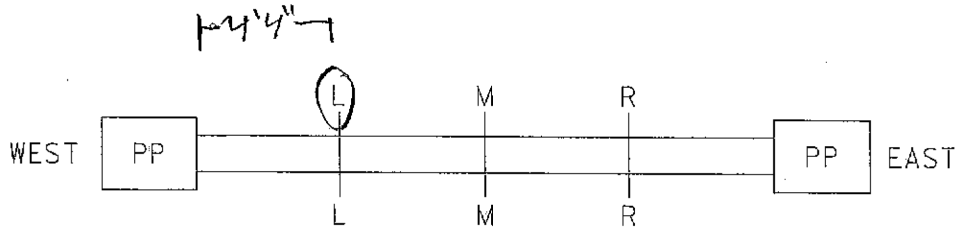


LEGEND

- ⊗ - BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE EAST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

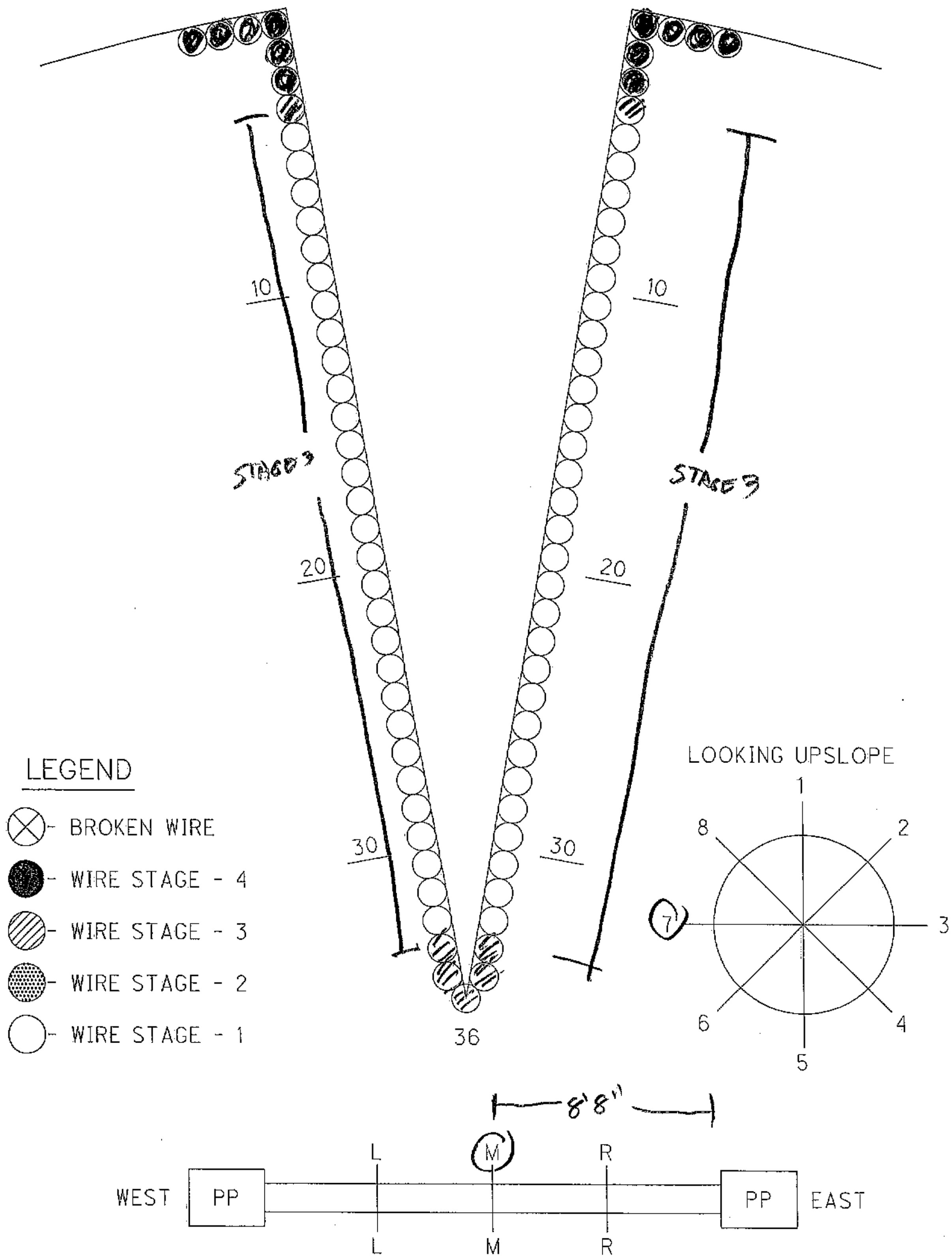
PREPARED BY: AOK

S CABLE ______ SIDE

DATE: 11-13-12

PANEL 34

DEPTH OF CABLE INSPECTED 7 3/4" (ALL WAY THROUGH



Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

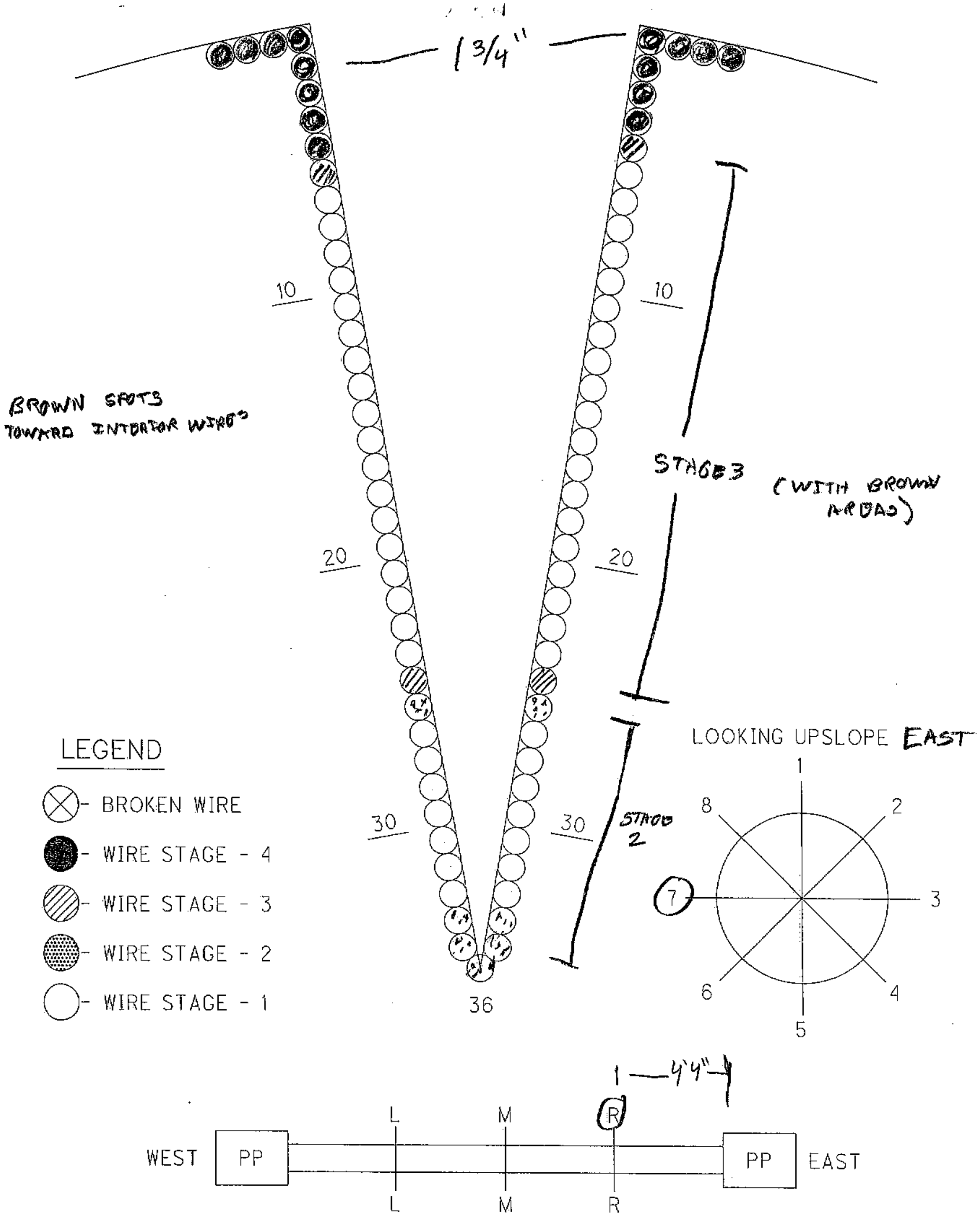
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-13-12

PANEL P 3-4

DEPTH OF CABLE INSPECTED 7 3/4" - (ALL WAY THROUGH)



Optional Cable Opening Location PP 58 – PP 59, South

19'2¼"

19'2¼" - HORIZONTAL DISTANCE FROM SIDEWALKS INSIDE SUSP. ROPE TO INSIDE SUSP. ROPE

Anthony Wayne Bridge Main Cable Investigation

Cable Circumference Measurements

Prepared by: AOK
Date: 11-13-12
No. Wires in cable (N): 8066
Wire Diameter (d): 0.192

Cable: SOUTH
Side: EAST BACKSTAY
Panel: 58-59

AOK 8368-59

[AOK 8374] - AFTER 4 WEDGE LINES

WEST — Cable Band / Panel Point 58

	Before Unwrapping		After Unwrapping		Density	After Compaction		Density	After Rewrapping	
	Measured Circumference	Calculated Diameter	Measured Circumference	Calculated Diameter		Measured Circumference	Calculated Diameter		Measured Circumference	Calculated Diameter
	Ci	Di	C	D	DENS	Cc	Dc	DENSc	Cf	Df
12 in from Cable Band (PP 58)	43"	13.7"	41 5/8"	13.26"		41 9/16"	13.23"		43 1/2"	13.85
	43 3/16"	13.75"	42 5/8"	13.57"		43"	13.69"		43 3/4"	13.93
Center Line	43 1/4"	13.77	42 3/4"	13.61"		43 5/8"	13.89"		44 5/16"	14.11"
	42 15/16"		42"	13.37"		42 3/16"	13.43"		43"	13.69"
12 in from Cable Band (PP 59)	42 9/16"		41 1/2"	13.21"		41 7/16"	13.19"		42 3/4	13.61"

17'7½"

EAST — Cable Band / Panel Point 59

SAMPLE #1 7'11 15/16"
#2 7'11 9/16"
SAMPLE 3 7'11 3/4"

$D_i = C_i/\pi$ $D = C/\pi$ $DENS = Nd^2/D^2$ $D_c = C_c/\pi$ $DENS_c = Nd^2/D_c^2$ $D_f = C_f/\pi$

Temperature	Temperature	Temperature	Temperature
37° F	31° F	38°	50°

RAL #2251 - OVERALL w/ WEDGES @ 12, 1:30, 3:00, 4:30, 7:30, 9:00

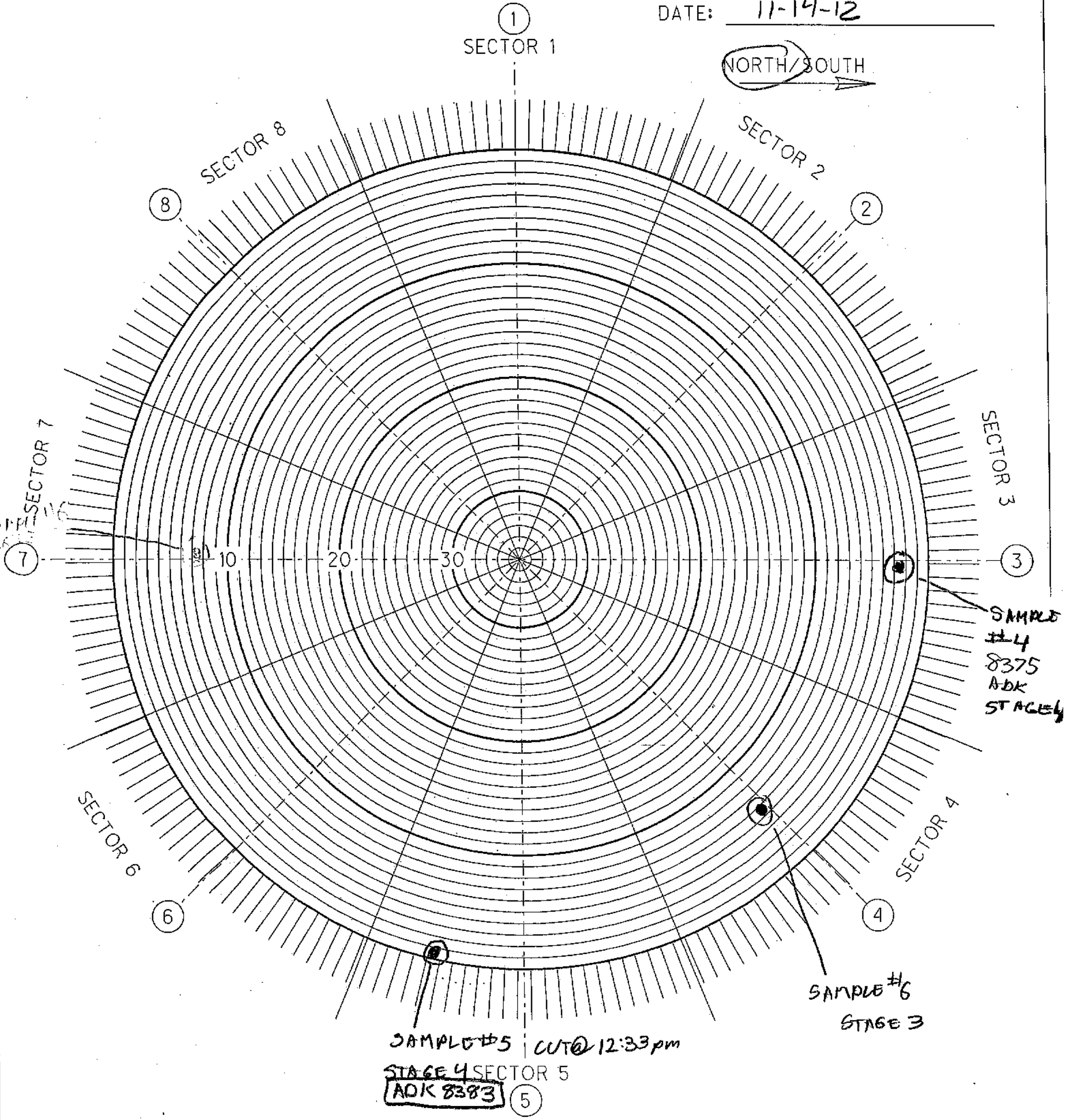
RAL #2229 - @ PP59 S. CABLE APPARENT WATER RETENTION INSIDE NEOPRENE COVER

RAL # 2230 - WATER LEAKING FROM CABLE AFTER TAPE REMOVAL
2231 - UNDERSIDE OF TOP HALF CABLE - MOISTURE PRESENT [?] PEELING PAINT
2232 - NEOPRENE WRAPPING / ORING @ PP59

BRIDGE NAME: ANTHONY WAYNE BRIDGE

PREPARED BY: ADK

DATE: 11-14-12



LEGEND

● - BROKEN WIRE NO.

(1) - WEDGE LOCATION

(●) - SAMPLE FOR TESTING

CABLE CROSS SECTION

S CABLE, LOOKING WEST

SPAN

PANEL 58-59

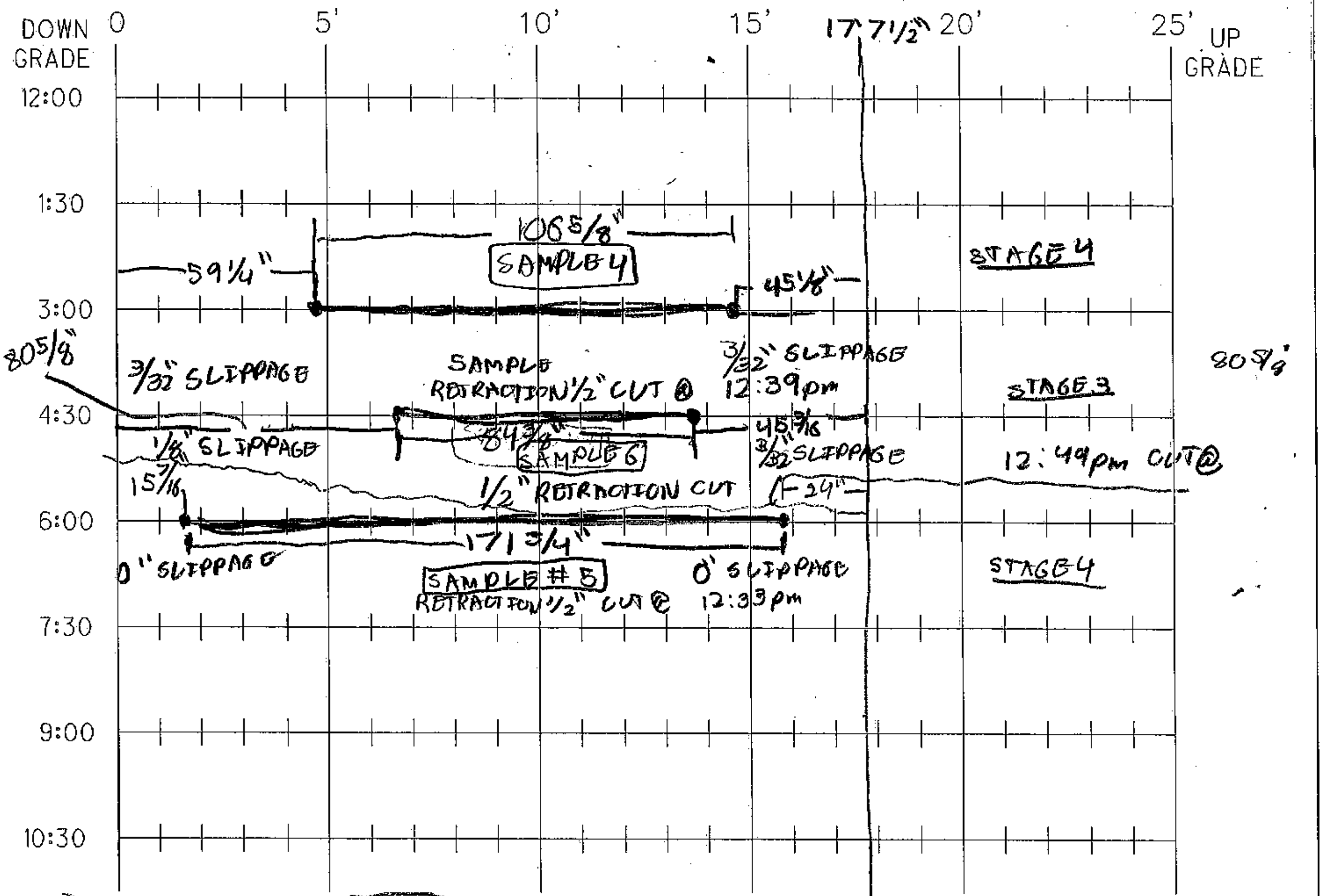
BRIDGE NAME: ANTHONY WAYNE

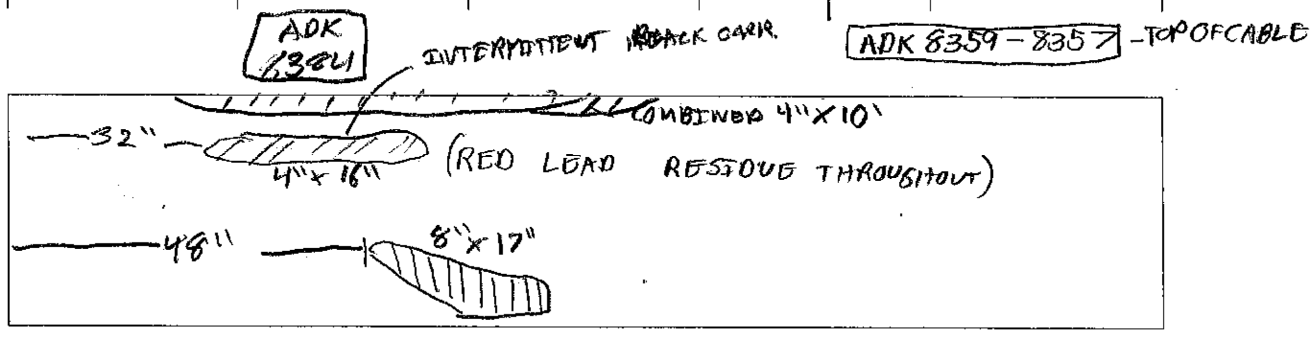
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-14-12

PANEL 58-59 TOTAL LENGTH EXPOSED 17'7"

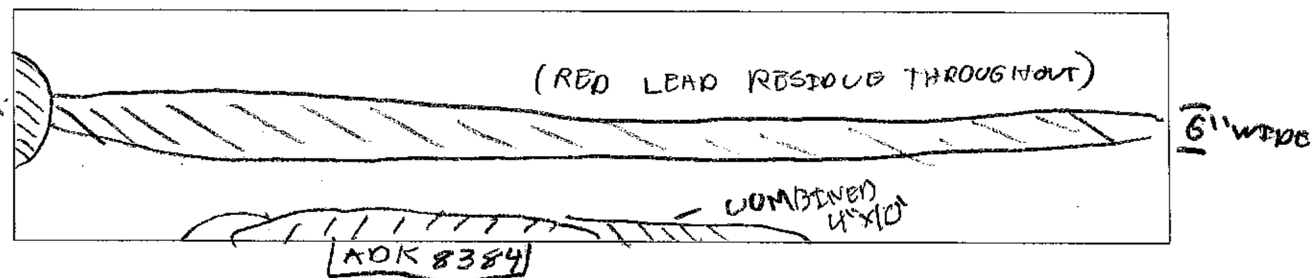




TOP OF CABLE EXTERIOR

▨ - CORRODED - BLACK AREA

AREA OF APPARENT WATER RETENTION



BOTTOM OF CABLE EXTERIOR

Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

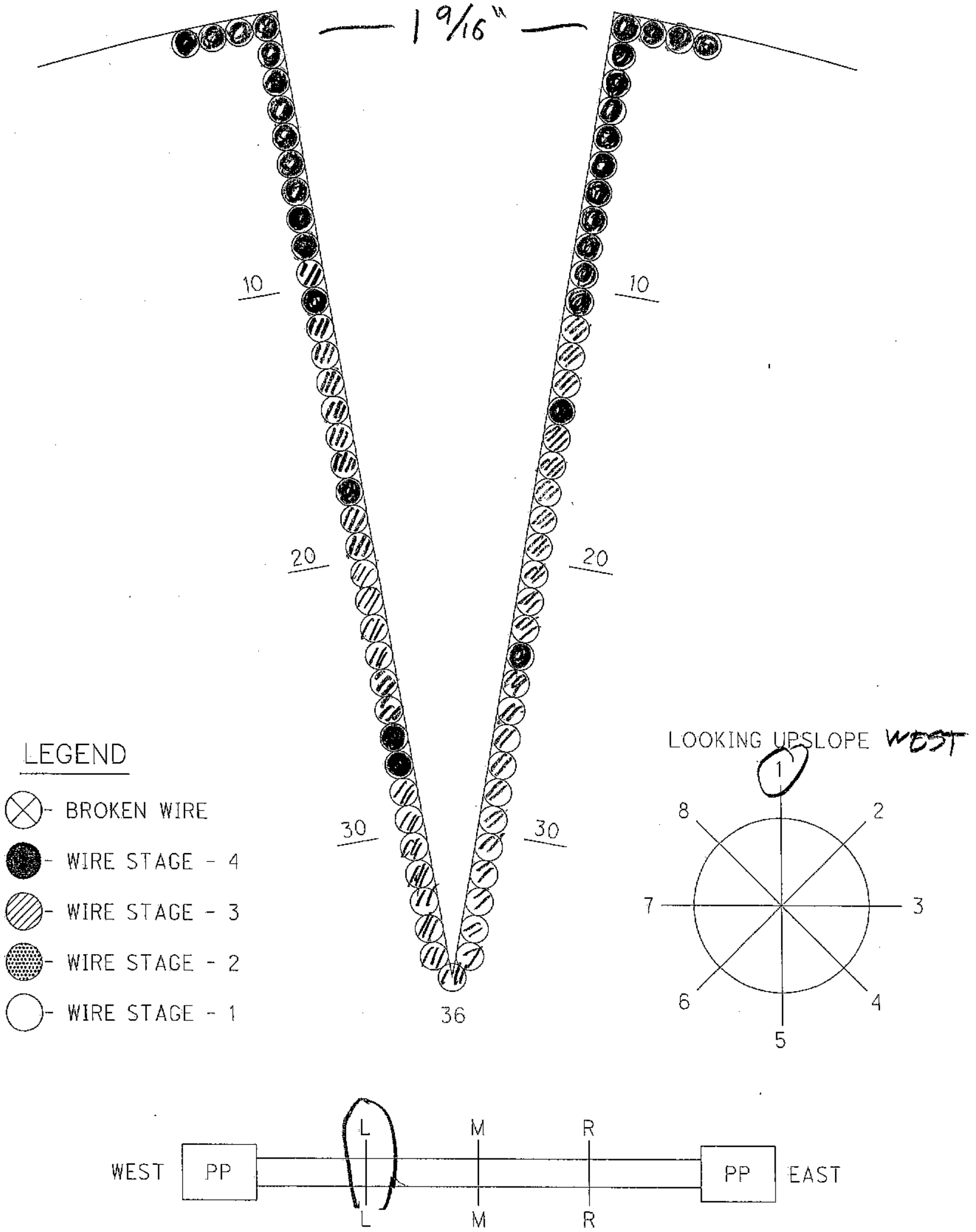
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-14-12

PANEL 58-59

DEPTH OF CABLE INSPECTED 7 1/4"



Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

PREPARED BY: ADK

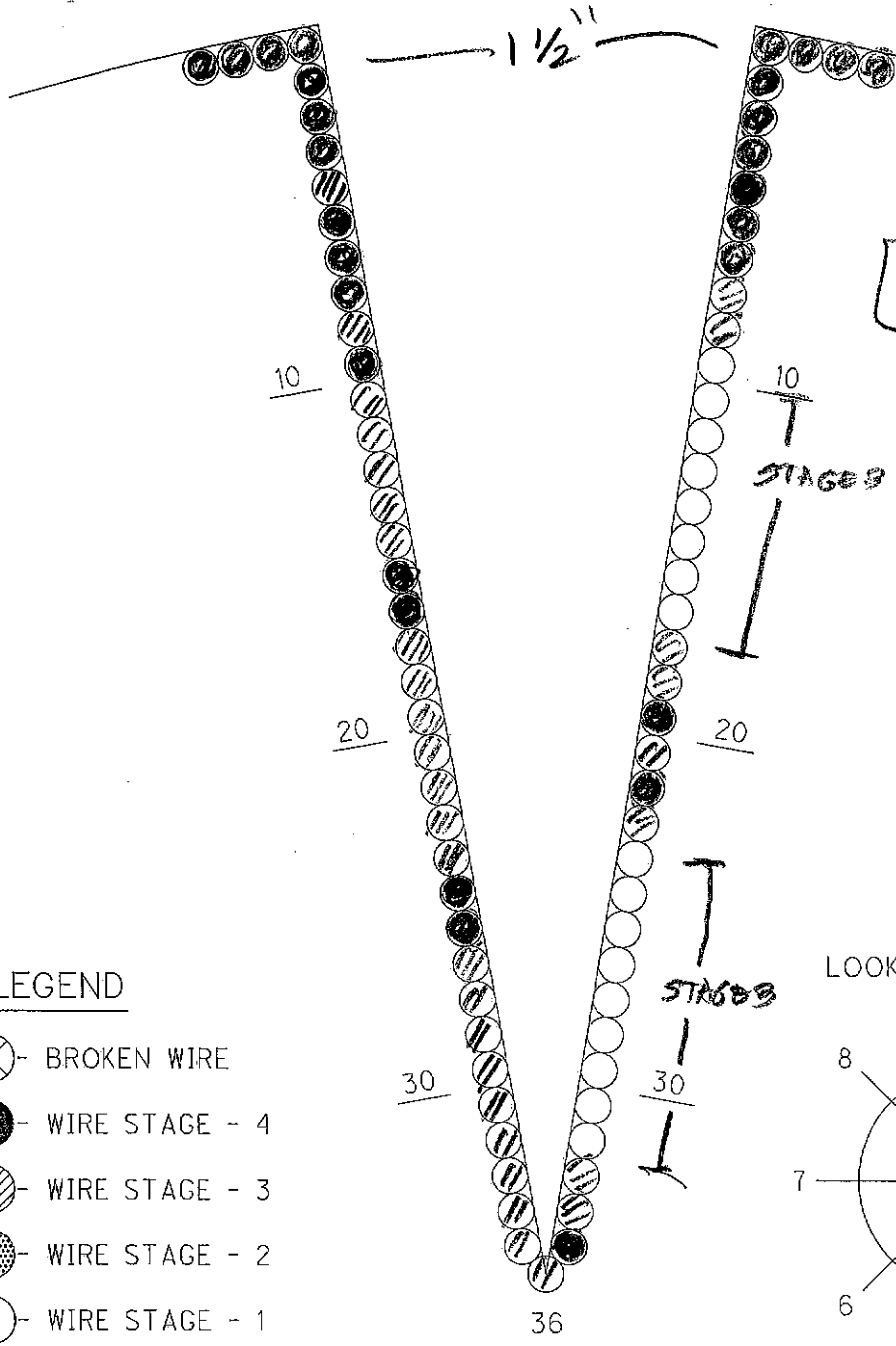
S CABLE ______ SIDE

DATE: 11-14-12

PANEL 58-59

DEPTH OF CABLE INSPECTED 7"

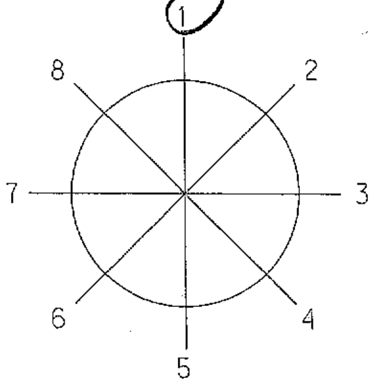
ADK
8363

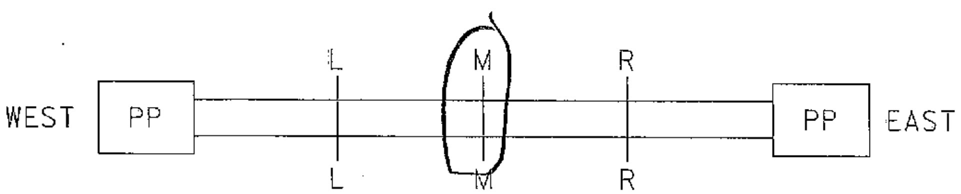


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE





Total Wires ~~53~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

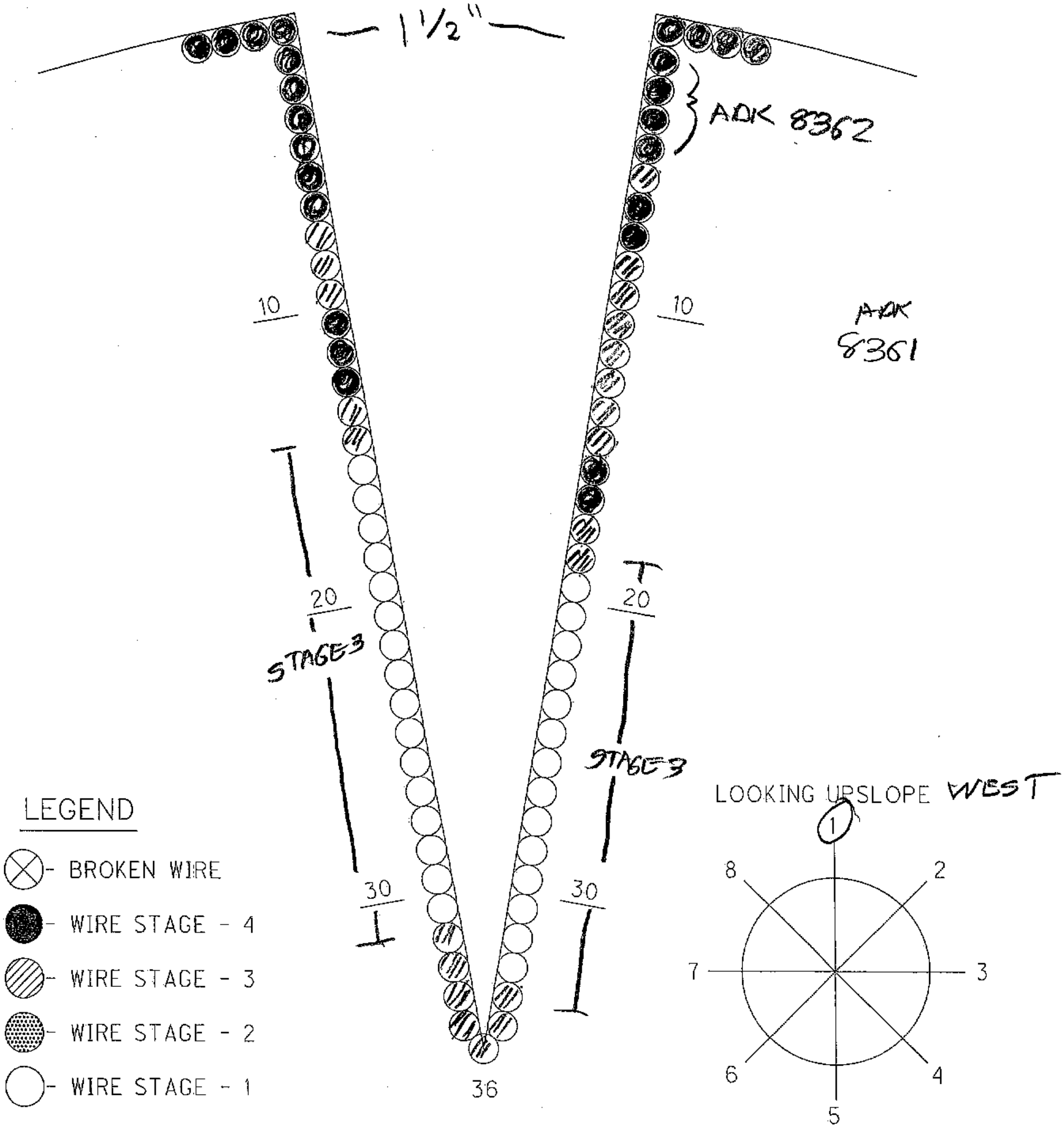
PREPARED BY: ADK

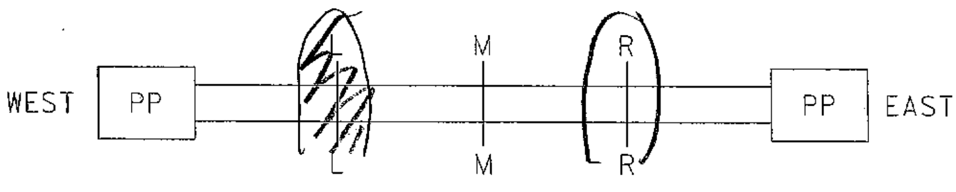
S CABLE ______ SIDE

DATE: 11-14-12

PANEL 58-59

DEPTH OF CABLE INSPECTED 6 3/4"





Total Wires 53 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

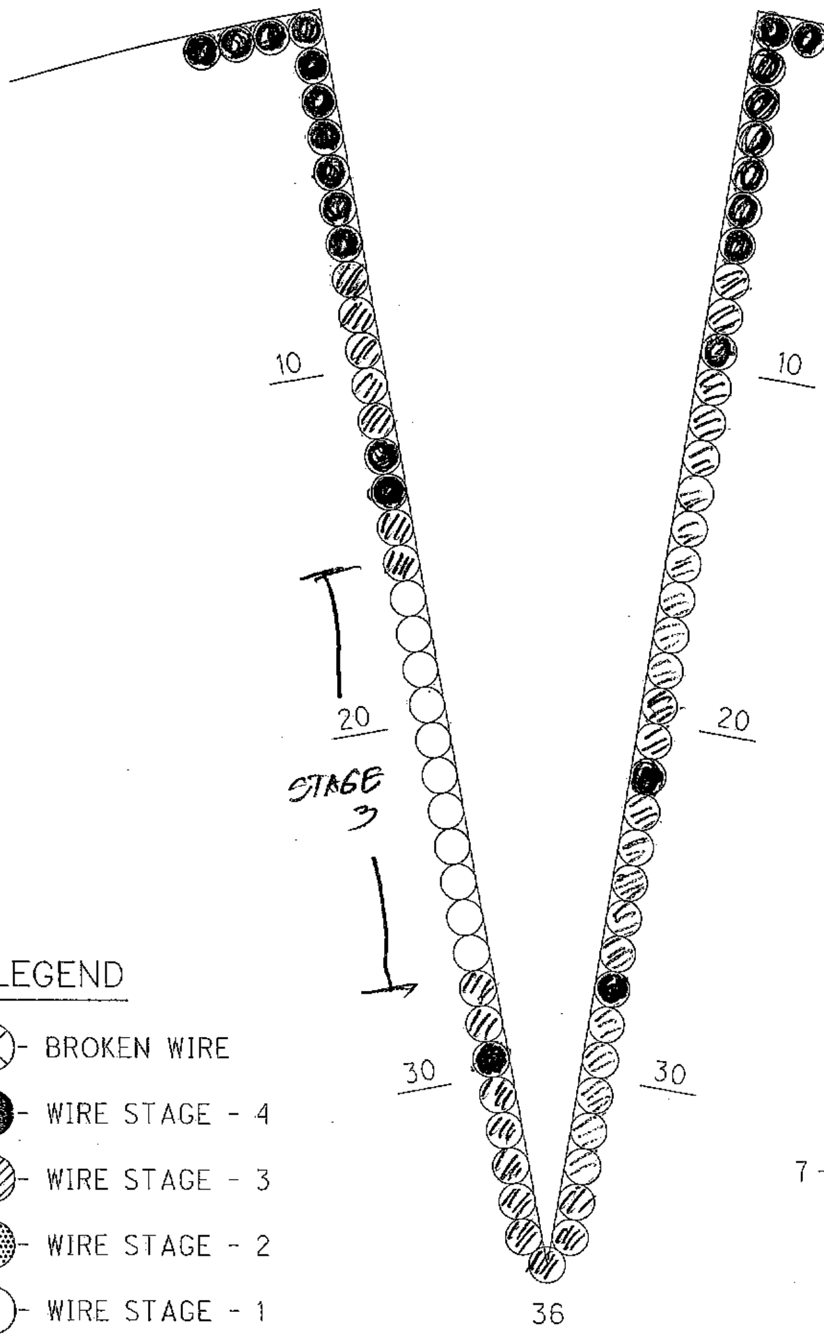
PREPARED BY: ADK

DATE: 11-15-12

______ CABLE ______ SIDE

PANEL ________

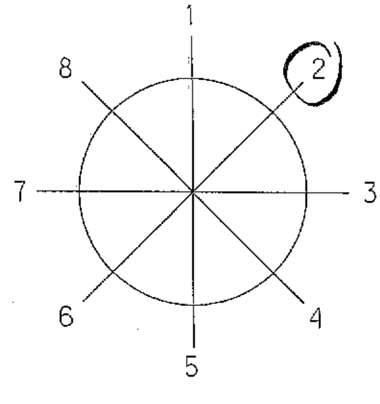
DEPTH OF CABLE INSPECTED ________

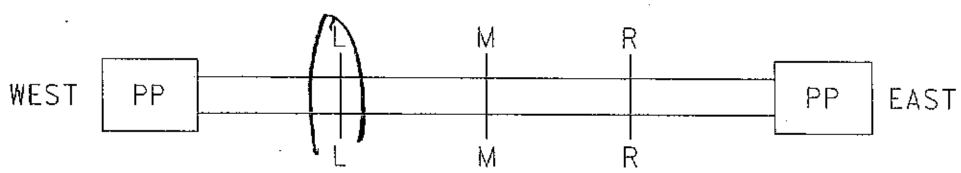


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

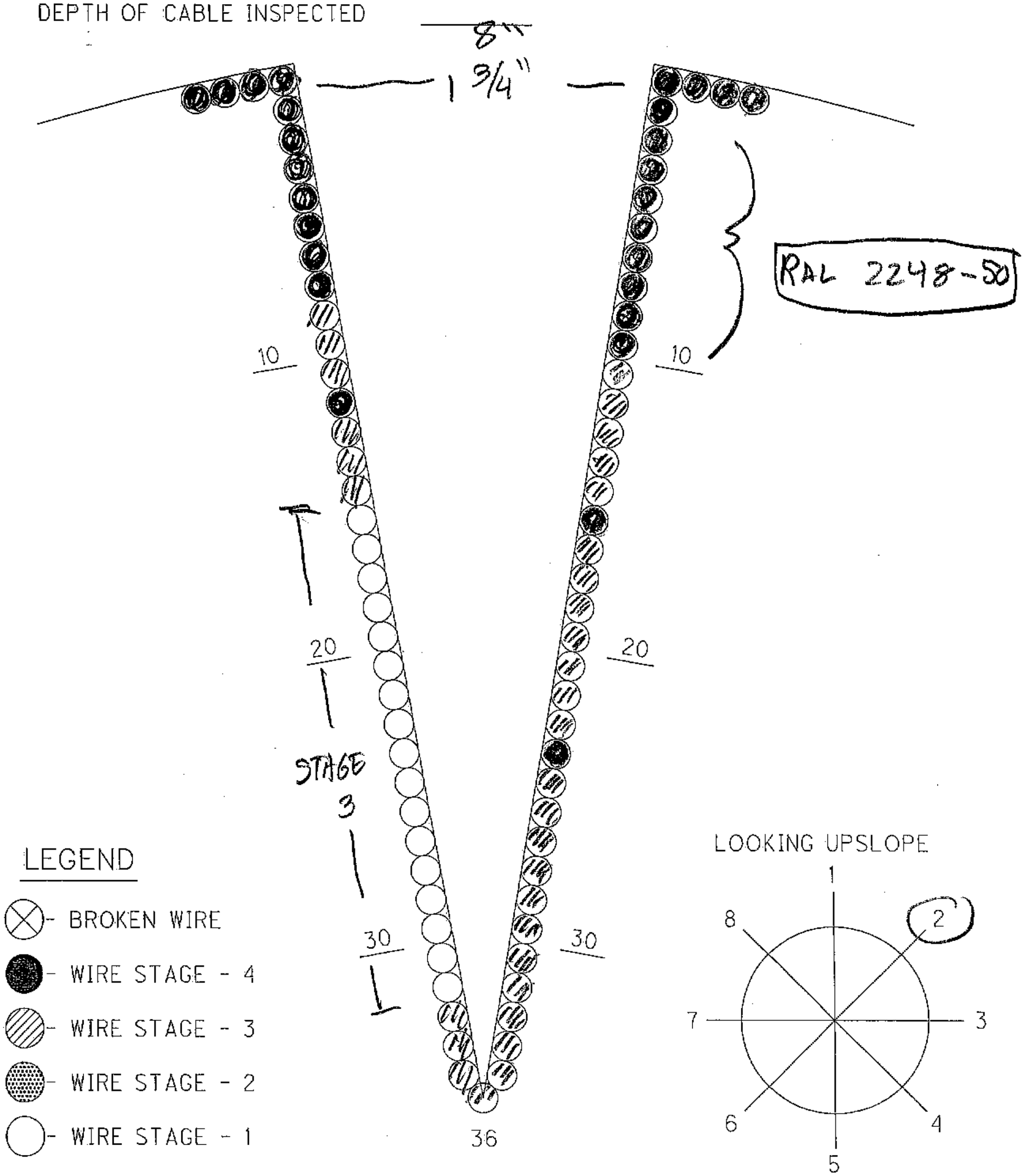
PREPARED BY: ADK

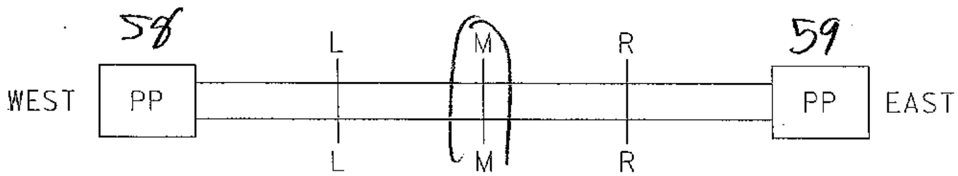
DATE: 11-15-12

______ CABLE ______ SIDE

PANEL ______

DEPTH OF CABLE INSPECTED





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

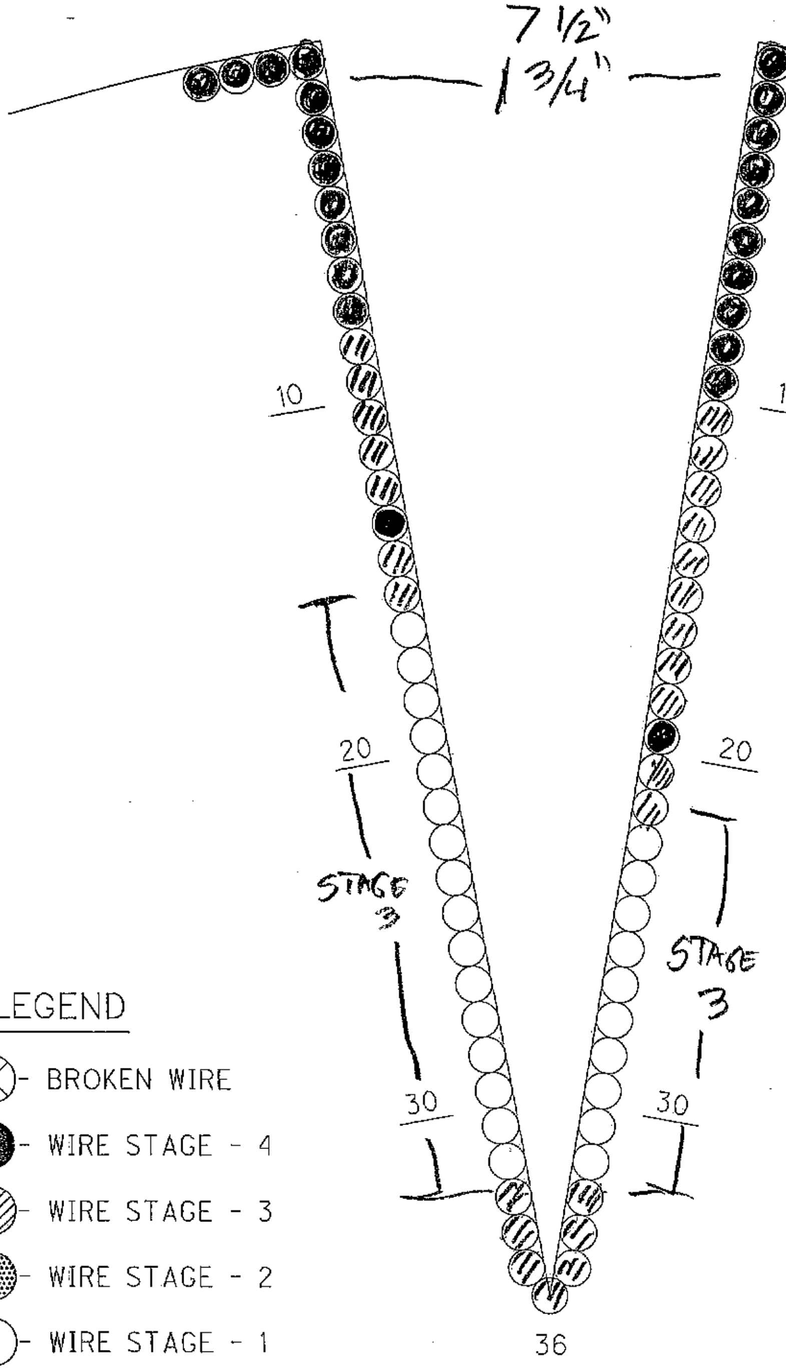
PREPARED BY: ADK

______ CABLE ______ SIDE

DATE: 11-15-12

PANEL ________

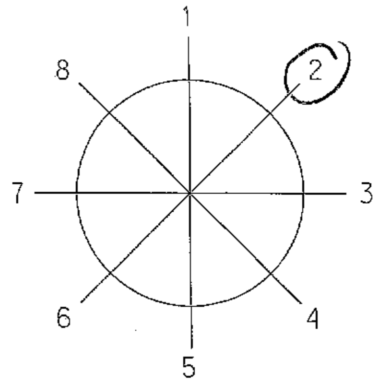
DEPTH OF CABLE INSPECTED ________

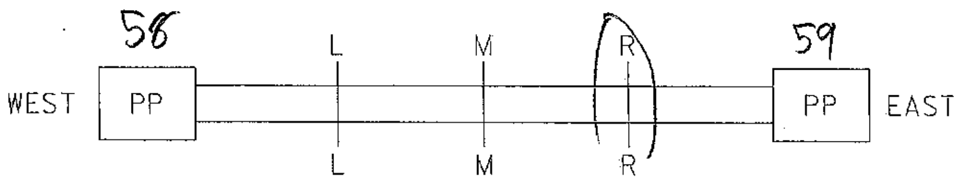


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires 55 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

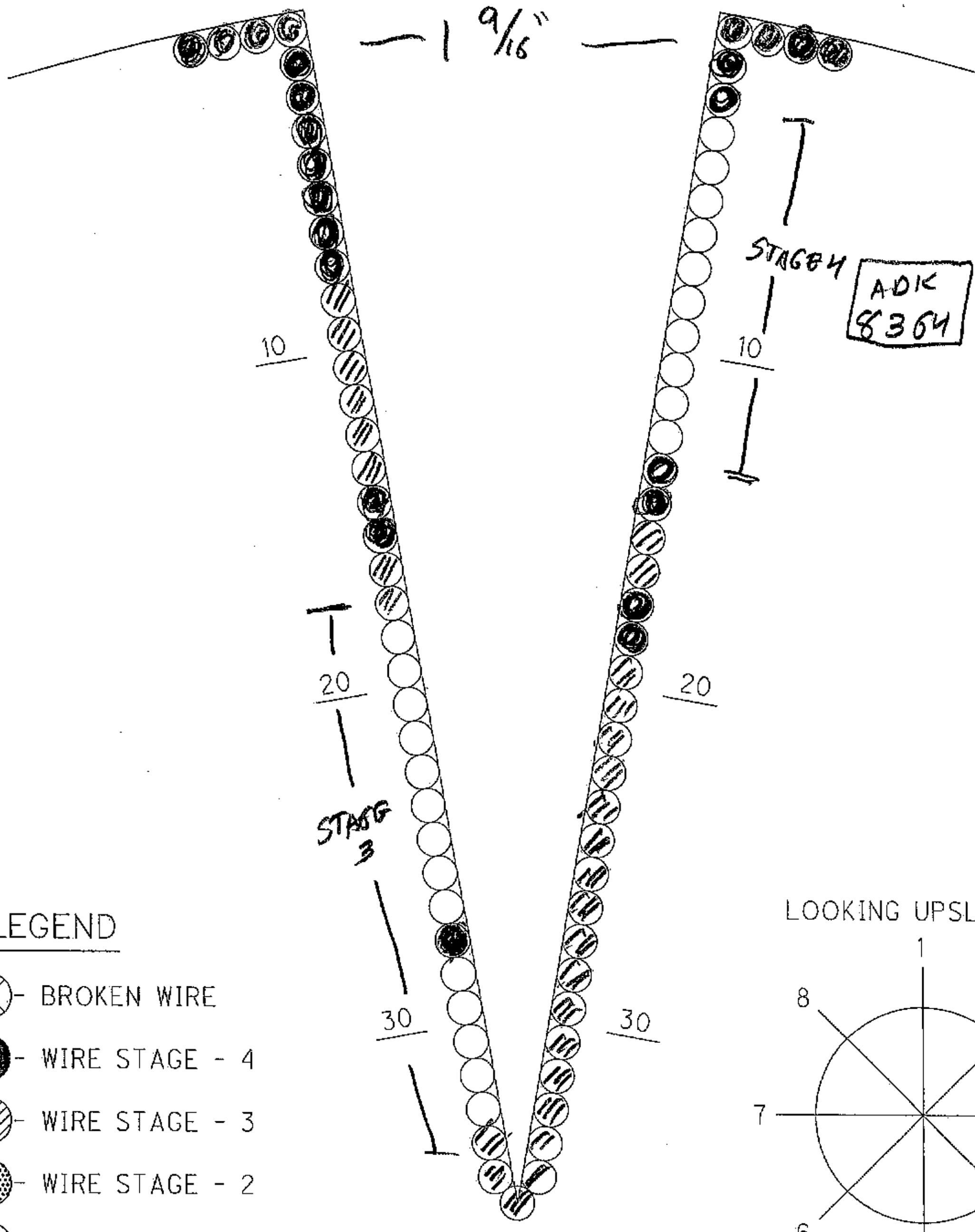
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-14-12

PANEL 58-59

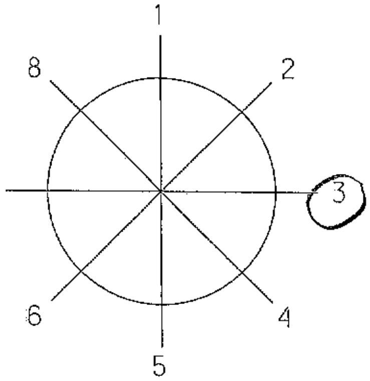
DEPTH OF CABLE INSPECTED 7"

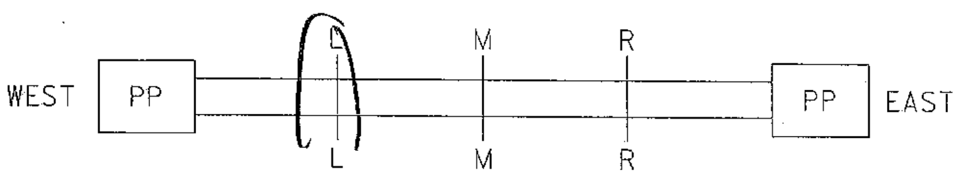


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

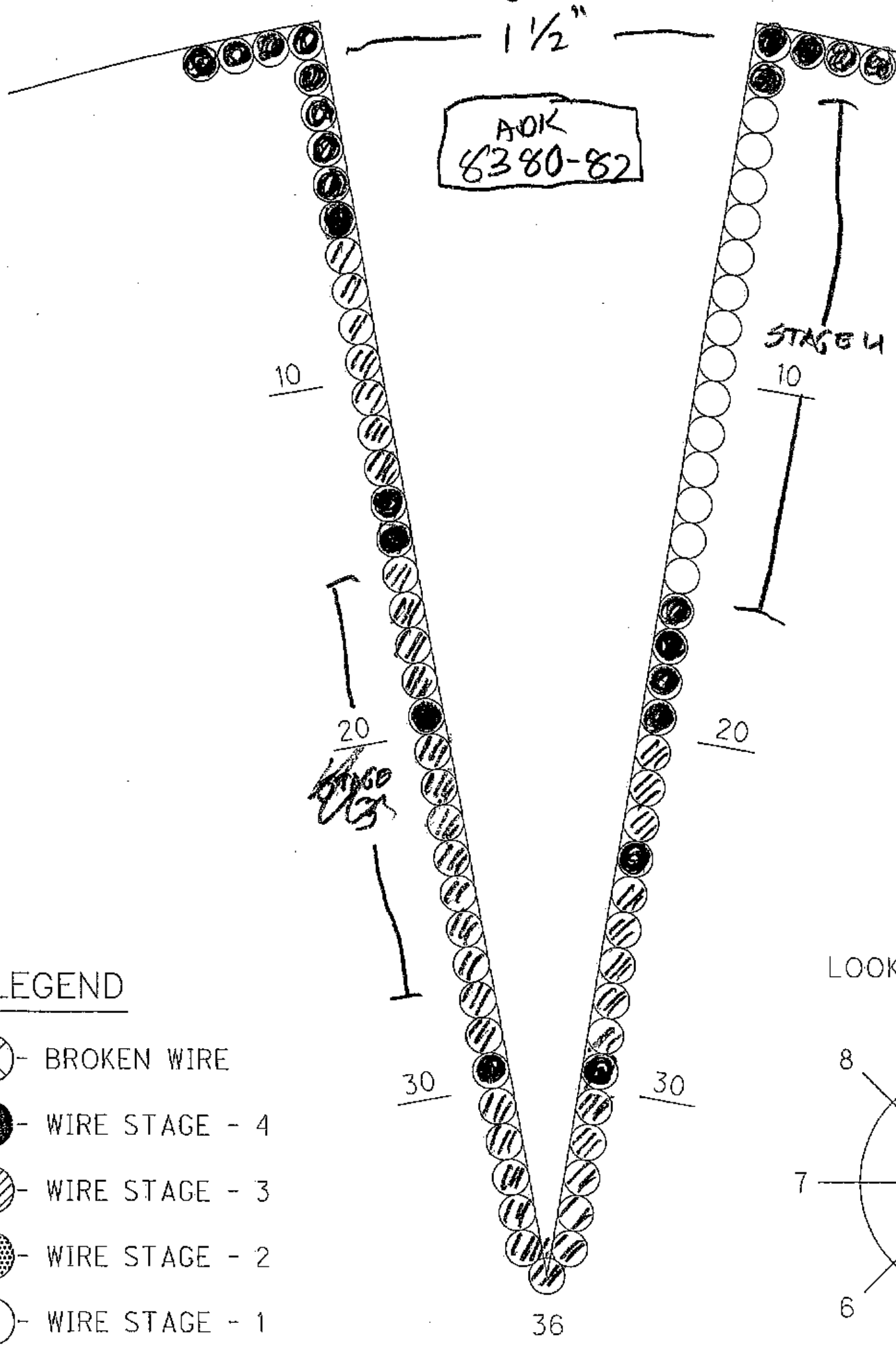
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-14-12

PANEL 58-59

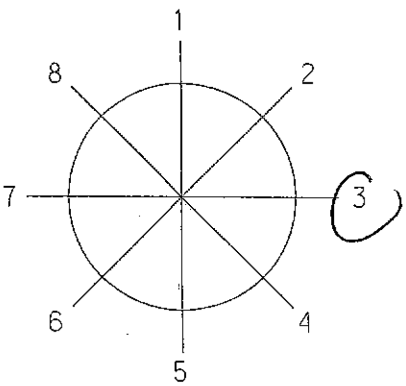
DEPTH OF CABLE INSPECTED ~~6 3/4"~~ 1 1/2"

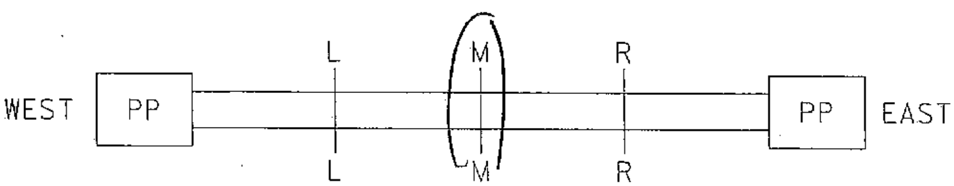


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE





Total Wires 55 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

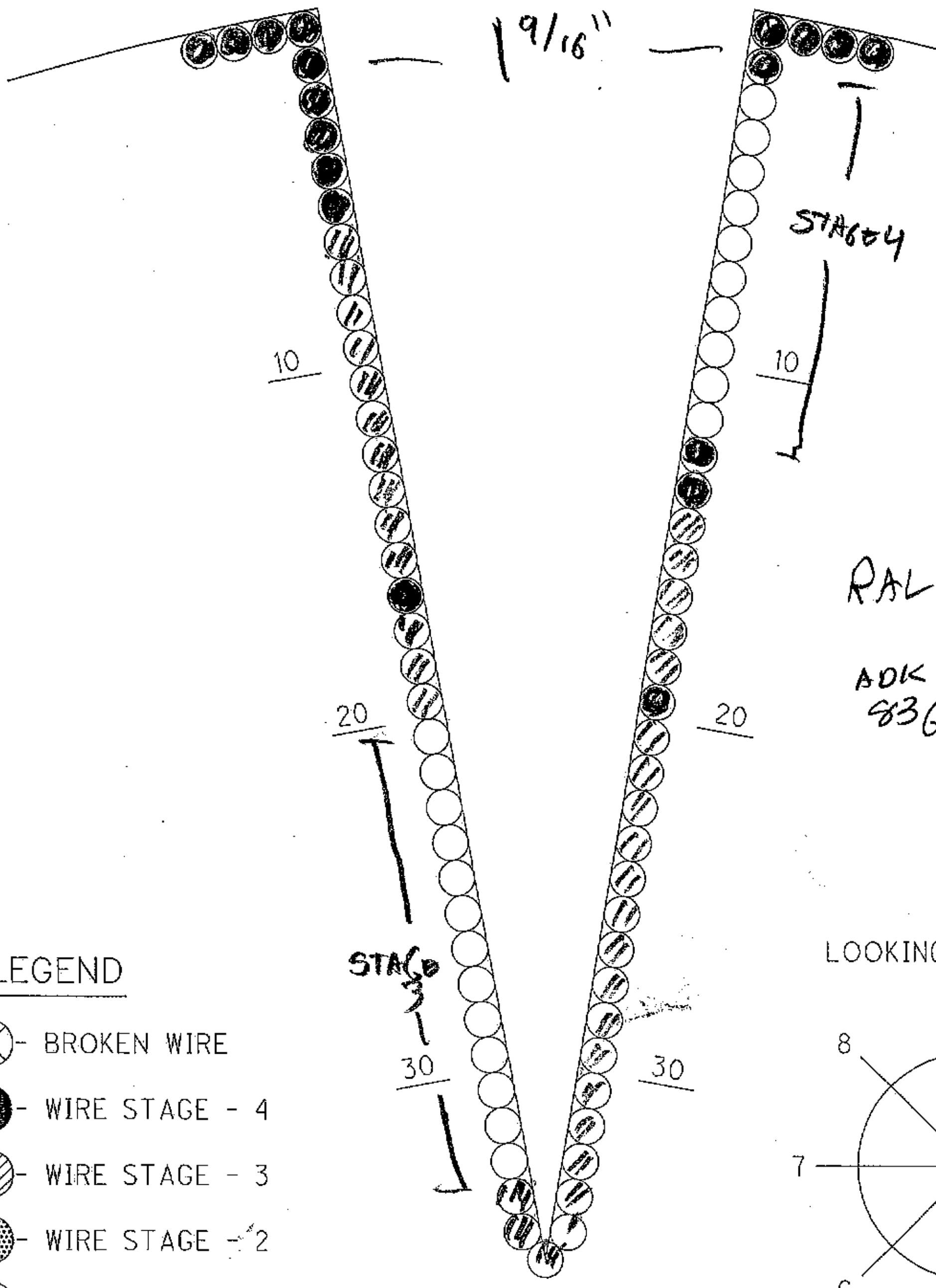
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-14-12

PANEL 58-59

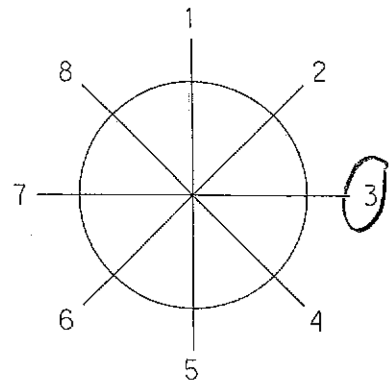
DEPTH OF CABLE INSPECTED 7"

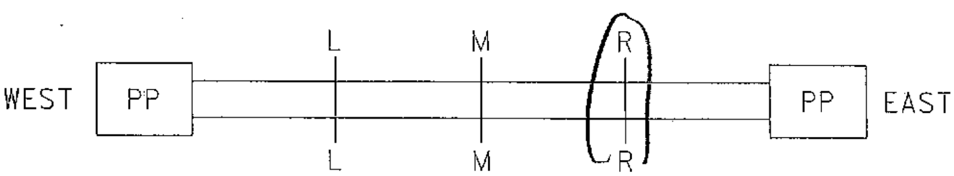


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

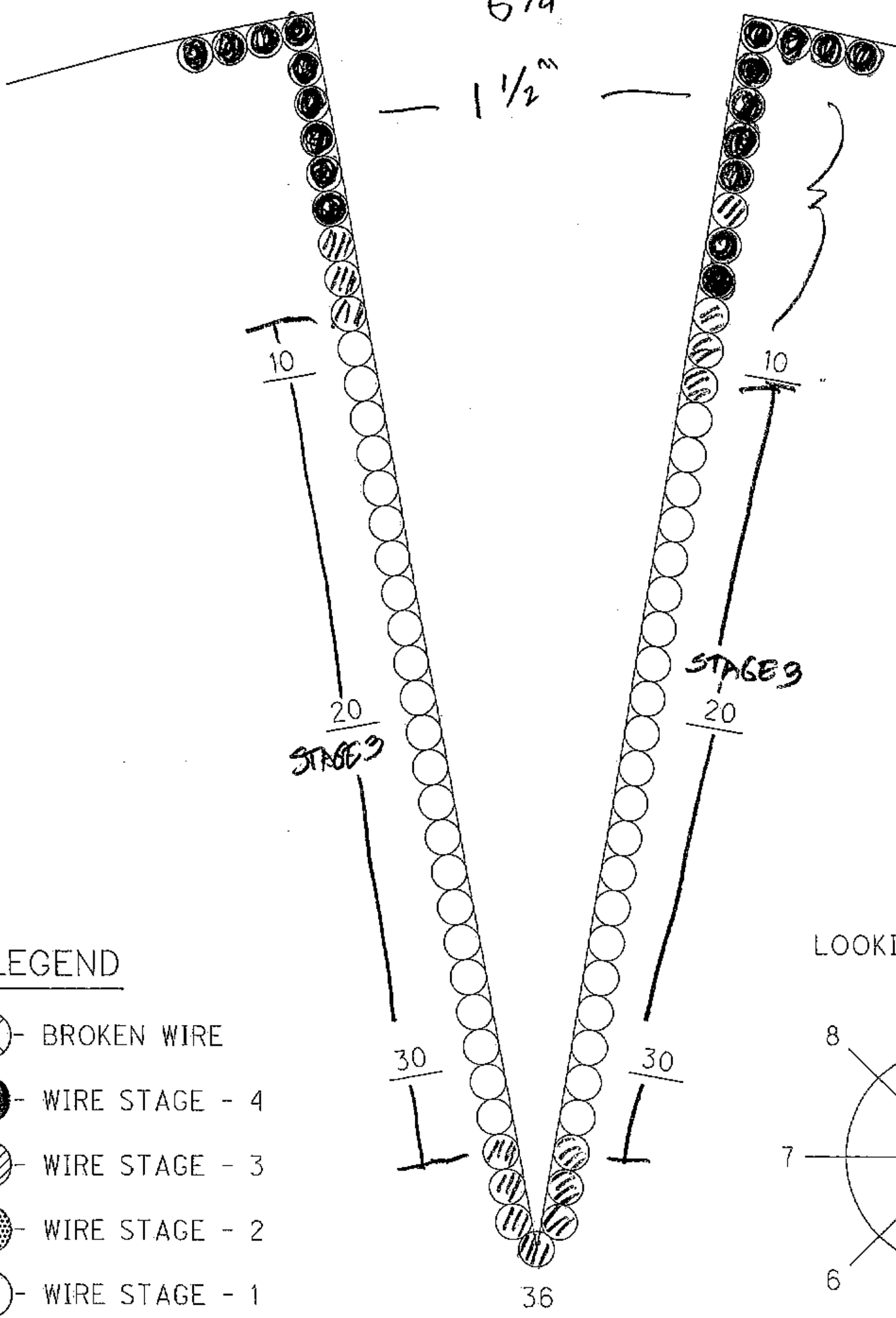
PREPARED BY: ____________

______ CABLE ______ SIDE

DATE: ____________

PANEL ________

DEPTH OF CABLE INSPECTED ______ 6 1/4"

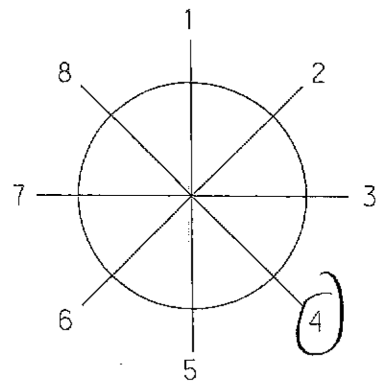


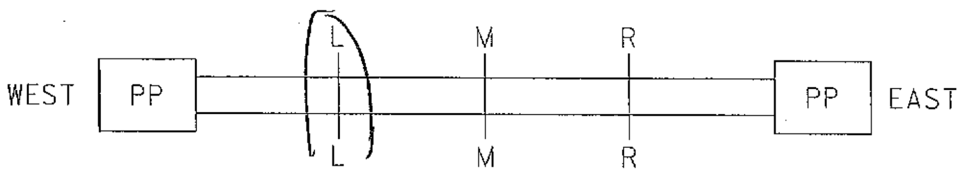
RAL
2248-47

LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE





Total Wires ~~53~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

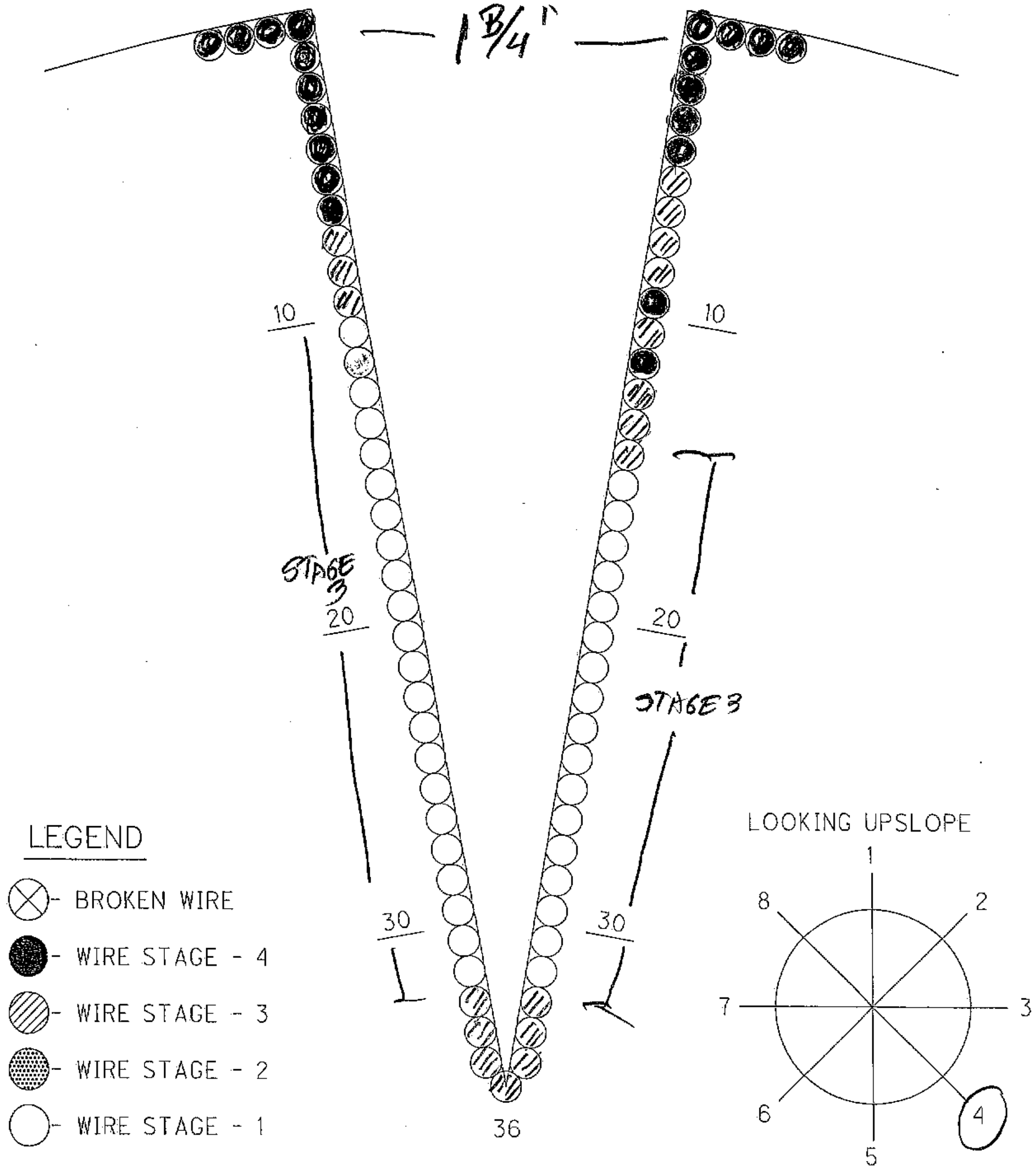
PREPARED BY: ____________

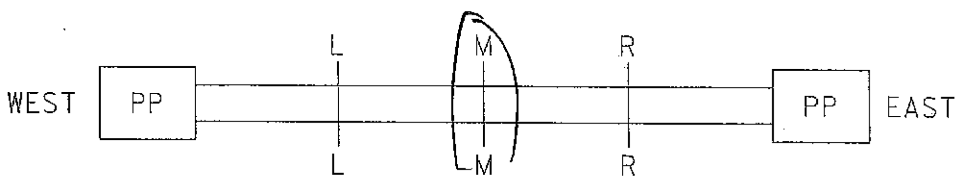
_______ CABLE _______ SIDE

DATE: ____________

PANEL ________

DEPTH OF CABLE INSPECTED 7 1/2"





Total Wires ~~53~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

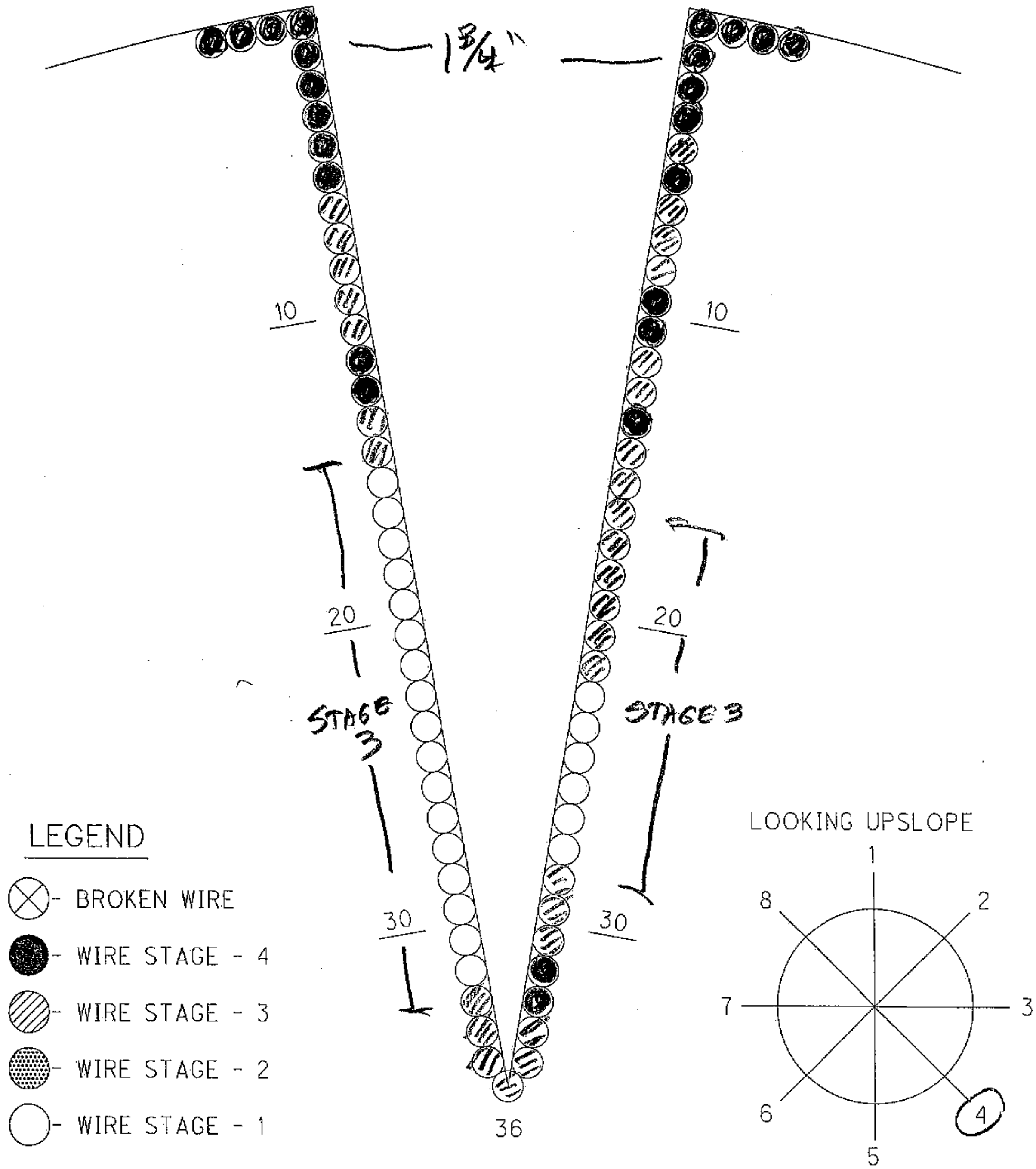
PREPARED BY: ____________

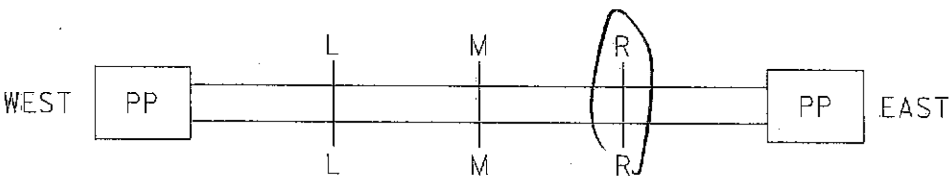
_______ CABLE _______ SIDE

DATE: ____________

PANEL ________

DEPTH OF CABLE INSPECTED 7"





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

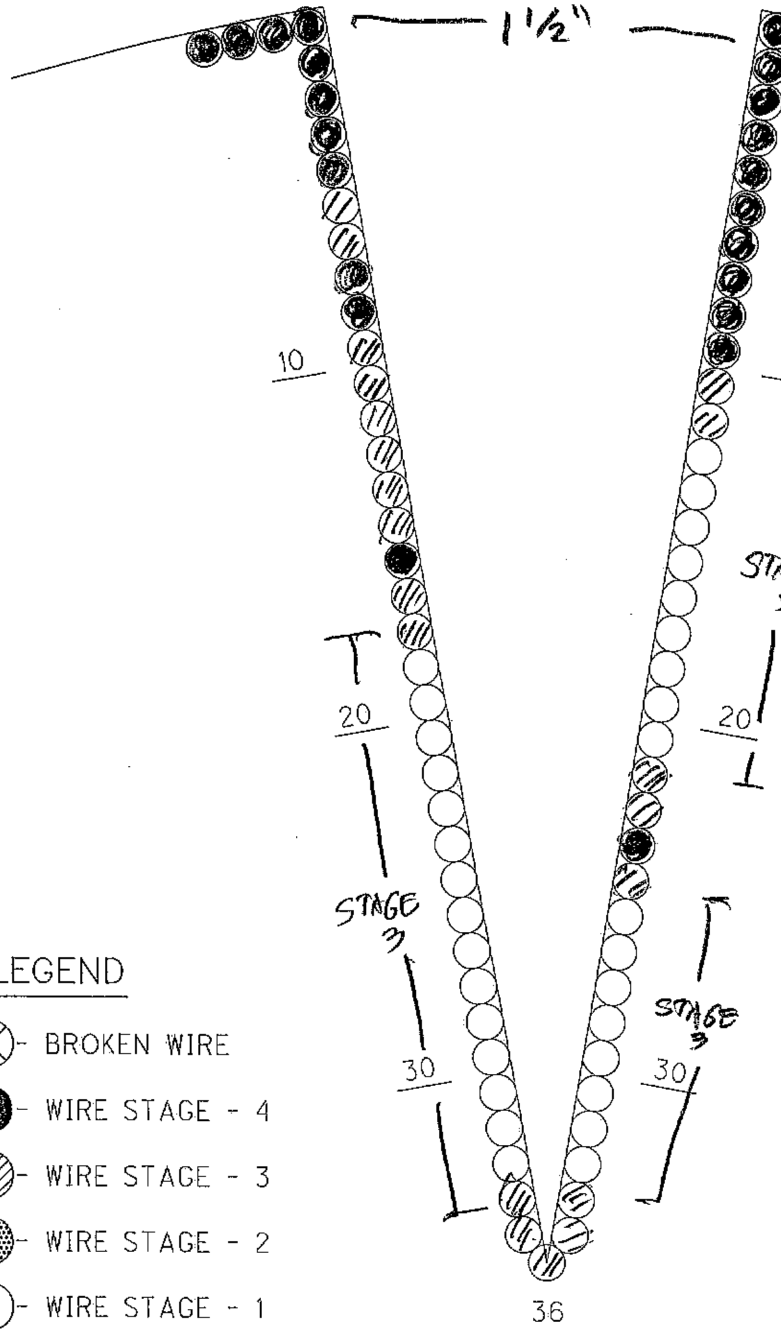
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-14-12

PANEL 58-59

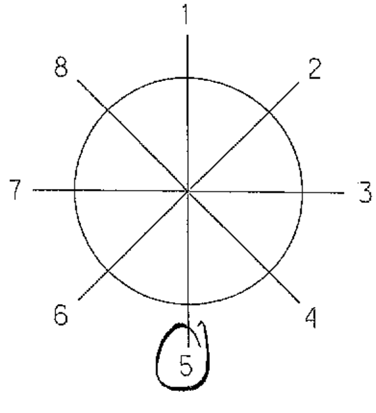
DEPTH OF CABLE INSPECTED 7"

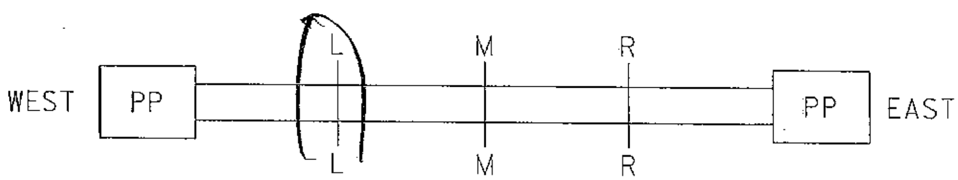


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

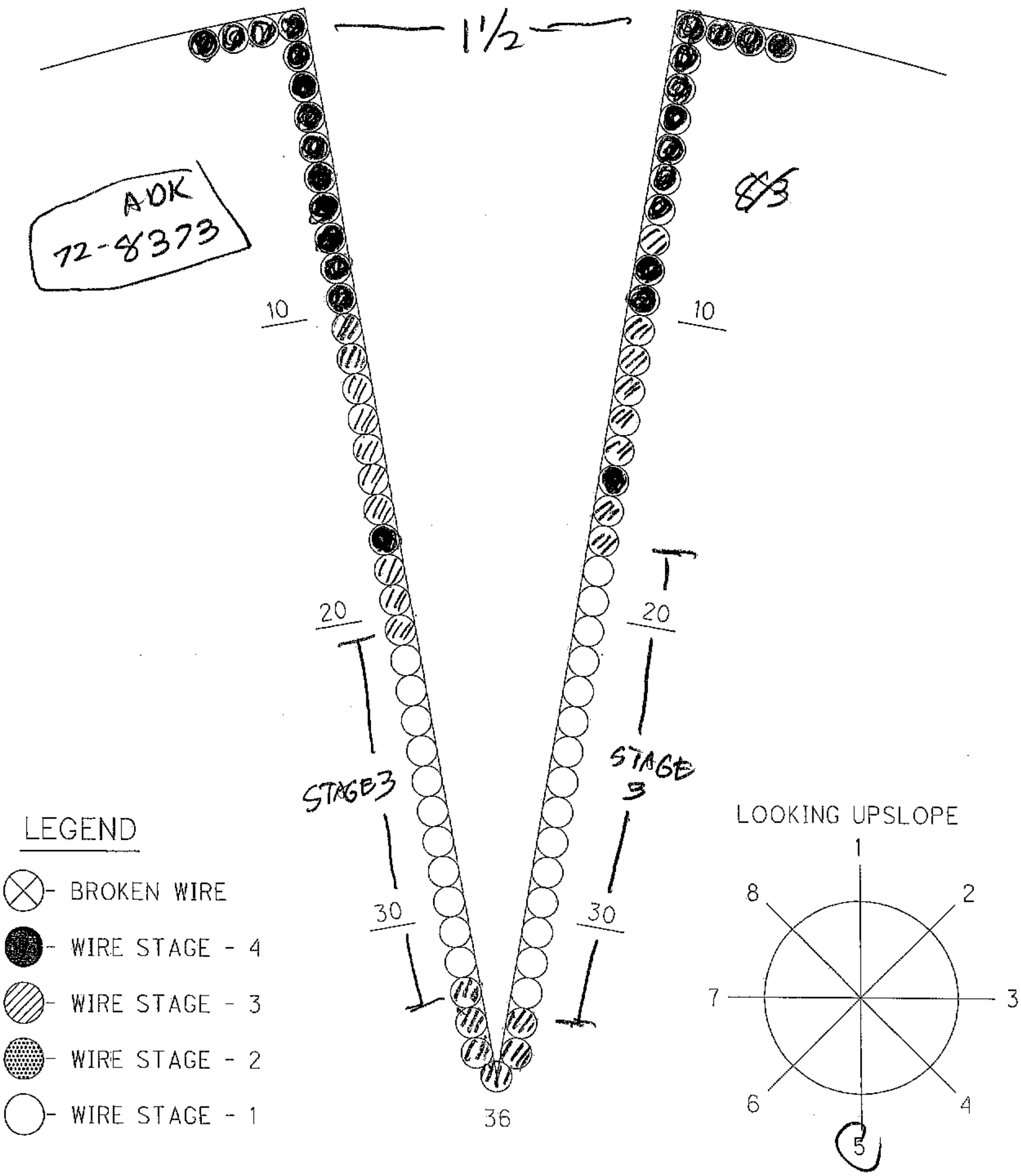
PREPARED BY: ADK

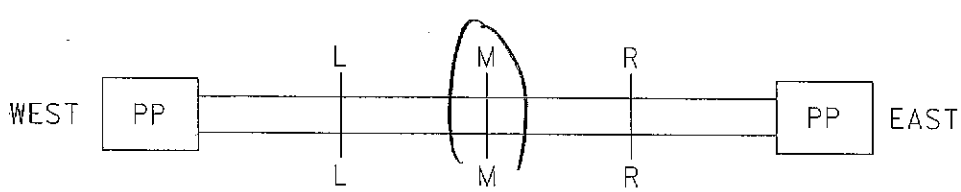
S CABLE ______ SIDE

DATE: 11-14-12

PANEL 58-59

DEPTH OF CABLE INSPECTED 7"





Total Wires 55 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

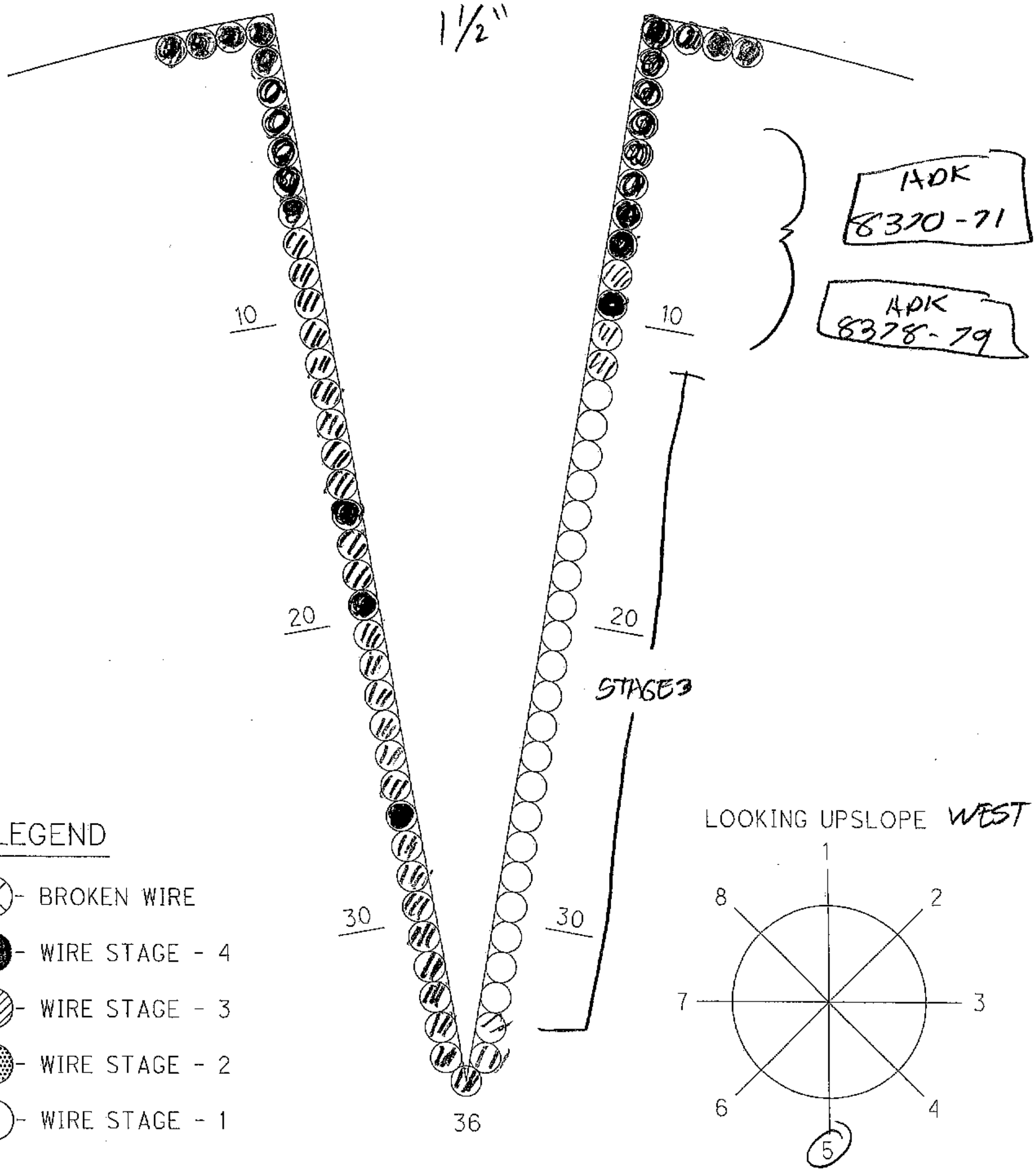
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-14-12

PANEL 58-59

DEPTH OF CABLE INSPECTED → 1½"

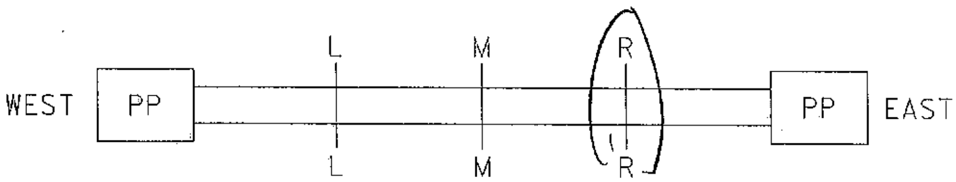


LEGEND

- ⊗ - BROKEN WIRE
- ● - WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- ○ - WIRE STAGE - 1

LOOKING UPSLOPE WEST

1 2 3 4 5 6 7 8



Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

PREPARED BY: ADK

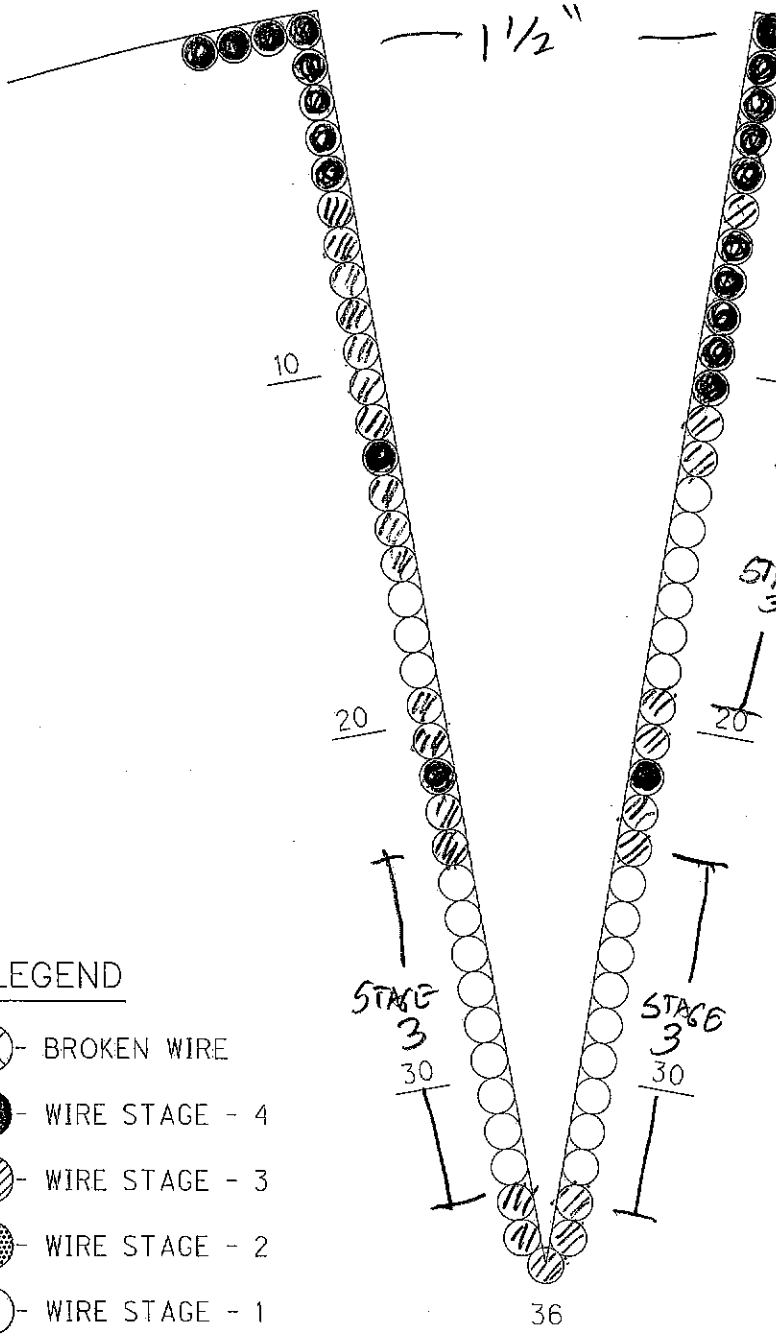
DATE: 11-15-12

______ CABLE ______ SIDE

PANEL ______

DEPTH OF CABLE INSPECTED ~~6 1/2"~~

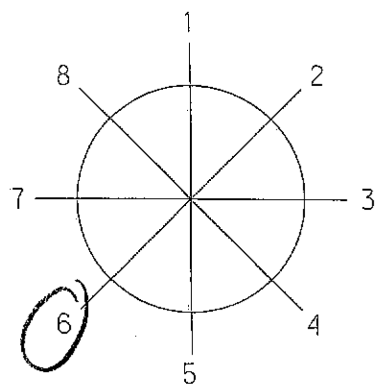
RAL 2244-45

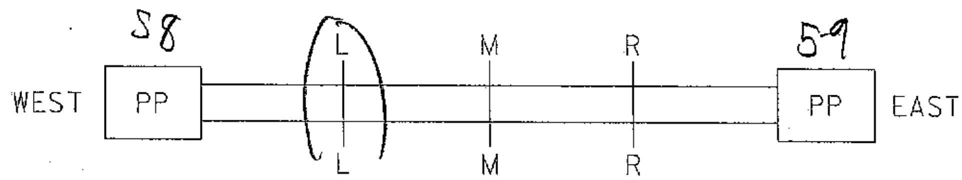


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

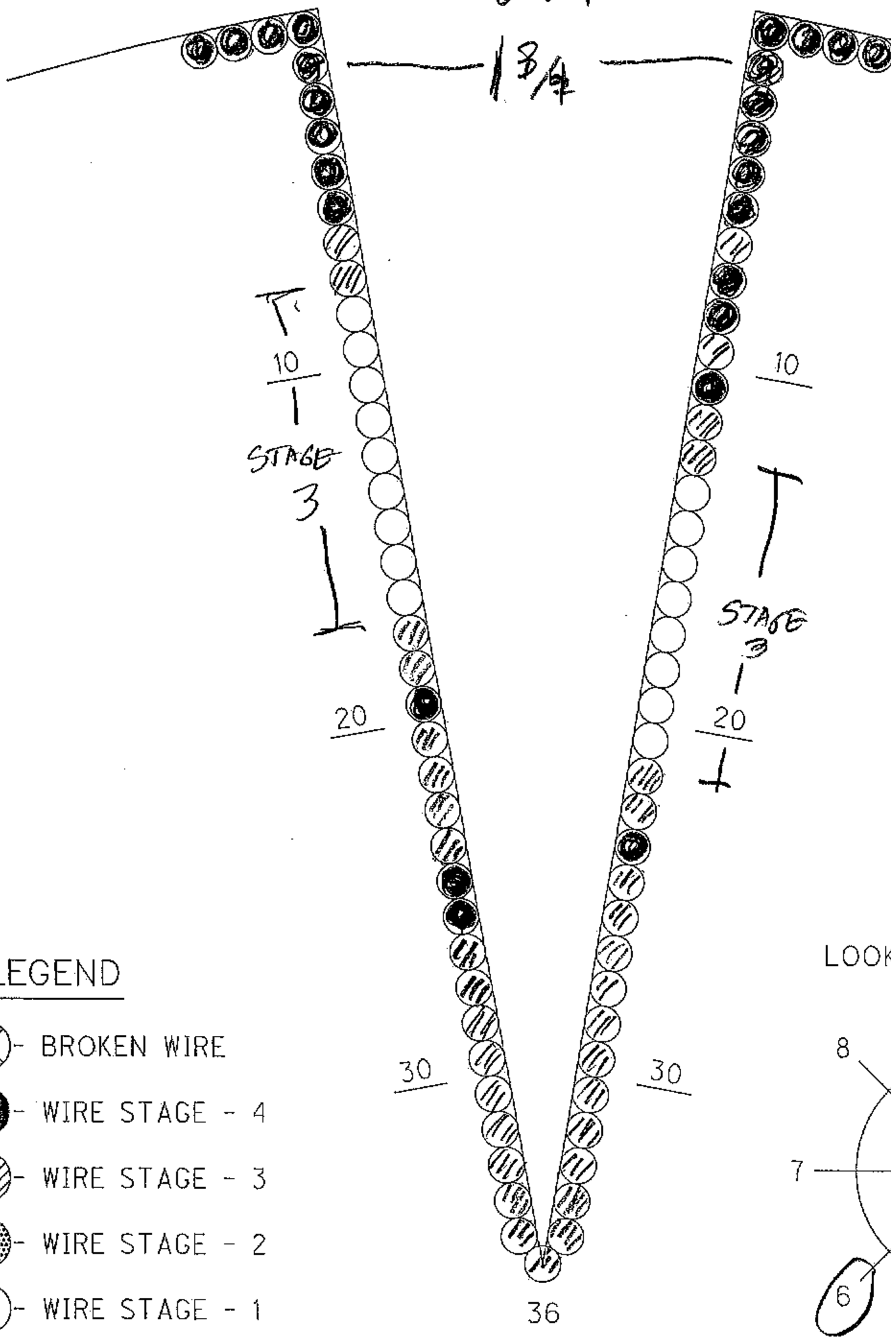
PREPARED BY: ADK

_______ CABLE _______ SIDE

DATE: 11-15-12

PANEL _________

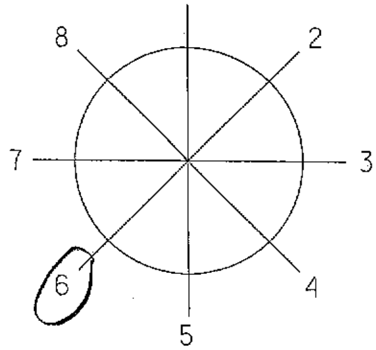
DEPTH OF CABLE INSPECTED 6 3/4

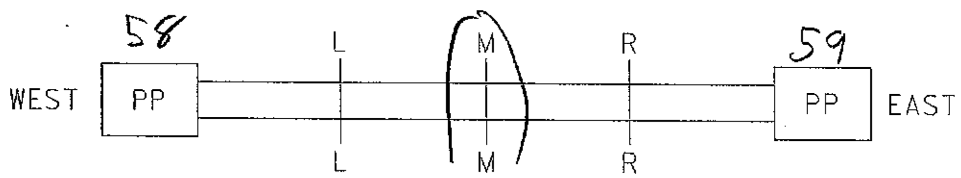


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

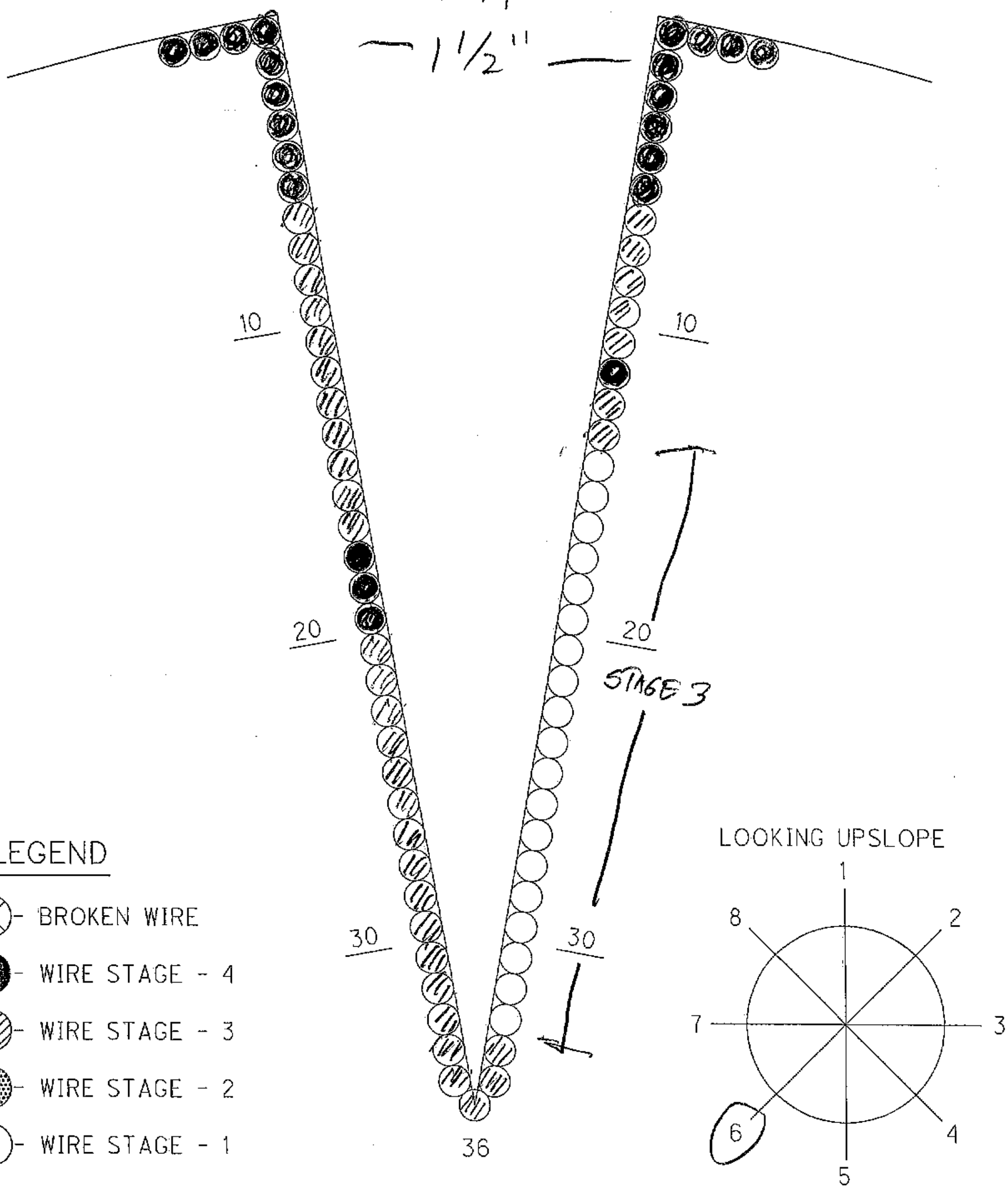
PREPARED BY: ADK

______ CABLE ______ SIDE

DATE: 11-15-12

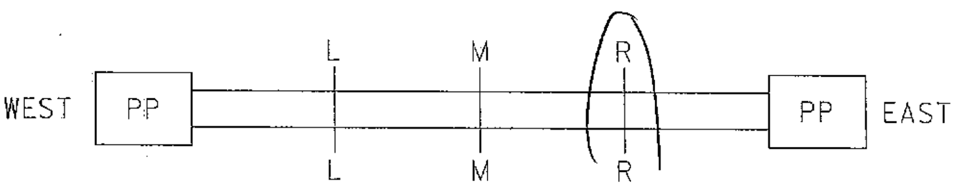
PANEL ________

DEPTH OF CABLE INSPECTED ~~6 3/4"~~ 1 1/2"



LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1



Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

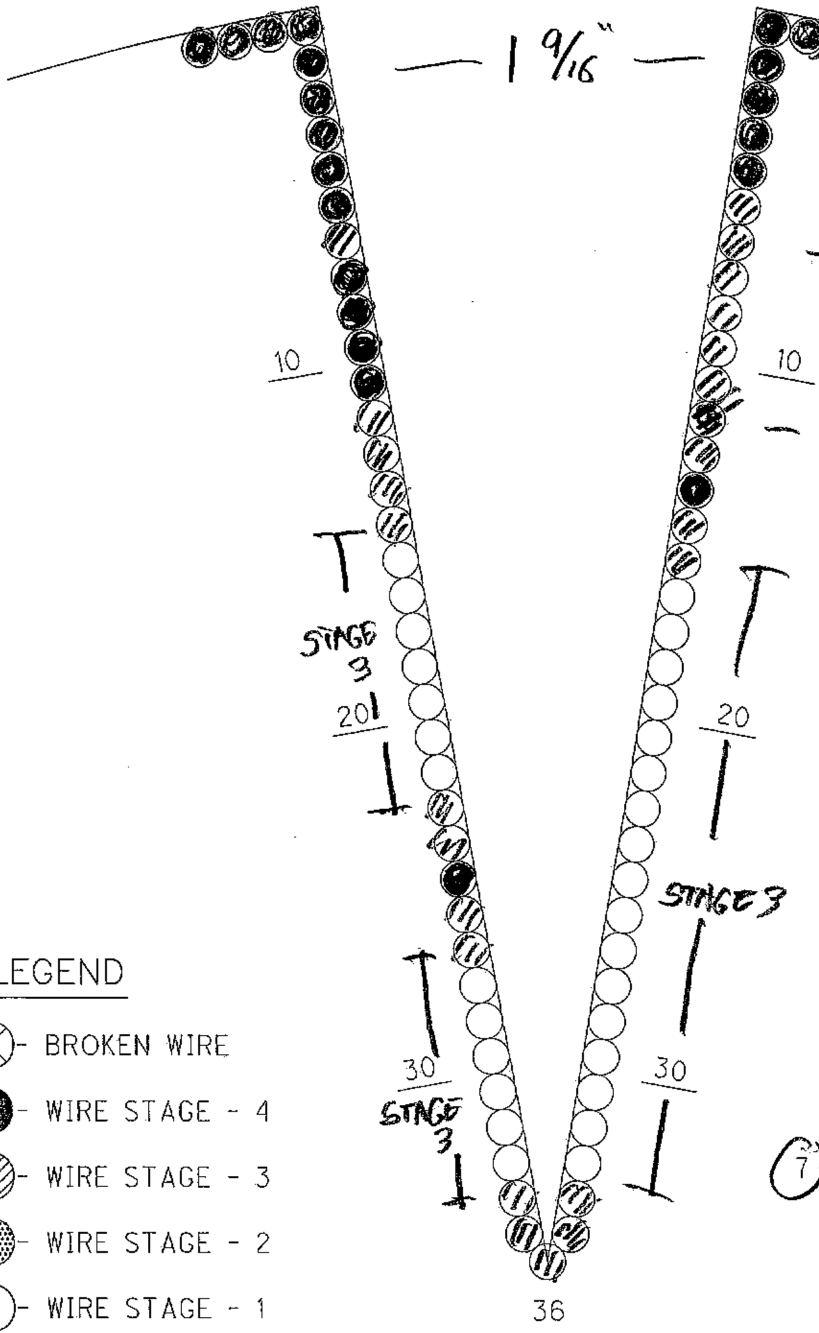
PREPARED BY: ADK

S CABLE ______ SIDE

DATE: 11-14-12

PANEL 58-59

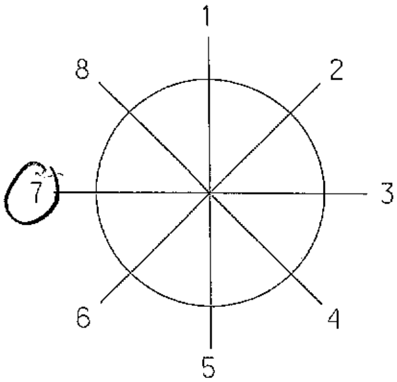
DEPTH OF CABLE INSPECTED ~~7 1/2"~~

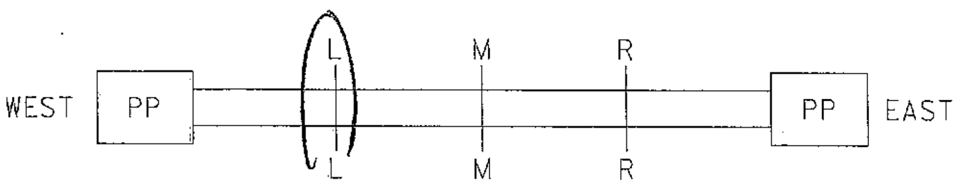


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

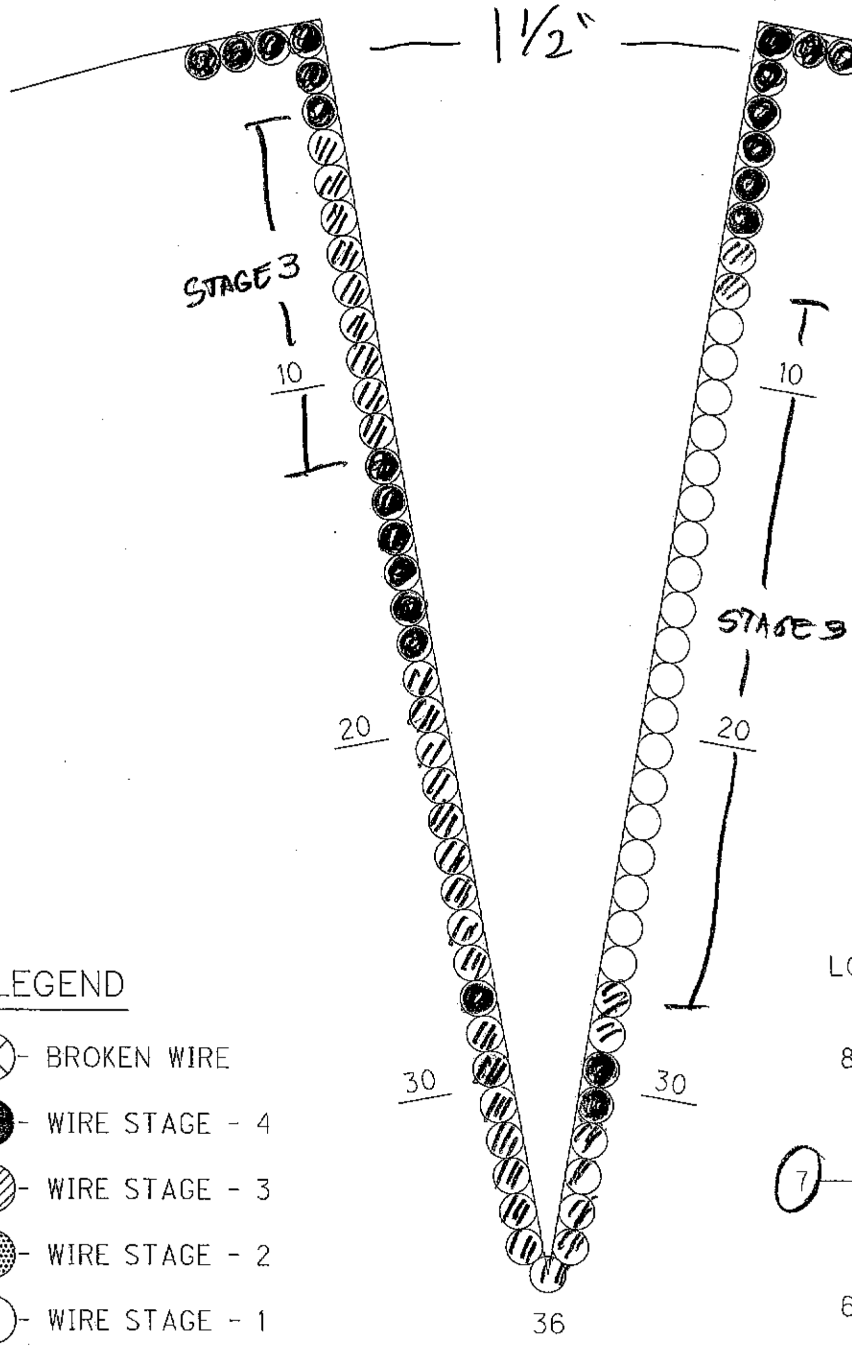
PREPARED BY: ADK

5 CABLE ______ SIDE

DATE: 11-14-12

PANEL 58-59

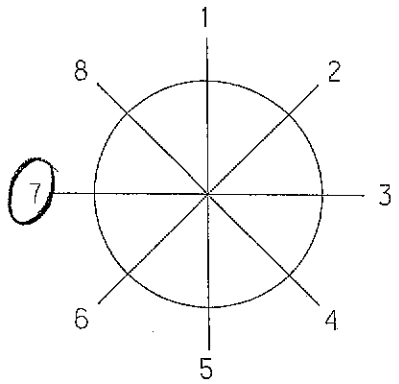
DEPTH OF CABLE INSPECTED 7"

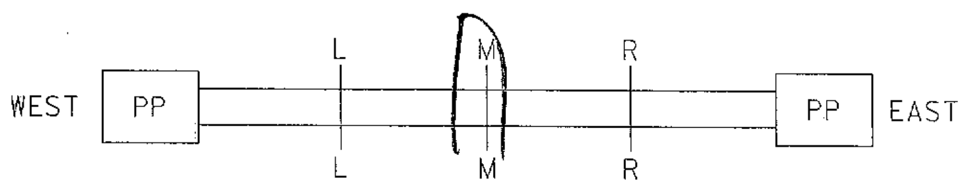


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~53~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

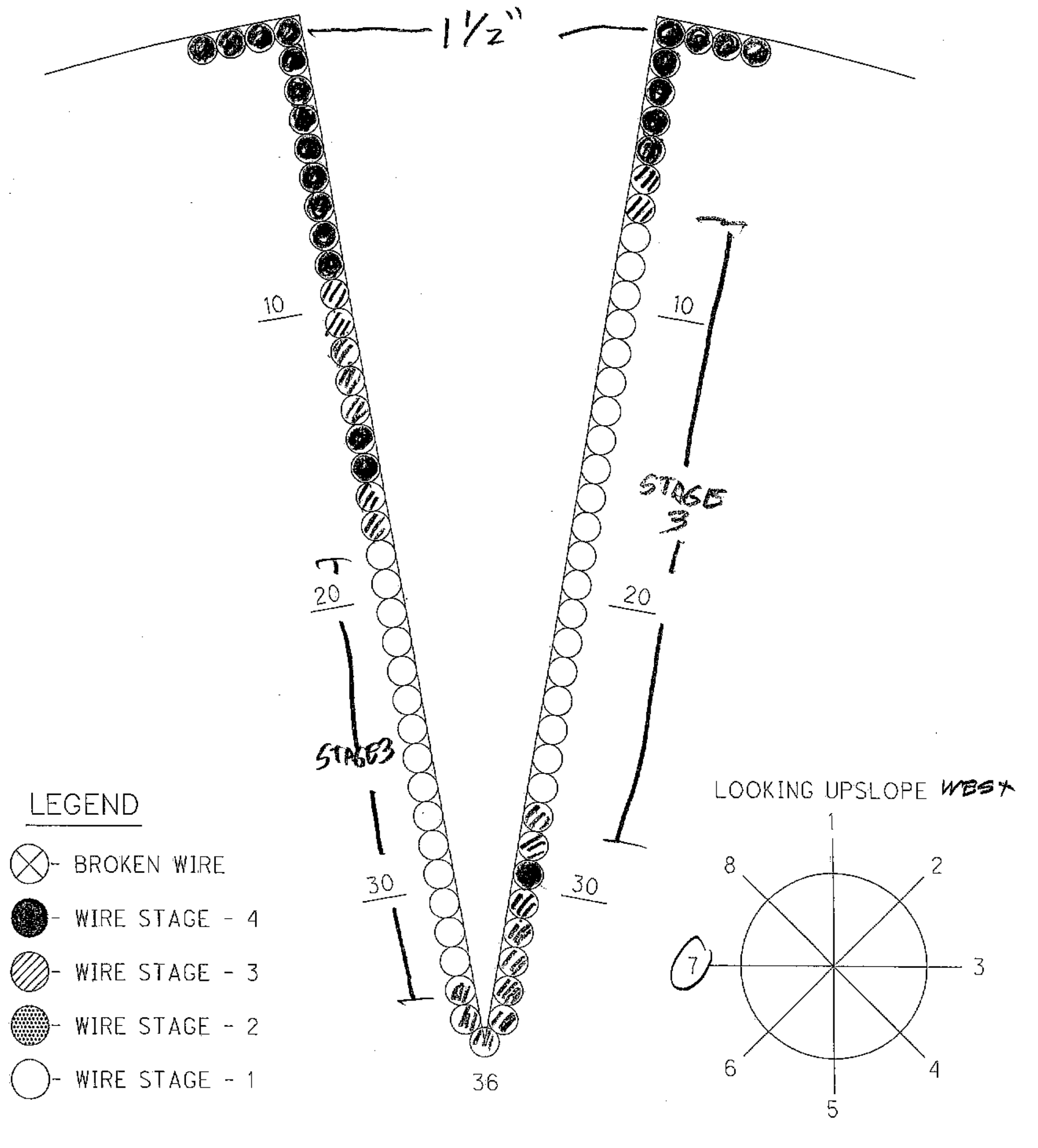
PREPARED BY: ADK

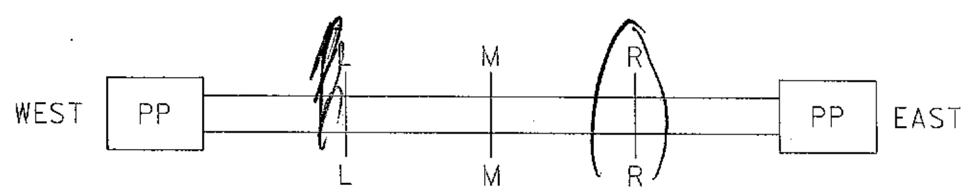
S CABLE ______ SIDE

DATE: 11-14-12

PANEL 58-59

DEPTH OF CABLE INSPECTED 7"





Primary Cable Opening Location East PP 65, North

ANTHONY WAYNE

~~Ambassador Bridge~~ Main Cable Investigation

Cable Circumference Measurements

Prepared by:	ADK
Date:	11-15-12
No. Wires in cable (N):	8066
Wire Diameter (d):	0.192

Cable:	N
Side:	E
Panel:	65-66

Location	Before Unwrapping: Measured Circumference Ci	Before Unwrapping: Calculated Diameter Di	After Unwrapping: Measured Circumference C	After Unwrapping: Calculated Diameter D	Density DENS	After Compaction: Measured Circumference Cc	After Compaction: Calculated Diameter Dc	Density *DENSc	After Rewrapping: Measured Circumference Cf	After Rewrapping: Calculated Diameter Df
Cable Band / Panel Point 65	43 3/16"	13.75"	42"	13.375"		41 3/4"	13.30"		43 7/16"	13.83
12 in	43 1/2"	13.85"	42 11/16"	13.91		43 3/16"	13.75"		43 11/16"	13.91
Center Line (OFFCENTER DUE TO PREVIOUS WINDOW)	43 5/16	13.79"	42 11/16	13.60		43 3/4	13.93"		44 3/8"	14.13
12 in	43 9/16"	13.87"	42 11/16	13.60		42 7/8	13.65"		43 11/16	13.91
~~Cable Band~~ / ~~Panel Point~~ 66	43 1/2"	13.85	42 9/16	13.56		42 5/8	13.58"		43 3/4	13.93

8444 ADK

@ TRANSITION TO ORIGINAL CABLE DIAMETER

HDK 8391 END OF OPEN

$Di=Ci/\pi$ $D=C/\pi$ $DENS=Nd^2/D^2$ $Dc=Cc/\pi$ $DENSc=Nd^2/Dc^2$ $Df=Cf/\pi$

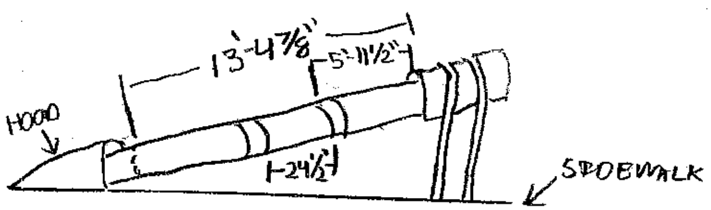
Temperature	Temperature	Temperature	Temperature
41°F	43°F	32°F	33°F

ADK 8385-86 - WINDOW @ EAST END OF N. CABLE

ADK 8387 - *APPEARS TO BE DOUBLE WRAPPED WITH WRAPPING WIRE* CONFIRMED 2 WRAPPING WIRES

@ 13' 4 7/8"
5' 11 1/2"
24 1/2"

WINDOW A

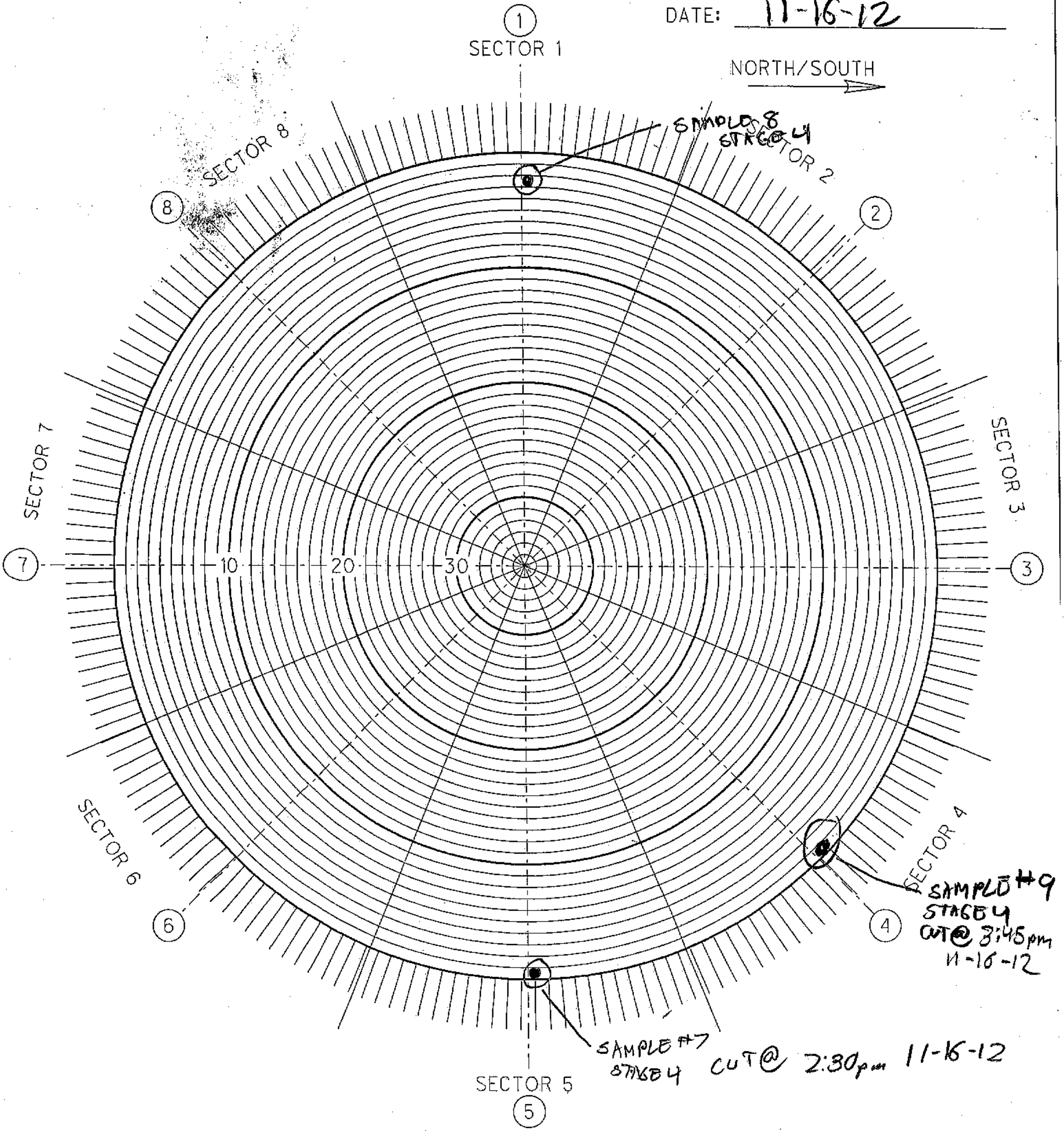


BRIDGE NAME: ANTHONY WAYNE BRIDGE

PREPARED BY: ADK

DATE: 11-16-12

NORTH/SOUTH →



LEGEND

● - BROKEN WIRE NO.

(1) - WEDGE LOCATION

(●) - SAMPLE FOR TESTING

CABLE CROSS SECTION

N CABLE, LOOKING WEST

SPAN ______

PANEL 68 EAST

BRIDGE NAME: ANTHONY WAYNE

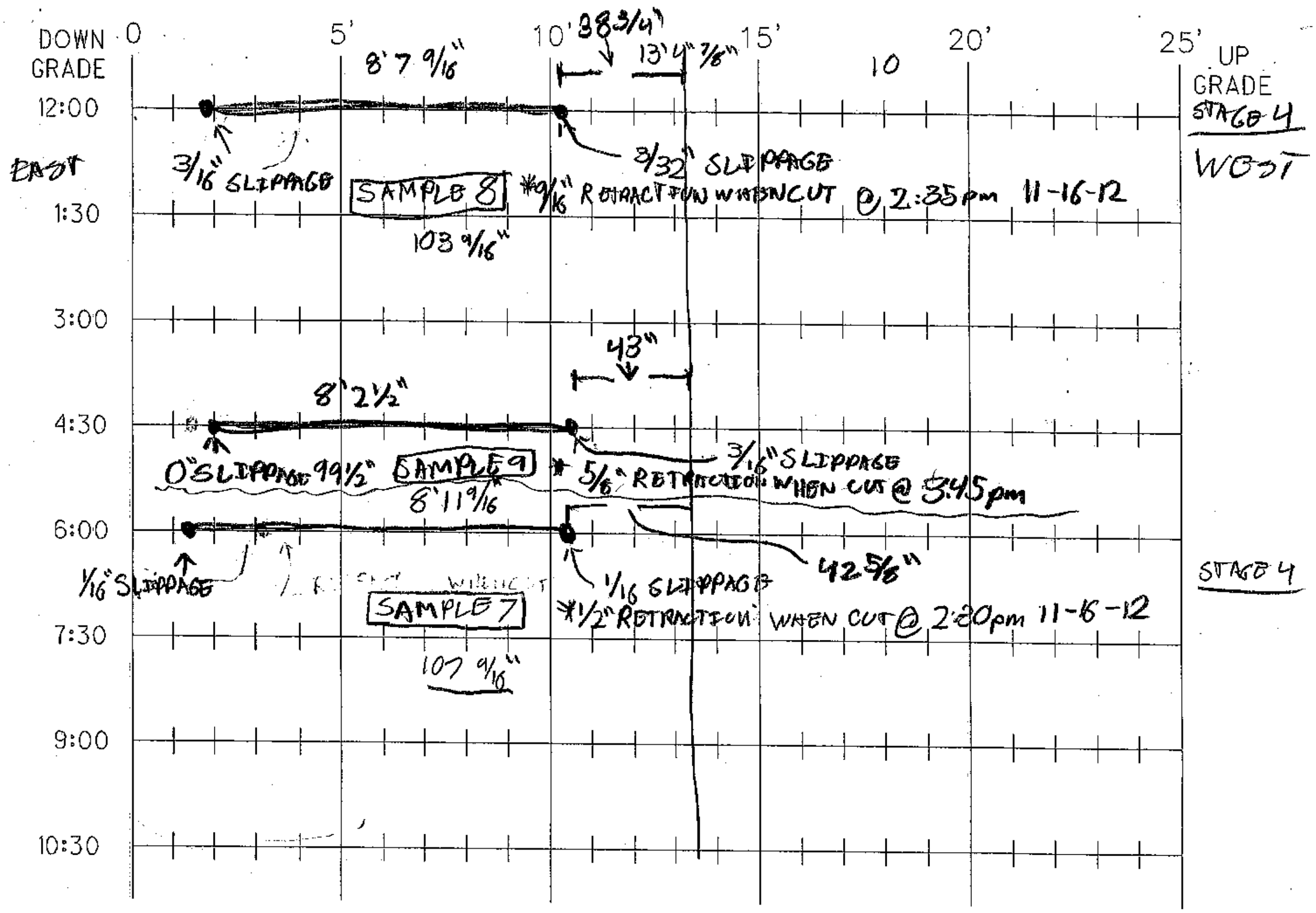
PREPARED BY: ADK

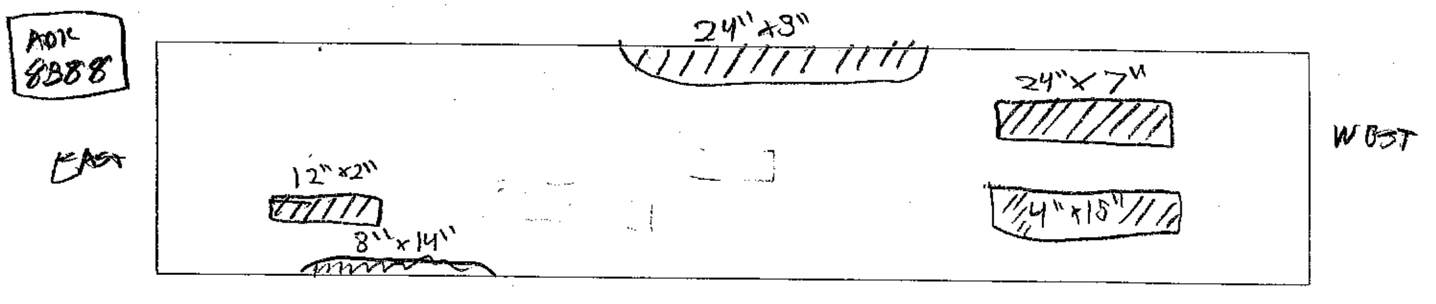
N CABLE ___ SIDE

DATE: 11-16-12

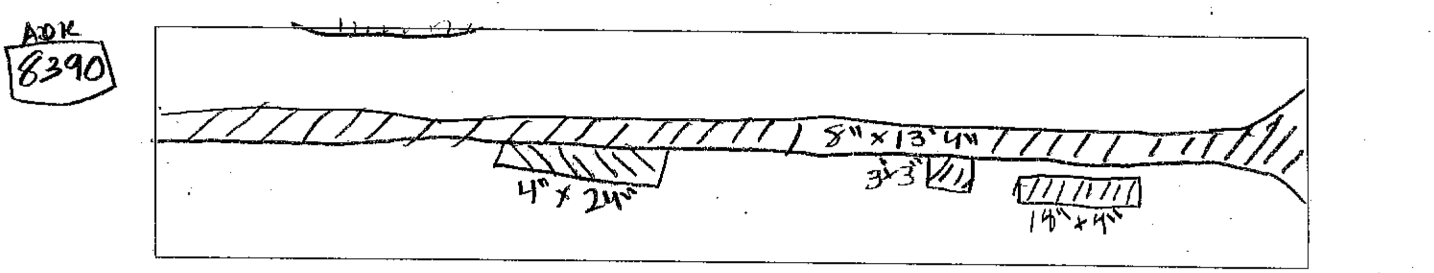
PANEL G5 EAST

TOTAL LENGTH EXPOSED 13'4 7/8"





TOP OF CABLE EXTERIOR



BOTTOM OF CABLE EXTERIOR

Total Wires 55 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

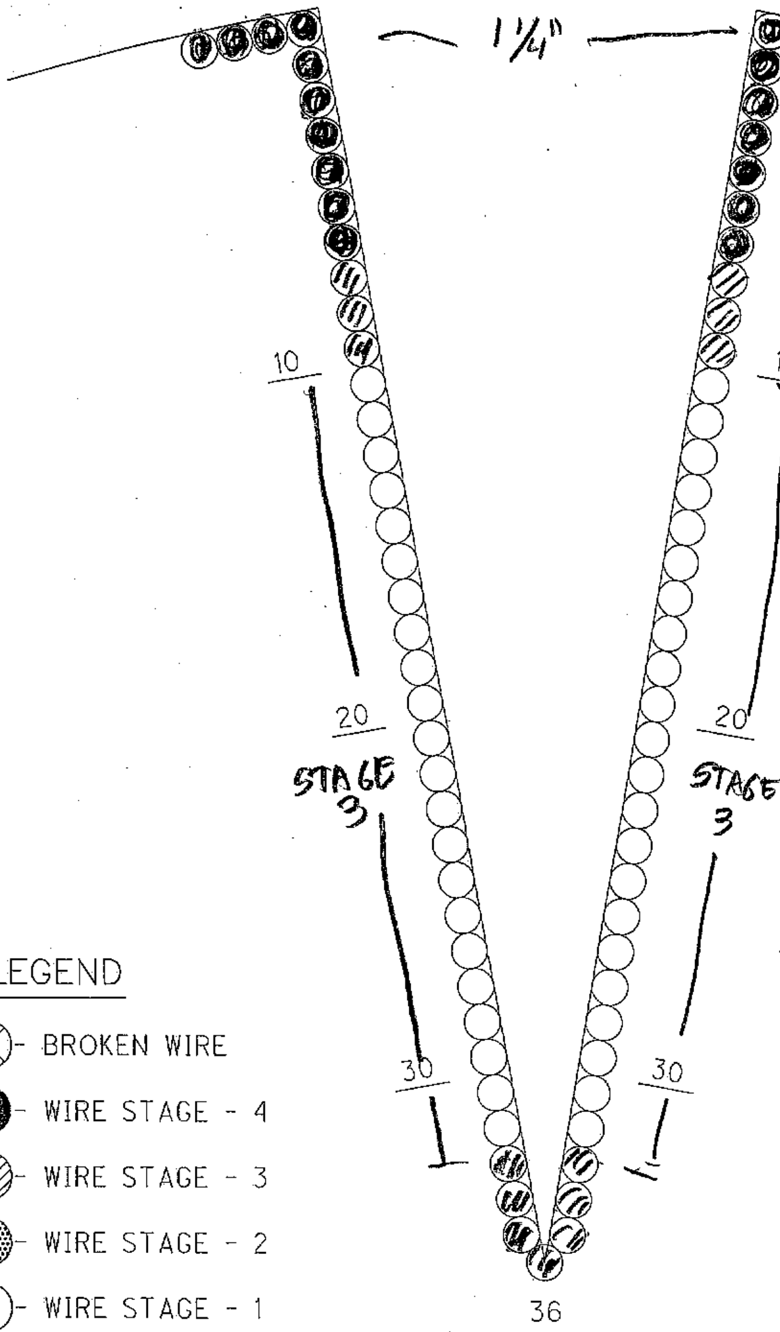
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 65B.

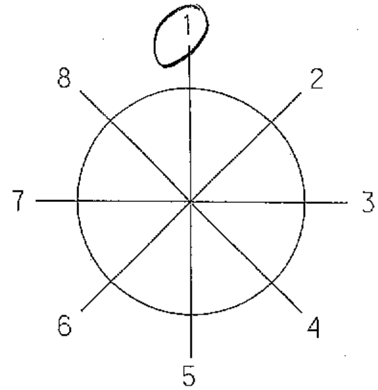
DEPTH OF CABLE INSPECTED 6 3/4"

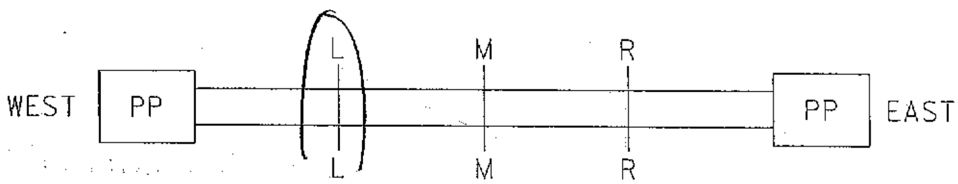


LEGEND

- ⊗ - BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

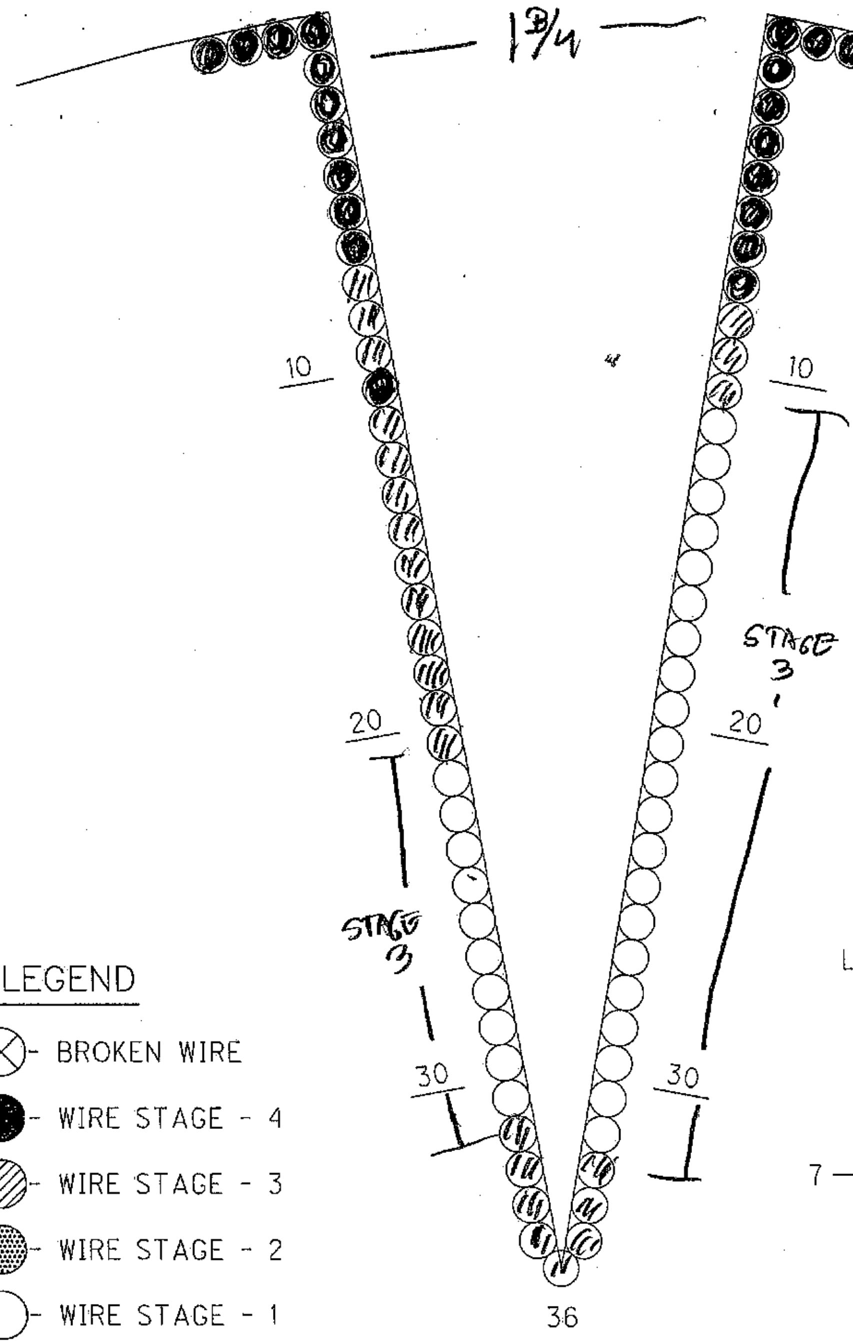
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 65 East

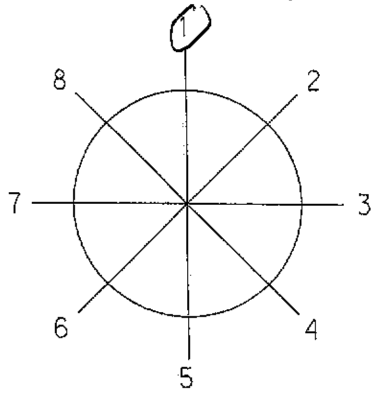
DEPTH OF CABLE INSPECTED 7

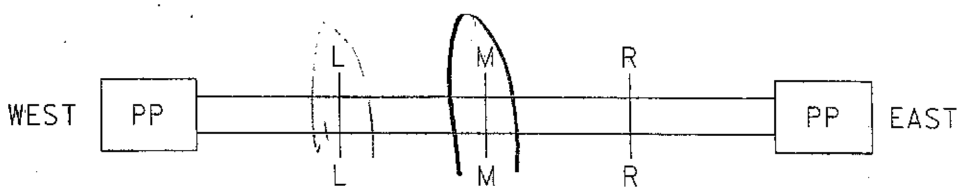


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

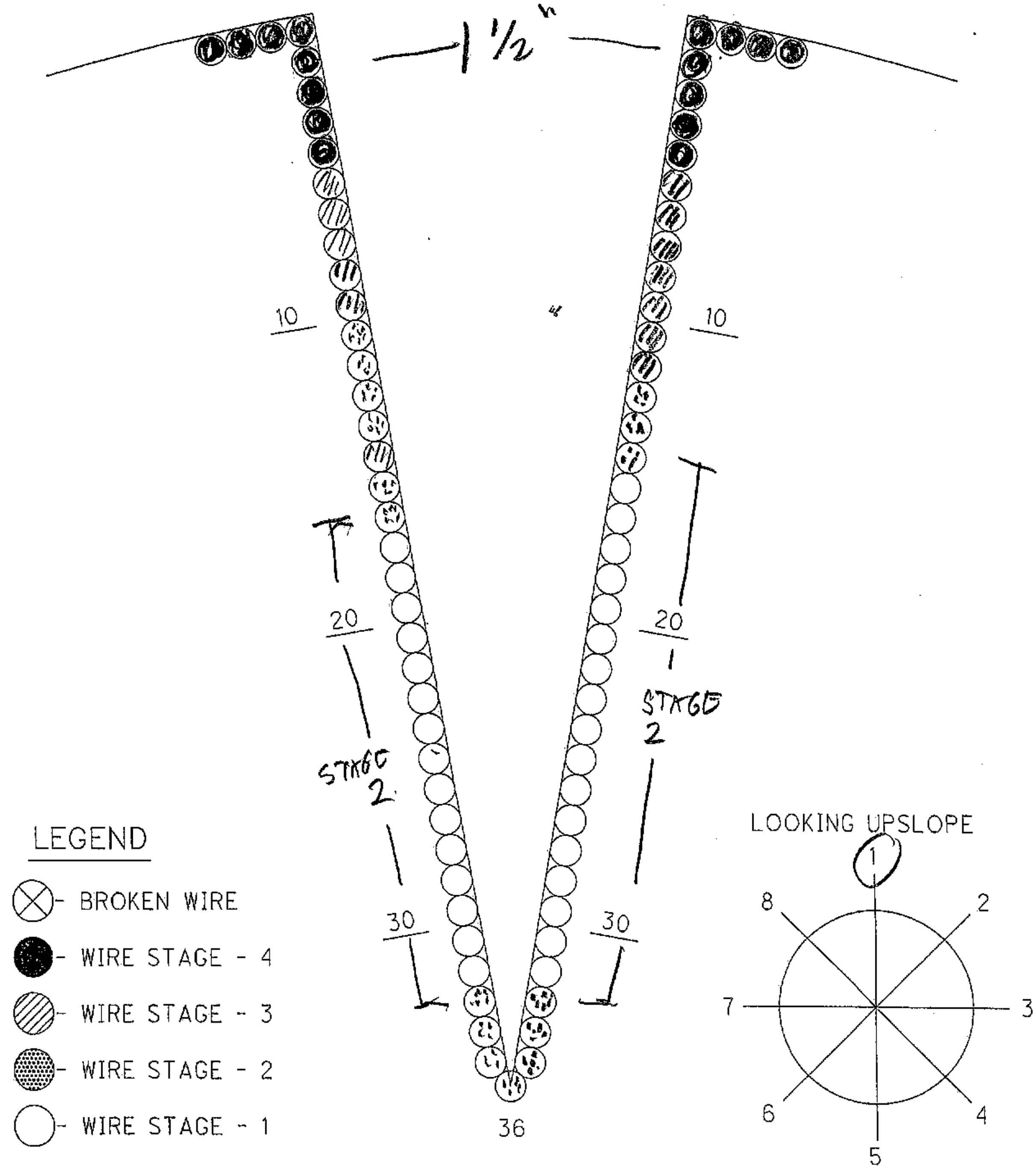
PREPARED BY: ADK

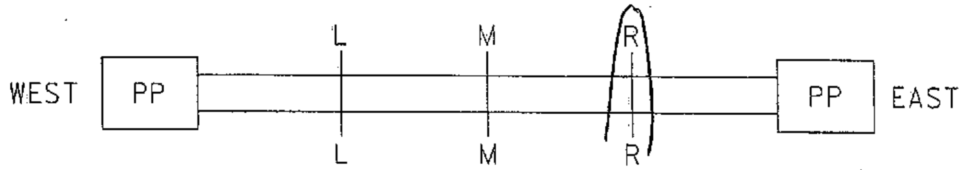
N CABLE ______ SIDE

DATE: 11-16-12

PANEL 65 EAST

DEPTH OF CABLE INSPECTED 6 3/4





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

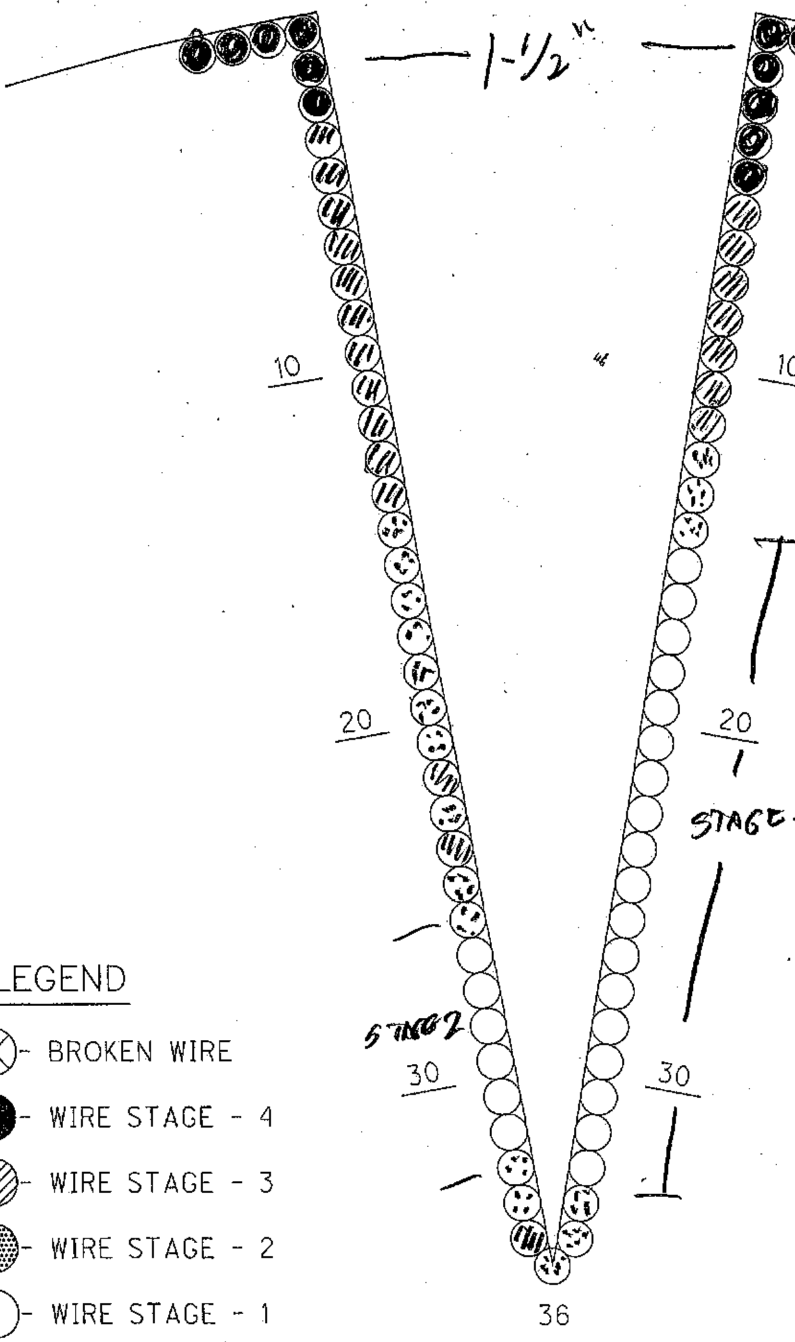
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 65 E

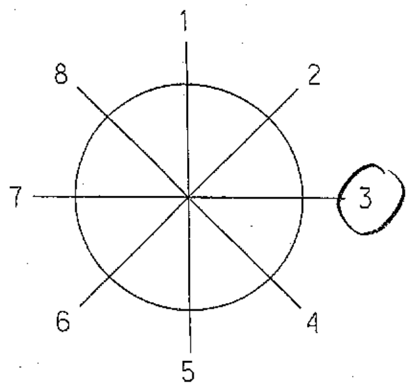
DEPTH OF CABLE INSPECTED 6 7/8"

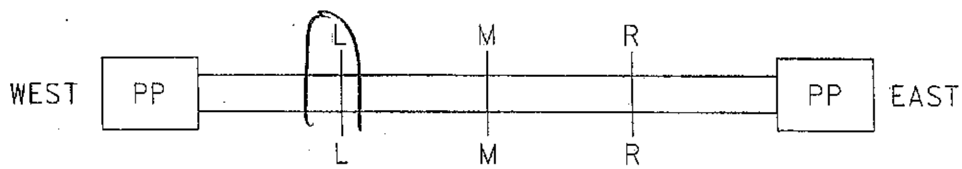


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

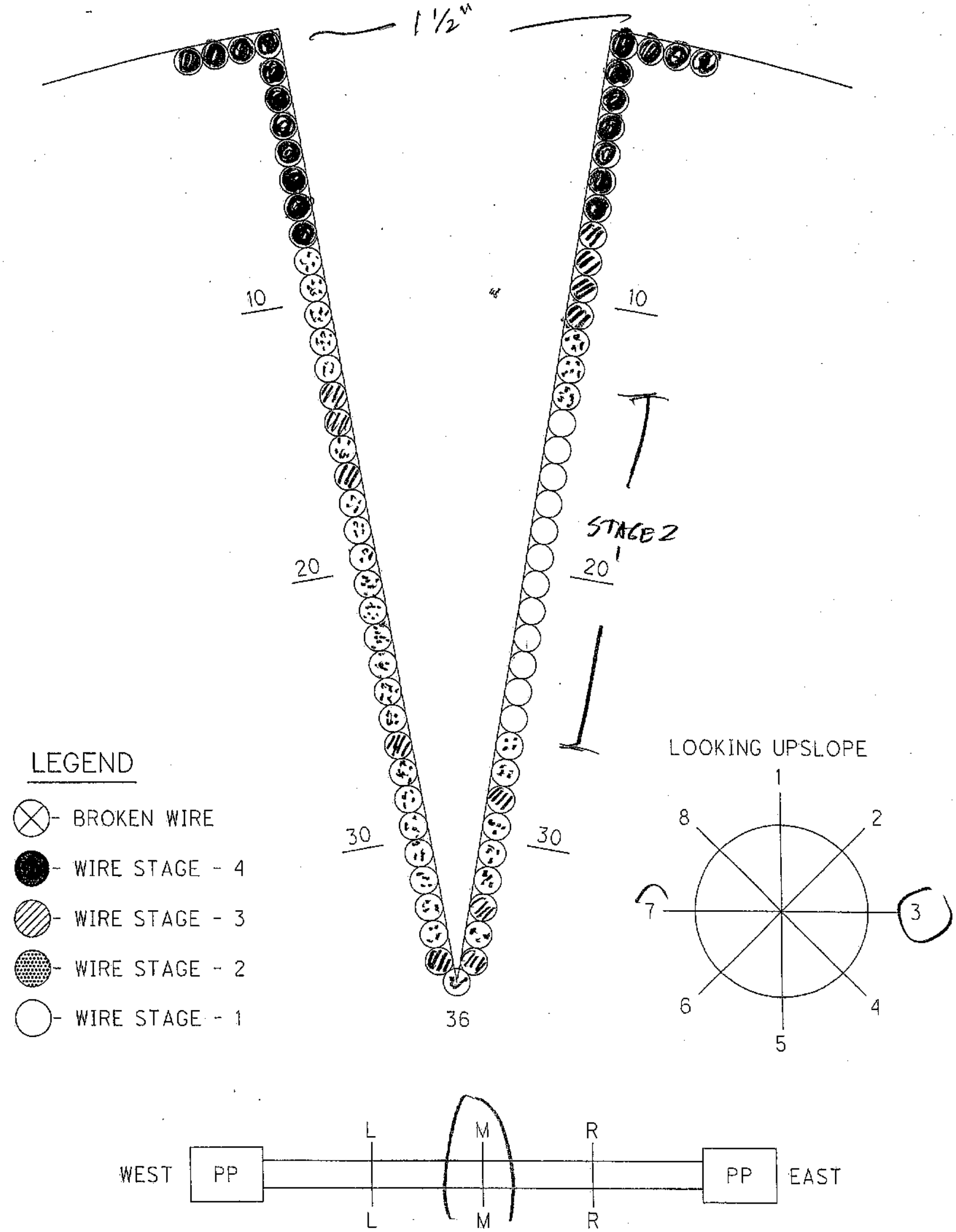
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 65 EAST

DEPTH OF CABLE INSPECTED 7"



Total Wires 55 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

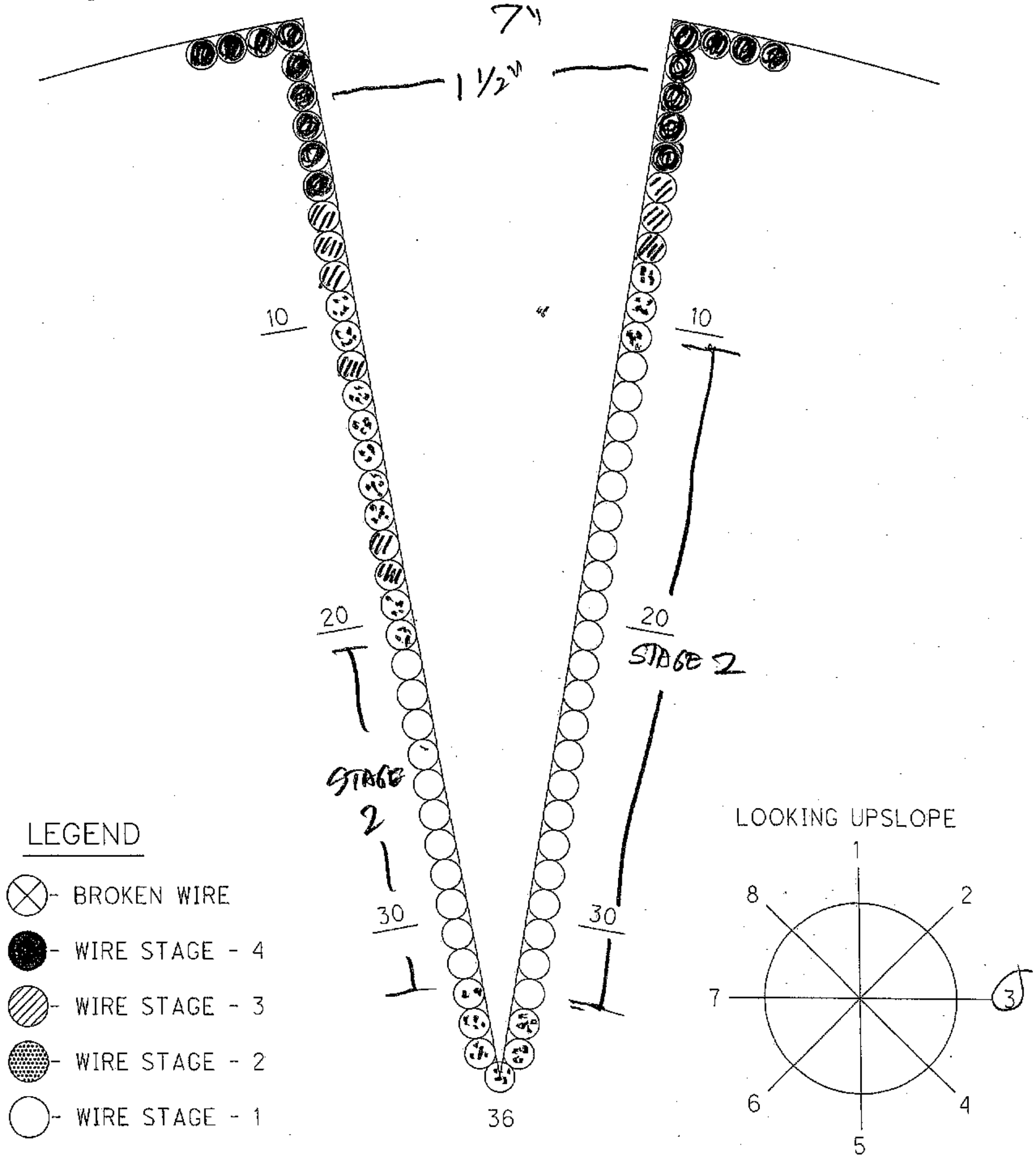
PREPARED BY: ADK

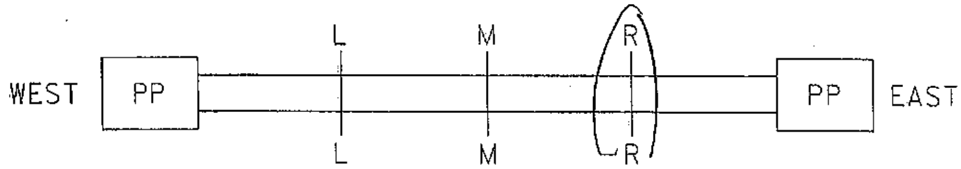
N CABLE ______ SIDE

DATE: 11-16-12

PANEL 65 E

DEPTH OF CABLE INSPECTED ______





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

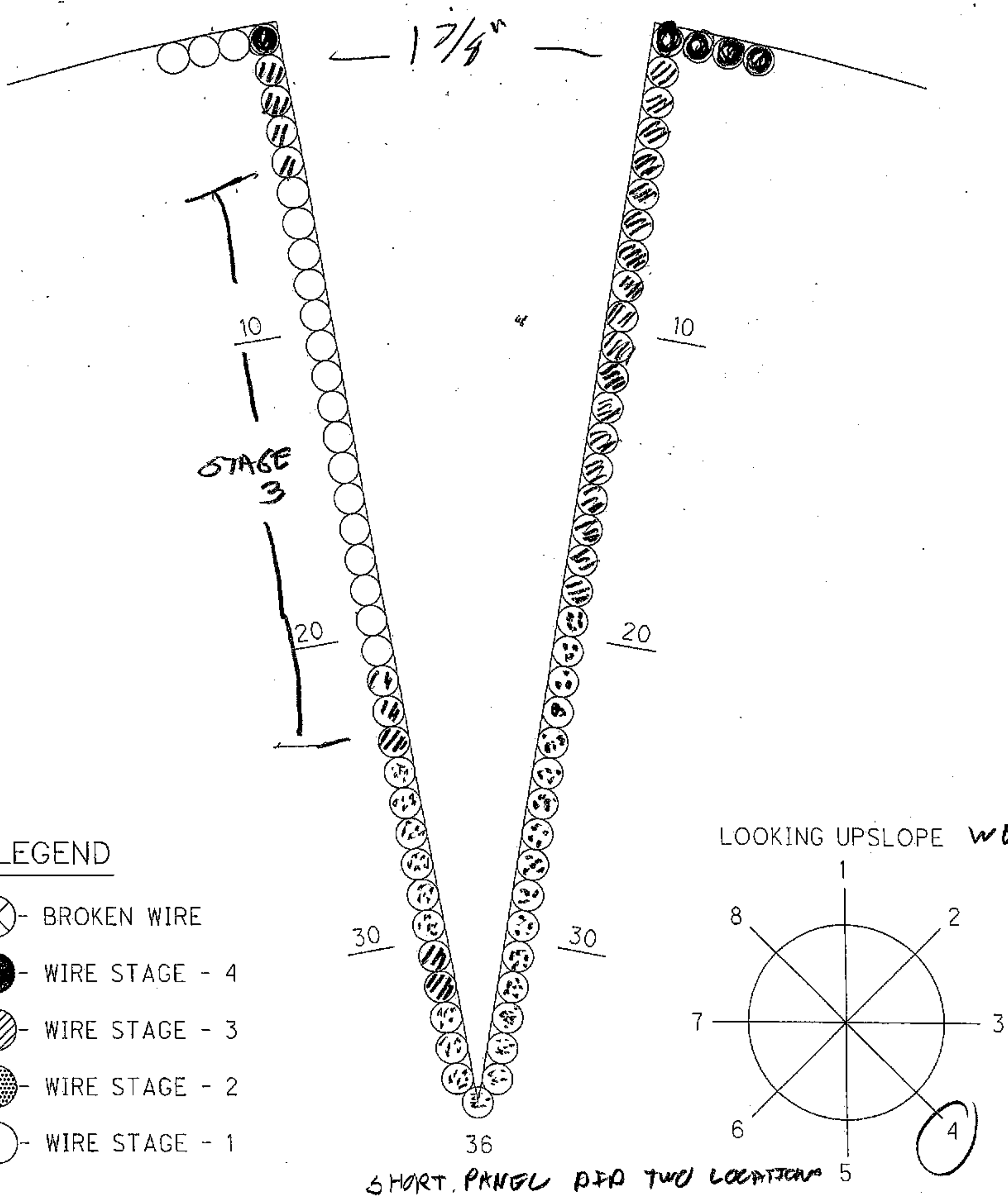
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 65 E

DEPTH OF CABLE INSPECTED 7"

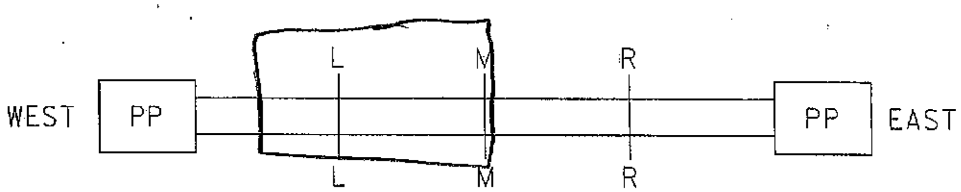


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST

SHORT PANEL AFD TWO LOCATIONS



Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

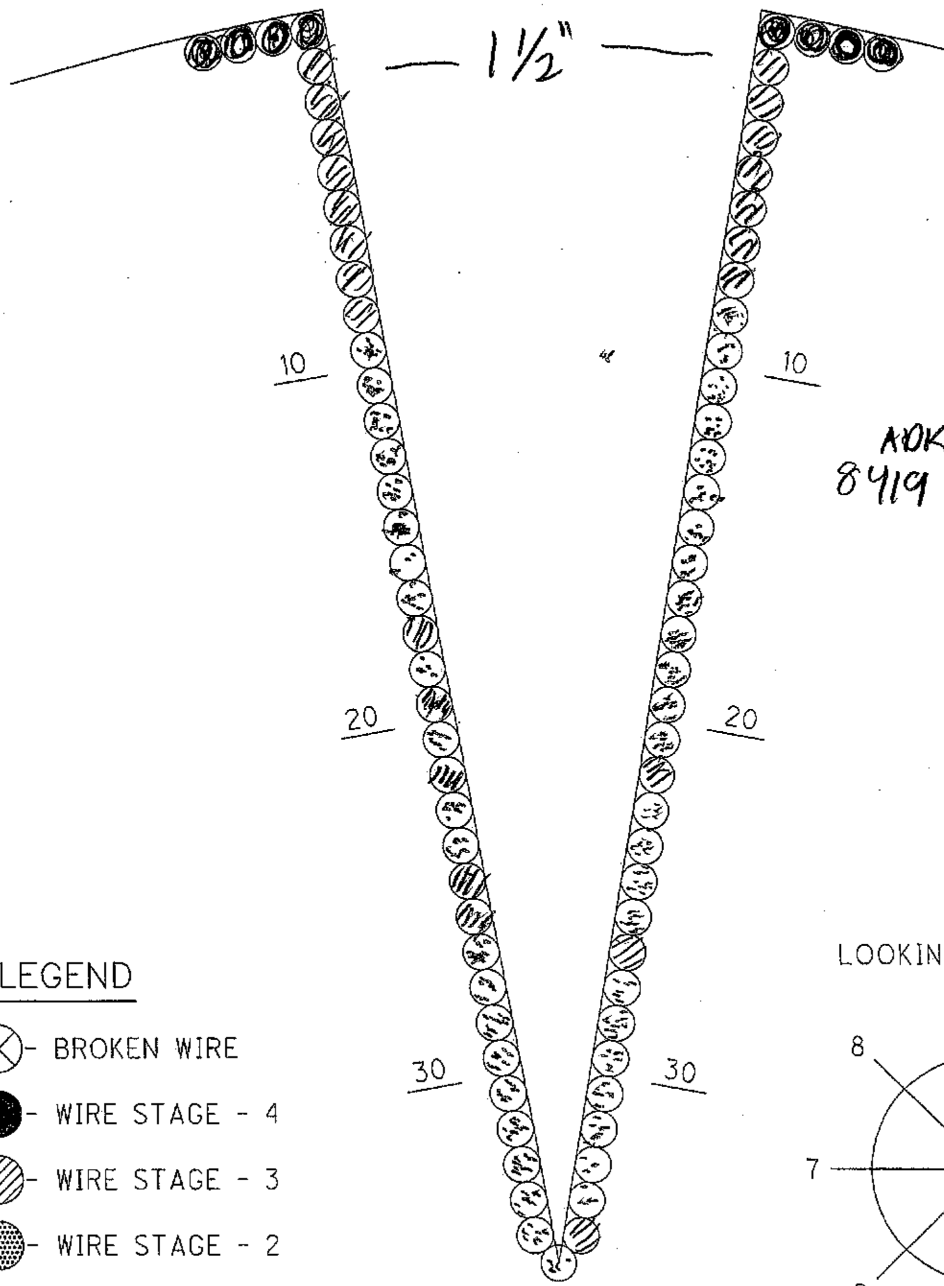
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 65E

DEPTH OF CABLE INSPECTED 7"

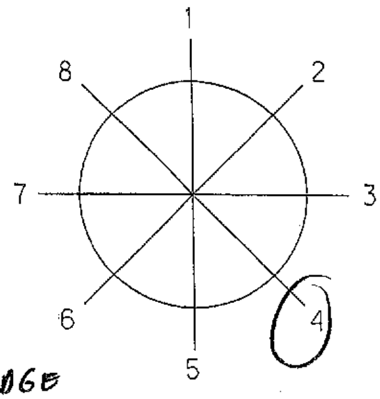


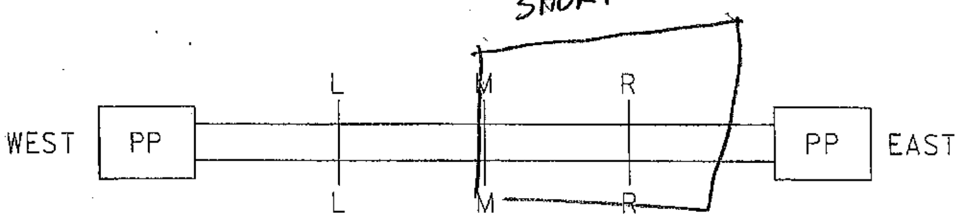
ADK
8419 LOWER SIDE

LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

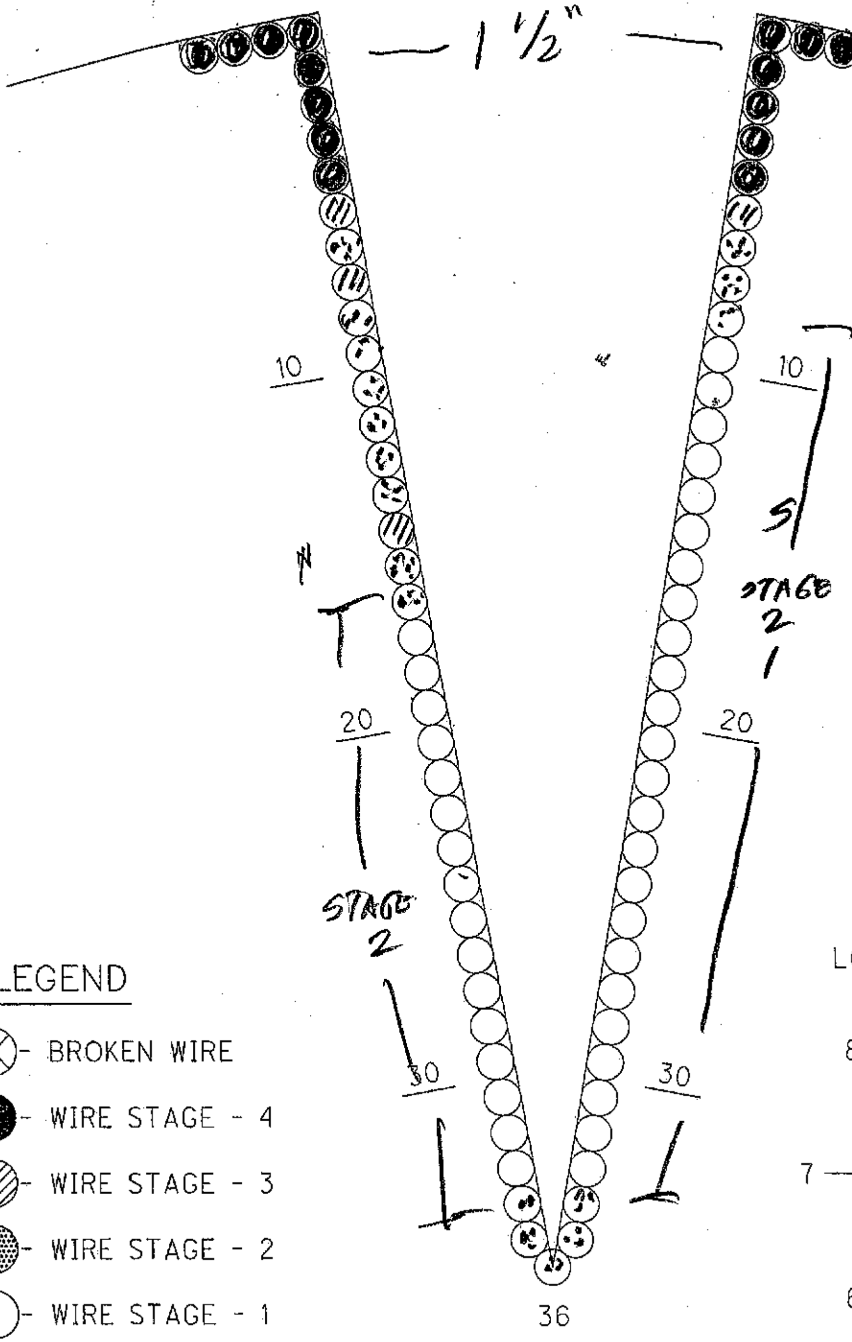
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 65 EAST

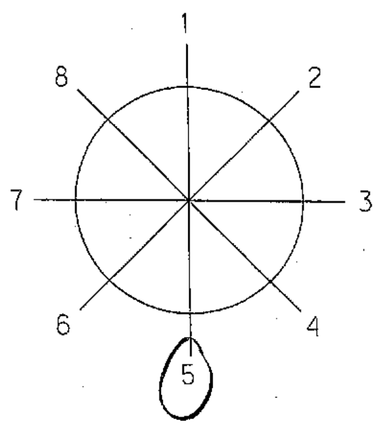
DEPTH OF CABLE INSPECTED 6 3/4

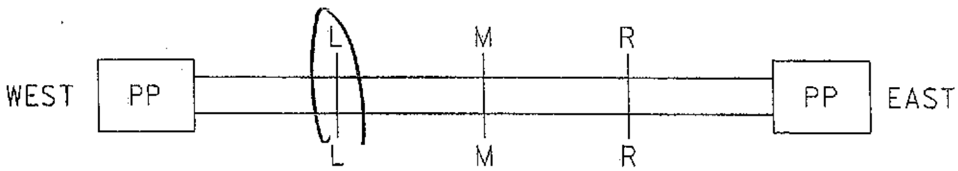


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

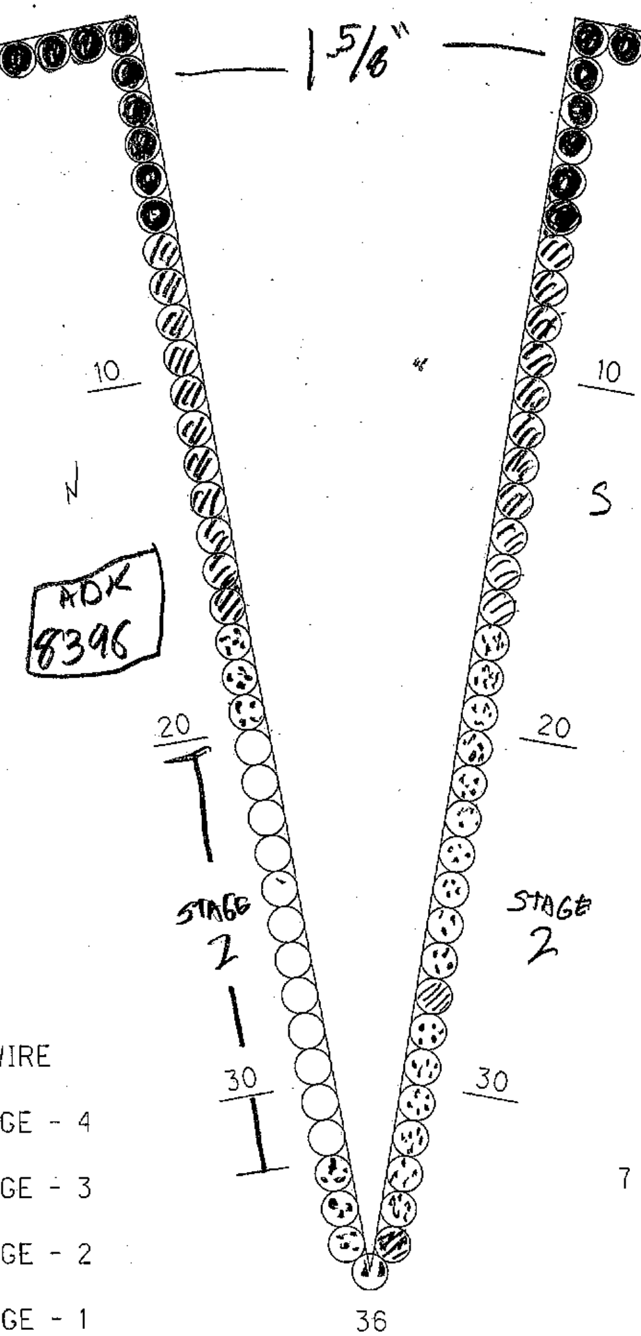
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

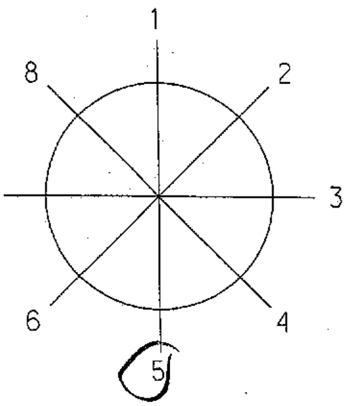
PANEL 65 EAST

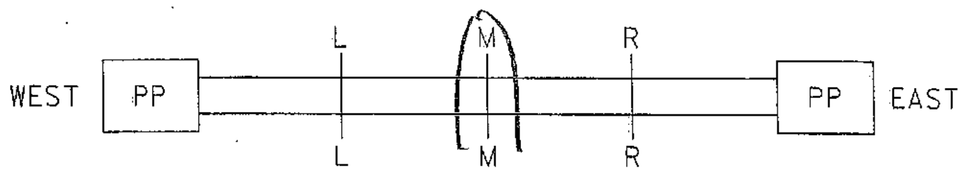
DEPTH OF CABLE INSPECTED 7"



LEGEND

- ⊗ - BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1





Total Wires ~~53~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

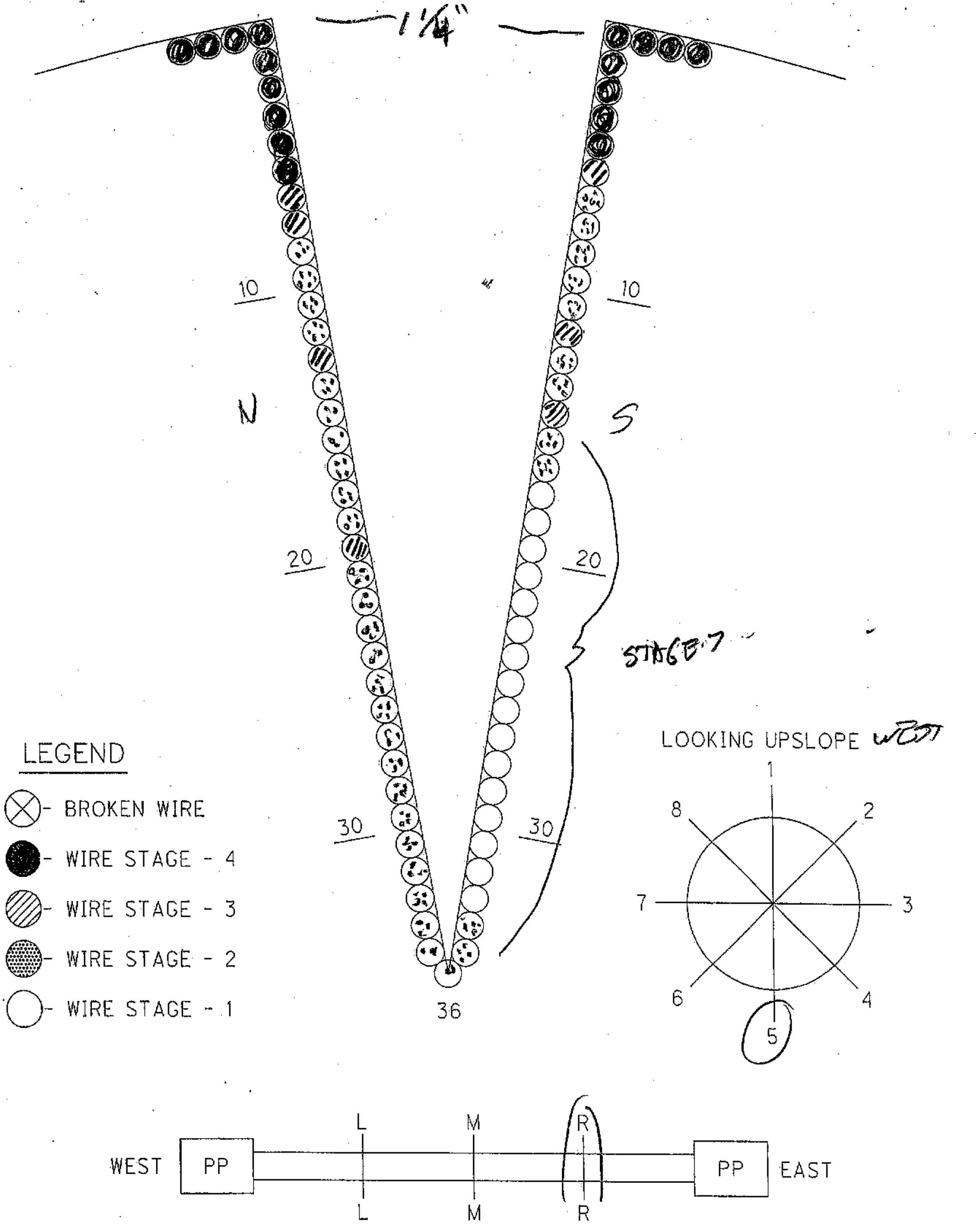
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 65 EAST

DEPTH OF CABLE INSPECTED: 7 1/4"



Total Wires ~~53~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

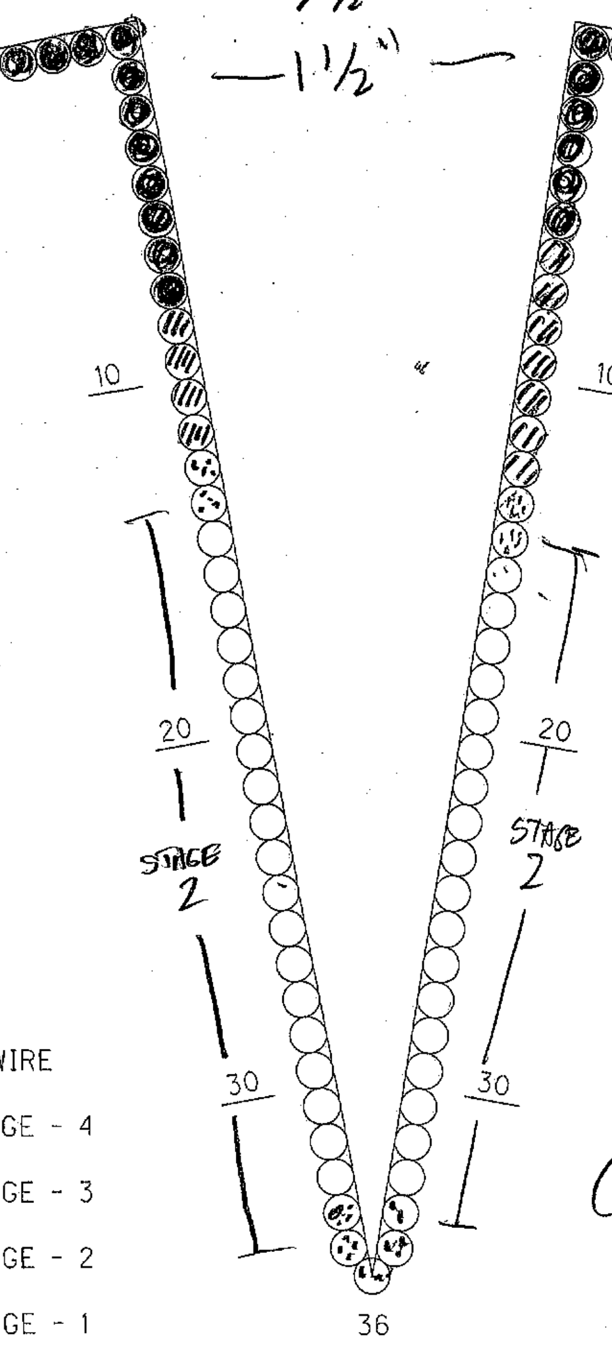
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 63 EAST

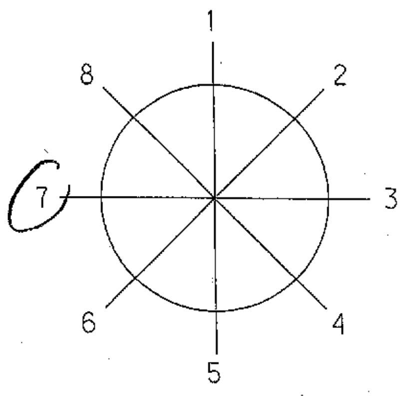
DEPTH OF CABLE INSPECTED 7½"

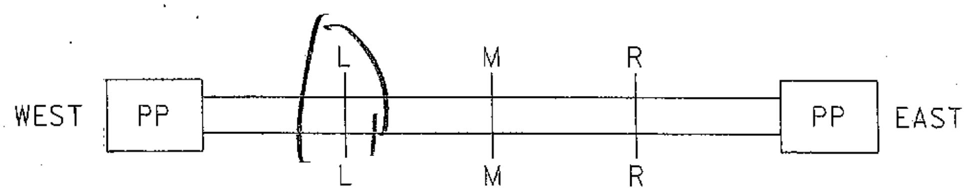


LEGEND

- ⊗ - BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~35~~ 34

BRIDGE NAME: ANTHONY WAYNE BRIDGE

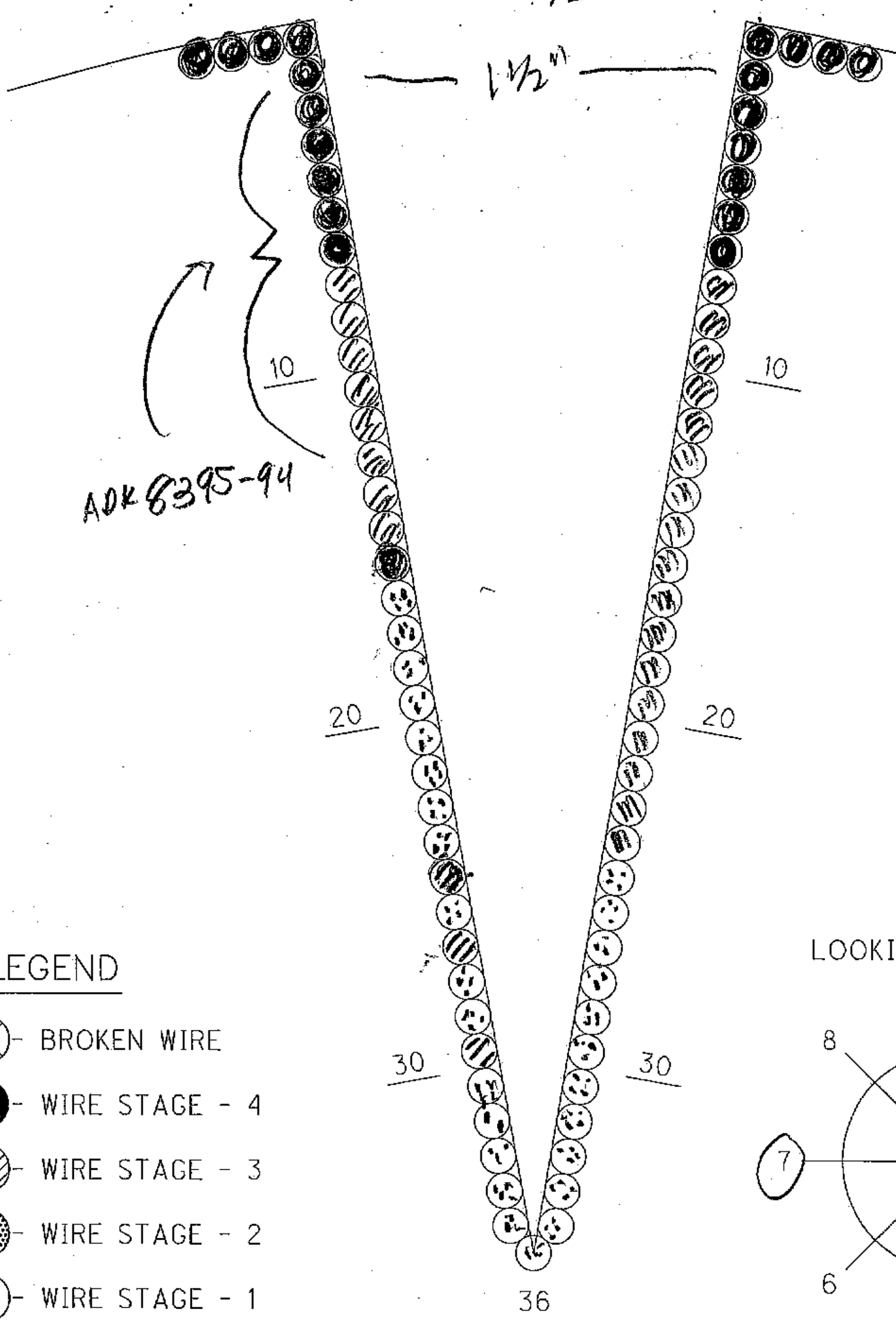
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 65 East

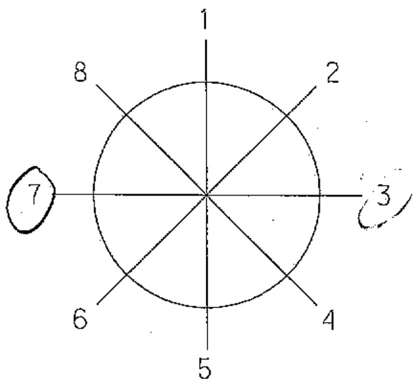
DEPTH OF CABLE INSPECTED ~~7 1/2"~~

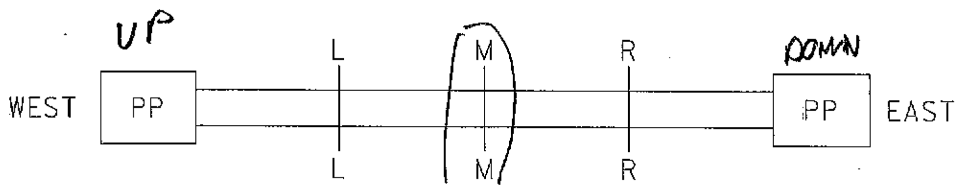


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

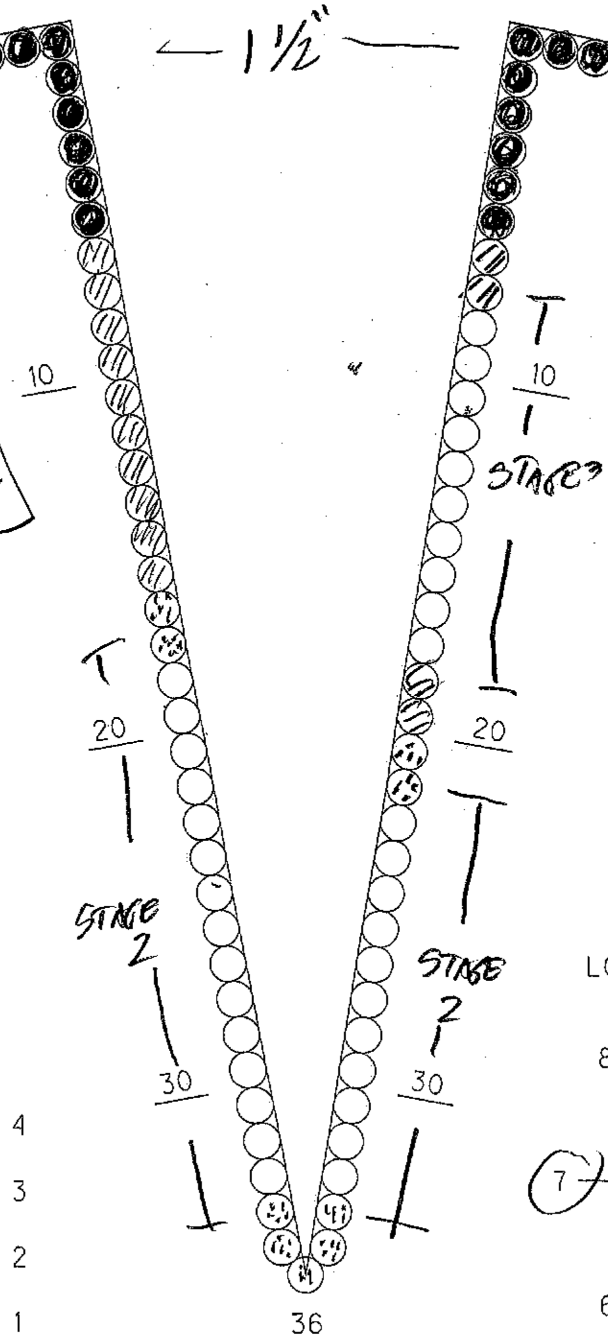
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 65 East

DEPTH OF CABLE INSPECTED 6 3/4"

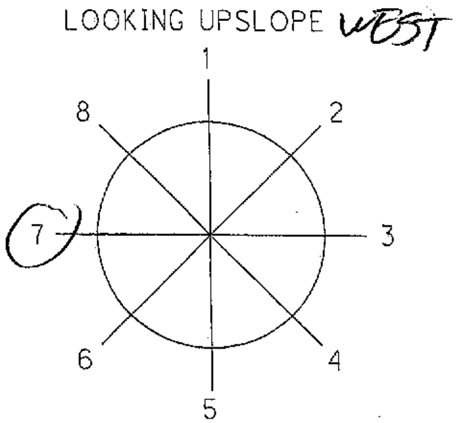


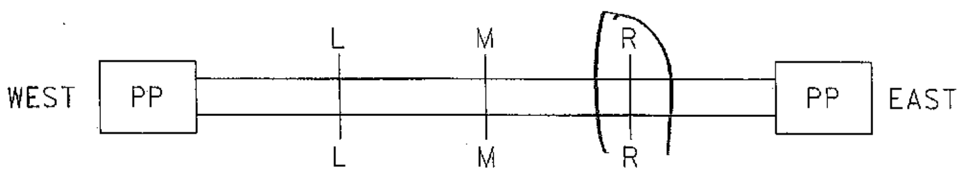
ADK 8392-98

ADK 8399 - SPLICE IN CABLE ON SOUTH SIDE

LEGEND

- ⊗ - BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1





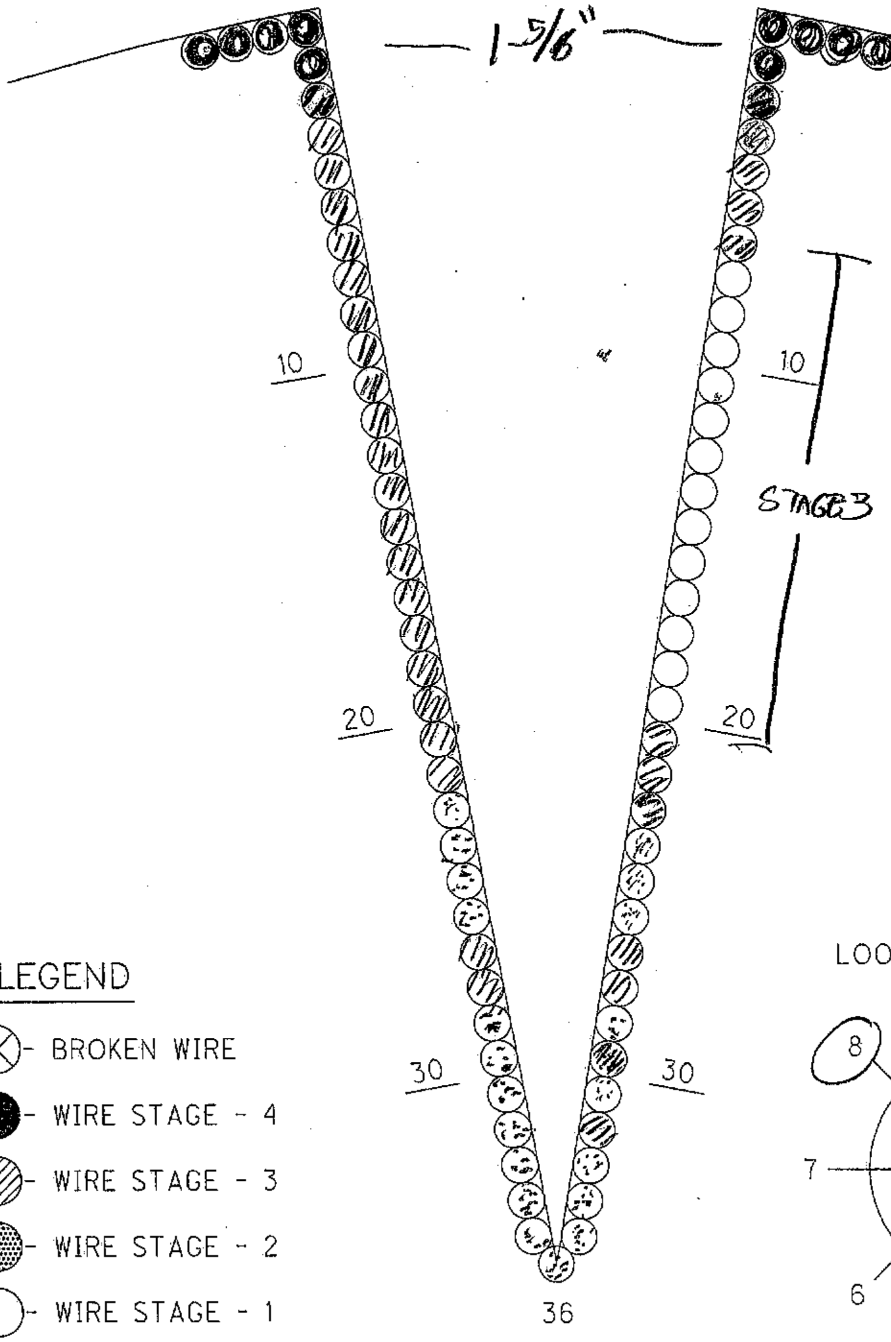
Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE PREPARED BY: ADK

N ~~60~~E CABLE ______ SIDE DATE: 11-16-12

PANEL 65E

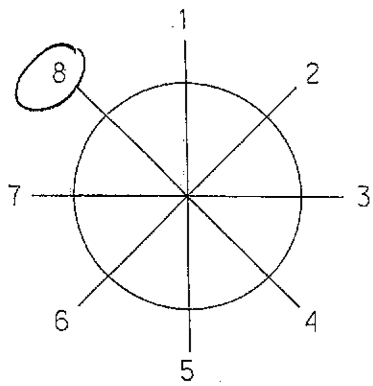
DEPTH OF CABLE INSPECTED 6 7/8"

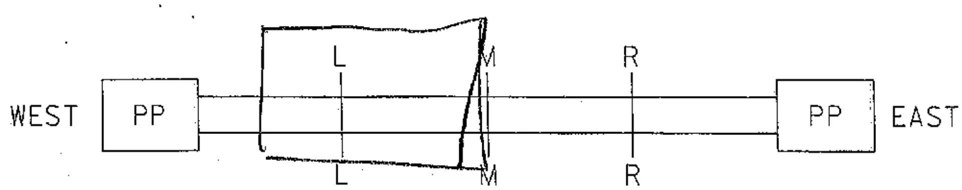


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

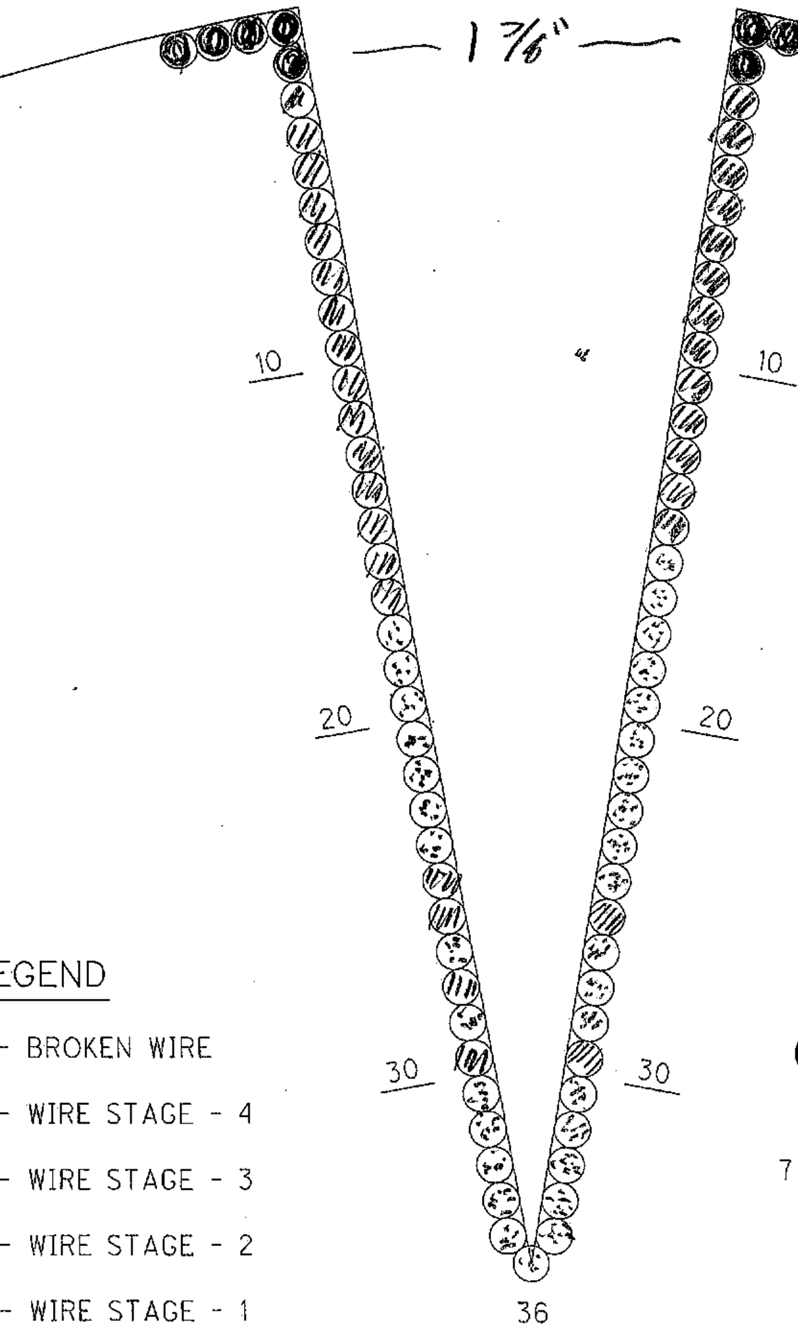
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

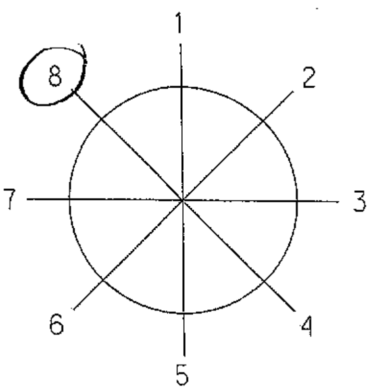
PANEL 65E

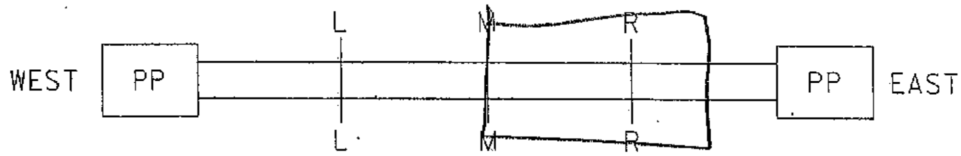
DEPTH OF CABLE INSPECTED 7"



LEGEND

LOOKING UPSLOPE





Optional Cable Opening Location PP 31 – PP 32, North

ANTHONY WAYNE
~~Ambassador Bridge~~ Main ~~Cable Investigation~~

Cable Circumference Measurements

Prepared by: MSL
Date: 11/15/12
No. Wires in cable (N): ~~8066~~
Wire Diameter (d): ~~0.192~~

Cable: NORTH
Side:
Panel:

Location	Before Unwrapping: Measured Circumference Ci	Before Unwrapping: Calculated Diameter Di	After Unwrapping: Measured Circumference C	After Unwrapping: Calculated Diameter D	Density DENS	After Compaction: Measured Circumference Cc	After Compaction: Calculated Diameter Dc	Density DENSc	After Rewrapping: Measured Circumference Cf	After Rewrapping: Calculated Diameter Df
Cable Band, Panel Point 32	42 13/16"	13.63"	41 1/2	13.21"		41 3/8	13.17"		42 7/8	13.65"
12 in	43"	~~42 15/16~~ 13.69"	41 15/16	13.35"		42 3/16"	13.43"		42 7/8"	13.65"
Center Line	43 1/8"	13.73"	42 3/4	13.61"		43 1/16"	13.71"		43 3/4"	13.93"
12 in	43"	13.69"	42 3/16" (Fused wire in ?)	13.43"		42 3/8"	13.49"		43	13.69"
Cable Band, Panel Point 31	42 7/8"	13.65	41 1/2	13.21"		41 5/8"	13.25"		43 1/8"	13.73"

$Di=Ci/\pi$ | $D=C/\pi$ | DENS= Nd^2/D^2 | $Dc=Cc/\pi$ | DENSc= Nd^2/Dc^2 | $Df=Cf/\pi$

Temperature	Temperature	Temperature	Temperature
35°F	36°F	35°F	41°F

17' 5 1/4"
209 1/4" CABLE BAND

← LOOKING NORTH

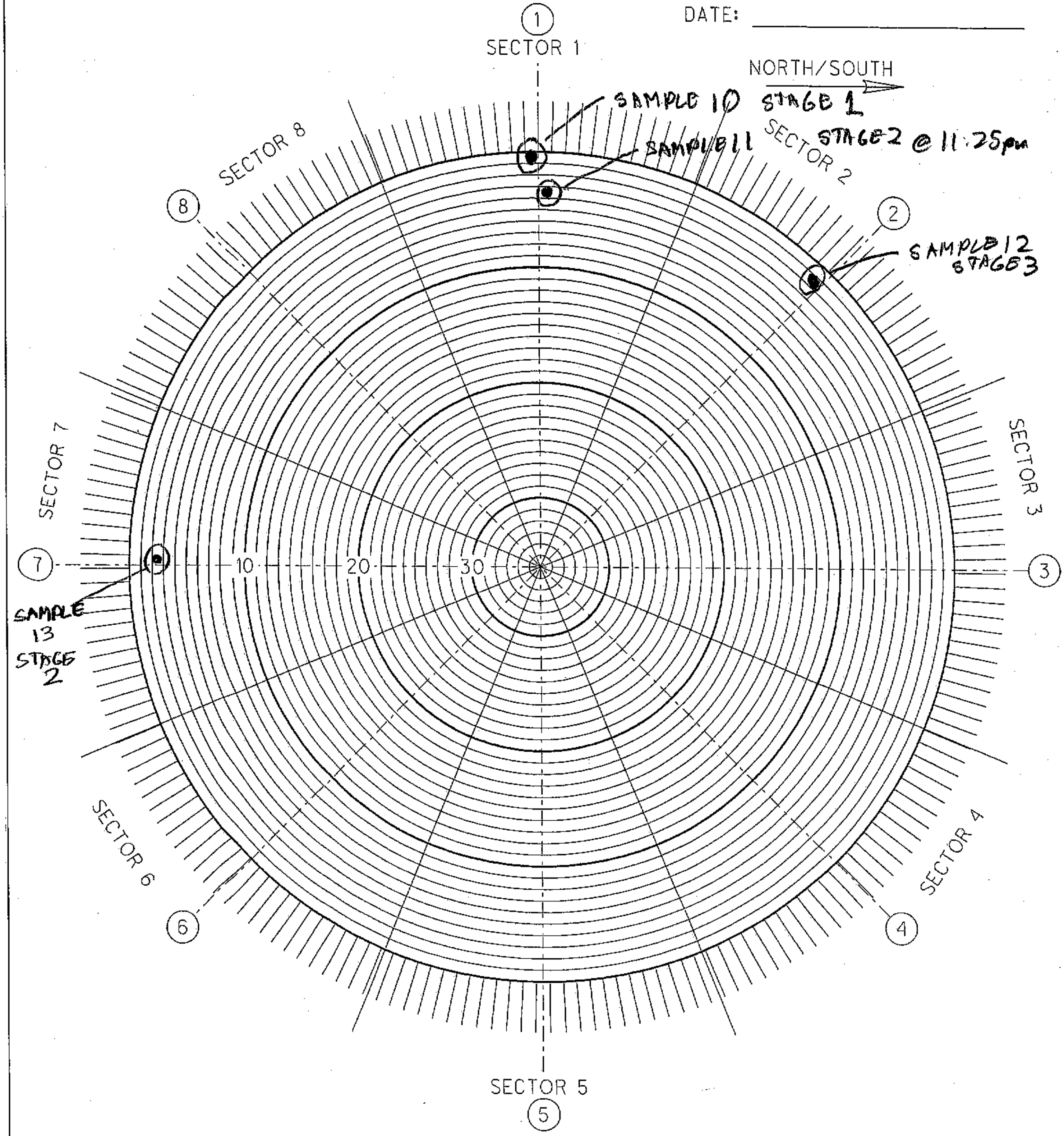
SAMPLE AMOUNTS
- #1 - 1
- #2 - 1
- #3 - 1111
- #4 - 𝍸1

—Started wedging 12/3/6/9 9:05 AM 31/32

BRIDGE NAME: ANTHONY WAYNE BRIDGE

PREPARED BY: ____________

DATE: ____________



LEGEND

● - BROKEN WIRE NO.

(1) - WEDGE LOCATION

(●) - SAMPLE FOR TESTING

CABLE CROSS SECTION

N CABLE, LOOKING WEST

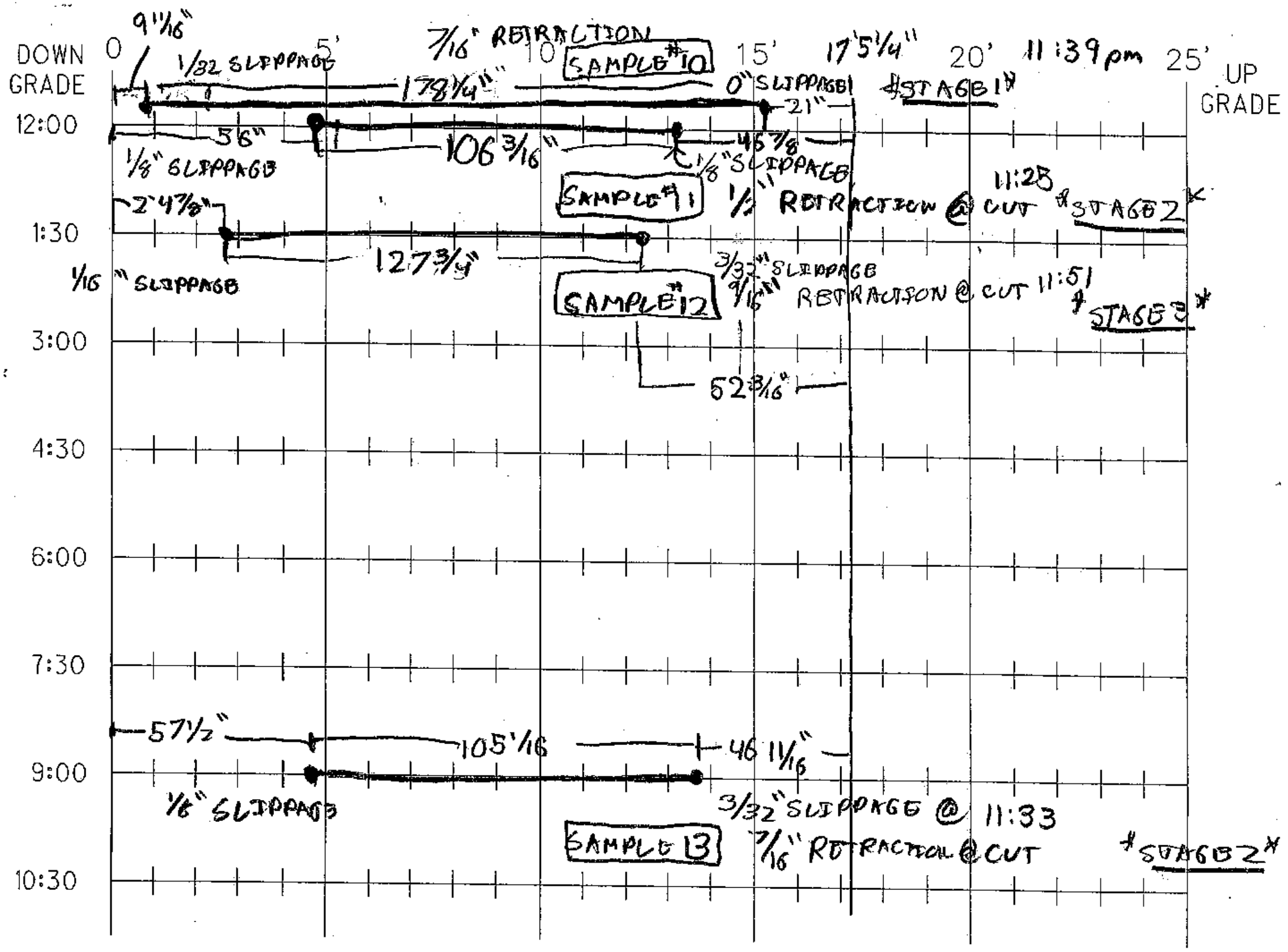
SPAN ____________

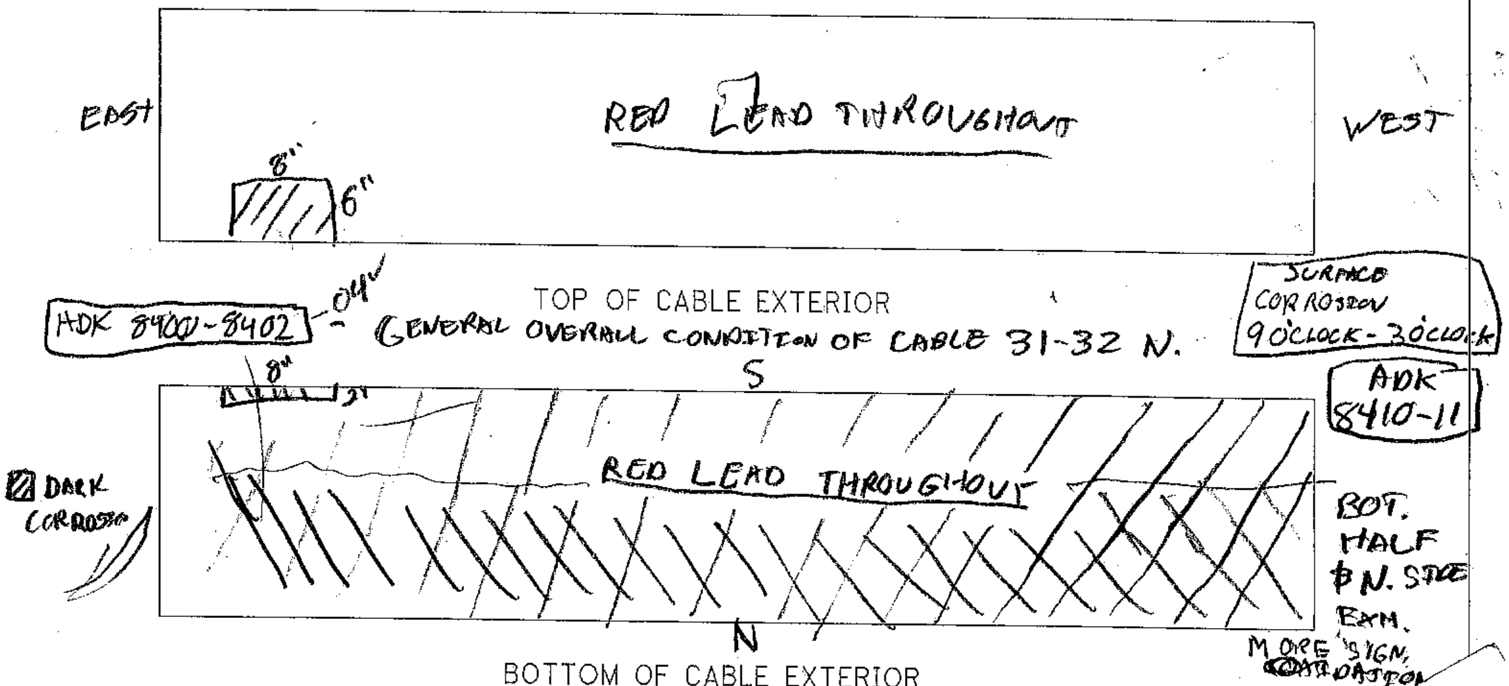
PANEL 31-32

BRIDGE NAME: ANTHONY WAYNE PREPARED BY: ADK

N CABLE ______ SIDE DATE: 11-16-12

PANEL 31-32 TOTAL LENGTH EXPOSED 17'5¼"





TOP OF CABLE EXTERIOR

- GENERAL OVERALL CONDITION OF CABLE 31-32 N.

BOTTOM OF CABLE EXTERIOR

Total Wires 55 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

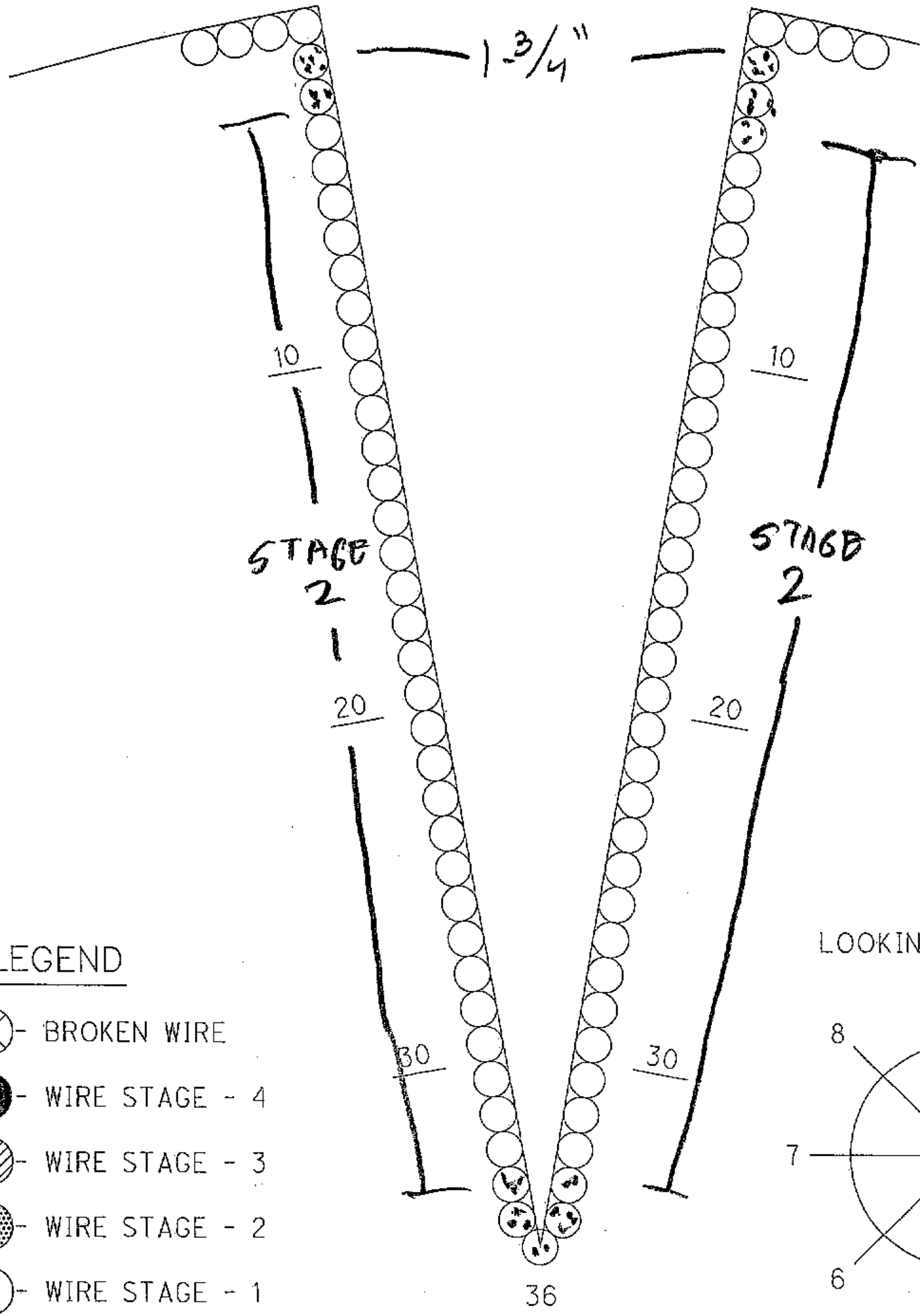
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 31-32

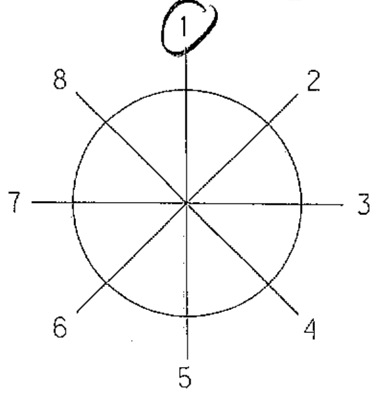
DEPTH OF CABLE INSPECTED 7"

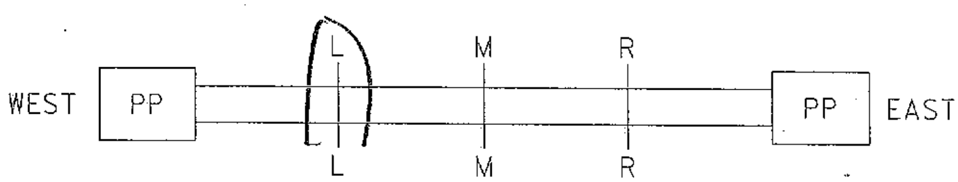


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

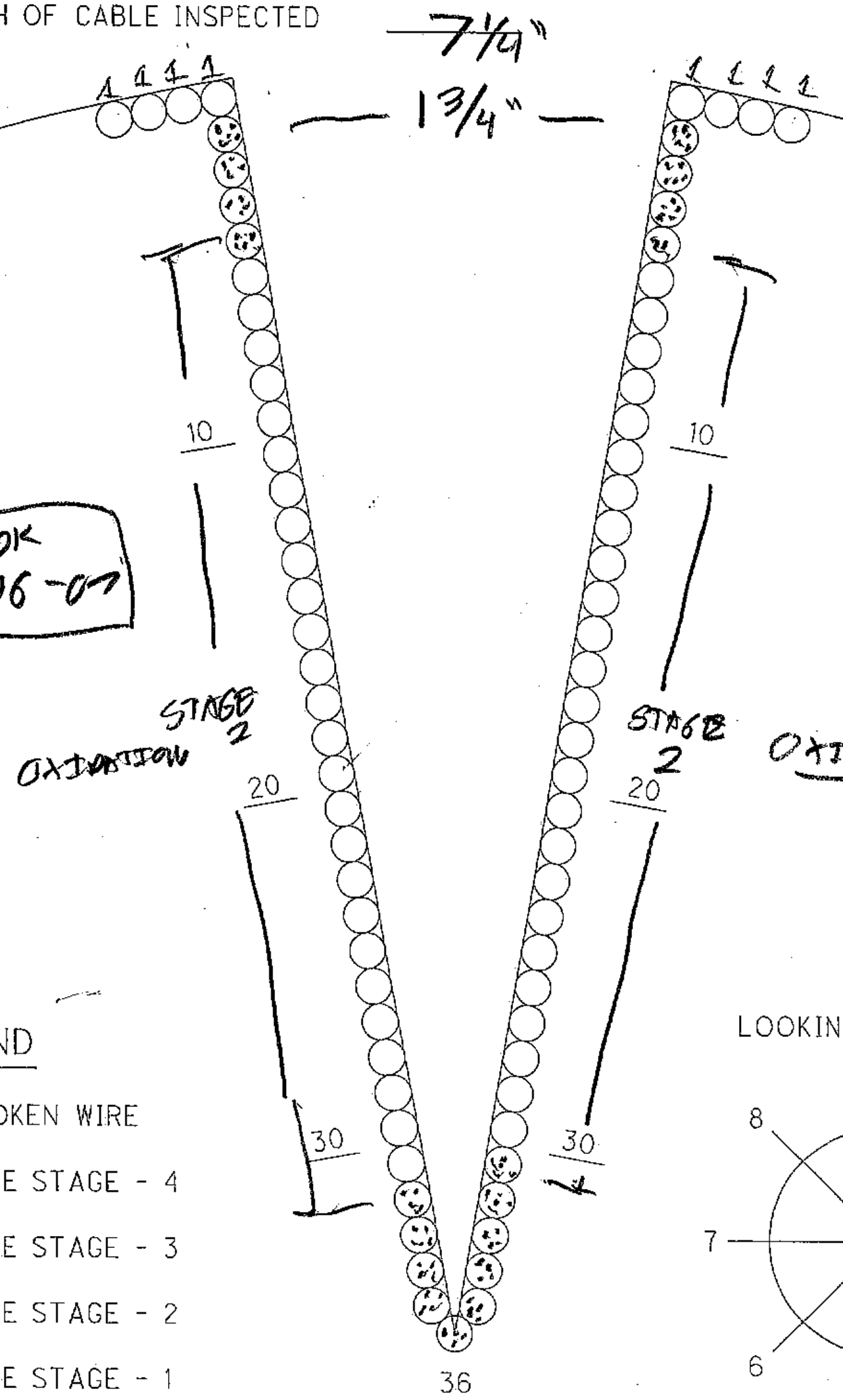
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 81-32

DEPTH OF CABLE INSPECTED

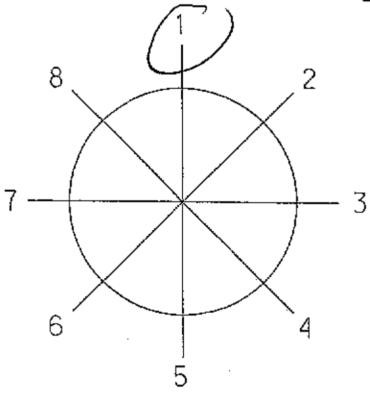


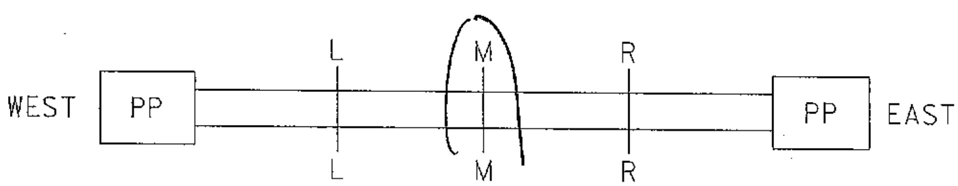
ADK
8406-07

LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

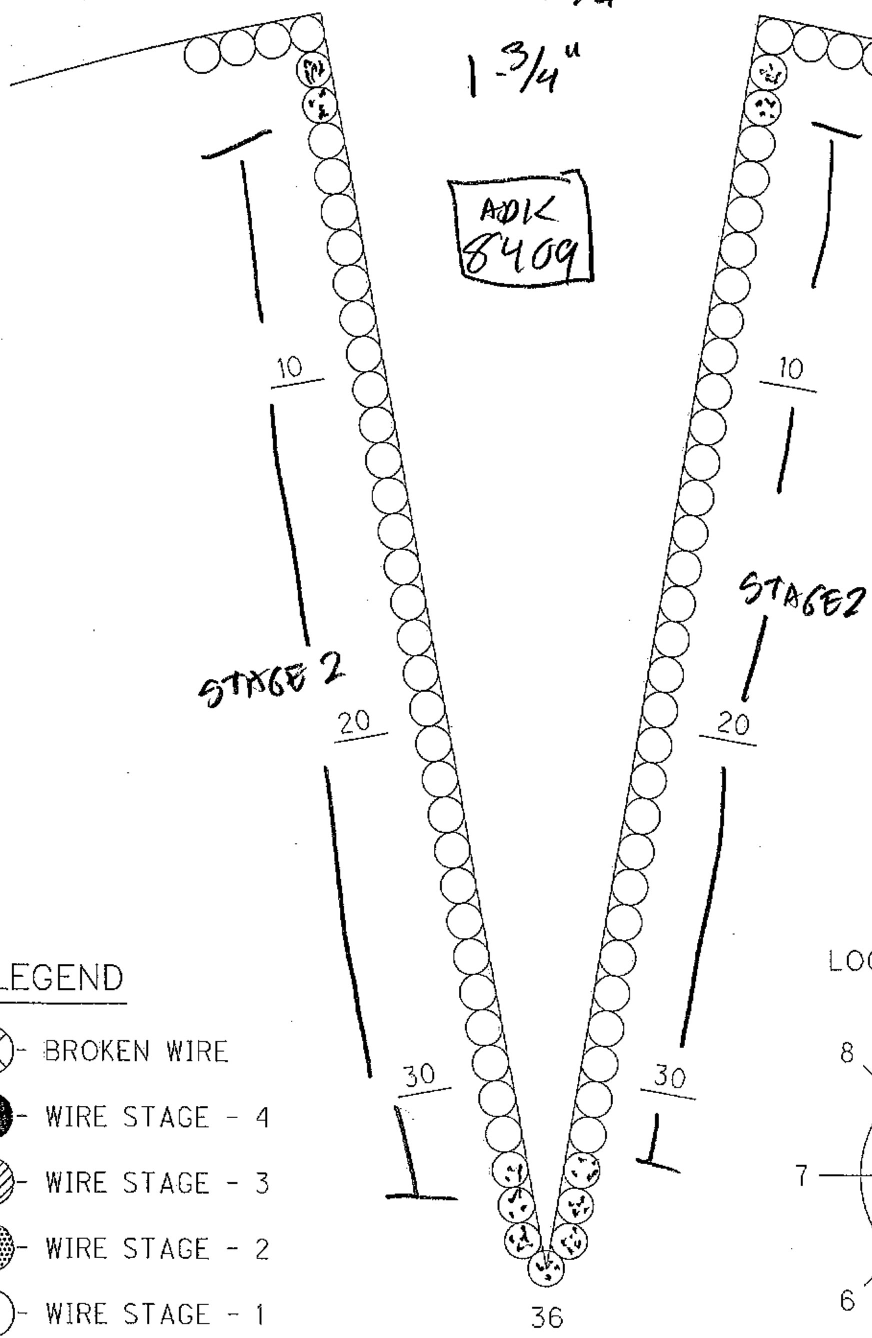
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 31-32

DEPTH OF CABLE INSPECTED 7 1/4"

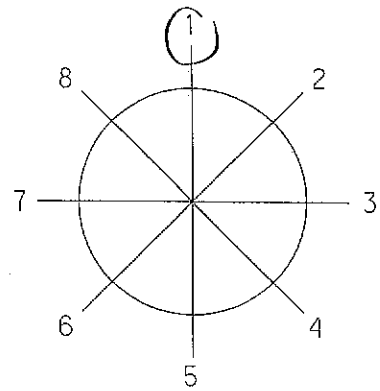


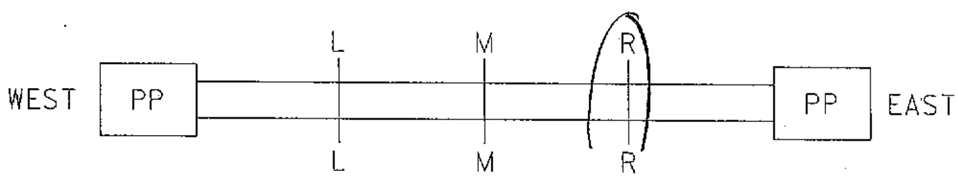
ORGINAL FERRELL SPL. ADK 8408

LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

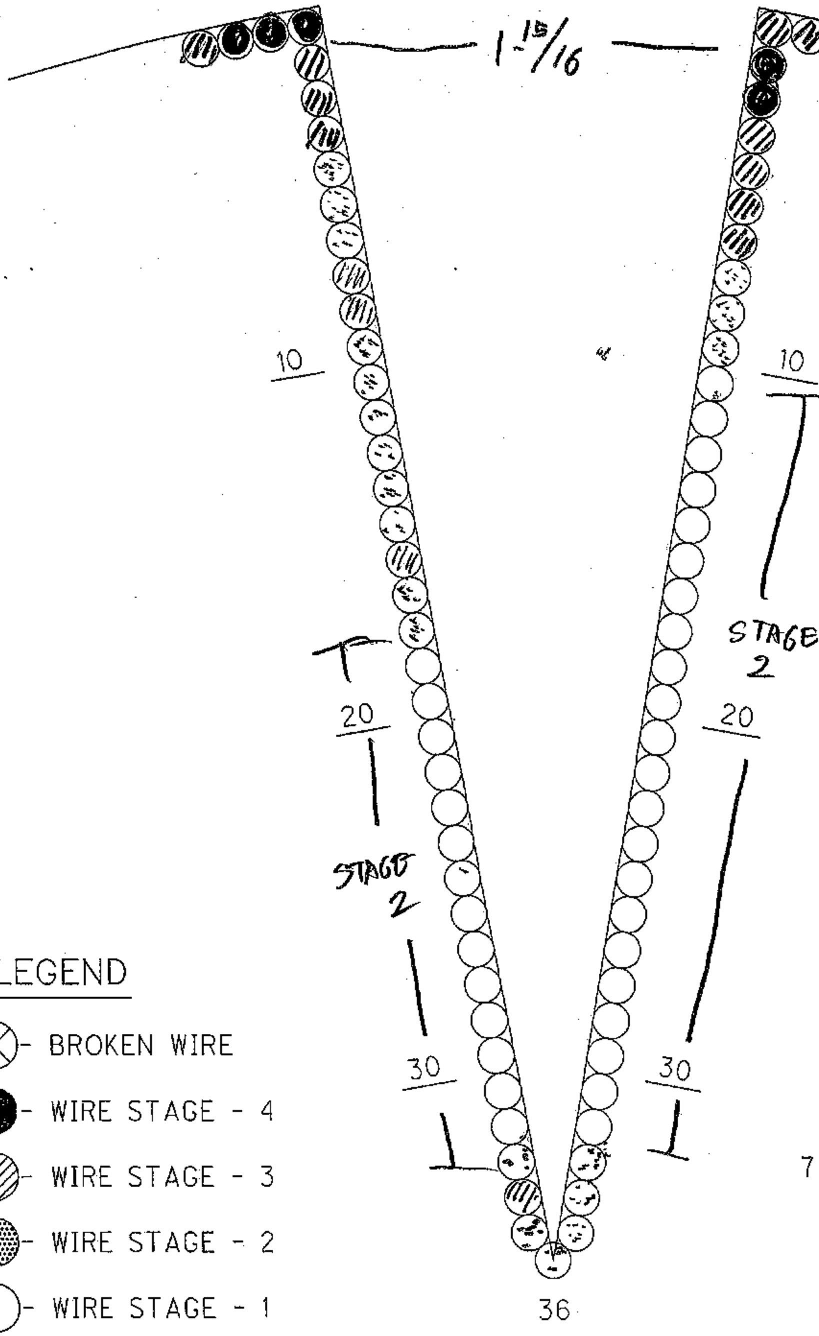
PREPARED BY: AOK

_______ CABLE _______ SIDE

DATE: 11-17-12

PANEL _______

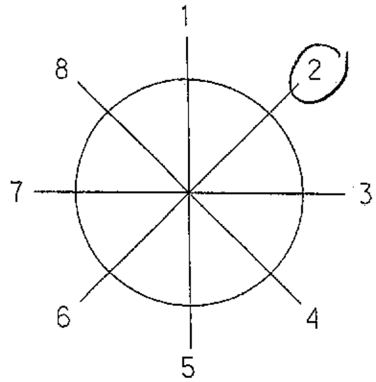
DEPTH OF CABLE INSPECTED 8"

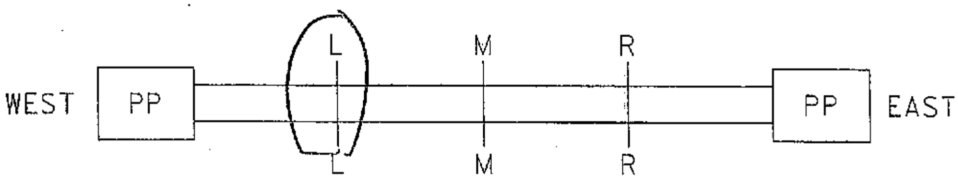


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





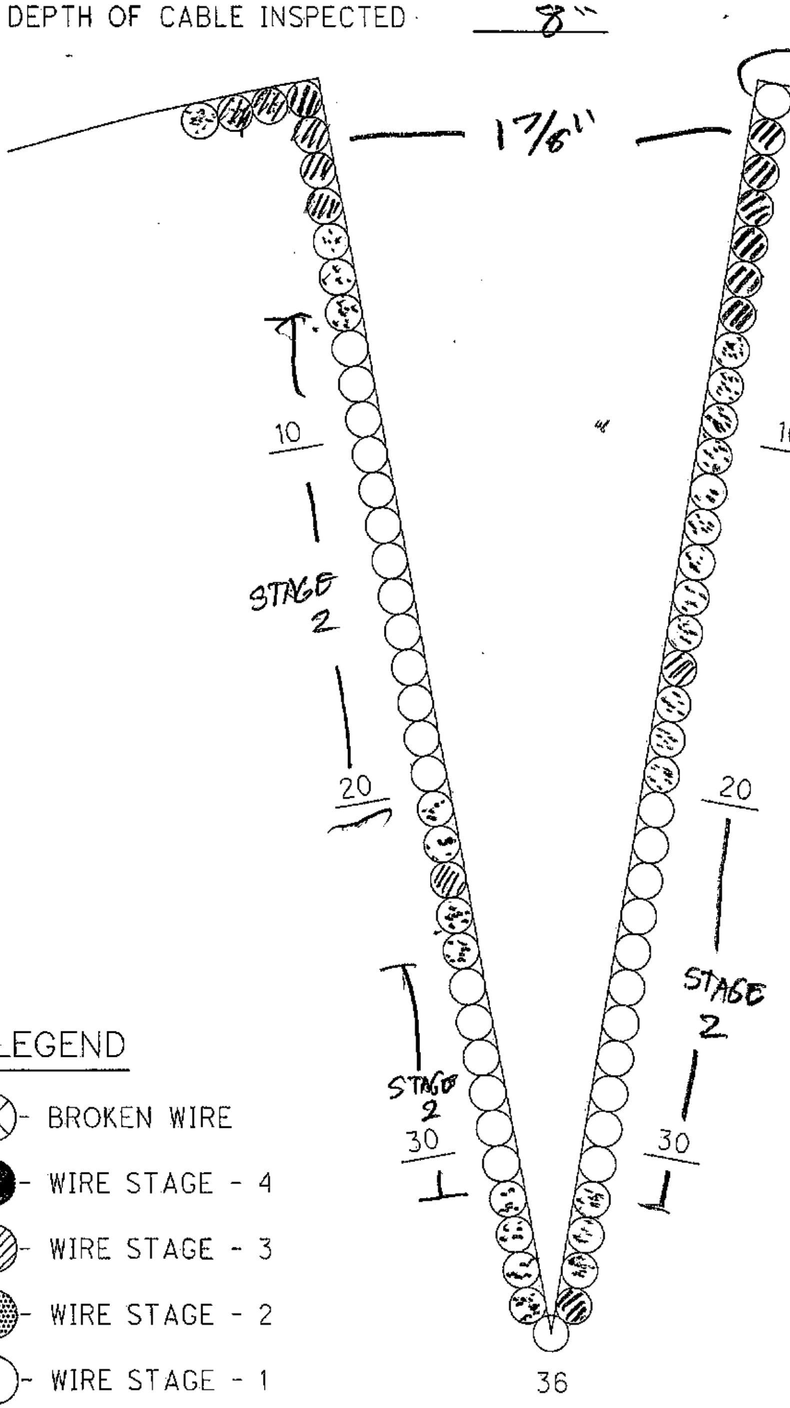
Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE   PREPARED BY: ADK

_______ CABLE   _______ SIDE   DATE: 11-17-12

PANEL _______

DEPTH OF CABLE INSPECTED 8"

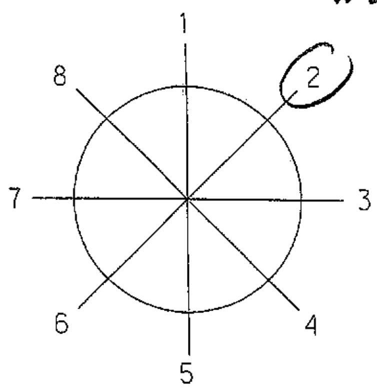


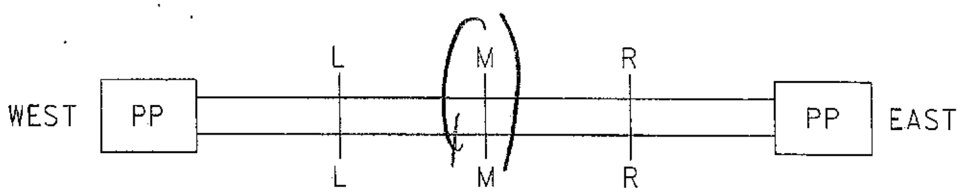
ADK 8432

LEGEND

- ⊗ - BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires 55 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

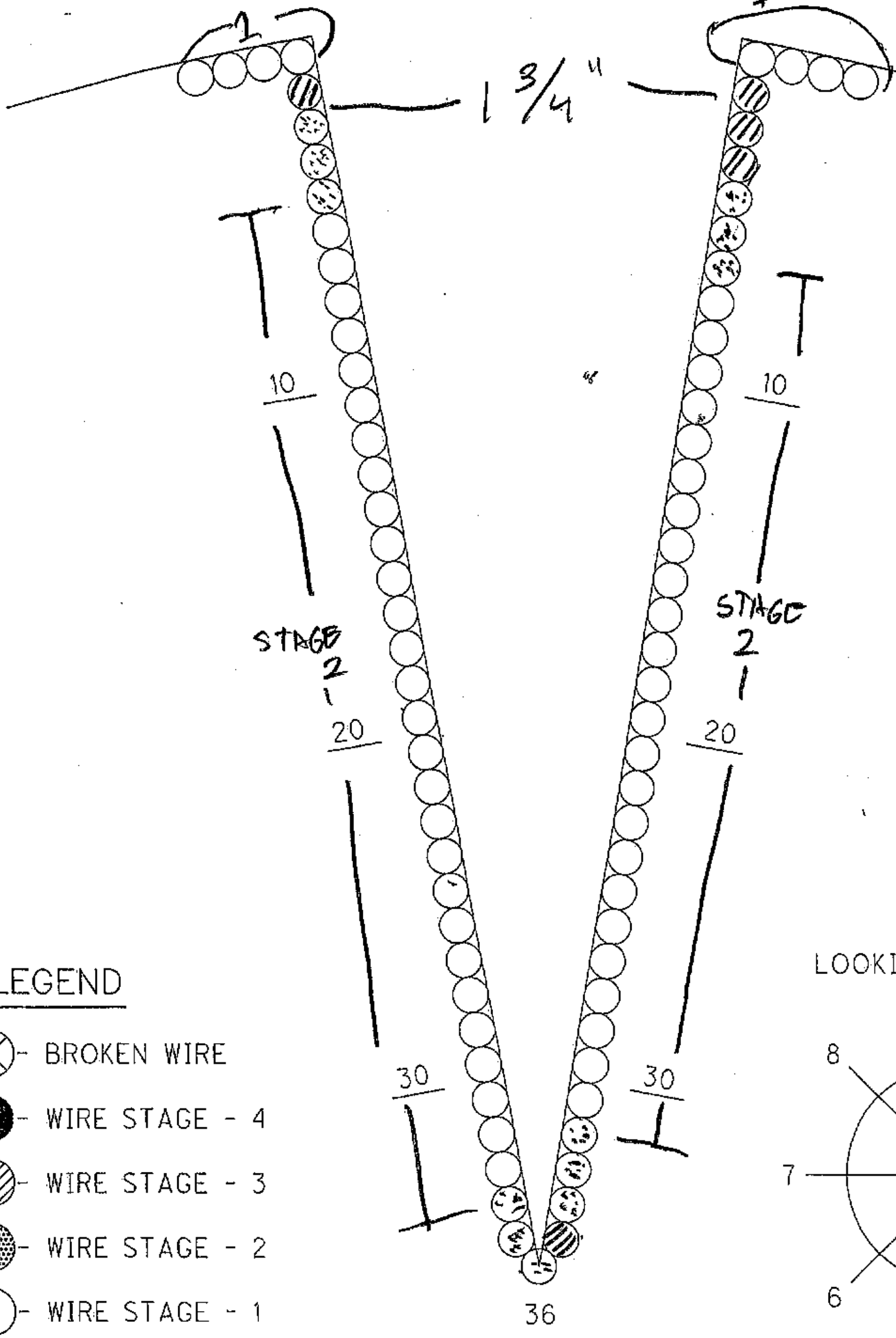
PREPARED BY: AOK

_____ CABLE _____ SIDE

DATE: 11-17-12

PANEL _____

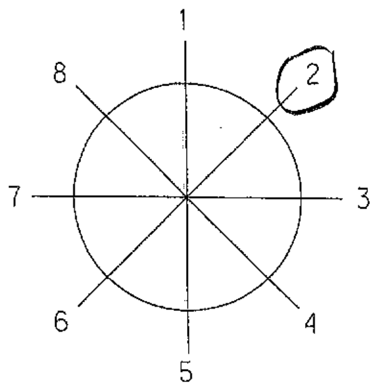
DEPTH OF CABLE INSPECTED 7"

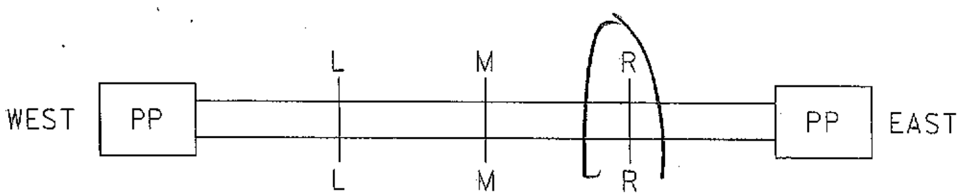


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

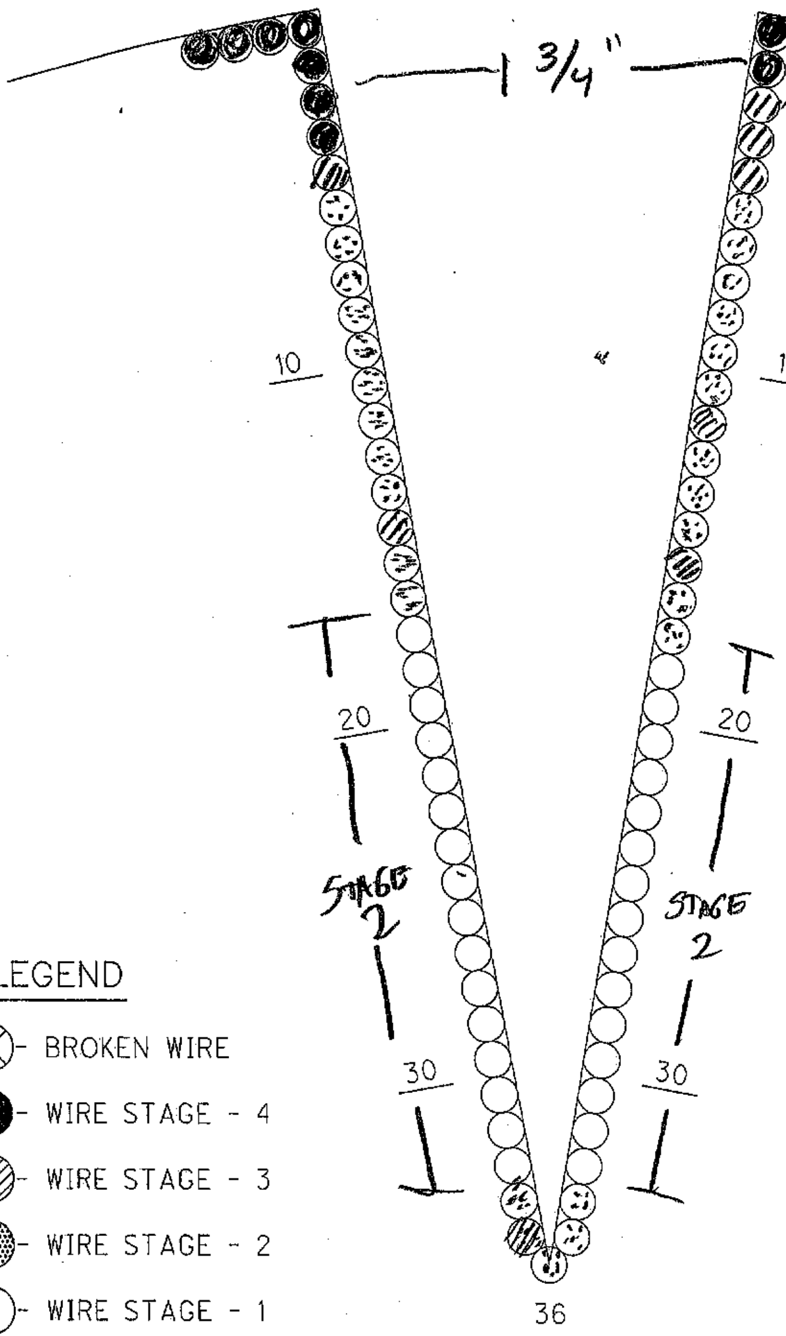
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 31-32

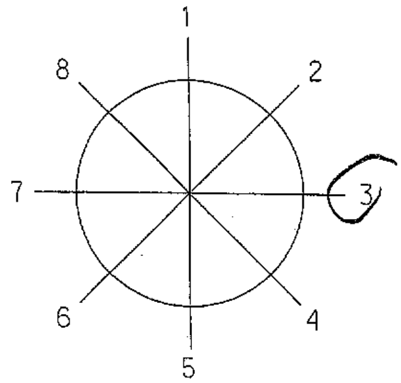
DEPTH OF CABLE INSPECTED 7 1/2"

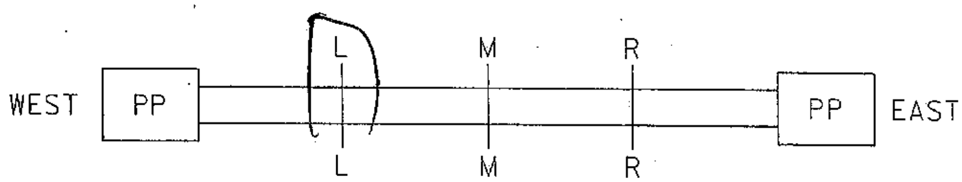


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

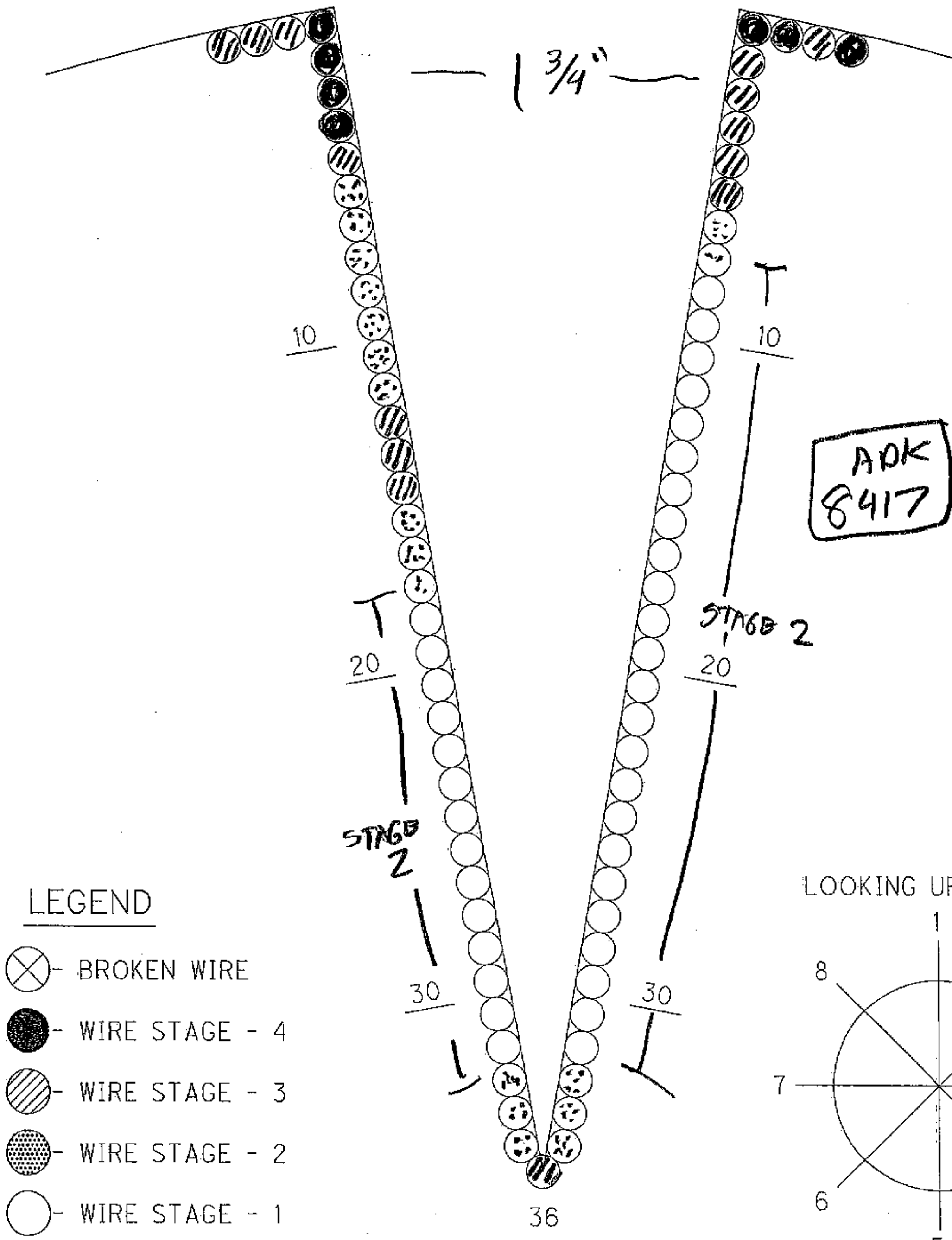
PREPARED BY: ADK

N CABLE ______ SIDE

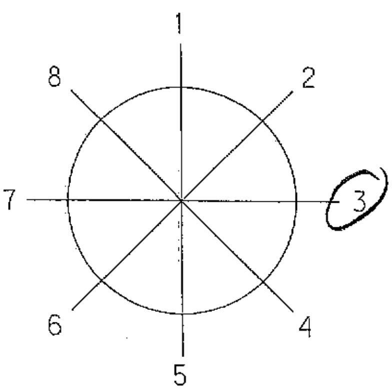
DATE: 11-16-12

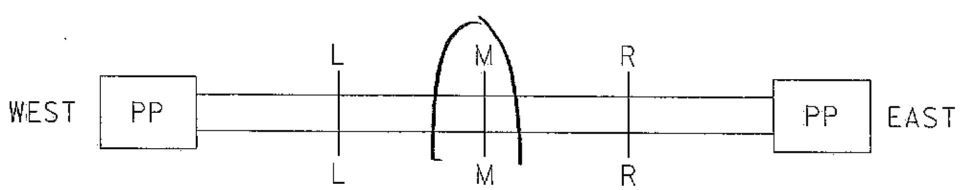
PANEL 31-32

DEPTH OF CABLE INSPECTED 7 1/4"



LOOKING UPSLOPE





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

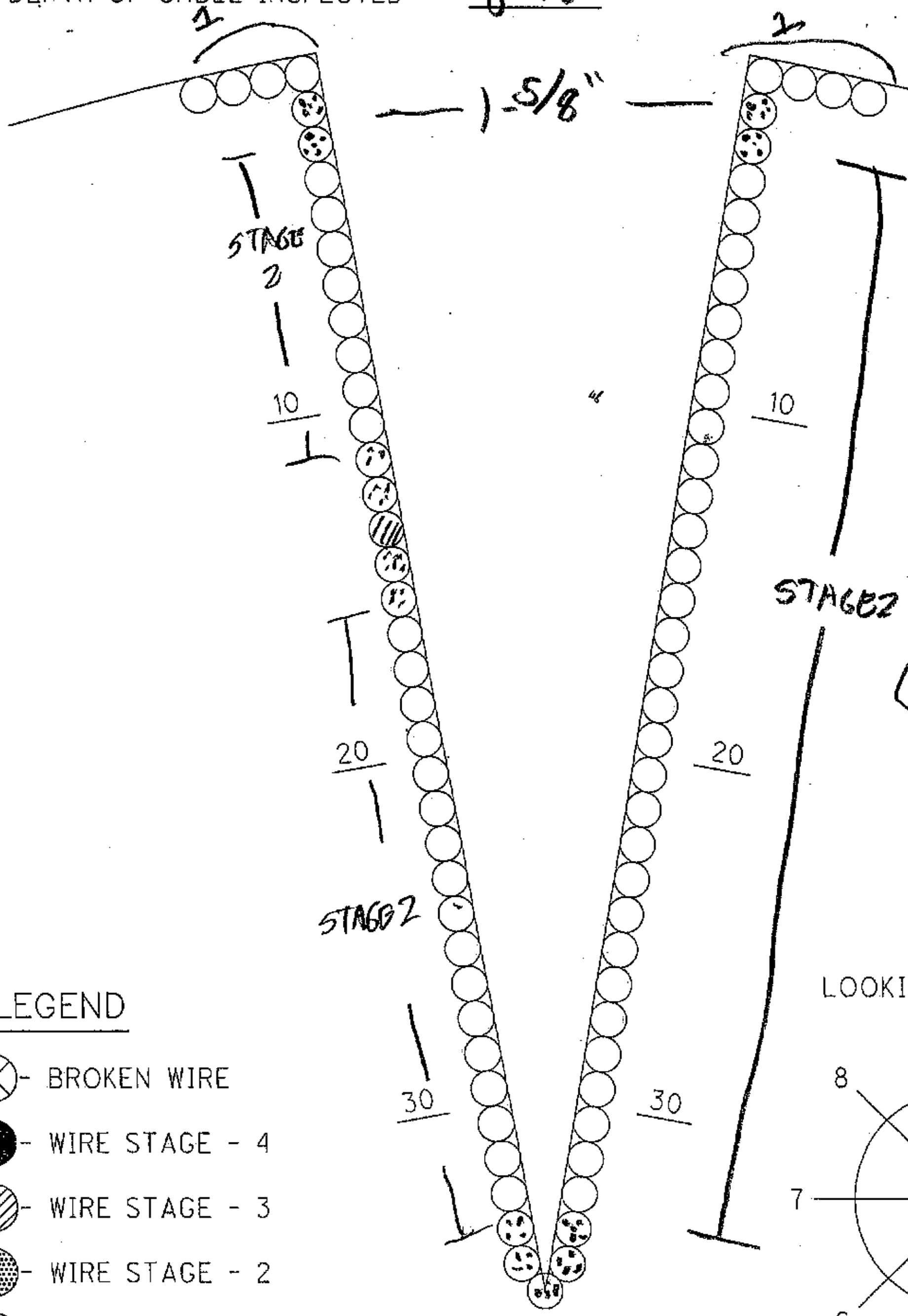
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 31-32

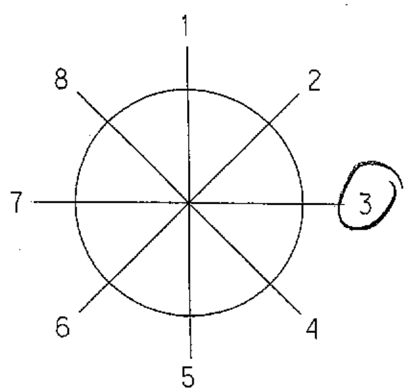
DEPTH OF CABLE INSPECTED 6 7/8"

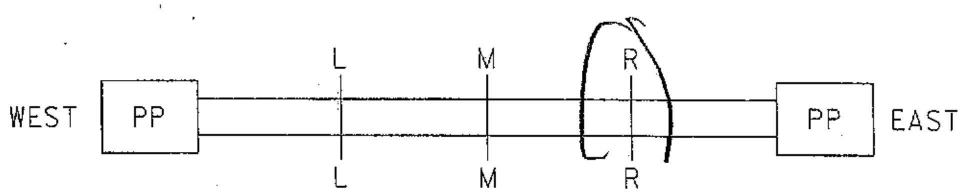


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

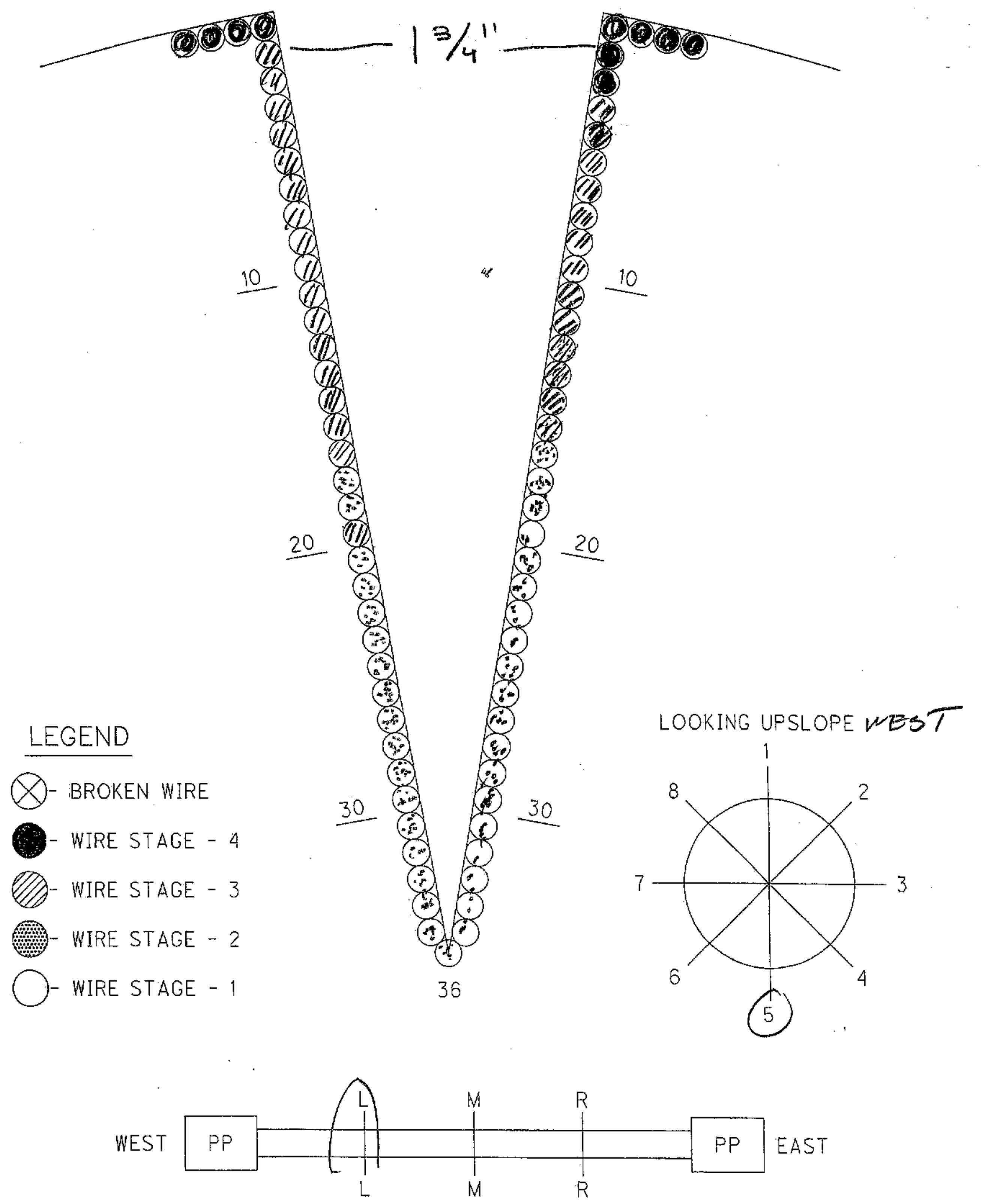
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL P31-32

DEPTH OF CABLE INSPECTED 7"



Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

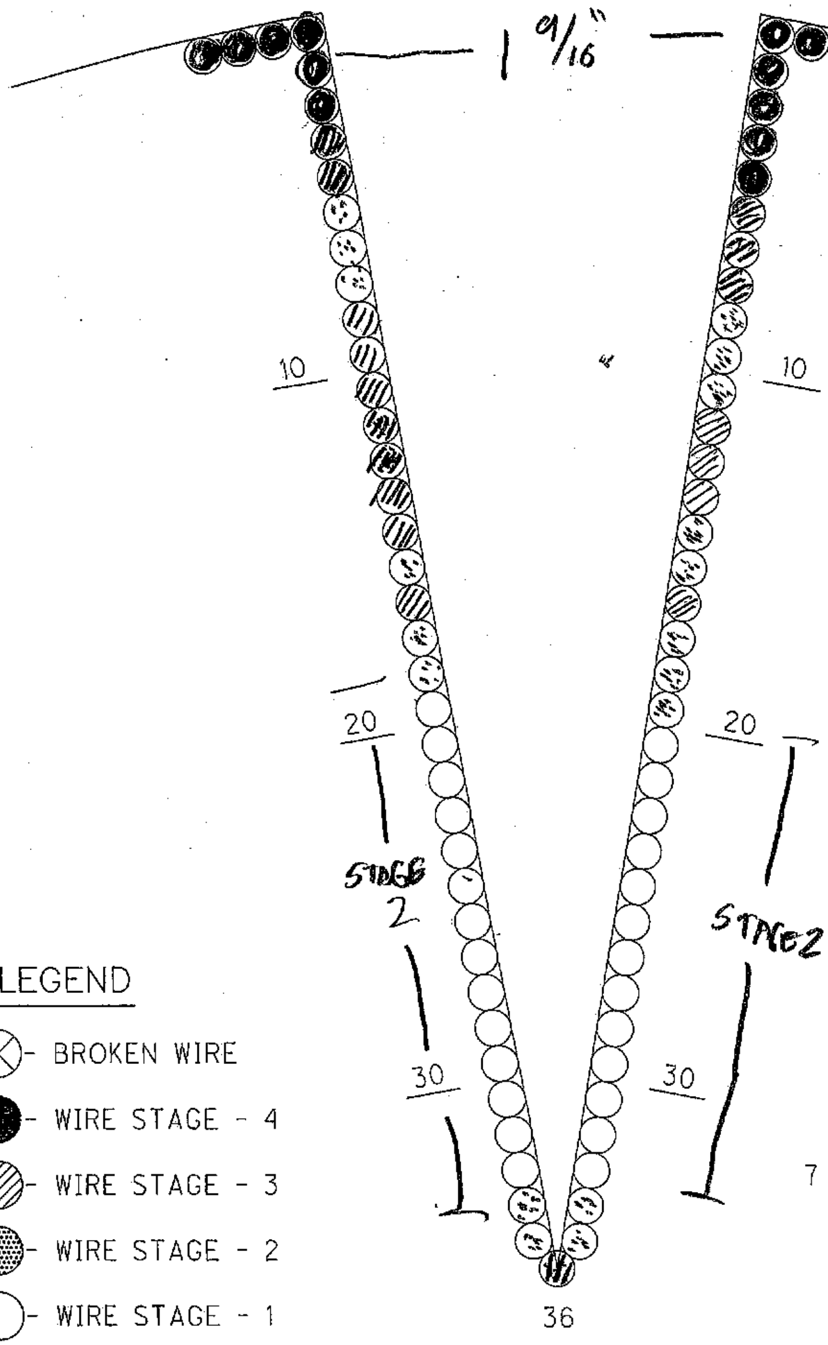
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 31-32

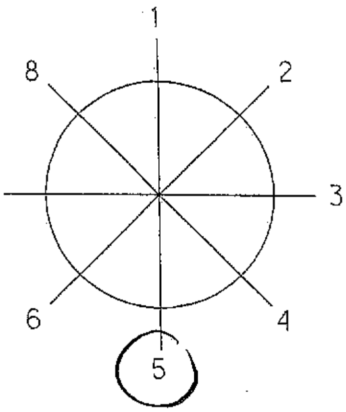
DEPTH OF CABLE INSPECTED ~~6 3/4"~~ 1 9/16"

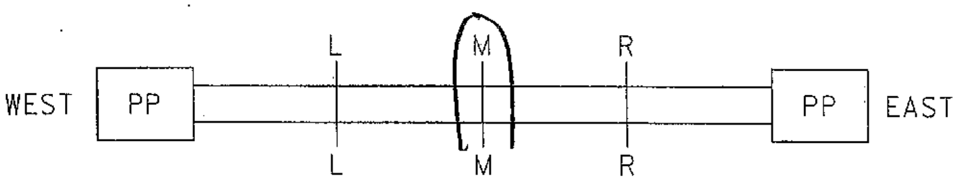


LEGEND

- ⊗ - BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

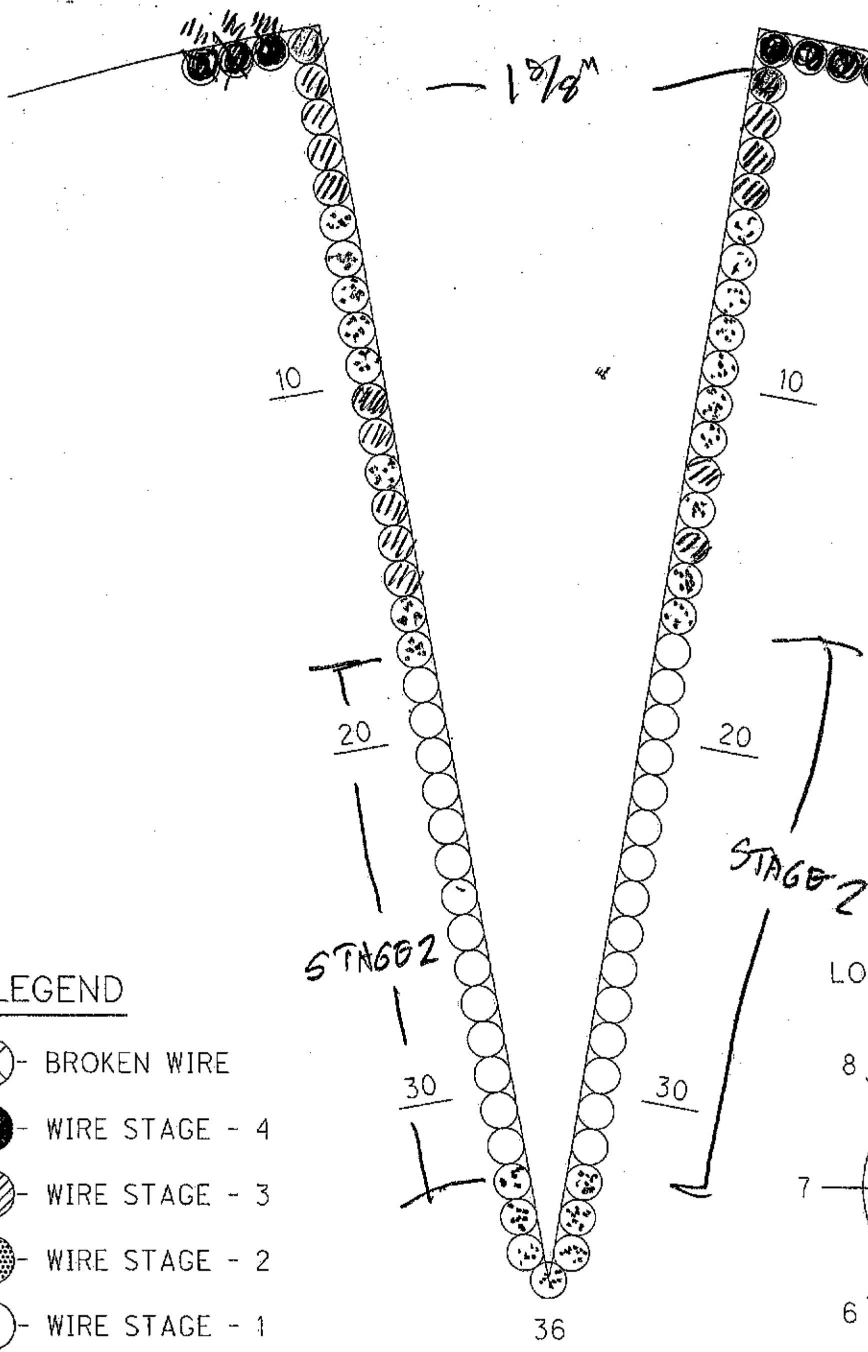
PREPARED BY: ADK

N CABLE ______ SIDE

DATE: 11-16-12

PANEL 31-32

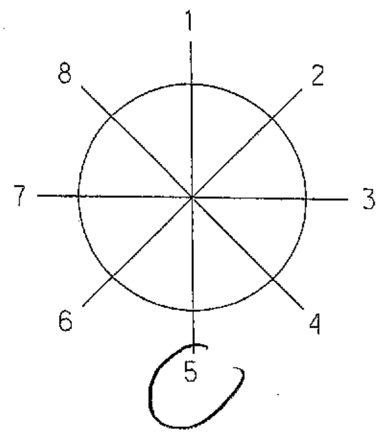
DEPTH OF CABLE INSPECTED 6 3/4"

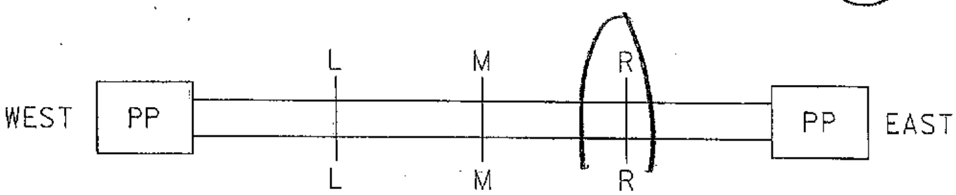


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE WEST





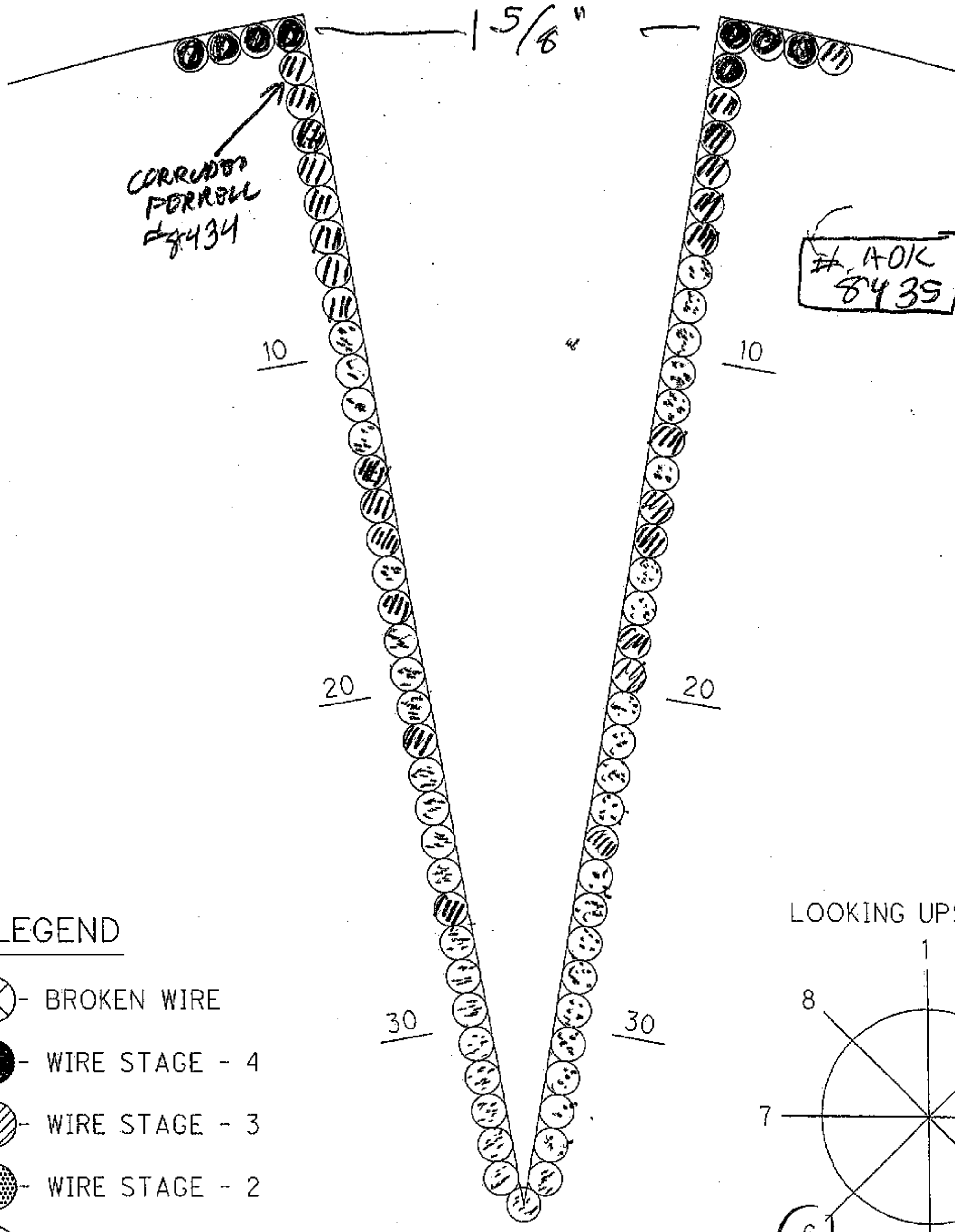
Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE PREPARED BY: ADK

_______ CABLE _______ SIDE DATE: 11-17-12

PANEL _______

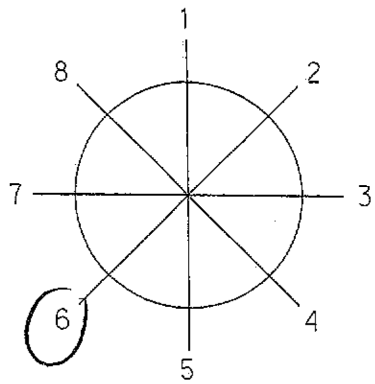
DEPTH OF CABLE INSPECTED 6"

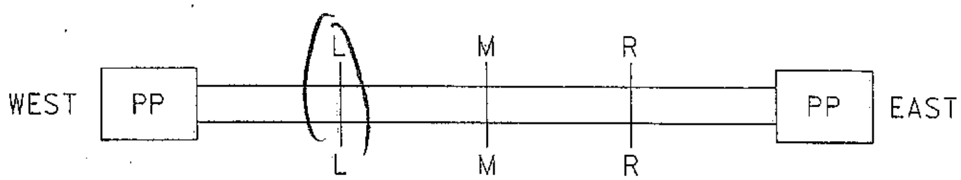


LEGEND

- ⊗ - BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

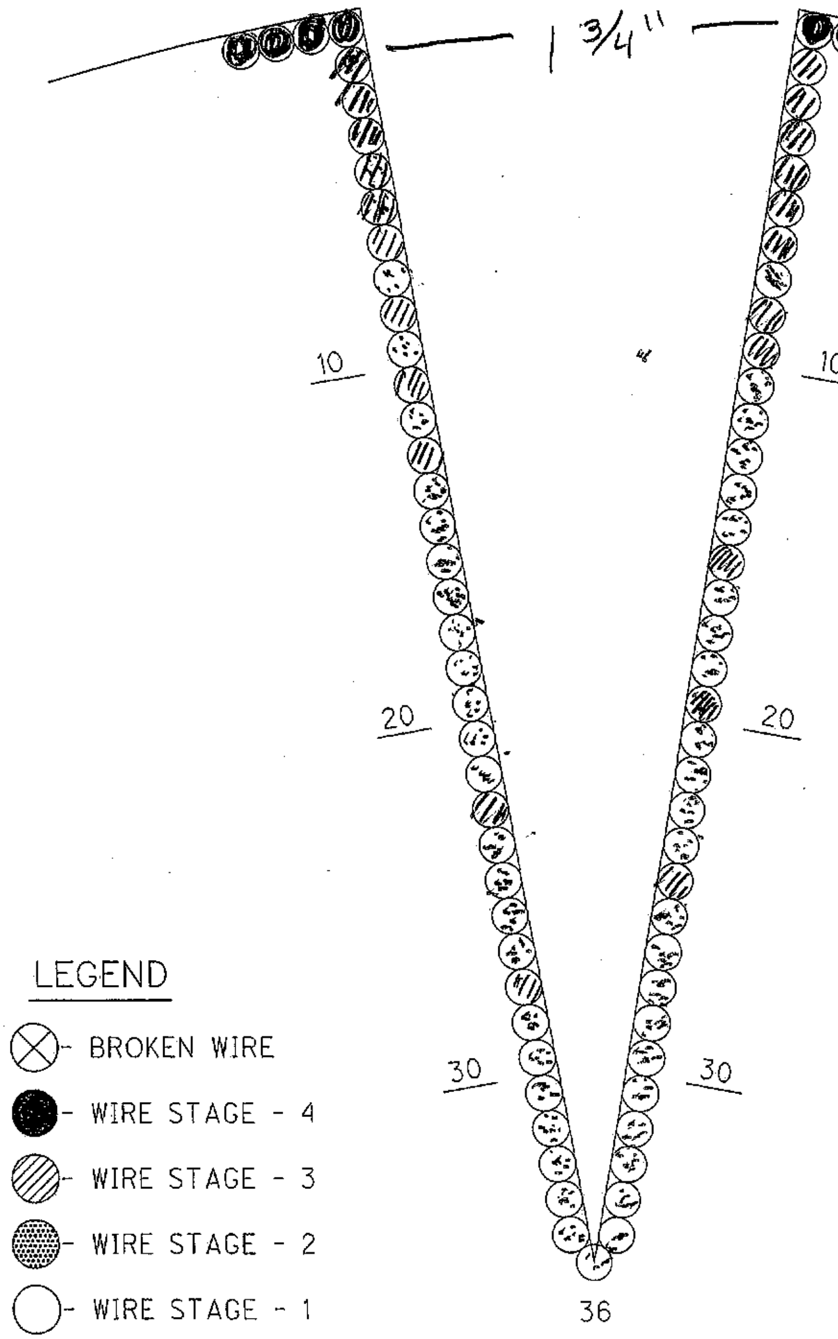
PREPARED BY: ADK

______ CABLE ______ SIDE

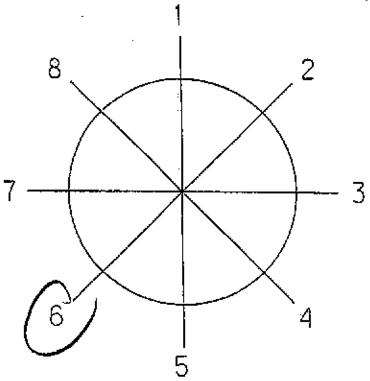
DATE: 11-17-12

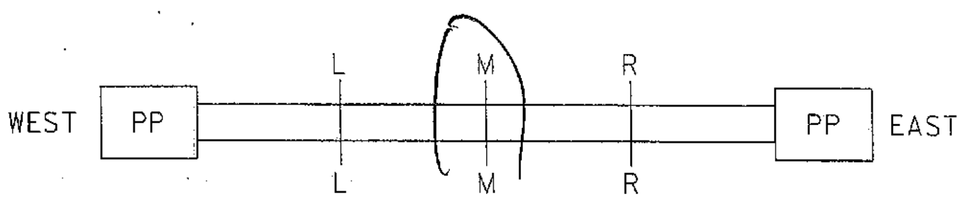
PANEL ______

DEPTH OF CABLE INSPECTED 7½



LOOKING UPSLOPE WEST





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

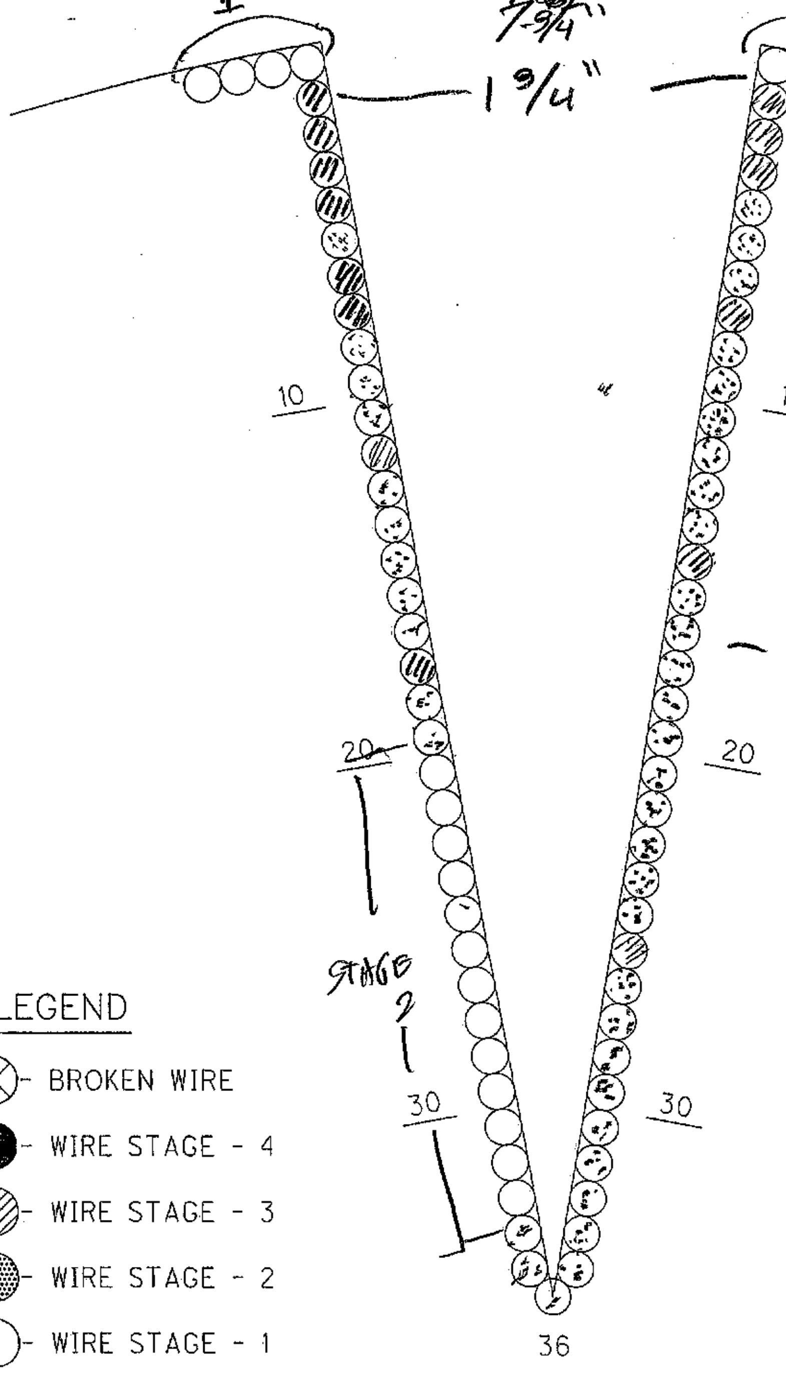
PREPARED BY: AOK

_______ CABLE _______ SIDE

DATE: 11-17-12

PANEL _________

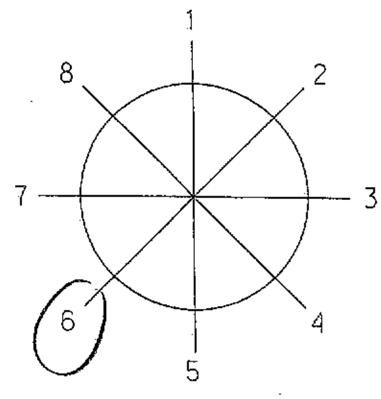
DEPTH OF CABLE INSPECTED ~~[illegible]~~ 1-3/4"

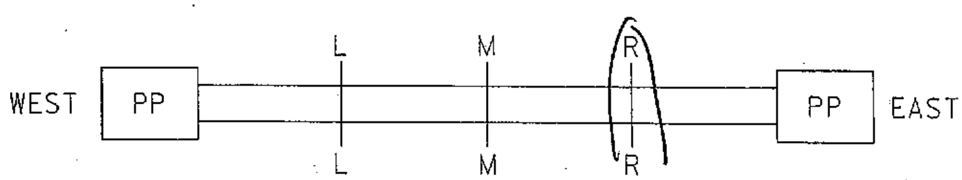


LEGEND

- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1

LOOKING UPSLOPE





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

PREPARED BY: ADK

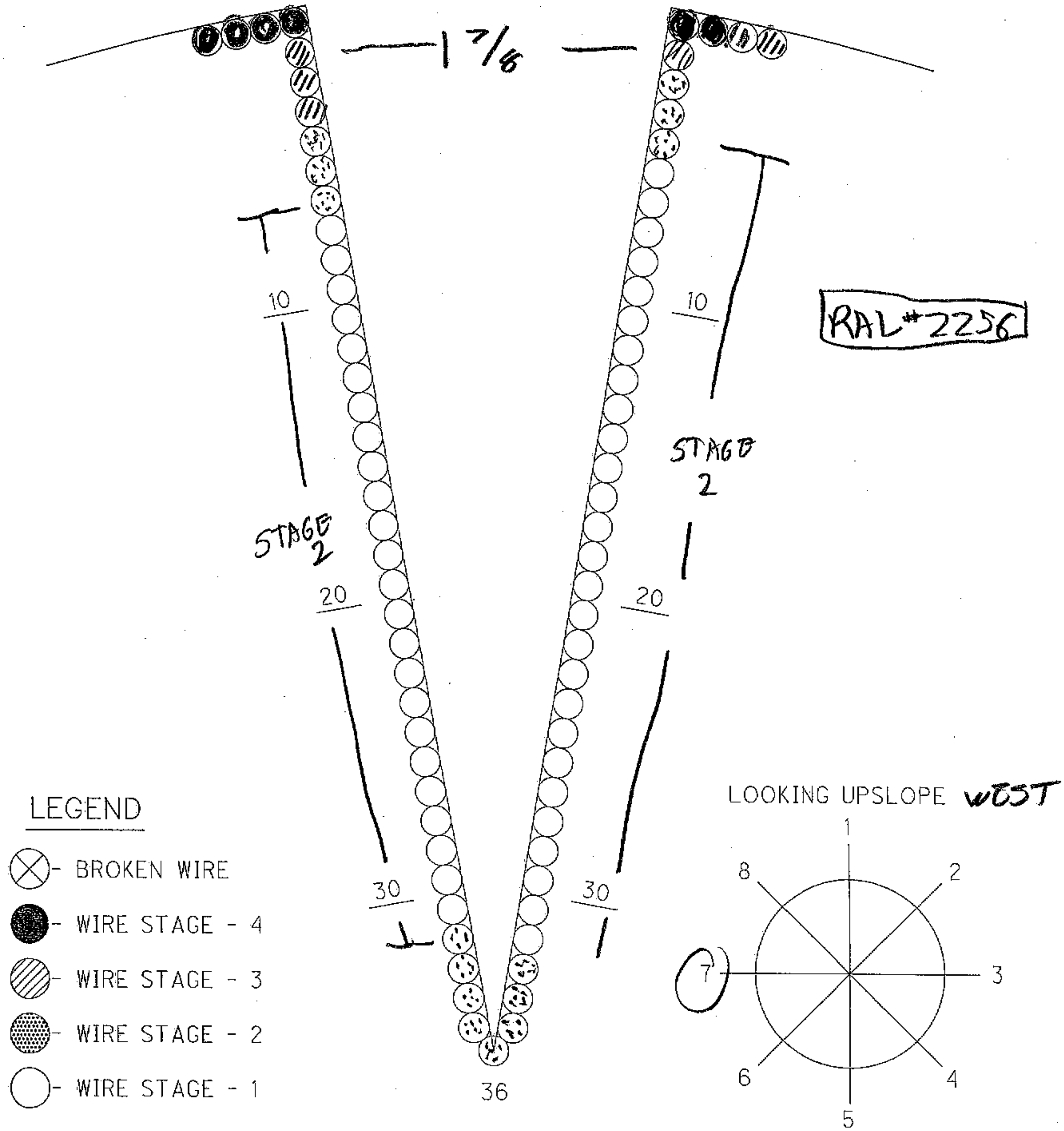
N CABLE ______ SIDE

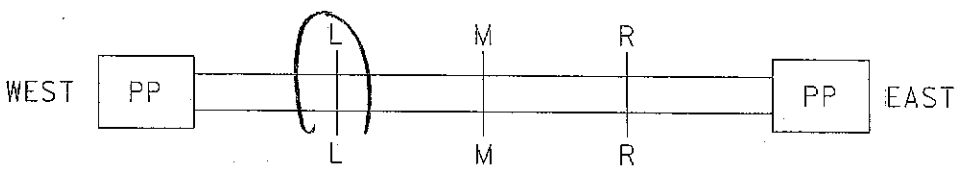
DATE: 11-16-12

PANEL 31-32

DEPTH OF CABLE INSPECTED 8 1/4"

RAL#2256





Total Wires ~~55~~ 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

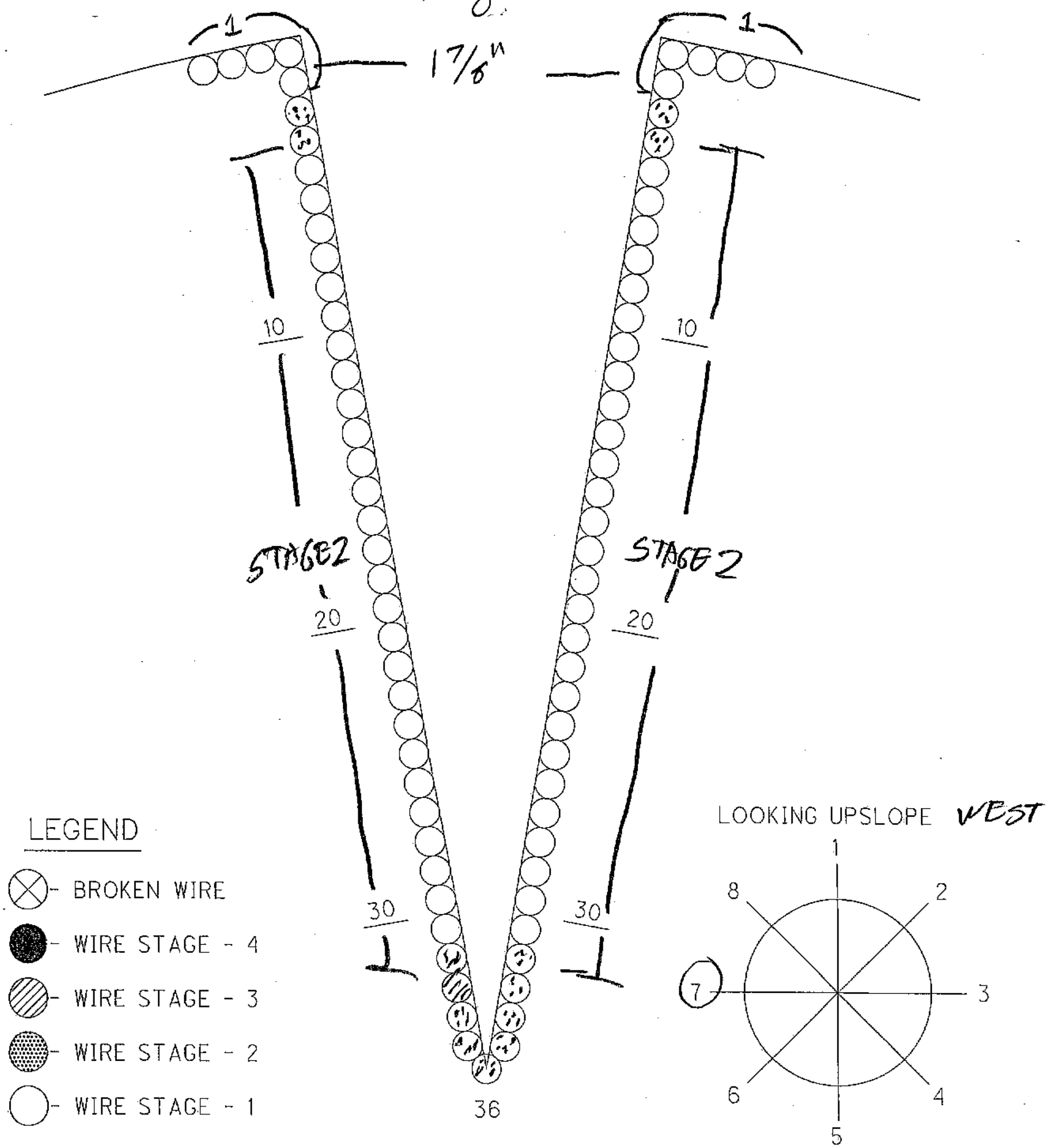
PREPARED BY: AOK

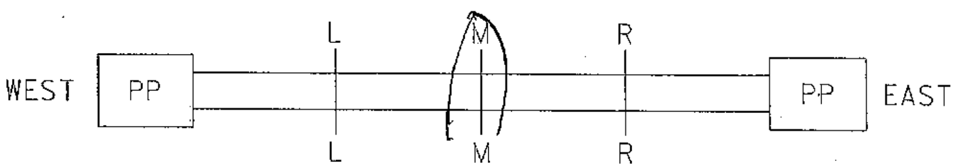
W CABLE ______ SIDE

DATE: 11-16-12

PANEL 31-32

DEPTH OF CABLE INSPECTED 8"





Total Wires 55 54

BRIDGE NAME: ANTHONY WAYNE BRIDGE

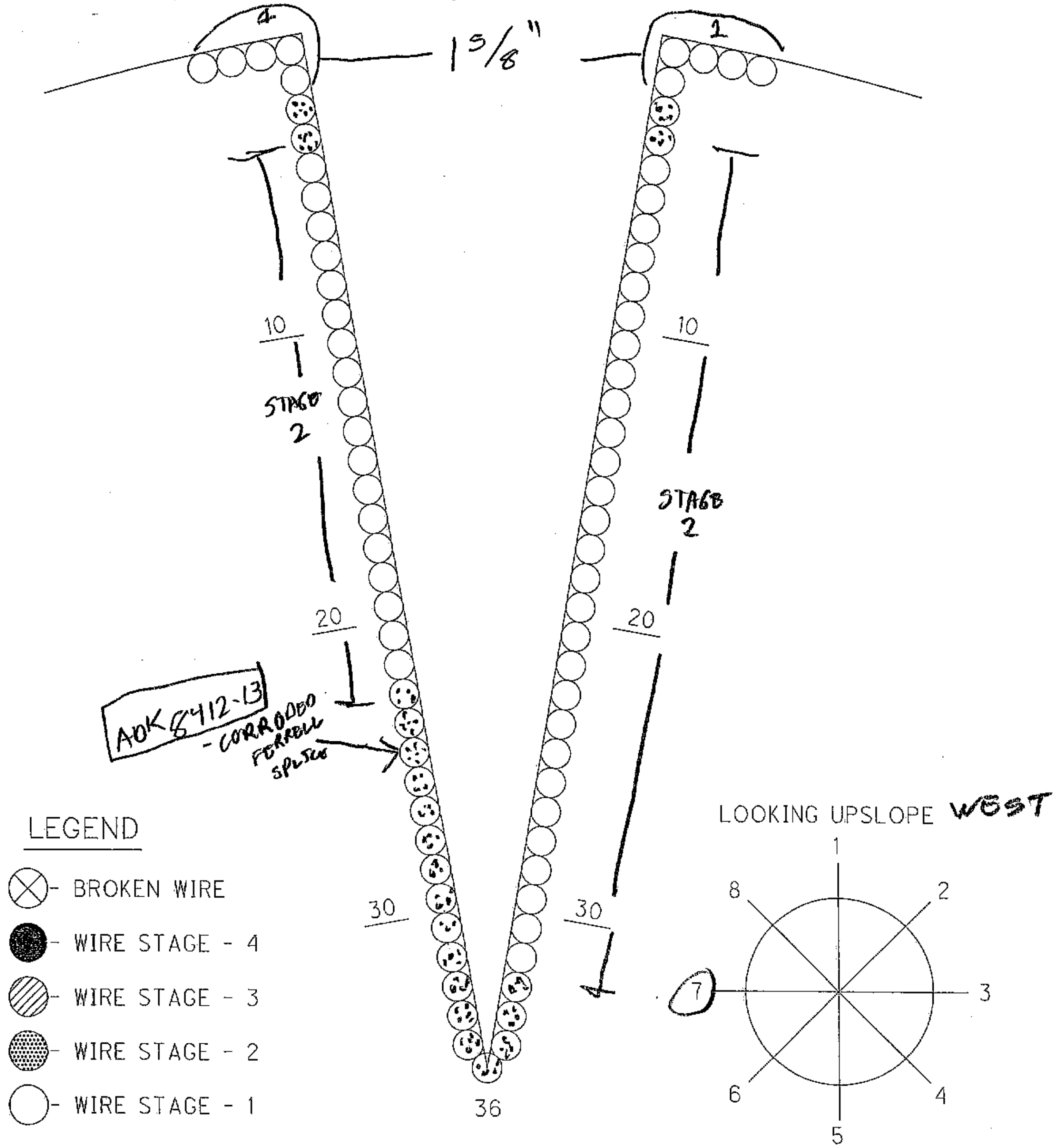
PREPARED BY: ADK

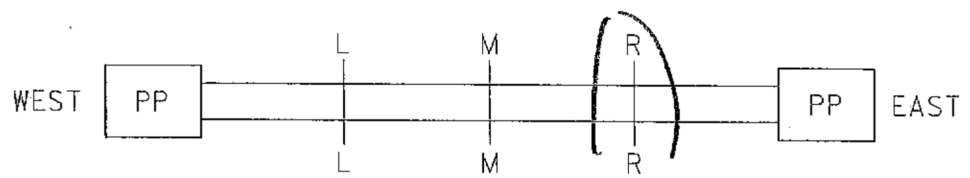
N CABLE ______ SIDE

DATE: 11-26-12

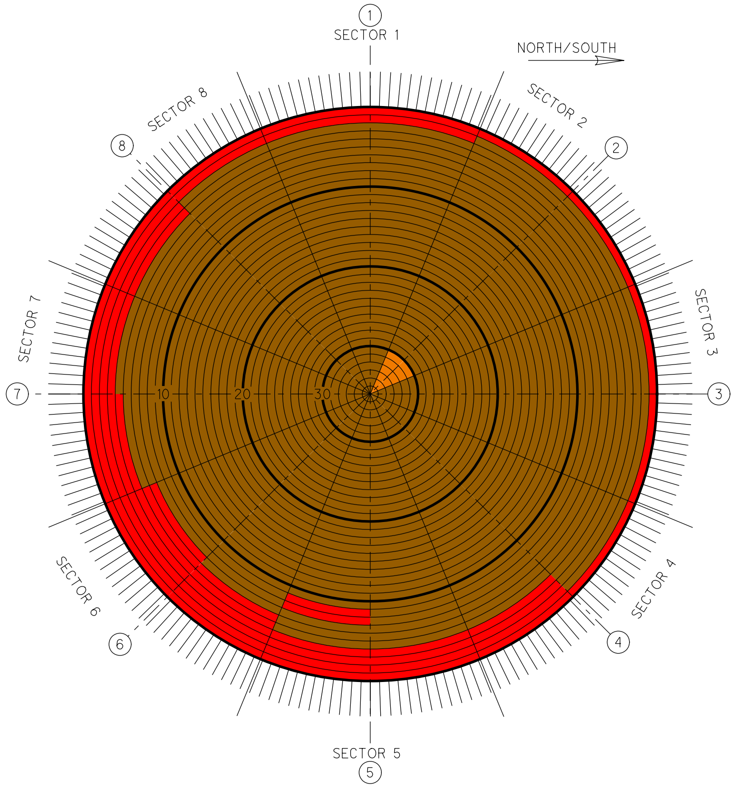
PANEL 31-32

DEPTH OF CABLE INSPECTED 6 3/4"



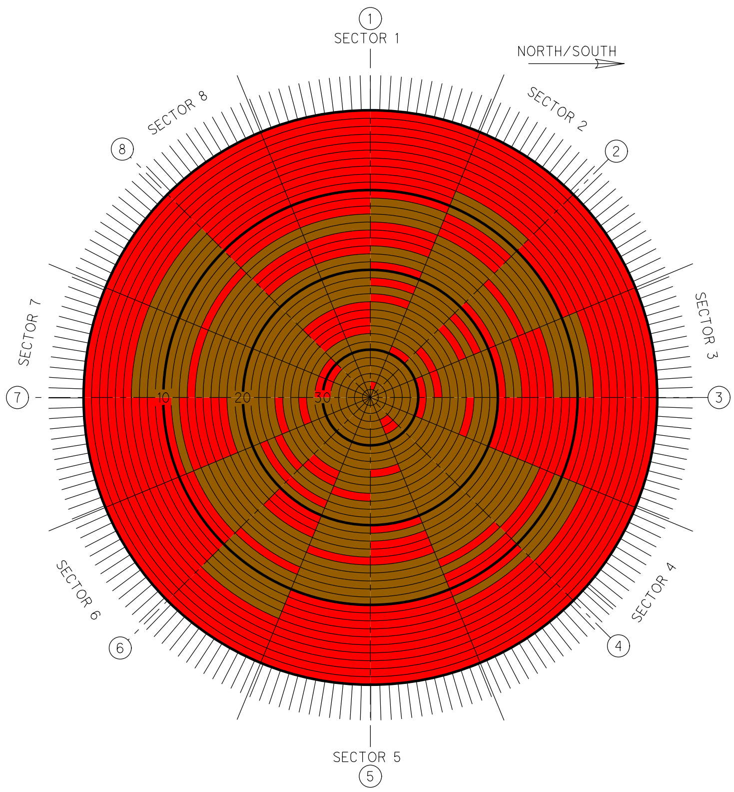


Cable Corrosion Plots

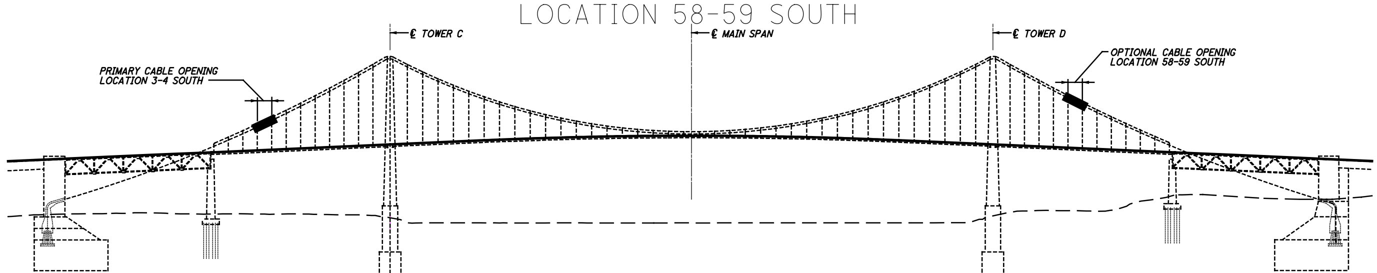


LOCATION 3-4 SOUTH

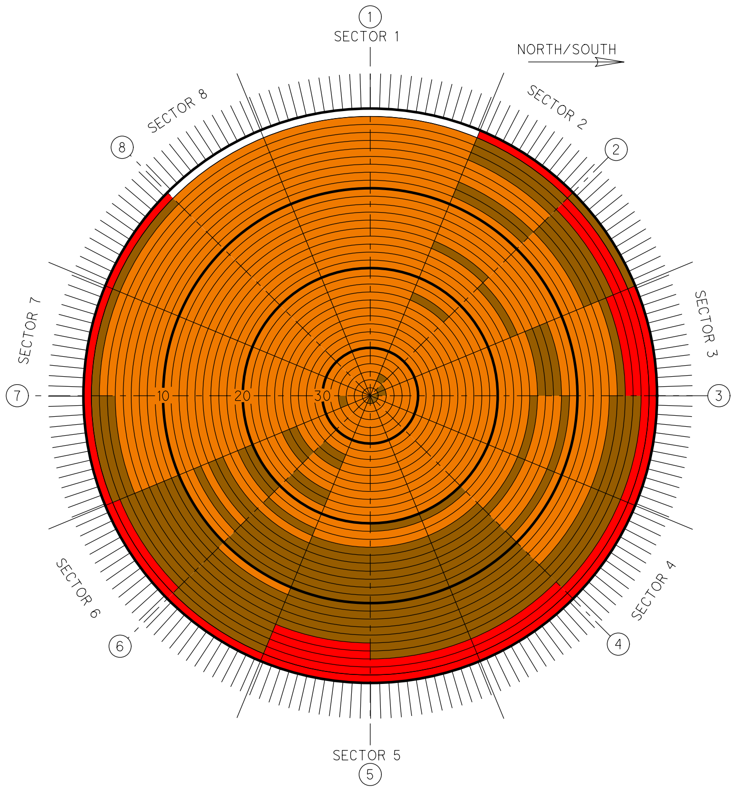
- BROKEN WIRE
- WIRE STAGE - 4
- WIRE STAGE - 3
- WIRE STAGE - 2
- WIRE STAGE - 1



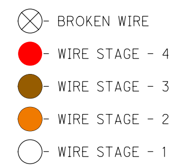
LOCATION 58-59 SOUTH

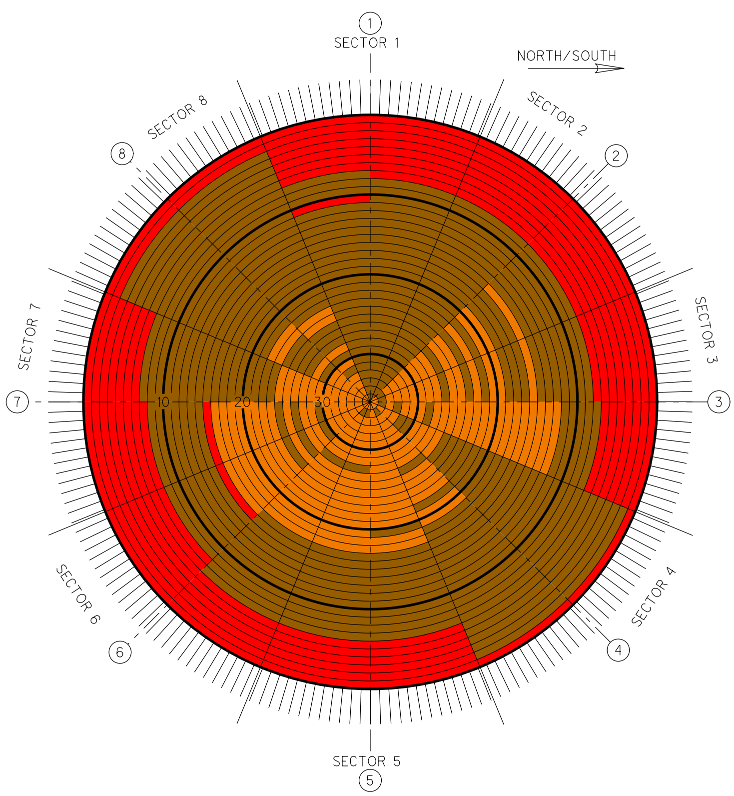


SOUTH CABLE ELEVATION
(LOOKING NORTH)

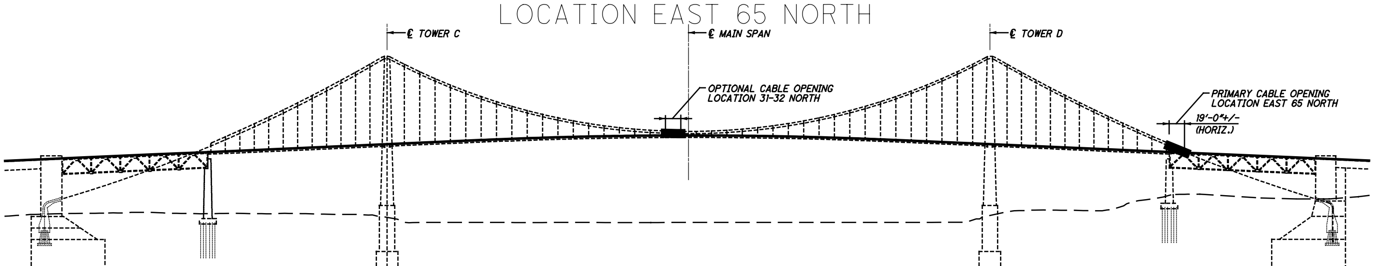


LOCATION 31-32 NORTH





LOCATION EAST 65 NORTH



NORTH CABLE ELEVATION
(LOOKING NORTH)

Daily Inspection Reports

ARCADIS
Infrastructure, environment, facilities

DAILY CONSTRUCTION REPORT

PROJECT: LUC-2-18.62 Cable Inspection Project CONTRACT: CL000681.B007 REPORT NO: 1

LOCATION: Toledo, Ohio DAY: Monday DATE: 11/12/12

CONTRACTOR: Piasecki Steel Const. Co. RPR/ENGINEER: M.S.L.

WEATHER		SITE CONDITIONS		WORK FORCE INCLUDING SUB-CONTRACTORS									OFF. ROUTING	
					F			F			F			
Temp AM	61	Dry		Superintendent	1		Ironworker		3	Plumber			PM	
Temp PM	38	Wet	X	Laborer			Mason			Millwright			PE	
Wind MPH	22	Frozen		Operators			Painter			Sheet Metal			CM	
Dry		Sand		Carpenter			Electrician			Trucker			Struct.	
Rain	X	Clay		Finisher			Flagger						Mech.	
Snow	X	Rock											Elect.	

OPERATING EQUIPMENT:

Loader [ ] Dozer [ ] Crane [X] Backhoe [ ] Road Grader [ ] Compactor [ ]

Others: To clarify, the crane is a truck crane. It is 1 of the 3 vehicles the Contractor has on site.

SUBCONTRACTORS:

WORK COMPLETED:

Since last visit:
First day on site. Construction crew arrived in Toledo Area yesterday evening.

Today:
Contractor self-preformed “maintenance of traffic” starting at 8am. The contractor notified a police officer to monitor the “maintenance of traffic” set-up. Both sides of the south side walk (downtown Toledo and East Toledo side) were also barricaded with a sign stating “sidewalk is closed”.

By mid-morning, the Contractor began installing scaffolding at “Primary Cable Opening Location 3-4 South (per contract drawing 15 of 16)”. The term Scaffolding may be a little misleading, its more of a 3’-0” wide walkway each side of cable and supported from the cable. To access the scaffolding, one must walk up the cable (while being tied off to cable walkway “guardrail cables”) and then step onto the scaffolding. The scaffolding has guardrail on each exterior side. The contractor finished erecting this scaffolding around 2 pm.

At 2pm, the Contractor moved his equipment and began installing scaffolding at “Optional Cable Opening Location 58-59 South (per contract drawing 15 of 16)”. The contractor finished erecting this scaffolding around 5:15pm.

No cables were unwrapped or opened today. Just the scaffolding was erected at the two south locations as explained above. The scaffolding guardrail was not installed because they needed some additional hardware to get them put together.

See attached photo’s documenting today’s work. The rain/snow stopped about 3pm.

COMMENTS:

Tomorrow, the Contractor plans to put the guardrail on both South cable opening scaffolding locations and then begin to unwrap “Primary Cable Opening Location 3-4 South (per contract drawing 15 of 16)”. Dick Little and Austin Kieffer (from Modjeski and Masters) is expected to be at the site in the morning. Dick and Austin’s cable inspection could start sometime tomorrow.

FYI – I have noticed approximately 10 people walking along the north sidewalk between 2-5pm.

BY: Matt Lotycz

ARCADIS
Infrastructure, environment, facilities

DAILY CONSTRUCTION REPORT

PROJECT: LUC-2-18.62 Cable Inspection Project — CONTRACT: CL000681.B007 — REPORT NO: 2

LOCATION: Toledo, Ohio — DAY: Tuesday — DATE: 11/13/12

CONTRACTOR: Piasecki Steel Const. Co. — RPR/ENGINEER: M.S.L.

WEATHER		SITE CONDITIONS		WORK FORCE INCLUDING SUB-CONTRACTORS									OFF. ROUTING	
					F			F			F			
Temp AM	37	Dry		Superintendent	1		Ironworker		4	Plumber			PM	
Temp PM	32	Wet	X	Laborer			Mason			Millwright			PE	
Wind MPH	13	Frozen		Operators			Painter			Sheet Metal			CM	
Dry		Sand		Carpenter			Electrician			Trucker			Struct.	
Rain		Clay		Finisher			Flagger						Mech.	
Snow		Rock											Elect.	

OPERATING EQUIPMENT:

Loader [ ] Dozer [ ] Crane [X] Backhoe [ ] Road Grader [ ] Compactor [ ]

Others: To clarify, the crane is a truck crane. It is 1 of the 3 vehicles the Contractor has on site.

SUBCONTRACTORS: Dick Little (Chief Investigator) and Austin Kieffer (Assistant Investigator) from Modjeski and Masters

WORK COMPLETED:

Today:

The contractor (Bill Bruno-Piasecki) approached me and David Geckle (ODOT) at 8am to discuss the “cable band bolt tightening plan”. The contractor raised his concern that he was very confident due to the current protective coating on the cable band bolts there was no way he could conduct the tightening plan without damaging the bolt. The result of a damaged bolt would require a tie-rod installed in its place to fix it. The contractor felt the tightening plan would do more damage to the bolts than good and felt very confident without the tightening plan the sample wires to be cut would still only “slide” 1/8 to ¼”. This issue was discussed at the pre-construction meeting held at ODOT BG office on Nov 2nd. ODOT bridge engineer deferred the decision to M&M. Scott Eshenaur of M&M was called and decided that he would waive the “cable band bolt tightening plan requirement. However, Scott required the contractor to monitor/record the “wire slip measurement”. Scott will be kept informed of this “wire slip measurement” and Scott reserved the right to revisit the “cable band bolt tightening plan” if the wire slipped more than expected.

<u>At “Primary Cable Opening Location 3-4 South (per contract drawing 15 of 16)”:</u>

Contractor began installing guardrail on exterior sides of scaffolding at “Primary Cable Opening Location 3-4 South (per contract drawing 15 of 16)”. Then at 9am the contractor removed the cableguard wrap and Dick/Austin measured the existing circumference of the cable (before the wire wrap was removed). At 9:45am the contractor began removing the lead paint on the wire wrap and began removing the wire wrap itself. Between 10:15-10:45 the contractor wedged the cables open at the 12/3/6//9 o’clock positions. Dick and Austin of M&M began their cable investigation following this. Shortly after lunch (about 1:30pm), the contractor installed 2 more wedge locations (total of 6 “clock positions”). Dick and Austin of M&M then completed their cable investigation and located/tagged 3 wires to be sampled. Please see M&M cable inspection report for more information. The contractor installed a double wrap of waterproof plastic around the main cable to protect it overnight.

<u>At “Optional Cable Opening Location 58-59 South (per contract drawing 15 of 16)”:</u>

While the “Primary Cable Opening Location 3-4 South” was being investigated by M&M”, the contractor began installing guardrail on exterior sides of scaffolding. Shortly after lunch, Dick and Austin of M&M measured the existing circumference of the cable. M&M noticed traces of water leaking from the underside of the wire wrap. Then the contractor began removing the lead paint and the existing wire wrap. Dick and Austin of M&M watched as this was removed and did not notice water after the wire wrap was removed. The contractor installed a double wrap of waterproof plastic around the main cable to protect it overnight.

FYI - Austin of M&M determined that the 1993 M&M report that indicated cable investigation on the south cable in Window D was actually in the current South Location 2-3.

ARCADIS
Infrastructure, environment, facilities

PROJECT:	LUC-2-18.62 Cable Inspection Project	CONTRACT:	CL000681.B007	REPORT NO:	2
LOCATION:	Toledo, Ohio	DAY:	Tuesday	DATE:	11/13/12
CONTRACTOR:	Piasecki Steel Const. Co.	RPR/ENGINEER:	M.S.L.		

See attached photo's documenting today's work. Very light snow started and stopped between 8:30 and 9am.

COMMENTS:

Tomorrow, the Contractor plans to wedge the "Optional Cable Opening Location 58-59 South" to allow for Dick and Austin of M&M to begin their investigation and then begin taking samples from the "Primary Cable Opening Location 3-4 South". the site in the morning. Dick and Austin's cable inspection could start sometime tomorrow.

FYI – I have noticed approximately 5 people walking along the north sidewalk between 8-10am.

BY: Matt Lotycz

ARCADIS
Infrastructure, environment, facilities

DAILY CONSTRUCTION REPORT

PROJECT: LUC-2-18.62 Cable Inspection Project   CONTRACT: CL000681.B007   REPORT NO: 3

LOCATION: Toledo, Ohio   DAY: Wednesday   DATE: 11/14/12

CONTRACTOR: Piasecki Steel Const. Co.   RPR/ENGINEER: M.S.L.

WEATHER		SITE CONDITIONS		WORK FORCE INCLUDING SUB-CONTRACTORS	F			F			F		OFF. ROUTING	
Temp AM	30	Dry		Superintendent	1		Ironworker		4	Plumber			PM	
Temp PM	41	Wet		Laborer			Mason			Millwright			PE	
Wind MPH	7	Frozen		Operators			Painter			Sheet Metal			CM	
Dry		Sand		Carpenter			Electrician			Trucker			Struct.	
Rain		Clay		Finisher			Flagger						Mech.	
Snow		Rock											Elect.	

OPERATING EQUIPMENT:

Loader [ ] Dozer [ ] Crane [X] Backhoe [ ] Road Grader [ ] Compactor [ ]

Others: To clarify, the crane is a truck crane. It is 1 of the 3 vehicles the Contractor has on site.

SUBCONTRACTORS: Dick Little (Chief Investigator) and Austin Kieffer (Investigator Assistant) from Modjeski and Masters

WORK COMPLETED:

Today:

At "Optional Cable Opening Location 58-59 South (per contract drawing 15 of 16)":

The contractor started at this location. Contractor removed the double wrap of waterproof plastic around the main cable (used to protect it overnight). Then, under the supervision of Dick and Austin of M&M, the contractor began to drive 4 wedges (12/3/6/9 o'clock positions) (7:50 to 8:50am). After this was done the contractor left this location and went to "Primary Cable Opening Location 3-4 South". Dick and Austin conducted their inspection of the cable. Then based on the condition of the cable, Dick and Austin determined 3 more locations for the cable to be wedged. The contractor did these 3 locations before finishing for the day. The contractor placed a double wrap of waterproof plastic around the main cable to protect it overnight.

At "Primary Cable Opening Location 3-4 South (per contract drawing 15 of 16)":

Contractor removed the double wrap of waterproof plastic around the main cable (used to protect it overnight). Then, under the supervision of Dick and Austin of M&M, the contractor took the 3 samples. The sample lengths were all about 7'-11 ¾" +/-. Dick and Austin of M&M mentioned that they measured the amount of wire slip (with marks) towards the bottom of the cable in the range of 1/16 to 1/8" (at the top the cut wire was approx ½" away when trying to line it up with the cut wire at the top). Austin made Scott of M&M aware of the wire slip amount due to the issue of "waiving of the cable band tightening". The 3 samples were taken at 9:40/9:54/10:04am. Once the samples were taken, the cable was prepared (loose red lead removed) and the splicing operations began. Please see daily photos for the tools and the process used on the splice. Like it was discussed at the pre-construction meeting at the ODOT BG office, the contractor used 1 ferrule and 1 turnbuckle along with a come-along to tension the existing and new wire together. Even though the contractor was utilizing a force gauge attached to the come-along (overheard the contractor reading and stating a range of 1500-2000# of force for the 3 splices), the contractor was keeping an eye to see the cut lines and the splices lines matched up since that is one way to know the newly splices wire has the same amount of tension as the old. The last process of the splice was to put the new splice wire back into location it had come from. Then the wedges were removed. Once all the wedges were pulled, it looked as though cable had resumed its original shape. Then the contractor began compacting the wire with the machine they submitted. They used ¾" SST straps with neoprene bond breaker between the strap and the cable wire. The SST straps were spaced at 18" c/c along the cable opening starting at the cable band. The contractor then took a soft brush and hose to remove the remaining red lead particles on the cable. The contractor placed a double wrap of waterproof plastic around the main cable to protect it overnight.

The contractor has the samples and will send them to Lucius Pitkin, Inc for testing as described on contract drawing #14.

See attached photo's documenting today's work.

ARCADIS
Infrastructure, environment, facilities

PROJECT:	LUC-2-18.62 Cable Inspection Project	CONTRACT:	CL000681.B007	REPORT NO:	3
LOCATION:	Toledo, Ohio	DAY:	Wednesday	DATE:	11/14/12
CONTRACTOR:	Piasecki Steel Const. Co.	RPR/ENGINEER:	M.S.L.		

COMMENTS:

Tomorrow, the Contractor plans to begin cableguard wrapping the "Primary Cable Opening Location 3-4 South (per contract drawing 15 of 16)". The D.S. Brown field representative is supposed to be at the site tomorrow to show/work with the contractor on the cableguard wrap.

Dick Little and Austin Kieffer (from Modjeski and Masters) will be starting at the "Optional Cable Opening Location 58-59 South (per contract drawing 15 of 16)" to finish their cable investigation now that the last 3 wedges have been driven. Then sampling will begin.

Sometime tomorrow the contractor expects to start setting up traffic control on the other side of the bridge so that he can start opening up the south cable locations sometime on Friday.

BY: Matt Lotycz

ARCADIS
Infrastructure, environment, facilities

DAILY CONSTRUCTION REPORT

PROJECT:	LUC-2-18.62 Cable Inspection Project	CONTRACT:	CL000681.B007	REPORT NO:	4
LOCATION:	Toledo, Ohio	DAY:	Thursday	DATE:	11/15/12
CONTRACTOR:	Piasecki Steel Const. Co.	RPR/ENGINEER:	M.S.L.		

WEATHER		SITE CONDITIONS		WORK FORCE INCLUDING SUB-CONTRACTORS									OFF. ROUTING	
					F			F			F			
Temp AM	32	Dry		Superintendent	1		Ironworker		4	Plumber			PM	
Temp PM	46	Wet		Laborer			Mason			Millwright			PE	
Wind MPH	6	Frozen		Operators			Painter			Sheet Metal			CM	
Dry		Sand		Carpenter			Electrician			Trucker			Struct.	
Rain		Clay		Finisher			Flagger						Mech.	
Snow		Rock											Elect.	

OPERATING EQUIPMENT:

Loader		Dozer		Crane	X	Backhoe		Road Grader		Compactor	

Others: To clarify, the crane is a truck crane. It is 1 of the 3 vehicles the Contractor has on site.

SUBCONTRACTORS: Dick Little (Chief Investigator) and Austin Kieffer (Investigator Assistant) from Modjeski and Masters.

WORK COMPLETED:

Today:

At “Optional Cable Opening Location 58-59 South (per contract drawing 15 of 16)”:

The contractor removed the double wrap of waterproof plastic around the main cable (used to protect it overnight). Dick and Austin continued their inspection of the cable since 3 additional wedges had been driven the day before. Dick marked 3 locations to be sampled. Ed Adamczyk from ARCADIS visited the site and inspected this location twice, once in the morning with Dick and Austin and once again in the afternoon with Dick, David Geckle (ODOT), Jim Bradley (ODOT), and 1 other ODOT inspector. The contractor placed a double wrap of waterproof plastic around the main cable to protect it overnight.

At “Primary Cable Opening Location 3-4 South (per contract drawing 15 of 16)”:

Contractor removed the double wrap of waterproof plastic around the main cable (used to protect it overnight). D.S. Brown, the cableguard wrap manufacturer arrived at the site around 9am and began working with the contractor to demonstrate how the cableguard wrap needs to be installed (i.e. wrap overlap dimensions, wrap splices, wrap heating requirements) and special products and sealant needed at each cable band bolt location. The contractor did install 2 pieces of neoprene over the top of every SST banding strap clips so that the cableguard would not be impacted. Then D.S. Brown also worked with the contractor to install the slip proof top walking surface on the finished cableguard surface. The contractor left the scaffolding in this location but all of cable related work is complete at this location.

At “Primary Cable Opening Location East 65 North (per contract drawing 15 of 16)”:

The contractor set up traffic control and closed the northbound lane in order to get to the work needed on the north cables. The contractor did put up a temporary kneewall when working at this location so that the sidewalk could be left open to pedestrians. The contractor would stop his work activities when pedestrians walked by just to be cautious. The contractor removed the existing cableguard, double layer of wire wrap with sheet metal between the layers, and wedged the cables (between 3:10 and 4:10pm) in 4 clock positions (12/3/6/9). Dick and Austin begin their inspection of the cable and worked till the end of the day. The contractor placed a double wrap of waterproof plastic around the main cable to protect it overnight.

See attached photo’s documenting today’s work.

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Infrastructure, environment, facilities

PROJECT:	LUC-2-18.62 Cable Inspection Project	CONTRACT:	CL000681.B007	REPORT NO:	4
LOCATION:	Toledo, Ohio	DAY:	Thursday	DATE:	11/15/12
CONTRACTOR:	Piasecki Steel Const. Co.	RPR/ENGINEER:	M.S.L.		

COMMENTS:

Tomorrow, the Contractor plans to begin taking samples from the "Optional Cable Opening Location 58-59 South (per contract drawing 15 of 16)".

Dick Little and Austin Kieffer (from Modjeski and Masters) will be starting at the "Primary Cable Opening Location East 65 North (per contract drawing 15 of 16)" to finish their cable.

BY: Matt Lotycz

ARCADIS
Infrastructure, environment, facilities

DAILY CONSTRUCTION REPORT

PROJECT: LUC-2-18.62 Cable Inspection Project CONTRACT: CL000681.B007 REPORT NO: 5

LOCATION: Toledo, Ohio DAY: Friday DATE: 11/16/12

CONTRACTOR: Piasecki Steel Const. Co. RPR/ENGINEER: M.S.L.

WEATHER		SITE CONDITIONS		WORK FORCE INCLUDING SUB-CONTRACTORS									OFF. ROUTING	
					F			F			F			
Temp AM	30	Dry		Superintendent	1		Ironworker		4	Plumber			PM	
Temp PM	50	Wet		Laborer			Mason			Millwright			PE	
Wind MPH	5	Frozen		Operators			Painter			Sheet Metal			CM	
Dry		Sand		Carpenter			Electrician			Trucker			Struct.	
Rain		Clay		Finisher			Flagger						Mech.	
Snow		Rock											Elect.	

OPERATING EQUIPMENT:
Loader [ ] Dozer [ ] Crane [X] Backhoe [ ] Road Grader [ ] Compactor [ ]
Others: To clarify, the crane is a truck crane. It is 1 of the 3 vehicles the Contractor has on site.

SUBCONTRACTORS: Dick Little (Chief Investigator) and Austin Kieffer (Investigator Assistant) from Modjeski and Masters.

WORK COMPLETED:

Today:
At “Optional Cable Opening Location 58-59 South (per contract drawing 15 of 16)”:
The contractor did not work at this location today and therefore left the double wrap of waterproof plastic around the main cable to protect it overnight.

At “Primary Cable Opening Location 3-4 South (per contract drawing 15 of 16)”:
Dave and I did one inspection at this location. Circumference dimensions were also taken (after wrapped condition) at this time to aid M&M so they could continue their cable investigations at other locations. The contractor placed a bead of caulk at the cableguard to cable band interface and then at any nicked/scratched locations on the cable band side edge itself. The contractor then removed the scaffolding and is now completely done at this location.

At “Primary Cable Opening Location East 65 North (per contract drawing 15 of 16)”:
When the contractor first arrived at the site in the morning he removed the double wrap of waterproof plastic around the main cable (which protected it overnight). Dick and Austin began their morning at this location by continuing their initial inspection of the cable from the day before. 2 samples were identified. Once completed with the initial inspection, the contractor drove 2 more wedge locations per Dick’s request (between 10:35-11am). Then 2 samples were taken. Sample #7 was cut at 2:29pm (it was a stage 4 wire, taken from the 6 o’clock position, sample length of 8’-11 9/16”, had 1/16” slippage top and bottom, and about ½” retraction of cut to existing wire at top location). Sample #8 was cut at 2:40pm (it was also a stage 4 wire, taken from the 12 o’clock position, sample length of 8’-7 9/16”, had 3/32” slippage top and 3/16” slippage at bottom and about 9/16” retraction of cut to existing wire at top location). Dick and Austin then continued their investigation of the 2 new wedge lines that had been driven for them and identified the need for one more sample. Sample #9 was cut at 3:46pm (it was a stage 4 wire, taken from the 4:30 clock position, sample length of 8’-3 1/2”, had no slippage at top and 3/16” slippage at bottom, and about 5/8” retraction of cut to existing wire at top location). The contractor then spliced these 3 locations using a 3,000# rated come-along, pressed on ferrule and turnbuckle. See photo’s to see the use of lining up marks on the bottom of Sample wire #9 to see that the put equal if not more tension into the newly spliced wire. After the splicing work was done, the contractor wrapped a tarp around the main cable numerous times to protect it overnight.

At “Optional Cable Opening Location 31-32 North (per contract drawing 15 of 16)”:
The contractor set-up scaffolding at this location when they first arrived at the site. They removed the cableguard wrap and then circumference dimensions were taken (before wire wrap was removed). Then the contractor removed the wire wrap. There were no signs of moisture before or after the wire wrap was removed. Again circumference dimensions were taken (after wire wrap was removed). Once completed, the contractor drove 4 wedge lines (12/3/6/9 o’clock positions). Dick and Austin conducted their review. 2 more wedge locations per Dick’s request were needed and the

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PROJECT: LUC-2-18.62 Cable Inspection Project | CONTRACT: CL000681.B007 | REPORT NO: 5

LOCATION: Toledo, Ohio | DAY: Friday | DATE: 11/16/12

CONTRACTOR: Piasecki Steel Const. Co. | RPR/ENGINEER: M.S.L.

contractor drove them (between 2:25-2:40pm). The contractor put a double wrap of waterproof plastic around the main cable to protect it overnight.

After now opening all 4 locations, it is safe to say "Optional Cable Opening Location 31-32 North" cable condition was the best that had been seen. 2nd best would be "Primary Cable Opening Location East 65 North". A close 3rd would be "Primary Cable Opening Location 3-4 South". A distant 4th and definitely the worst existing cable condition investigated was the "Optional Cable Opening Location 58-59 South".

See attached photo's documenting today's work.

COMMENTS:

Tomorrow, the Contractor plans to begin compacting and installing SST band straps with neoprene bond breaker at "Primary Cable Opening Location East 65 North (per contract drawing 15 of 16)". He also intends to cut samples at "Optional Cable Opening Location 31-32 North (per contract drawing 15 of 16)" & "Optional Cable Opening Location 58-59 South (per contract drawing 15 of 16)".

Dick Little and Austin Kieffer (from Modjeski and Masters) will be starting at the "Optional Cable Opening Location 31-32 North (per contract drawing 15 of 16)" to finish their cable investigation of the 2 additional wedge lines that were provided.

BY: Matt Lotycz

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Infrastructure, environment, facilities

DAILY CONSTRUCTION REPORT

PROJECT: LUC-2-18.62 Cable Inspection Project CONTRACT: CL000681.B007 REPORT NO: 6

LOCATION: Toledo, Ohio DAY: Saturday DATE: 11/17/12

CONTRACTOR: Piasecki Steel Const. Co. RPR/ENGINEER: M.S.L.

WEATHER		SITE CONDITIONS		WORK FORCE INCLUDING SUB-CONTRACTORS	F			F			F		OFF. ROUTING	
Temp AM	29	Dry		Superintendent	1		Ironworker		4	Plumber			PM	
Temp PM	54	Wet		Laborer			Mason			Millwright			PE	
Wind MPH	9	Frozen		Operators			Painter			Sheet Metal			CM	
Dry		Sand		Carpenter			Electrician			Trucker			Struct.	
Rain		Clay		Finisher			Flagger						Mech.	
Snow		Rock											Elect.	

OPERATING EQUIPMENT:
Loader [ ] Dozer [ ] Crane [X] Backhoe [ ] Road Grader [ ] Compactor [ ]
Others: To clarify, the crane is a truck crane. It is 1 of the 3 vehicles the Contractor has on site.

SUBCONTRACTORS: Dick Little (Chief Investigator) and Austin Kieffer (Investigator Assistant) from Modjeski and Masters.

WORK COMPLETED:

Today:

At “Optional Cable Opening Location 58-59 South (per contract drawing 15 of 16)”:
The contractor removed the double wrap of waterproof plastic around the main cable to protect it overnight. The contractor cut 3 samples at this location. Sample #4 was cut at 12:39pm (it was a stage 4 wire, taken from the 3 o’clock position, sample length of 8’-10 5/8”, had 3/32” slippage each side, and ½” retraction of cut to existing wire at top location). Sample #5 was cut at 12:33pm (it was also a stage 4 wire, taken from the 6 o’clock position, sample length of 14’-3 3/4”, had no slippage each side, and 1/2” retraction of cut to existing wire at top location). Sample #6 was cut at 12:49pm (it was a stage 3 wire, taken from the 4:30 clock position, sample length of 7’-0 3/8”, had 1/8” slippage on cable band 59 side and 3/32” slippage on cable band 58 side, and ½” retraction of cut to existing wire at top location). Dick and Austin of M&M witnessed and marked the samples being cut (for slippage and splicing purposes) since I was at another location watching the contractor splice. Then the contractor placed a double wrap of waterproof plastic around the main cable to protect it overnight.

At “Primary Cable Opening Location East 65 North (per contract drawing 15 of 16)”:
When the contractor first arrived at the site in the morning he removed the double wrap of waterproof plastic around the main cable (which protected it overnight). The contractor then began compacting the cable and banding it with SST straps and neoprene bond breakers. Then circumference dimensions were taken (after compacted). Then the contractor installed the cableguard wrap per the manufacturers installation instructions paying extra attention to the existing/new overlap at the hood and the special detailing needed at the cable band at the top. The contractor decided to wait on installing the slip resistant top surface to the cableguard until after “Optional Cable Opening Location 31-32 North (per contract drawing 15 of 16)” cableguard is completed so they can do all at once. This location is almost done.

At “Optional Cable Opening Location 31-32 North (per contract drawing 15 of 16)”:
Dick and Austin began their review of the 2 additional wedge lines that were driven. Sample #10 was cut at 11:35am (it was a stage 1 wire, taken from the 12 o’clock position, sample length of 14’-10 1/4”, had no slippage on cable band 31 side and 3/32” slippage on cable band 32 side, and 7/16” retraction of cut to existing wire at top location). Sample #11 was cut at 11:24am (it was a stage 2 wire, taken from the 12 o’clock position, sample length of 8’-10 3/16”, had 1/8” slippage each side, and 1/2” retraction of cut to existing wire at top location). Sample #12 was cut at 11:51am (it was a stage 3 wire, taken from the 1:30 clock position, sample length of 10’-7 3/4”, had 3/32” slippage on cable band 31 side and 1/16” slippage on cable band 32 side, and 9/16” retraction of cut to existing wire at top location). Sample #13 was cut at 11:33am (it was a stage 2 wire, taken from the 9 o’clock position, sample length of 8’-9 1/16”, had 3/32” slippage on cable band 31 side and 1/8” slippage on cable band 32 side, and 7/16” retraction of cut to existing wire at top location). The contractor then spliced all 4 locations together by matching the pre-cut lines to ensure the newly spliced wire had the same if not more tension than in its original condition (newly spliced line was about 1/16” (on each end) if not more past

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PROJECT:	LUC-2-18.62 Cable Inspection Project	CONTRACT:	CL000681.B007	REPORT NO:	6
LOCATION:	Toledo, Ohio	DAY:	Saturday	DATE:	11/17/12
CONTRACTOR:	Piasecki Steel Const. Co.	RPR/ENGINEER:	M.S.L.		

mark line for each spliced location). See photos for documentation of the match line approach. Then the contractor began compacting the cable and banding it with SST straps and neoprene bond breakers. The contractor got about ½ way done with compaction before calling it a day. The contractor put a double wrap of waterproof plastic around the main cable to protect it overnight.

Dick and Austin of M&M left for back home after all the samples were cut, measured, and recorded. I will take the remaining circumference dimensions (after compaction and after cableguard wrap at the last two locations).

See attached photo's documenting today's work.

COMMENTS:

Tomorrow, the Contractor plans to finish compacting and installing SST band straps with neoprene bond breaker at "Optional Cable Opening Location 31-32 North (per contract drawing 15 of 16)". Then plans on wrapping cableguard at this location and putting non-slip top surface on this location and "Primary Cable Opening Location East 65 North (per contract drawing 15 of 16)". When done with that, the contractor will be completely done with all but the "Optional Cable Opening Location 58-59 South (per contract drawing 15 of 16)" location. The contractor will also most likely strip scaffolding from the "Optional Cable Opening Location 31-32 North (per contract drawing 15 of 16)" location and pick traffic control/open back up the north land of traffic.

Depending whether the contractor received the extra turnbuckles and ferrules in the mail yesterday afternoon will determine if he can get started on the last location to splice/compact/strap/cableguard wrap ("Optional Cable Opening Location 58-59 South (per contract drawing 15 of 16)").

BY: Matt Lotycz

ARCADIS
Infrastructure, environment, facilities

DAILY CONSTRUCTION REPORT

PROJECT: LUC-2-18.62 Cable Inspection Project CONTRACT: CL000681.B007 REPORT NO: 7

LOCATION: Toledo, Ohio DAY: Sunday DATE: 11/18/12

CONTRACTOR: Piasecki Steel Const. Co. RPR/ENGINEER: M.S.L.

WEATHER		SITE CONDITIONS		WORK FORCE INCLUDING SUB-CONTRACTORS									OFF. ROUTING	
					F			F			F			
Temp AM	30	Dry		Superintendent	1		Ironworker		4	Plumber			PM	
Temp PM	53	Wet		Laborer			Mason			Millwright			PE	
Wind MPH	10	Frozen		Operators			Painter			Sheet Metal			CM	
Dry		Sand		Carpenter			Electrician			Trucker			Struct.	
Rain		Clay		Finisher			Flagger						Mech.	
Snow		Rock											Elect.	

OPERATING EQUIPMENT:
Loader [ ] Dozer [ ] Crane [X] Backhoe [ ] Road Grader [ ] Compactor [ ]
Others: To clarify, the crane is a truck crane. It is 1 of the 3 vehicles the Contractor has on site.

SUBCONTRACTORS:

WORK COMPLETED:

Today:
The contractor received the extra turnbuckles and ferrules in the mail yesterday afternoon. The contractor now has all the supplies he needs to get started on the last location to splice/compact/strap/cableguard wrap (“Optional Cable Opening Location 58-59 South (per contract drawing 15 of 16)”).

<u>At “Optional Cable Opening Location 58-59 South (per contract drawing 15 of 16)”:</u>
The contractor removed the double wrap of waterproof plastic around the main cable to protect it overnight. The contractor spliced all 3 locations together by matching the pre-cut lines to ensure the newly spliced wire had the same if not more tension than in its original condition [newly spliced line was about 1/16”+/- (on each end) if not more past mark line for each spliced location, signifying more equal to if not more tension than existing condition]. See photos for documentation of the match line approach. The contractor then started to compact the cable but only got about ¼ of the way done before calling it a day. Then the contractor placed a double wrap of waterproof plastic around the main cable to protect it overnight.

<u>At “Primary Cable Opening Location East 65 North (per contract drawing 15 of 16)”:</u>
The contractor placed the slip resistant top surface to the cableguard. This location is all done.

<u>At “Optional Cable Opening Location 31-32 North (per contract drawing 15 of 16)”:</u>
The contractor finished compacting the cable and banded it with SST straps and neoprene bond breakers. Circumference dimensions were taken after banding. Then the contractor installed the cableguard with special details at each end at the cable band. (FYI – The contractor, like in all locations, placed 2 small pieces of cut cableguard over the SST band clip so it did not puncture the cableguard). Circumference dimensions were taken after the cableguard was wrapped. The contractor removed his scaffolding. This location is all done. The only reason contractor did not remove the traffic control is because the rental place he used for traffic control is closed on Sunday.

See attached photo’s documenting today’s work.

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Infrastructure, environment, facilities

PROJECT:	LUC-2-18.62 Cable Inspection Project	CONTRACT:	CL000681.B007	REPORT NO:	7
LOCATION:	Toledo, Ohio	DAY:	Sunday	DATE:	11/18/12
CONTRACTOR:	Piasecki Steel Const. Co.	RPR/ENGINEER:	M.S.L.		

COMMENTS:

Now that all his work is done on the north side cable, tomorrow the contractor plans on removing the traffic control on the north bound lane and opening the traffic back up to its normal two lanes.

The Contractor plans to finish compacting and installing SST band straps with neoprene bond breaker at “Optional Optional Cable Opening Location 58-59 South (per contract drawing 15 of 16)”. Then plans on wrapping cableguard at this location and putting non-slip top surface on this location. When done with that, the contractor will be completely done with all but removing scaffolding from this location and removing traffic control on the south side of the bridge.

BY: Matt Lotycz

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Infrastructure, environment, facilities

DAILY CONSTRUCTION REPORT

PROJECT: LUC-2-18.62 Cable Inspection Project   CONTRACT: CL000681.B007   REPORT NO: 8

LOCATION: Toledo, Ohio   DAY: Monday   DATE: 11/19/12

CONTRACTOR: Piasecki Steel Const. Co.   RPR/ENGINEER: M.S.L.

WEATHER		SITE CONDITIONS		WORK FORCE INCLUDING SUB-CONTRACTORS									OFF. ROUTING	
					F			F			F			
Temp AM	30	Dry		Superintendent	1		Ironworker		4	Plumber			PM	
Temp PM	56	Wet		Laborer			Mason			Millwright			PE	
Wind MPH	4	Frozen		Operators			Painter			Sheet Metal			CM	
Dry		Sand		Carpenter			Electrician			Trucker			Struct.	
Rain		Clay		Finisher			Flagger						Mech.	
Snow		Rock											Elect.	

OPERATING EQUIPMENT:

Loader [ ] Dozer [ ] Crane [X] Backhoe [ ] Road Grader [ ] Compactor [ ]

Others: To clarify, the crane is a truck crane. It is 1 of the 3 vehicles the Contractor has on site.

SUBCONTRACTORS:

WORK COMPLETED:

Today:

At “Optional Cable Opening Location 58-59 South (per contract drawing 15 of 16)”:

The contractor removed the double wrap of waterproof plastic around the main cable to protect it overnight. The contractor finished compacting the cable and installing SST band straps with neoprene bond breaker. Circumference dimensions were taken (after compaction). Then the contractor installed the cableguard wrap with special detailing at the cable bands at each end. Circumference dimensions were taken (after cableguard wrap installed). When done with that, the contractor removed the scaffolding. Then once done with that, the contractor installed the non-slip surface to the top of the cable. This cable opening location is now all done.

The contractor plans on “boxing up the samples” on Wednesday when they get back to their shop. The samples will be shipped out on Friday to the testing company. The contractor will let me know if something changes with the sample shipping schedule.

See attached photo’s documenting today’s work.

COMMENTS:

First thing tomorrow morning, the contractor plans on removing the traffic control and opening the south side of the bridge back to its 2 lanes of original traffic. At that time the contractor will be complete with the entire project. They are leaving the area on Tuesday morning after the traffic control work is complete.

BY: Matt Lotycz

ARCADIS
Infrastructure, environment, facilities

DAILY CONSTRUCTION REPORT

PROJECT: LUC-2-18.62 Cable Inspection Project

CONTRACT: CL000681.B007

REPORT NO: 9

LOCATION: Toledo, Ohio

DAY: Tuesday

DATE: 11/20/12

CONTRACTOR: Piasecki Steel Const. Co.

RPR/ENGINEER: M.S.L.

WEATHER		SITE CONDITIONS		WORK FORCE INCLUDING SUB-CONTRACTORS									OFF. ROUTING	
					F			F			F			
Temp AM	32	Dry		Superintendent	1		Ironworker		4	Plumber			PM	
Temp PM	58	Wet		Laborer			Mason			Millwright			PE	
Wind MPH	3	Frozen		Operators			Painter			Sheet Metal			CM	
Dry		Sand		Carpenter			Electrician			Trucker			Struct.	
Rain		Clay		Finisher			Flagger						Mech.	
Snow		Rock											Elect.	

OPERATING EQUIPMENT:

Loader [ ] Dozer [ ] Crane [X] Backhoe [ ] Road Grader [ ] Compactor [ ]

Others: To clarify, the crane is a truck crane. It is 1 of the 3 vehicles the Contractor has on site.

SUBCONTRACTORS:

WORK COMPLETED:

Today:
The contractor removed the traffic controls and opened the south side of the bridge back to its 2 lanes of original traffic.

The contractor is now complete with the entire project. They are leaving the area this morning now that the project is complete.

COMMENTS:

BY: Matt Lotycz

APPENDIX C – EVALUATION OF MAIN CABLE WIRES ANTHONY WAYNE BRIDGE (LUCIUS PITKIN, INC.)

Report No. F12454 – Evaluation of Main Cable Wires Anthony Wayne Bridge, Toledo, OH

Wire Specimen Stress-Strain Curves

Report No. F12454 – Evaluation of Main Cable Wires Anthony Wayne Bridge, Toledo, OH

Lucius Pitkin, Inc. *Consulting Engineers*

Fitness-For-Service
Failure & Materials Evaluation
Nondestructive Engineering

Est. 1885

REPORT NO. F12454

EVALUATION OF MAIN CABLE WIRES
ANTHONY WAYNE BRIDGE, TOLEDO, OH

ARCADIS U.S., INC.

JANUARY 25, 2013

304 Hudson Street, New York, NY 10013-1026 Tel: 212-233-2737 Fax: 212-406-1417 www.lpiny.com

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Est.1885

January 25, 2013

Report No. F12454

Arcadis US., Inc.
1100 Superior Avenue
Cleveland, Ohio 44114

Attention: Mr. Edward J. Adamczyk, PE.
Project Manager

Subject: **EVALUATION OF MAIN CABLE WIRES**
ANTHONY WAYNE BRIDGE, TOLEDO, OH

1.0 INTRODUCTION

LPI was requested by Arcadis US, Inc. to provide engineering services in the evaluation of wires from the Anthony Wayne Bridge located over the Maumee River in Toledo, OH, as shown in Fig. 1. According to the Historic Bridges Book the Anthony Wayne Bridge was designed by Waddell and Hardesty and built in 1931 by McClintic Marshall Company. The basic bridge technical data are given in Table 1.

TABLE 1
BASIC TECHNICAL DATA
ANTHONY WAYNE BRIDGE – TOLEDO, OH

Type of bridge for the main span unit:	Wire Cable Suspension
Main span unit length (3 spans):	1252 feet (233.5 feet, 785 feet, 233.5 feet)
Width center to center of cables:	59 feet
Roadway width :	52 feet (26 feet each direction)
Total length of bridge including approach spans:	3215 feet

2.0 WORK SCOPE

The purpose of this evaluation was to determine the general condition of the wires with respect to corrosion attack and tensile strength. To this end, the scope of work requested by Arcadis US, Inc. and performed by LPI was as follows:

- Visual evaluation and dimensional measurements;
- Tensile test (ASTM A370, E8) to failure, including stress/strain Diagram and determination of yield strength by the offset method;
- Fractographic evaluation;
- Scanning electron microscopy (SEM) of fractured wire ends after tests;
- Composition of corrosion product/deposits using Energy Dispersive X-ray Spectroscopy (EDS) analysis;
- Written report on findings.

3.0 PROCEDURES AND OBSERVATIONS

3.1 Visual Evaluation

A total of thirteen sample wires, approximately 0.192 in. original diameter and different lengths, were submitted for tensile testing to failure of the specimens in accordance with standard ASTM A370 and E8. The submitted wire samples in the as-received condition are shown in Fig. 2. The customer tag indications of wire locations in the main cable are given in Table 2 along with corrosion stage determined by LPI during preliminary evaluation. All wire surfaces were examined using a binocular microscope at low and high magnification. Typical wire surfaces with different corrosion stages are shown in Fig. 3. Wire surfaces in the as-received condition are shown in Figs. 4 through 10. LPI also evaluated the corrosion stage of each wire after tensile testing since during tensile testing more wire surface was exposed as a result of spalled paint coatings and corrosion/product deposits.

The National Cooperative Highway Research Program (NCHRP) Report 534 “Guidelines for Inspection and Strength Evaluation of Suspension Bridge Parallel Wire Cables” section 1.4.2.2 states: “wire corrosion is categorized visually by corrosion stage”. The four corrosion stages are characterized by the presence of the following indications:

- Stage 1—spots of zinc oxidation on the wires;
- Stage 2—zinc oxidation on the entire wire surface;
- Stage 3—spots of brown rust covering up to 30% of the surface of a 3-inch to 6-inch length of wire; and

- Stage 4—brown rust covering more than 30% of the surface of a 3-inch to 6-inch length of wire.

TABLE 2
WIRE IDENTIFICATION

Number on TAG	Tag on wires			Length (ft.)	LPI Corr. Stage
	Panel	Location	Orientation		
1	PP-3-4	S. Cable	3 O'clock	8	3
2	PP-3-4	S. Cable	12 O'clock	8	2
3	PP-3-4	S. Cable	6 O'clock	8	4
4	PP-58-59	S. Cable	3 O'clock	8.11	4
5	PP-58-59	S. Cable	6:30 O'clock	14. 4	4
6	PP-58-59	S. Cable	4:30 O'clock	7.2	3
7	PP-65-E	N. Cable	6 O'clock	9	4
8	PP-65-E	N. Cable	12 O'clock	8.4	4
9	PP-65-E	N. Cable	4:30 O'clock	8.4	2
10	PP-31-32	N. Cable	12 O'clock	15	1
11	PP-31-32	N. Cable	12 O'clock	8.1	2
12	PP-31-32	N. Cable	1:30 O'clock	10.8	2
13	PP-31-32	N. Cable	9 O'clock	8.9	2

3.2 Tensile Tests

LPI cut each of the thirteen submitted wire samples into specimens approximately 16 in. long in preparation for tensile testing. All corrosion stages of the wires after tensile testing are also given in Table 3 along with tensile test results. It should be noted that LPI did not observe any visually evident surface cracks or service-related fractures or mechanical damage on the surfaces of those wire specimens prepared for tensile testing.

A total of 84 wire specimens were cut from the sample wires for tensile tests. The wire specimens were tested in accordance with ASTM A370 at room temperature using a 10-inch gage length, as shown in Fig. 11. Tensile tests were performed using a 120 kip Baldwin universal testing machine (120BTE) calibrated on 4-25-12.

Tensile test results for the wire specimens exhibiting all four corrosion stages, are given in Table 3 along with statistical analysis of all wires. The analysis was performed in terms of average (AVG), standard deviation (STDEV), minimum (MIN) and maximum (MAX). Since statistical analysis of mechanical test results depends on corrosion stages, all wires were grouped by surface corrosion Stages 1 through 4 as presented in Table 4. The wire mechanical properties decreased with increased corrosion from Stage 1 to Stage 4.

After tensile testing, all wire surfaces and fracture surfaces were also evaluated under a stereomicroscope. The wires primarily exhibited significant necking-down and somewhat cup-cone profiles, as shown in Fig. 12. Some exhibited shear or mixed cup-cone and shear profiles. Regardless of the fracture mode profiles, the wires exhibited approximately similar mechanical properties. All wire surface and fracture surface evaluations are shown in Figs.13 through 96.

Many wires with corrosion Stages 3 and 4 exhibited a fracture surface with non-circular cross-sections where the fracture started from surface corrosion pits. Several wires exhibited severe corroded surfaces in the vicinity of the tensile test fracture surfaces. One wire fractured in the jaws with minimum tensile strength or elongation and reduction in area and one slip in jaws with minimum modulus, as given in Table 3 (see notes under the table).

TABLE 3
TENSILE TEST OF WIRES

No.	LPI ID	Corr. Stage	Proport. Limit (lb)	Ultimate Load (lb)	Modulus (ksi)	Tensile Strength (ksi)	Yield Strength (ksi)	Elong. (%)	Reduction in Area (%)
1	1-1	3	4887	6822	28583	235	204	5	38
2	1-2	3	4574	6703	29765	231	196	4	31
3	1-3	3	4596	6743	27664	233	196	3	35
4	1-4	3	4584	6579	28699	227	195	4	31
5	1-5	3	4353	6495	25536	224	185	4	31
6	1-6	3	4502	6715	24963	232	191	4	32
7	2-1	2	4341	6431	27072	222	189	6	33
8	2-2	2	4236	6293	24814	217	179	5	41
9	2-3	2	4252	6078	27506	210	178	4	35
10	2-4[a]	2	3873	5890	21899	203	162	5	38
11	2-5	2	3802	5795	26351	200	161	5	38
12	3-1	4	4093	6724	28621	232	187	3	32
13	3-2	4	4392	6801	27875	235	193	5	34
14	3-3[c]	4	4302	6160	27116	212	185	1	12

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TABLE 3 – CONT'D
TENSILE TEST OF WIRES

No.	LPI ID	Corr. Stage	Proport. Limit (lb)	Ultimate Load (lb)	Modulus (ksi)	Tensile Strength (ksi)	Yield Strength (ksi)	Elong. (%)	Reduction in Area (%)
15	3-4	4	4039	6448	26036	222	181	4	33
16	3-5	4	4473	6401	28251	221	182	3	34
17	3-6	4	4026	6309	26945	218	180	4	31
18	4-1	4	4422	6296	27547	217	186	5	33
19	4-2	4	4160	6062	27407	209	178	3	31
20	4-3	4	4136	6033	27508	208	178	3	26
21	4-4	4	4216	6064	24477	209	176	3	39
22	4-5	4	4378	6247	26060	215	185	3	34
23	4-6	4	4347	6167	25627	213	181	3	31
24	5-1	4	4357	6168	27102	213	182	3	38
25	5-2[d]	4	4019	5691	22910	196	165	2	26
26	5-3[d]	4	4099	5937	24248	205	171	2	27
27	5-4[d]	4	4026	5684	24920	196	169	1	14
28	5-5[d]	4	4086	5576	25842	192	169	2	22
29	5-6[d]	4	3819	5585	26265	193	160	2	31
30	5-7[d]	4	3964	5248	24736	181	161	2	20
31	5-8[d]	4	4036	5020	26193	173	150	3	22
32	6-1	3	3854	5771	25336	199	164	5	35
33	6-2	3	3823	5762	26525	199	153	4	31
34	6-3	3	3818	5603	24873	193	159	4	38
35	6-4	3	3690	5317	26705	183	145	4	31
36	6-5	3	4412	6667	27189	230	191	4	31
37	7-1	4	4249	6445	27214	222	183	3	32
38	7-2	4	4301	6469	27292	223	183	4	35
39	7-3[d]	4	4714	6450	27786	222	194	2	26
40	7-4[c]	4	4303	5768	25037	199	180	0	18
41	7-5[d]	4	4252	5682	25374	196	173	1	22
42	7-6[d]	4	4628	6046	28337	208	181	1	30
43	8-1	3	4208	6280	28080	217	183	6	35
44	8-2	4	4187	6027	25334	208	175	3	32
45	8-3	4	3988	5844	26540	202	169	3	34
46	8-4	4	4066	5848	24647	202	168	3	31

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TABLE 3 – CONT'D
TENSILE TEST OF WIRES

No.	LPI ID	Corr. Stage	Proport. Limit (lb)	Ultimate Load (lb)	Modulus (ksi)	Tensile Strength (ksi)	Yield Strength (ksi)	Elong. (%)	Reduction in Area (%)
47	8-5	4	4081	5864	24152	202	167	4	31
48	8-6	4	4554	6229	27484	215	179	2	35
49	9-1	2	4361	6461	27958	223	187	5	32
50	9-2	2	4350	6393	25805	220	182	4	38
51	9-3	2	4374	6694	28490	231	190	4	38
52	9-4	2	4293	6619	26672	228	188	4	39
53	9-5	2	4307	6564	27594	226	190	4	41
54	9-6	3	3838	6146	24587	212	165	2	36
55	10-1	1	4875	6930	29091	239	205	5	39
56	10-2	1	4668	6795	26891	234	196	4	39
57	10-3	1	4602	6732	26755	232	194	3	38
58	10-4	1	4584	6638	25284	216	181	5	39
59	10-5	1	4682	6631	28832	229	195	4	39
60	10-6	1	4753	6613	29373	228	194	3	39
61	10-7	1	4698	6495	29658	224	191	4	41
62	10-8	1	4446	6407	28070	221	187	5	39
63	10-9	1	4249	6262	26682	216	181	3	38
64	10-10	1	4315	6199	28283	214	180	5	39
65	10-11	1	4253	6183	27563	213	179	4	39
66	11-1	2	4122	6124	26343	211	176	4	39
67	11-2[b]	2	4090	6020	25595	208	172	3	37
68	11-3	2	4027	6005	24746	207	168	4	42
69	11-4	2	4074	5948	26384	205	170	4	33
70	11-5	2	3919	5793	23512	200	161	4	39
71	11-6	2	3957	5792	23858	200	163	3	39
72	12-1	2	4491	5961	28975	206	175	5	39
73	12-2	2	4018	5867	25544	202	168	4	41
74	12-3	2	3936	5832	25567	201	167	5	41
75	12-4	2	3931	5769	24904	199	165	4	39
76	12-5	2	4054	5812	27777	200	169	5	39
77	12-6	2	4684	6806	27575	235	199	6	40
78	12-7	2	5401	6767	28864	233	201	5	38

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TABLE 3 – CONT'D
TENSILE TEST OF WIRES

No.	LPI ID	Corr. Stage	Proport. Limit (lb)	Ultimate Load (lb)	Modulus (ksi)	Tensile Strength (ksi)	Yield Strength (ksi)	Elong. (%)	Reduction in Area (%)
79	13-1	2	4680	6722	28291	232	199	5	27
80	13-2	2	4633	6675	27312	230	195	4	36
81	13-3	2	4446	6548	26127	226	187	4	36
82	13-4	2	4611	6708	28355	231	197	5	39
83	13-5	2	4523	6621	26376	228	191	4	38
84	13-6	2	4242	6551	28187	226	186	4	39
AVG			4286	6218	26647	214	180	3.7	34.0
STDEV			305	418	1621	14	13	1.2	6.2
MIN			3690	5020	21899	173	145	0	12
MAX			5401	6930	29765	239	205	6	42
Note: [a] – slip in jaws; [b] – fractured in jaws; [c] – pre-existing crack ; [d] – wire surface severe corrosion									

TABLE 4
STATISTICAL ANALYSIS OF WIRE MECHANICAL PROPERTIES DEPEND ON CORROSION STAGE

	Proport. Limit (lb)	Ultimate Load (lb)	Modulus (ksi)	Tensile Strength (ksi)	Yield Strength (ksi)	Elong. (%)	Reduction in Area (%)
Corrosion Stage 1							
AVG	4557	6535	27862	224	189	4.1	39.0
STDEV	212	249	1359	9	8	0.8	0.8
Corrosion Stage 2							
AVG	4277	6260	26498	216	180	4.4	37.7
STDEV	334	372	1713	13	13	0.7	3.2
Corrosion Stage 3							
AVG	4241	6277	26808	217	179	4.1	33.5
STDEV	393	508	1681	18	19	1.0	2.8
Corrosion Stage 4							
AVG	4217	6042	26287	208	176	2.7	28.9
STDEV	208	399	1440	14	10	1.2	6.7

3.3 Scanning Electron Microscopy (SEM) and EDS analysis

Ten tensile tested wires, which exhibited lower fracture strengths or elongations as compared to with two wires (1-2 and 13-6), which exhibited higher than average mechanical properties, were examined in a SEM at an accelerating voltage of 20 kV. Prior to examination in the SEM the fracture surfaces of the wires were ultrasonically cleaned in an alcohol-acetone solution.

Fracture surfaces of specimens 1-2 and 13-6 exhibited cup-cone profiles. Examination of the fracture surfaces of the ten lower mechanical properties wires revealed that the fractures initiated at surface pitting corrosion zones, as shown in Figs. 97 through 119. Two wires, 3-3 and 7-4, exhibited stepped fracture profiles. EDS analyses of these steps on the fracture surfaces revealed high percentages of oxygen, indicating that the wires contained pre-existing corrosion cracks. However, SEM analysis revealed that the final fracture region exhibited microvoid coalescence, which is indicative of final ductile overload fracture. Other specimens (5-4, 5-7, 6-4, 8-1, 11-2, 12-4) exhibited a somewhat cup-cone profile with crack initiation from surface corrosion pits, which reduced the wires' cross-section. Specimen 9-6 exhibited low elongation since it was tested with an original butt splice (see Fig. 66). However, the wire fractured remote from the butt splice area with a cup-cone profile.

4.0 DISCUSSION AND CONCLUSIONS

Results of this evaluation indicated that many of the submitted main cable wires sustained general non-uniform oxidation corrosion attack and were classified as Stages 1 through 4.

Of the 84 wire specimens which were tensile tested, 13.1% were classified by LPI as Stage 1, 34.5% as Stage 2, 15.5% as Stage 3 and 36.9% as Stage 4. The statistical analyses of the wire mechanical properties revealed that the wire mechanical properties decreased with increased corrosion from Stage 1 to Stage 4.

After tensile testing the wire surfaces were evaluated visually, stereomicroscope and SEM analyses which revealed that the submitted wires, in general, sustained corrosion attack with partial or complete depletion of the zinc coating and exhibited formation of corrosion products. Additionally, the wires sustained corrosion penetration as evidenced by the formation of dark-brown iron oxide deposits. Tensile tested wires with corrosion Stage 1 to Stage 3 exhibited predominately significant necking-down and cup-cone profiles. The tensile

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tested wires with corrosion Stage 4 exhibited fracture surfaces with non-circular cross-sections where the fracture started from surface corrosion pits. In addition, spalling from the surface occurred during testing and a stepped shear fracture surface profile was observed. These wire fractures initiated at the pitting corrosion zones. However, the final fracture regions exhibited microvoid coalescence, indicative of an overstress fracture failure mechanism.

Two wires, 3-3 and 7-4, exhibited stepped fracture surface profiles which were indicative of pre-existing corrosion cracks.

Respectfully submitted,

LUCIUS PITKIN, INC.

Boris Goldenberg, Ph.D.
Senior Metallurgical Engineer

Joseph P. Crosson, P.E.,
Principal

BG:JPC/P: Projects/2012/F12454 Report-Arcadis-Evalofmaincablewires-AnthonyWayneBridge

Fig. 1 Views of the Anthony Wayne Suspension Bridge.

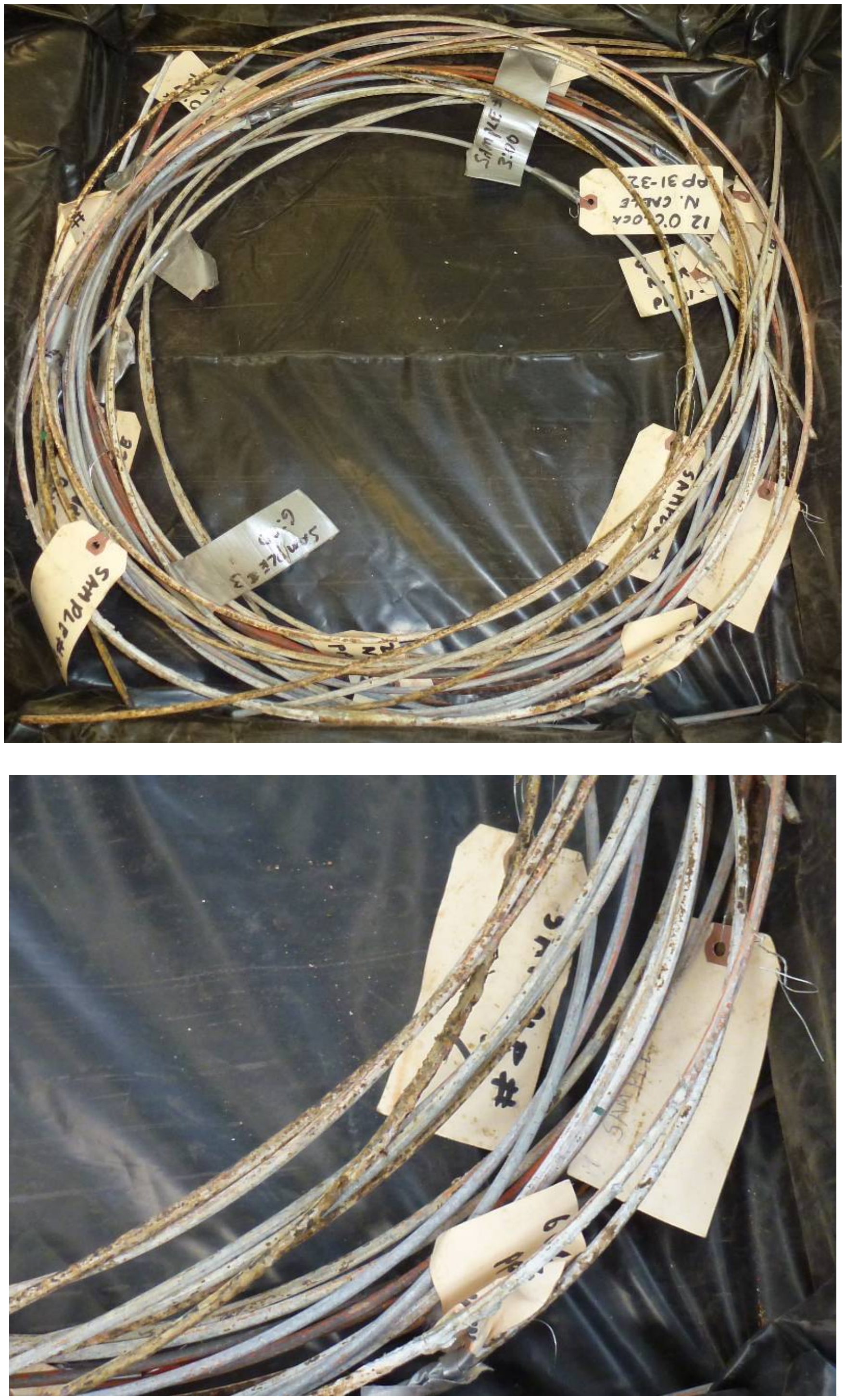
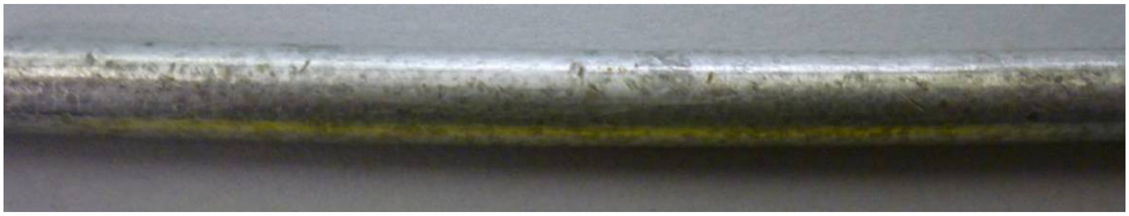


Fig. 2 Main cable wire samples in the as received condition.



STAGE 1

STAGE 2

STAGE 3

STAGE 4

Fig. 3 Typical wire surfaces with different corrosion stages.

Fig. 4 Views of wire 1 and 2 surfaces (see Table 2).

Fig. 5 Views of wire 3 and 4 surfaces (see Table 2).

Fig. 6 Views of wire 5 and 6 surfaces (see Table 2).

Fig. 7 Views of wire 7 and 8 surfaces (see Table 2).

Fig. 8 Views of wire 9 and 10 surfaces (see Table 2).

Fig. 9 Views of wire 11 and 12 surfaces (see Table 2).

Fig. 10 Views of wire 13 surfaces (see Table 2).

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Fig. 11 General view of a wire during the tensile test.

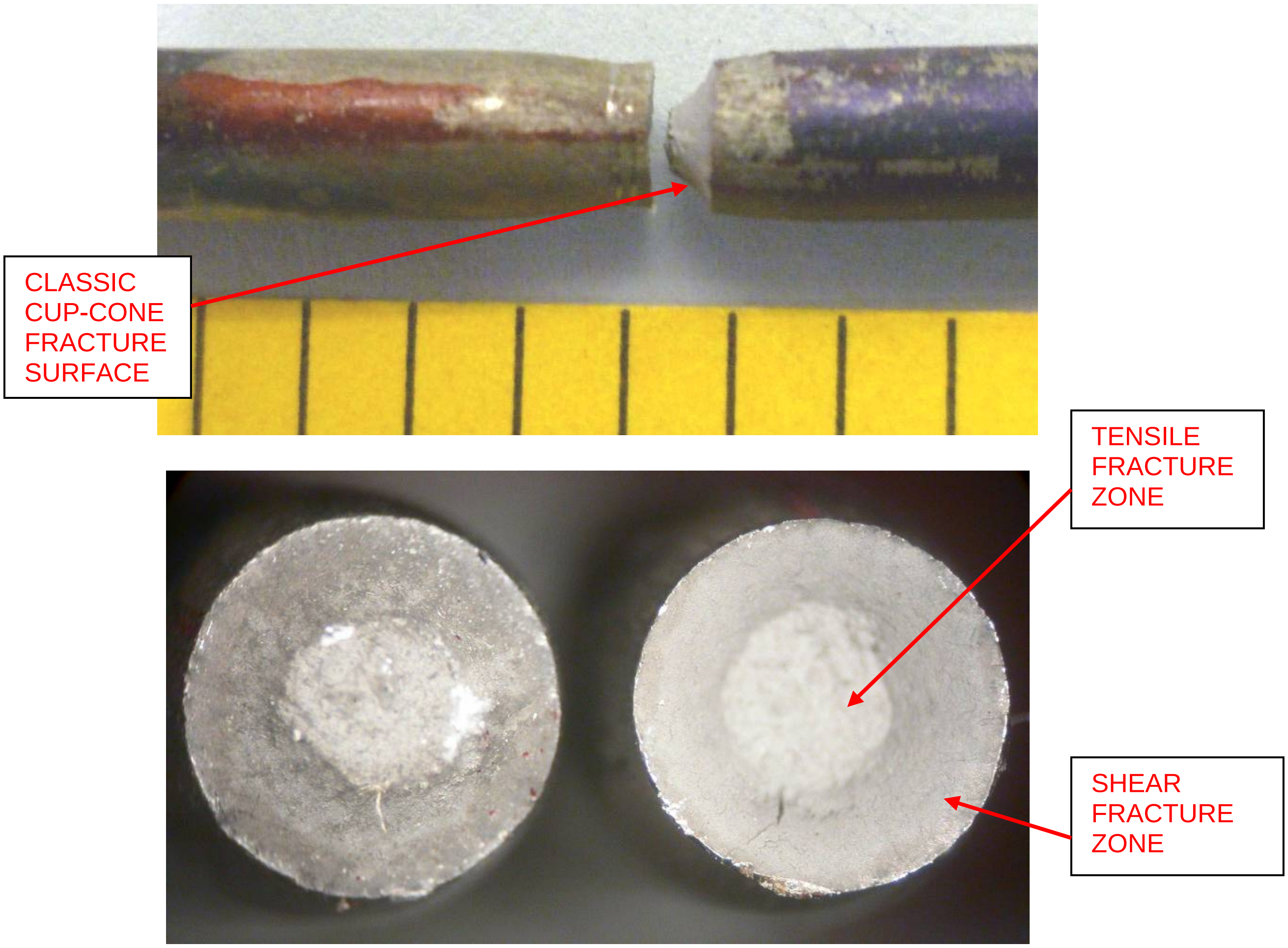


Fig. 12 Sample of classic cup-cone fracture surface with corrosion Stage 1.

Fig.13 Wire 1-1 surface (top) and fracture surface after tensile testing (bottom).

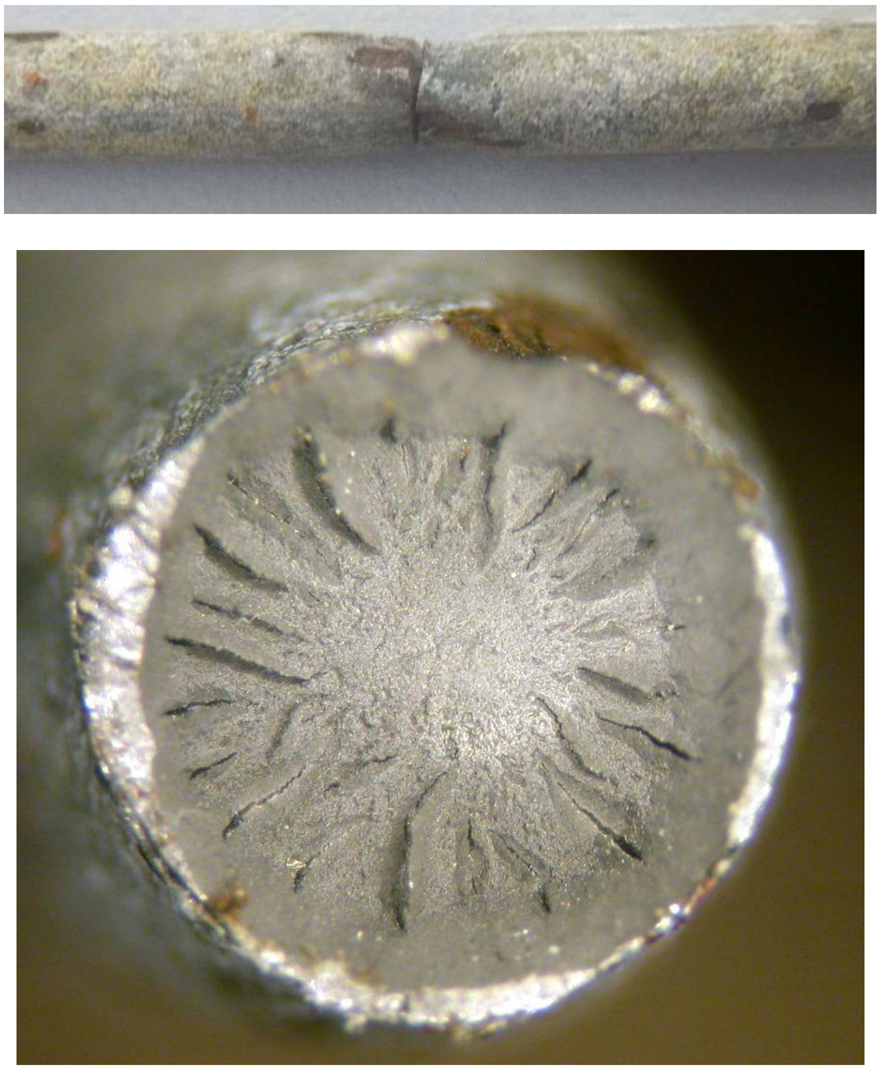


Fig.14 Wire 1-2 surface (top) and fracture surface after tensile testing (bottom).

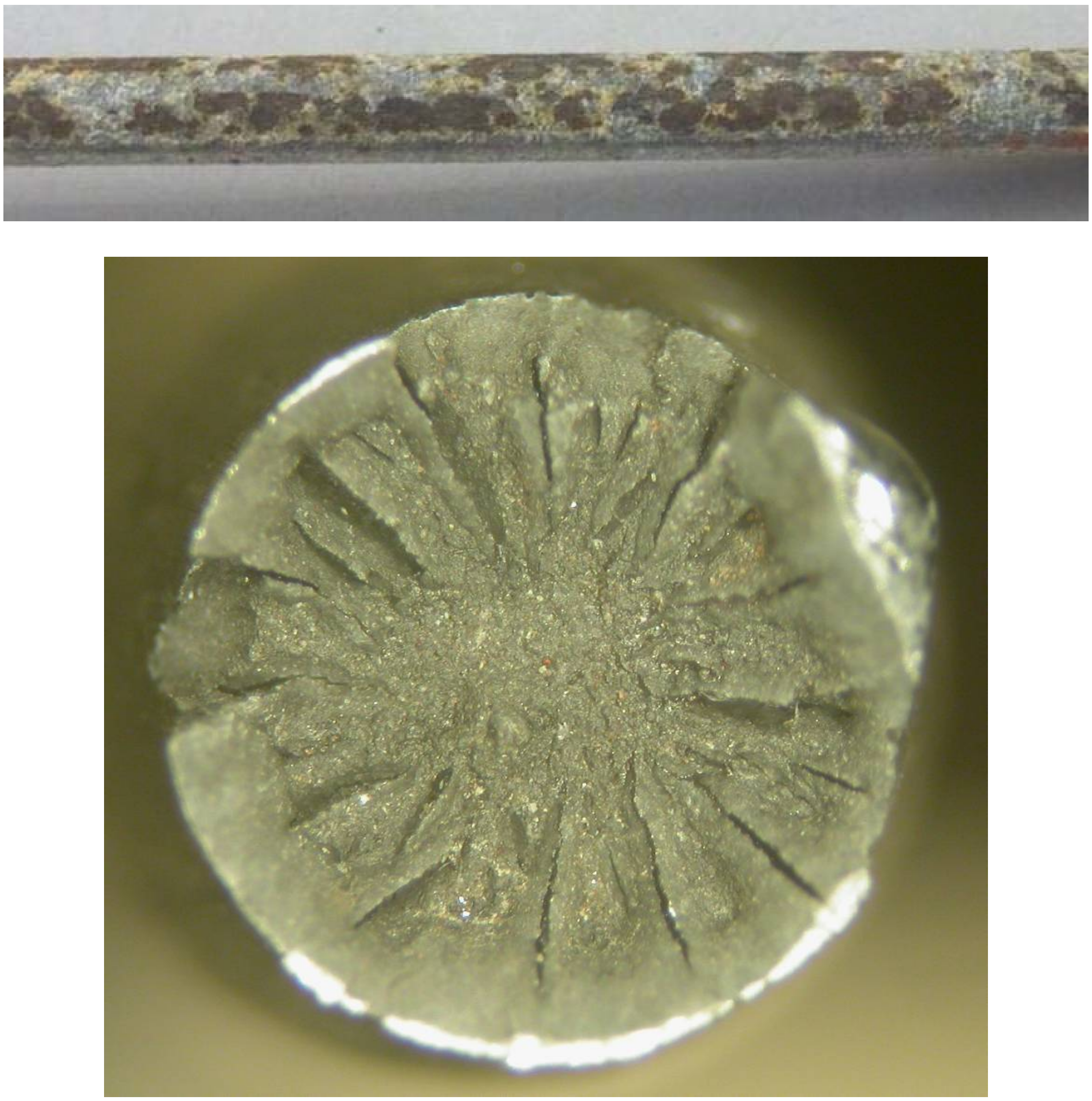


Fig.15 Wire 1-3 surface (top) and fracture surface after tensile testing (bottom).

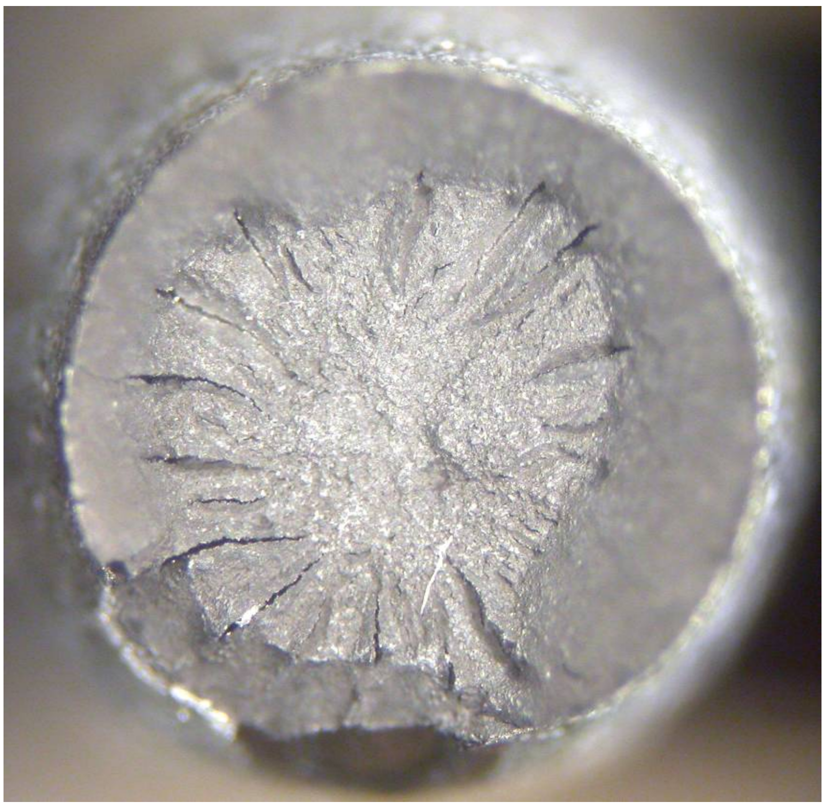


Fig.16 Wire 1-4 surface (top) and fracture surface after tensile testing (bottom).

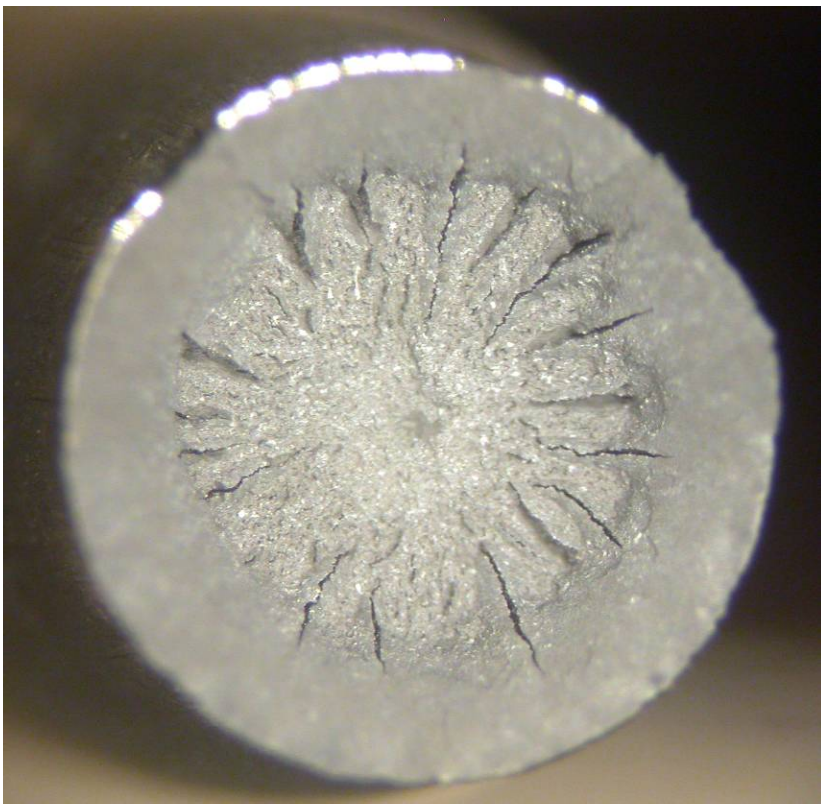


Fig.17 Wire 1-5 surface (top) and fracture surface after tensile testing (bottom).

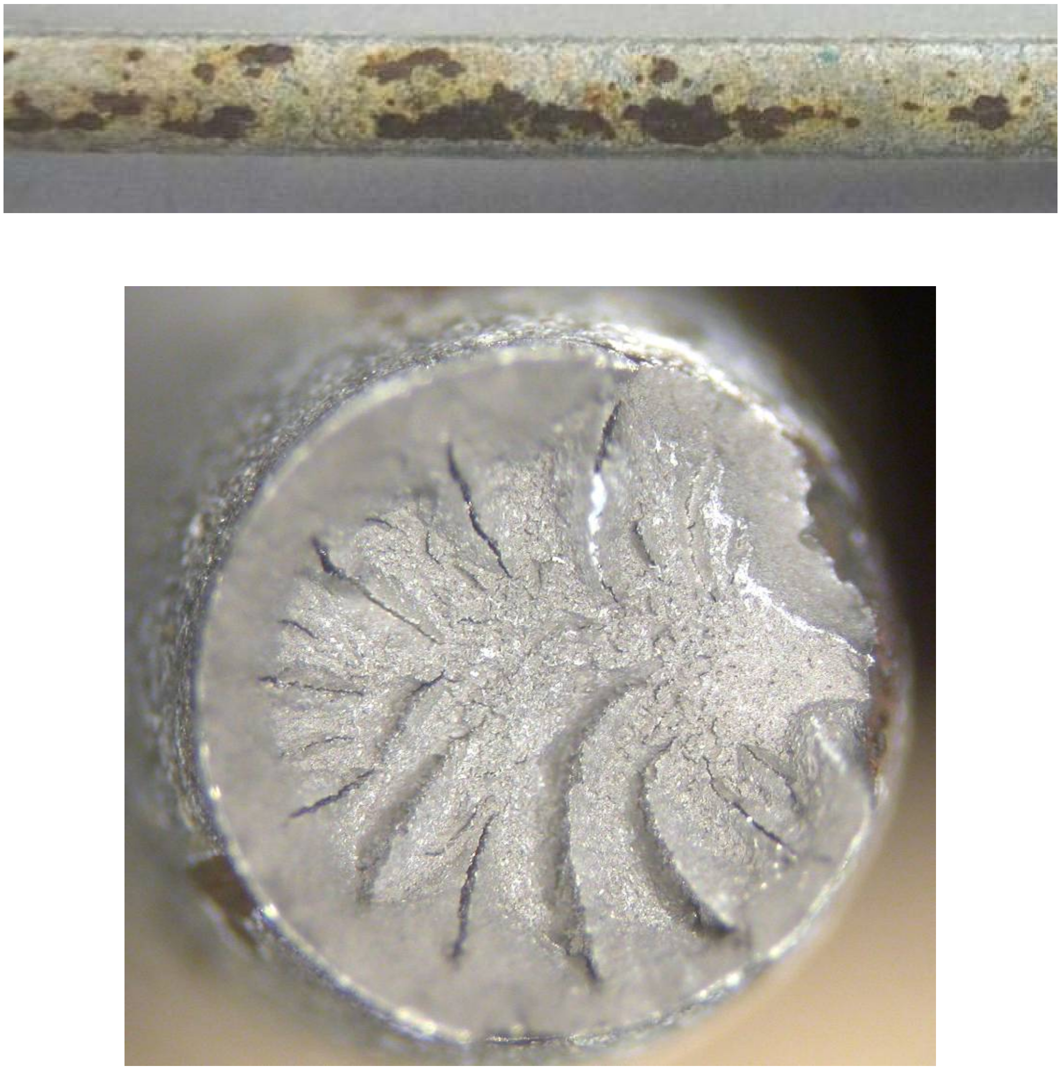


Fig.18 Wire 1-6 surface (top) and fracture surface after tensile testing (bottom).

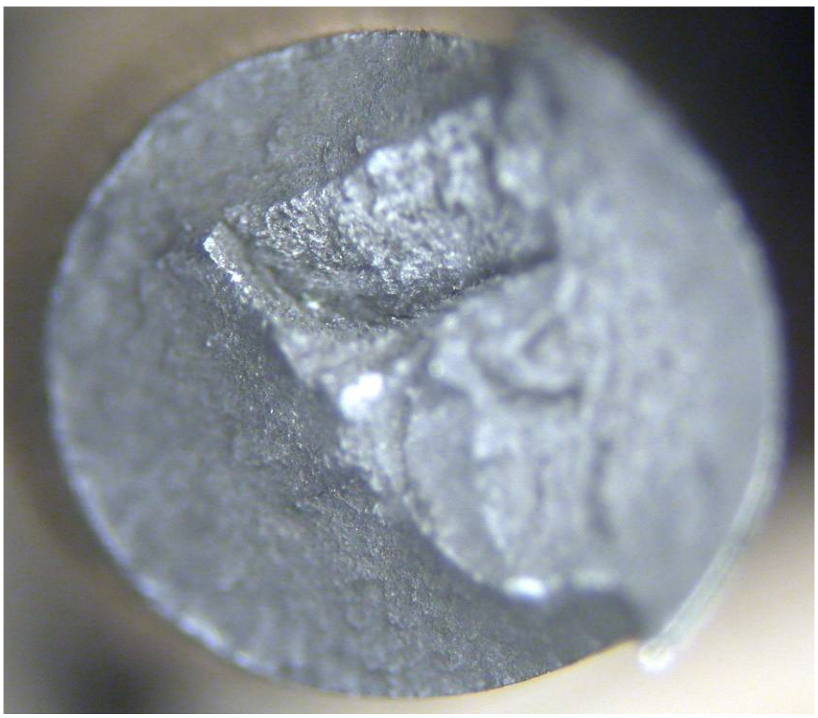


Fig. 19 Wire 2-1 surface (top) and fracture surface after tensile testing (bottom).

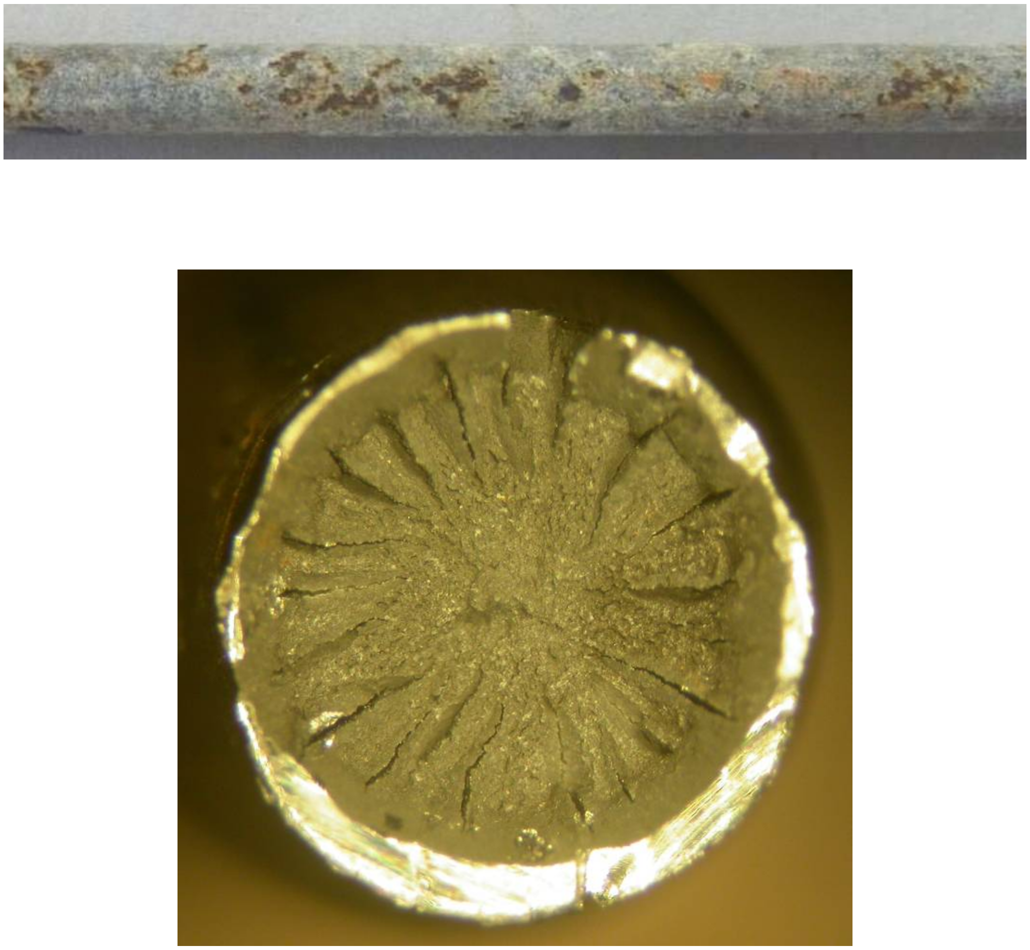


Fig. 20 Wire 2-2 surface (top) and fracture surface after tensile testing (bottom).

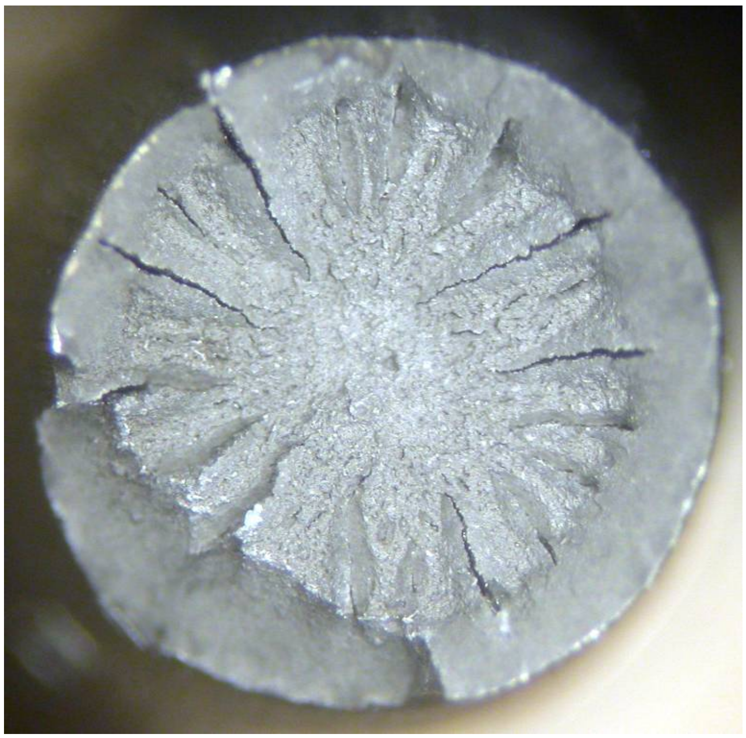


Fig. 21 Wire 2-3 surface (top) and fracture surface after tensile testing (bottom).

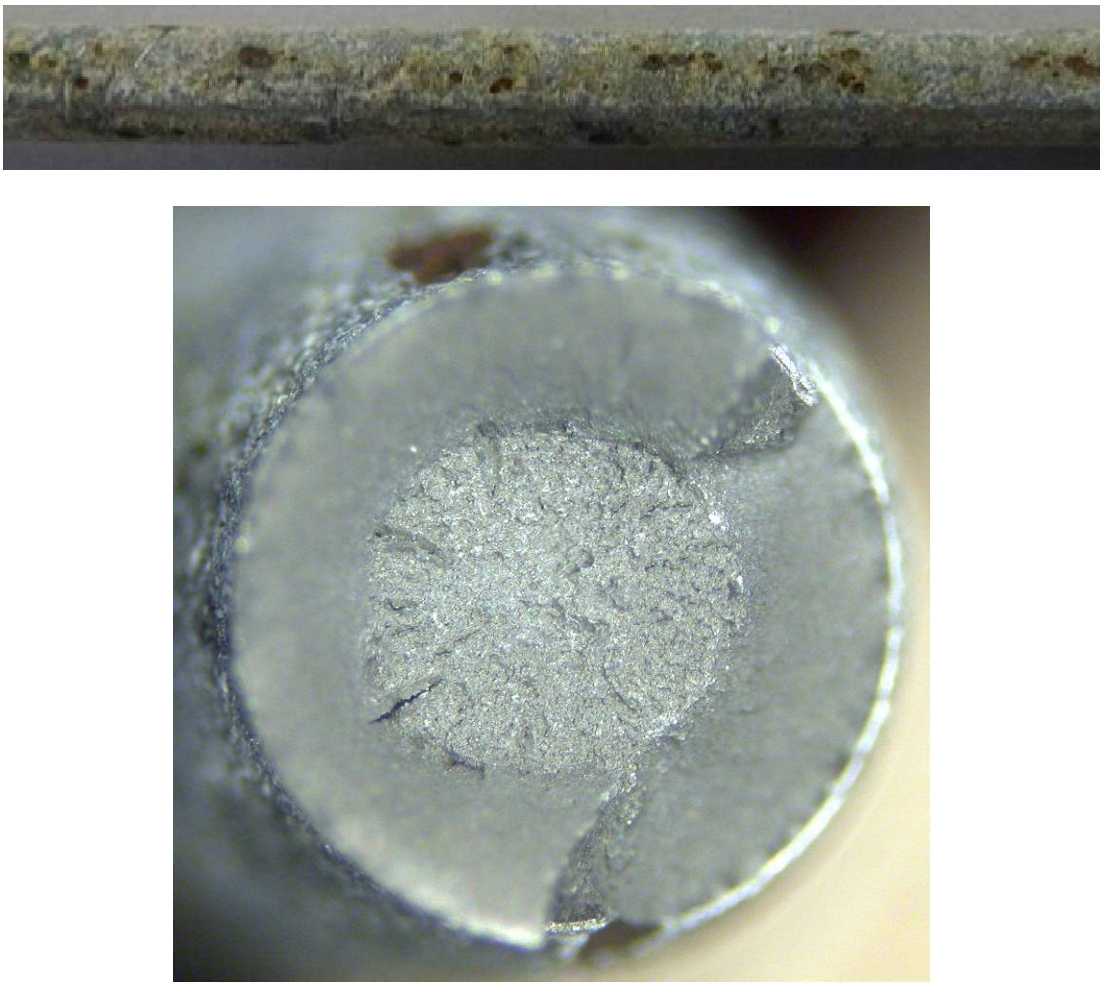


Fig. 22 Wire 2-4 surface (top) and fracture surface after tensile testing (bottom).

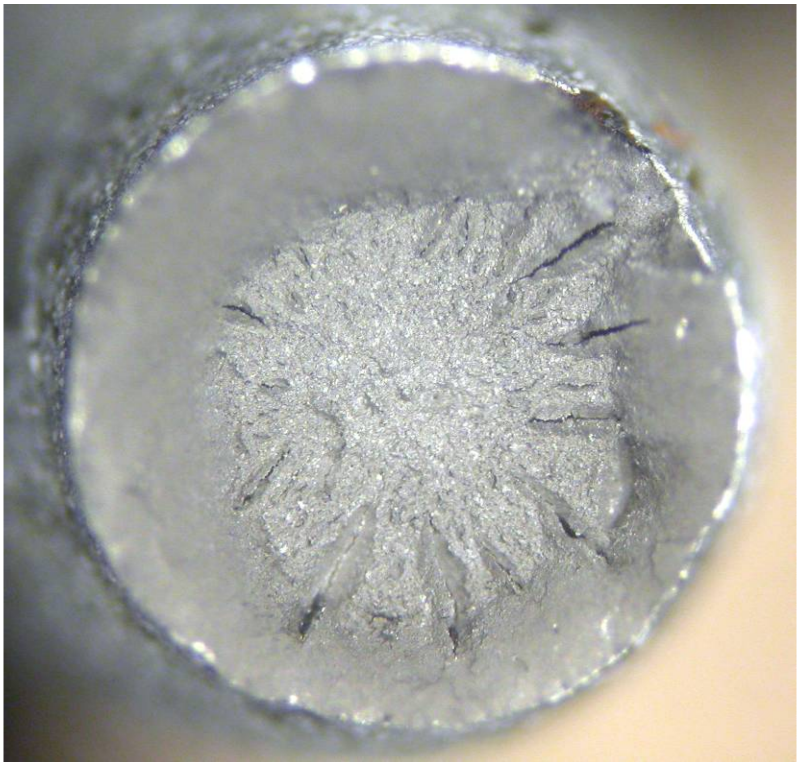


Fig. 23 Wire 2-5 surface (top) and fracture surface after tensile testing (bottom).

Fig. 24 Wire 3-1 surface (top) and fracture surface after tensile testing (bottom).

Fig. 25 Wire 3-2 surface (top) and fracture surface after tensile testing (bottom).

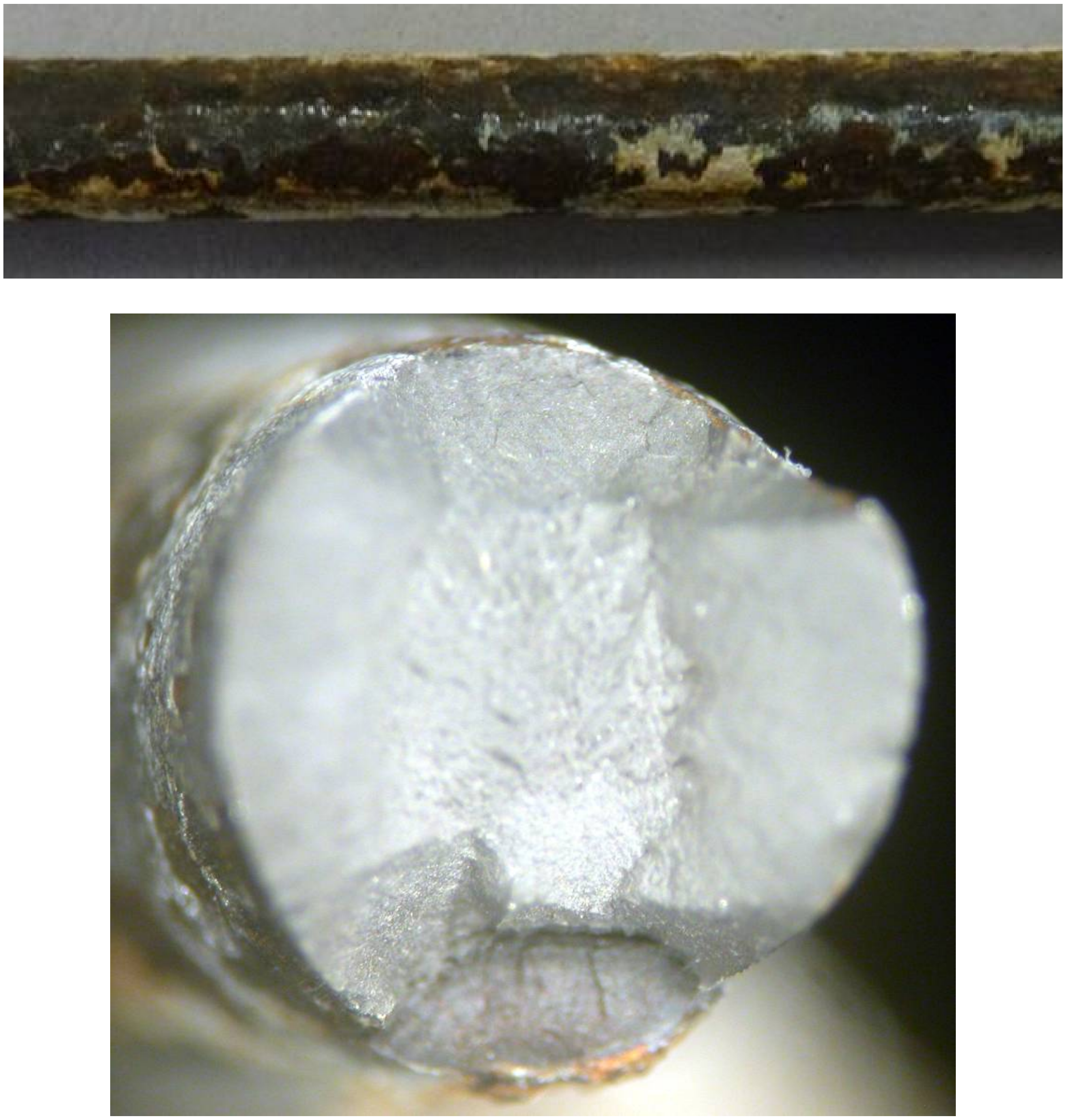


Fig. 26 Wire 3-3 surface (top) and fracture surface after tensile testing (bottom).

Fig. 27 Wire 3-4 surface (top) and fracture surface after tensile testing (bottom).

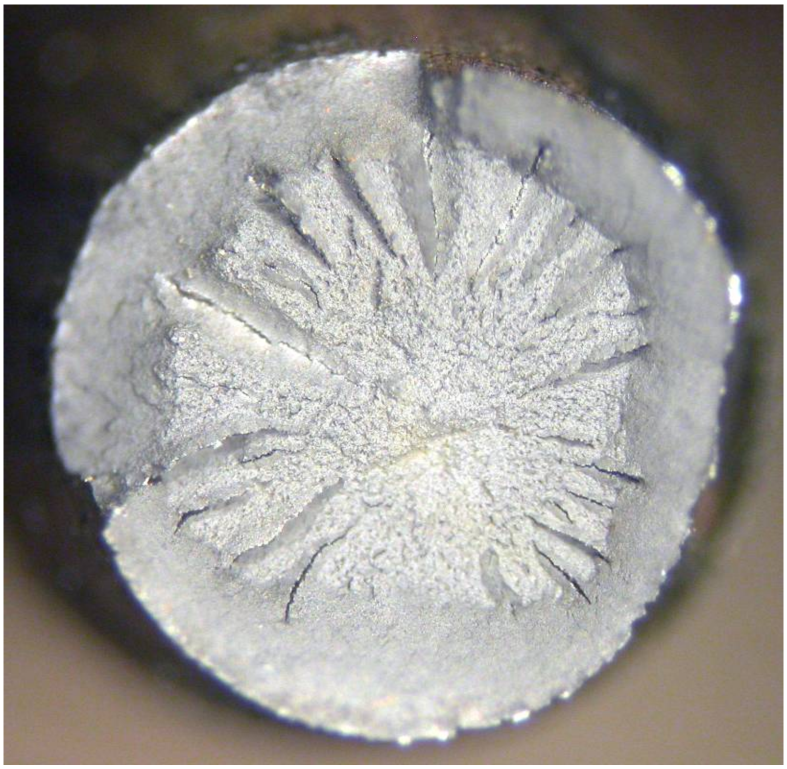


Fig. 28 Wire 3-5 surface (top) and fracture surface after tensile testing (bottom).

Fig. 29 Wire 3-6 surface (top) and fracture surface after tensile testing (bottom).

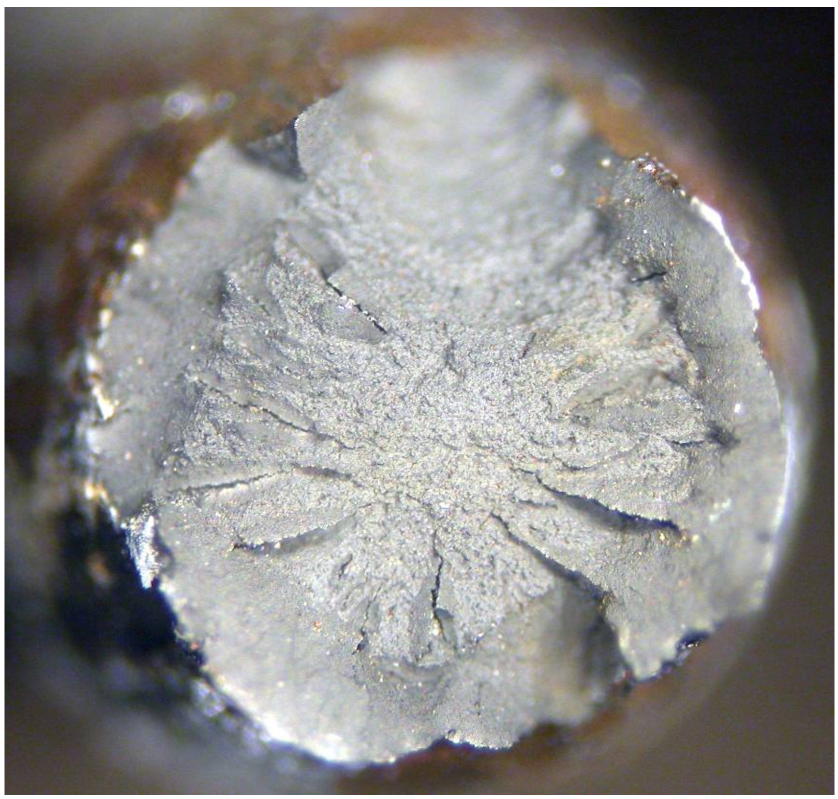


Fig. 30 Wire 4-1 surface (top) and fracture surface after tensile testing (bottom).

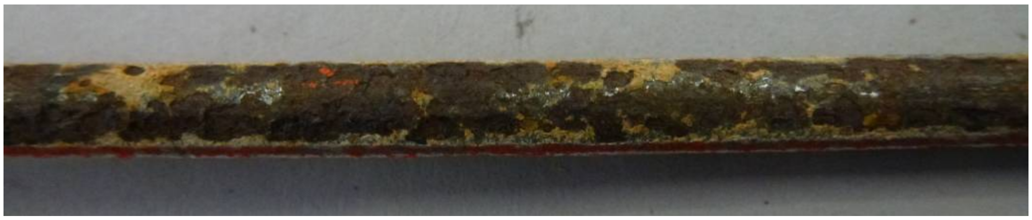
Fig. 31 Wire 4-2 surface (top) and fracture surface after tensile testing (bottom).

Fig. 32 Wire 4-3 surface (top) and fracture surface after tensile testing (bottom).

Fig. 33 Wire 4-4 surface (top) and fracture surface after tensile testing (bottom).

Fig. 34 Wire 4-5 surface (top) and fracture surface after tensile testing (bottom).

Fig. 35 Wire 4-6 surface (top) and fracture surface after tensile testing (bottom).



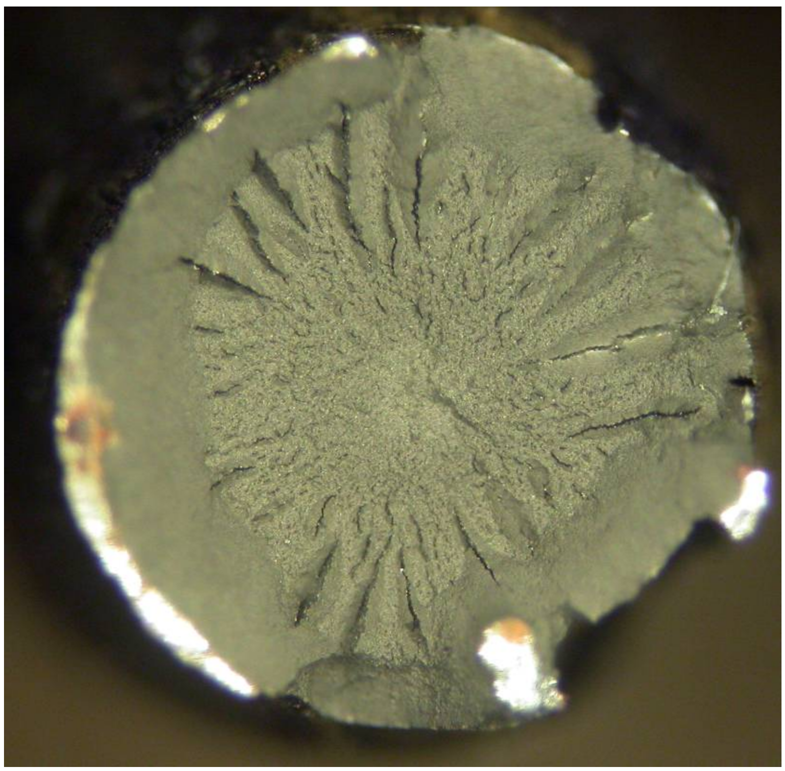


Fig. 36 Wire 5-1 surface (top) and fracture surface after tensile testing (bottom).

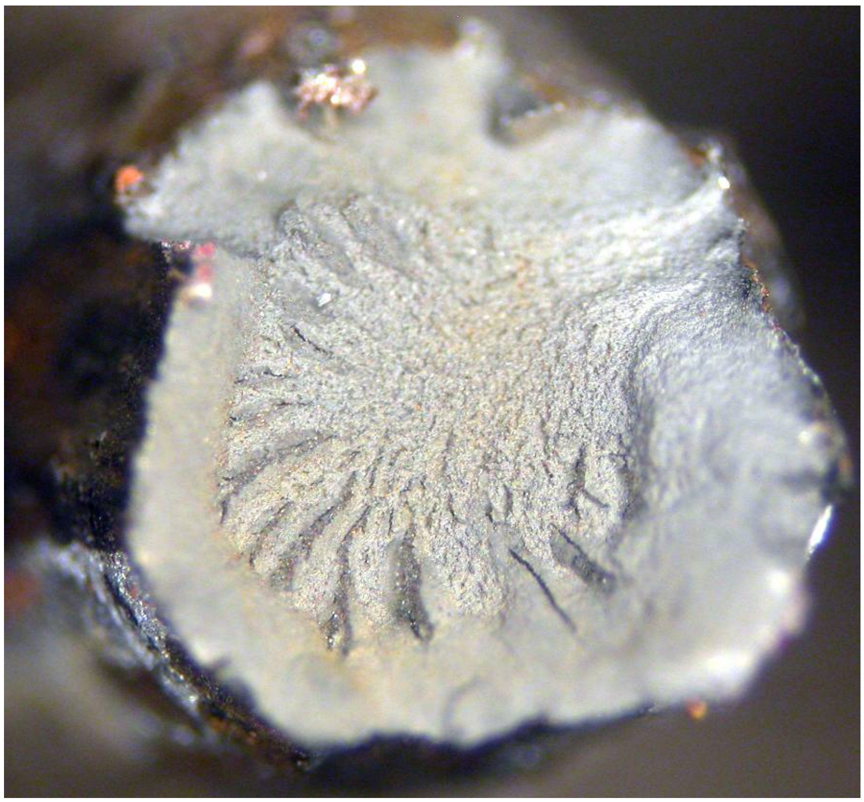


Fig. 37 Wire 5-2 surface (top) and fracture surface after tensile testing (bottom).

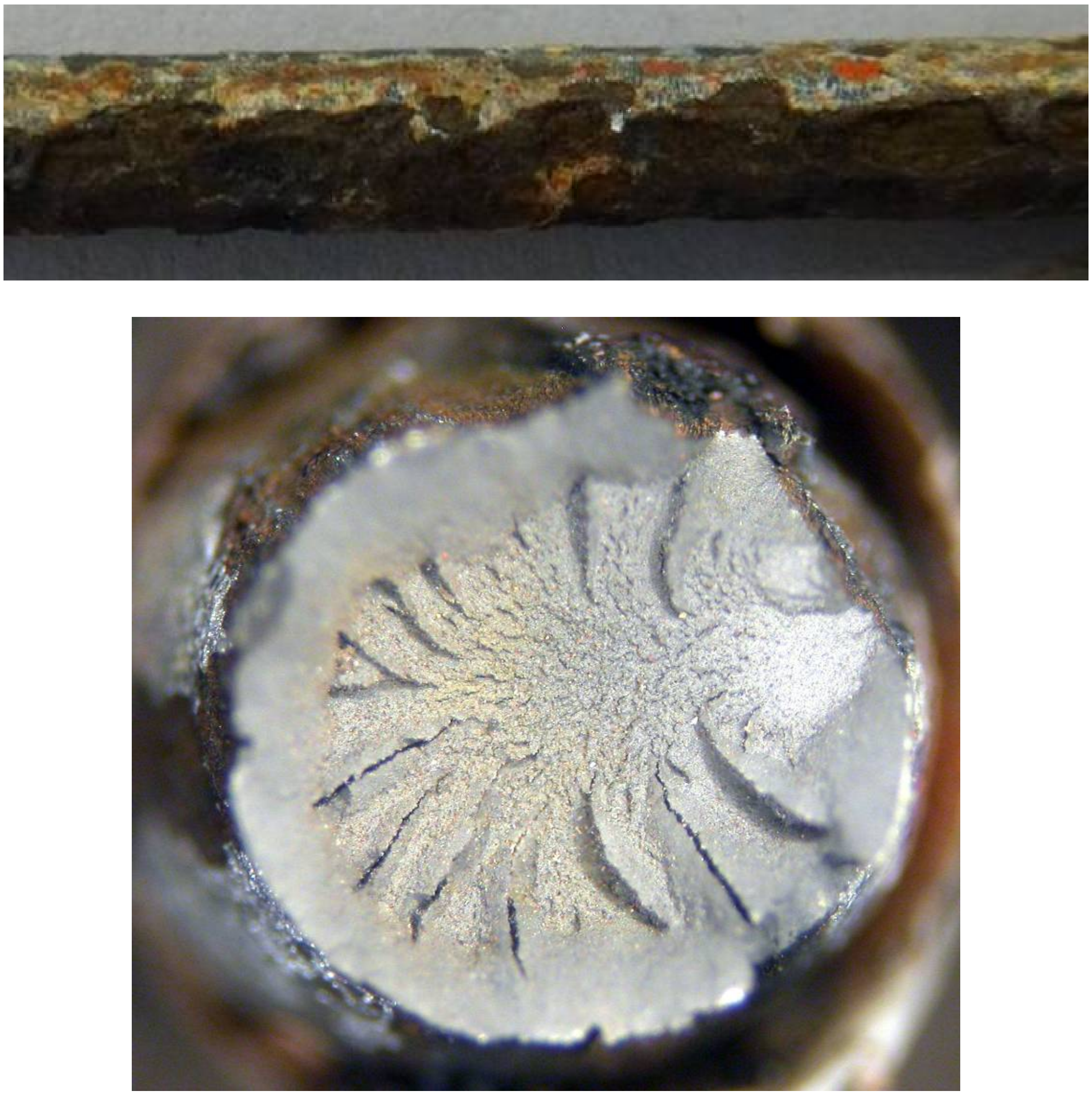


Fig. 38 Wire 5-3 surface (top) and fracture surface after tensile testing (bottom).

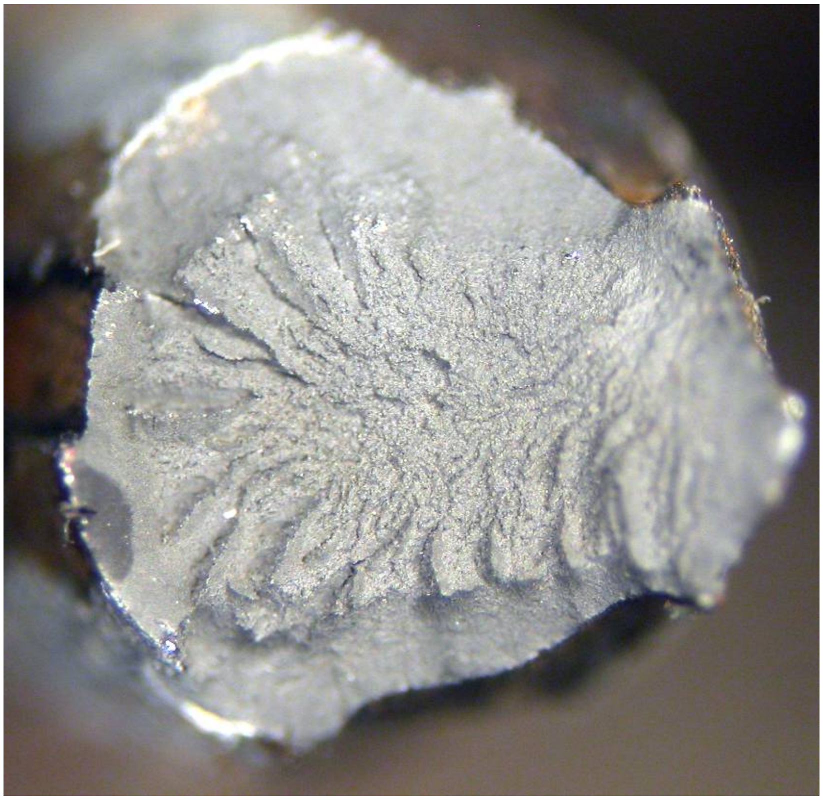


Fig. 39 Wire 5-4 surface (top) and fracture surface after tensile testing (bottom).

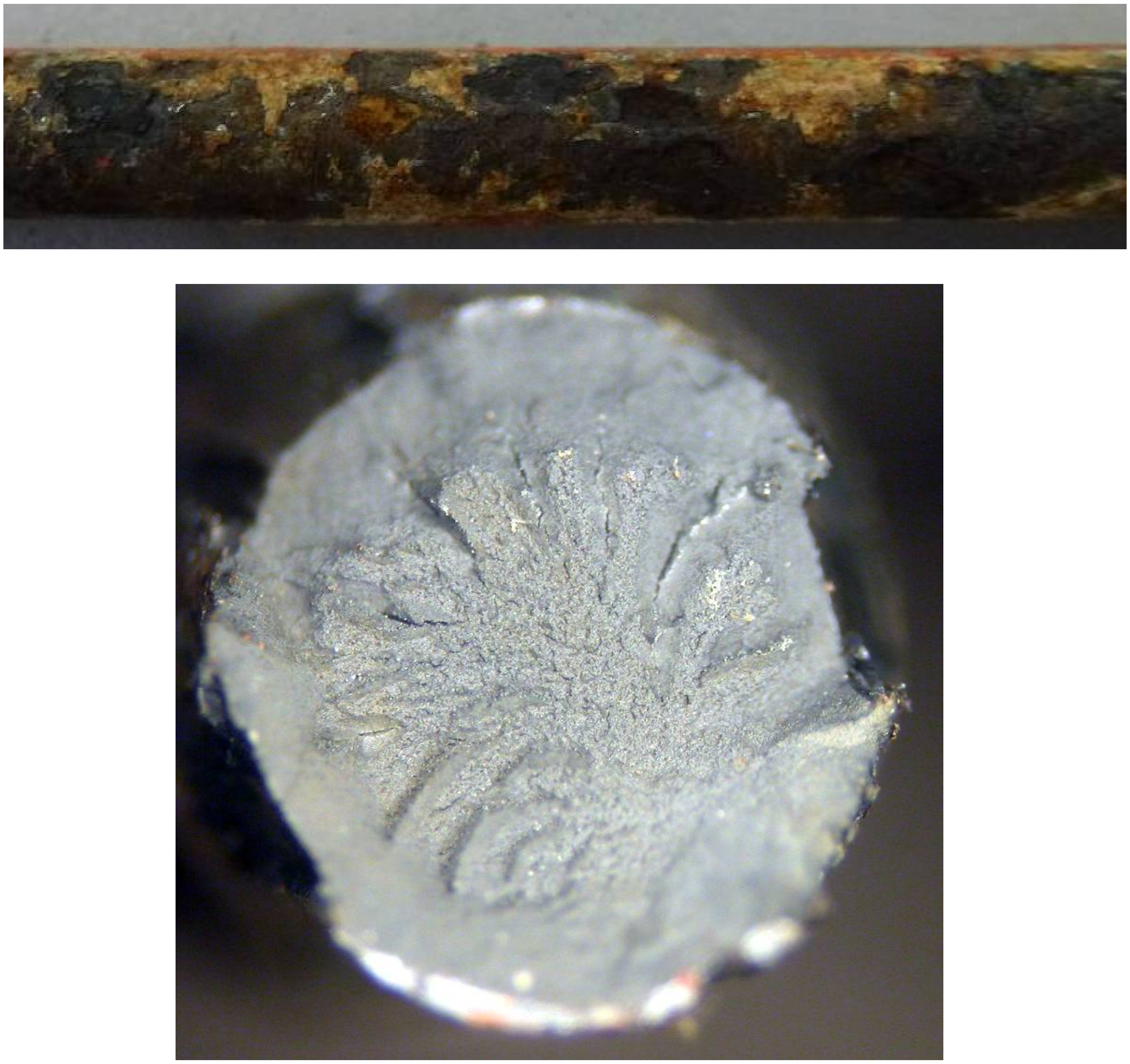


Fig. 40 Wire 5-5 surface (top) and fracture surface after tensile testing (bottom).

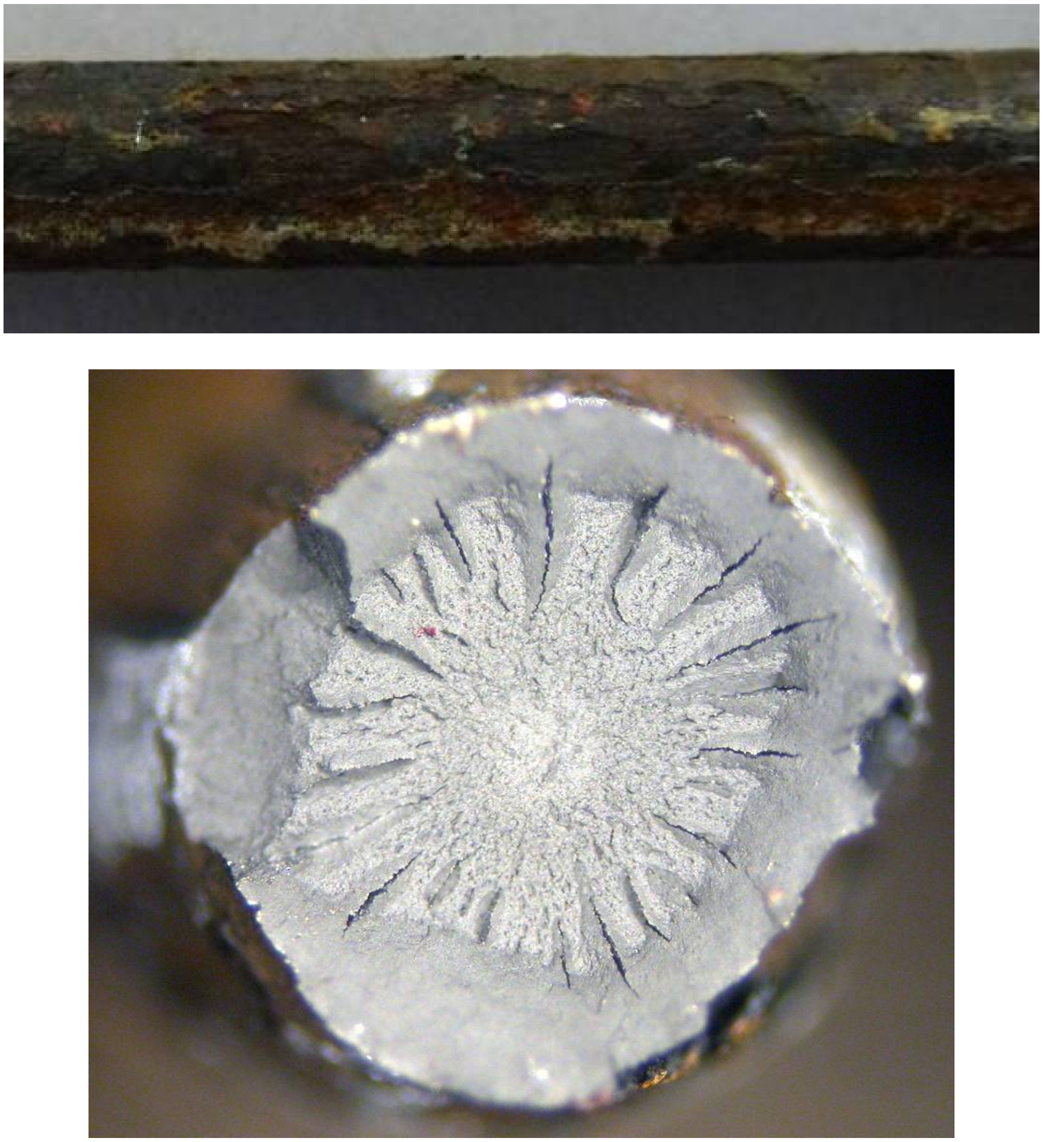


Fig. 41 Wire 5-6 surface (top) and fracture surface after tensile testing (bottom).

Fig. 42 Wire 5-7 surface (top) and fracture surface after tensile testing (bottom).

Fig. 43 Wire 5-8 surface (top) and fracture surface after tensile testing (bottom).

Fig. 44 Wire 6-1 surface (top) and fracture surface after tensile testing (bottom).

Fig. 45 Wire 6-2 surface (top) and fracture surface after tensile testing (bottom).

Fig. 46 Wire 6-3 surface (top) and fracture surface after tensile testing (bottom).

Fig. 47 Wire 6-4 surface (top) and fracture surface after tensile testing (bottom).

Fig. 48 Wire 6-5 surface (top) and fracture surface after tensile testing (bottom).

Fig. 49 Wire 7-1 surface (top) and fracture surface after tensile testing (bottom).

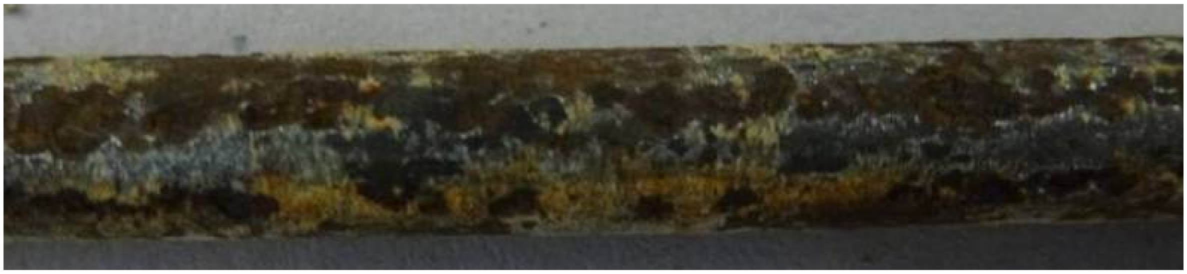


Fig. 50 Wire 7-2 surface (top) and fracture surface after tensile testing (bottom).

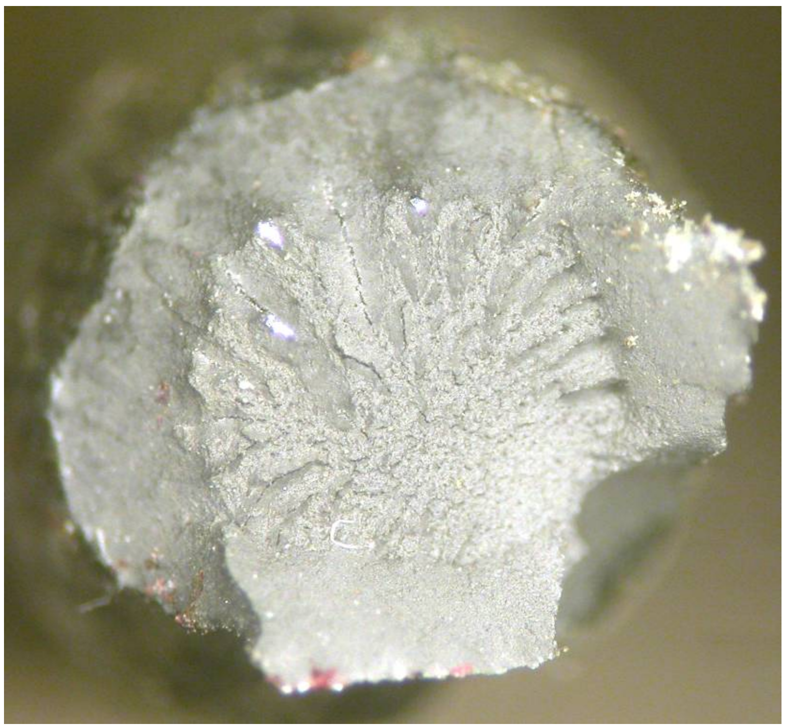


Fig. 51 Wire 7-3 surface (top) and fracture surface after tensile testing (bottom).

Fig. 52 Wire 7-4 surface (top) and fracture surface after tensile testing (bottom).

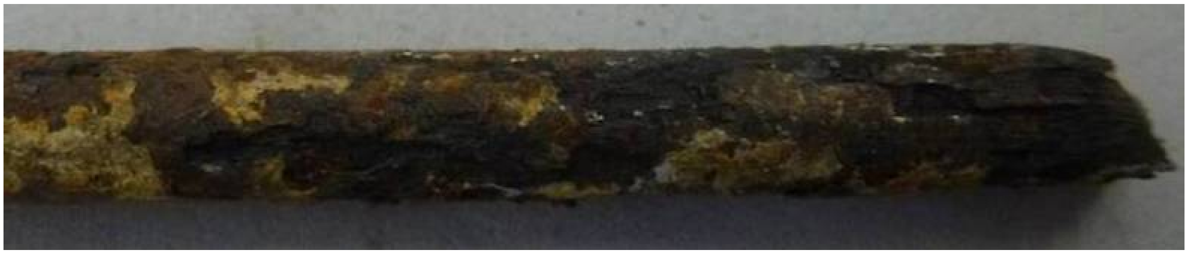


Fig. 53 Wire 7-5 surface (top) and fracture surface after tensile testing (bottom).

Fig. 54 Wire 7-6 surface (top) and fracture surface after tensile testing (bottom).

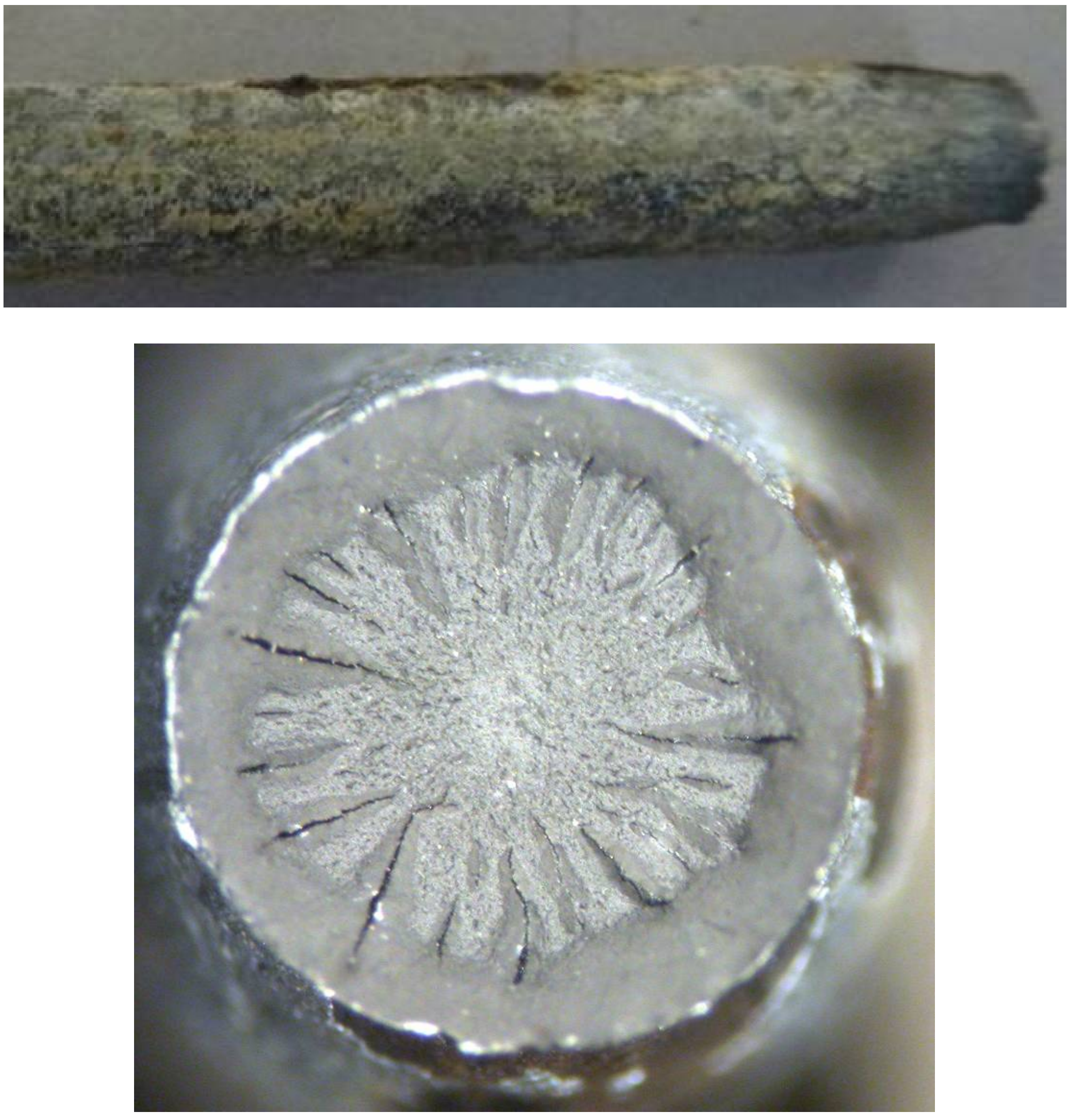


Fig. 55 Wire 8-1 surface (top) and fracture surface after tensile testing (bottom).

Fig. 56 Wire 8-2 surface (top) and fracture surface after tensile testing (bottom).

Fig. 57 Wire 8-3 surface (top) and fracture surface after tensile testing (bottom).

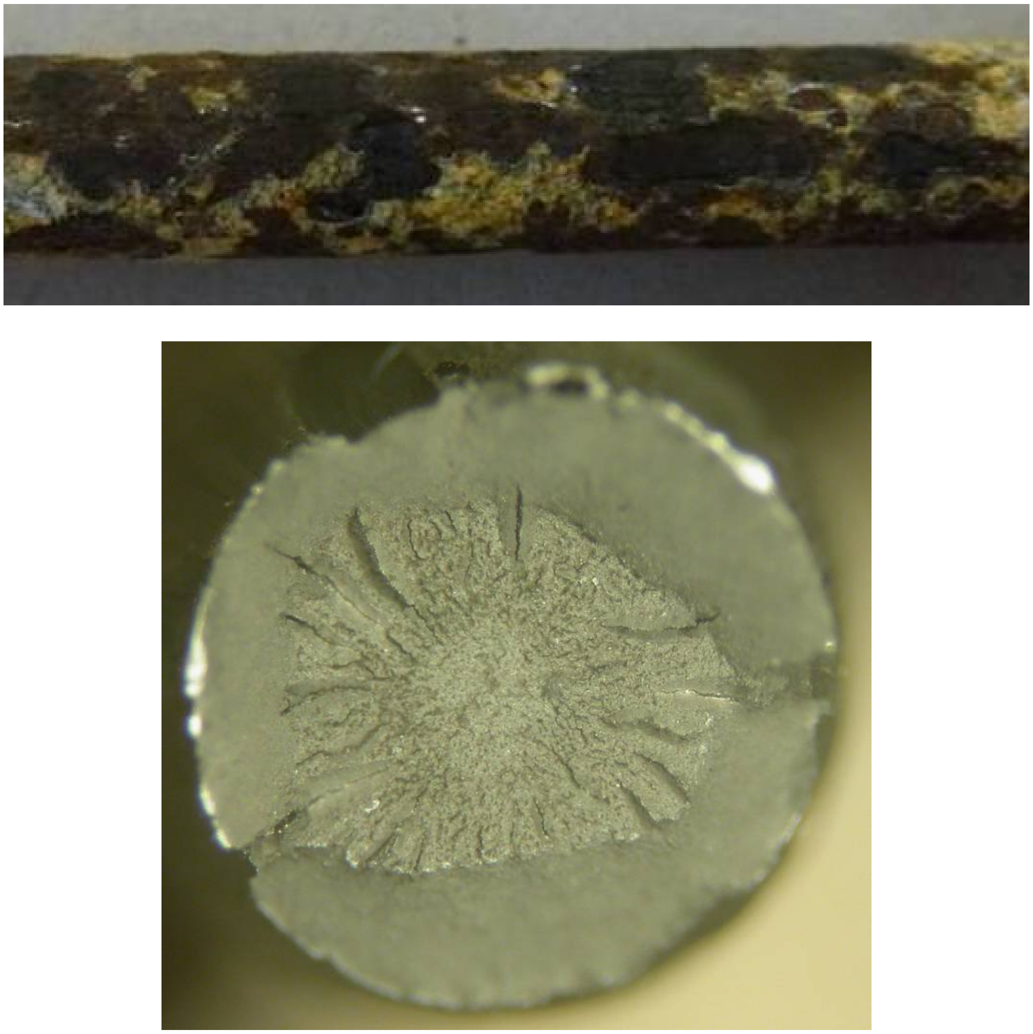


Fig. 58 Wire 8-4 surface (top) and fracture surface after tensile testing (bottom).

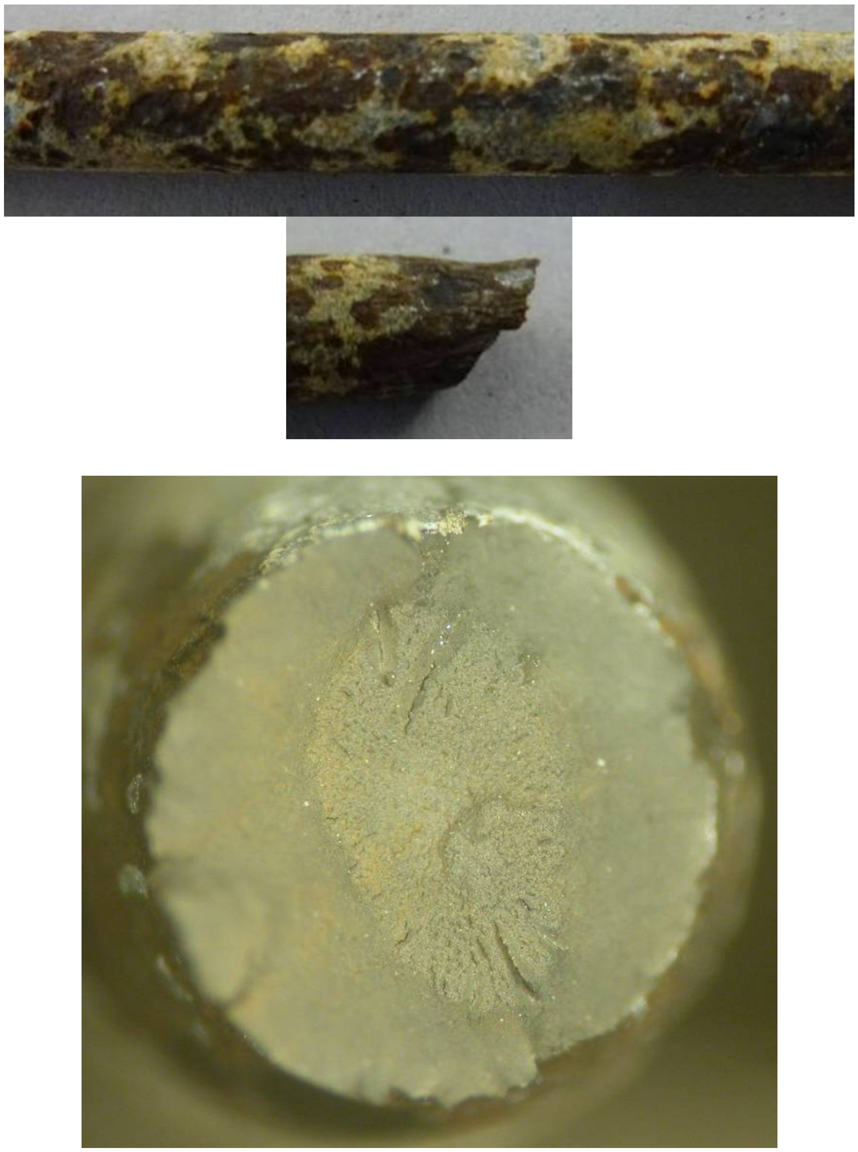


Fig. 59 Wire 8-5 surface (top) and fracture surface after tensile testing (bottom).

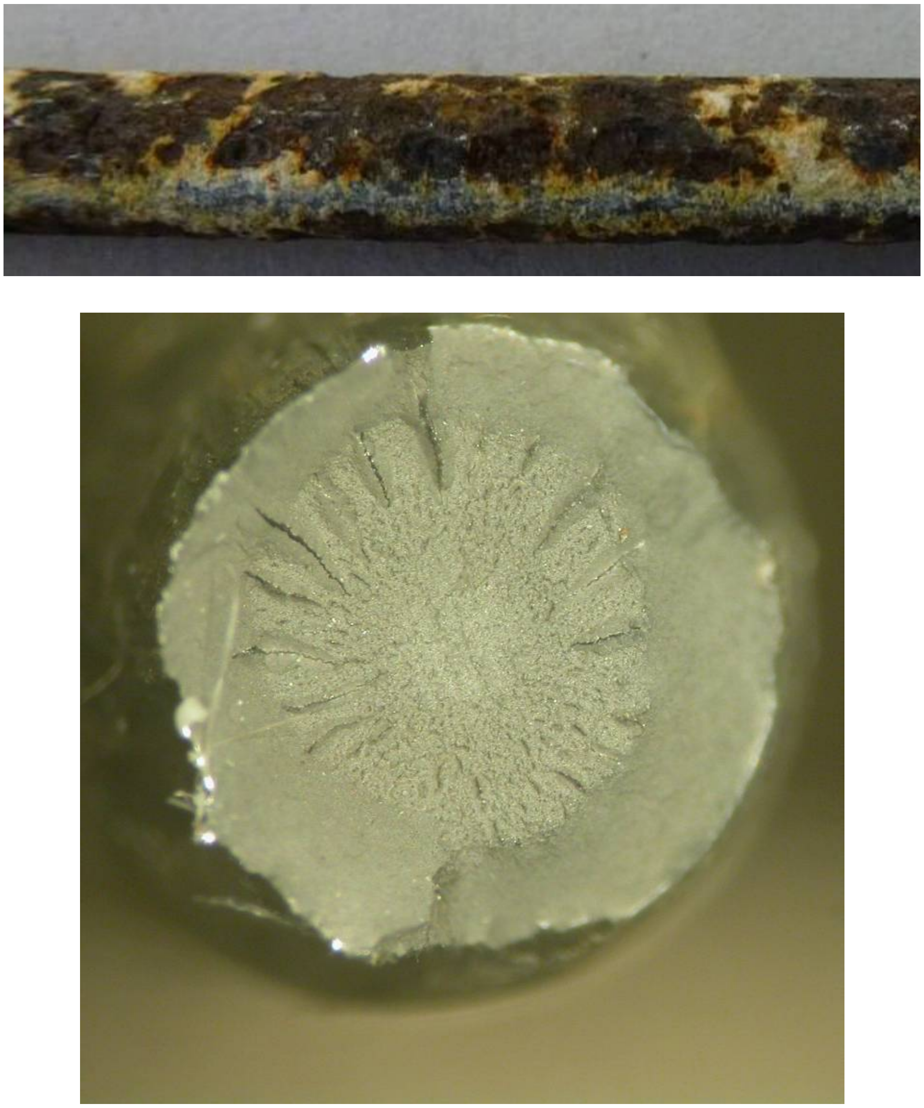


Fig. 60 Wire 8-6 surface (top) and fracture surface after tensile testing (bottom).

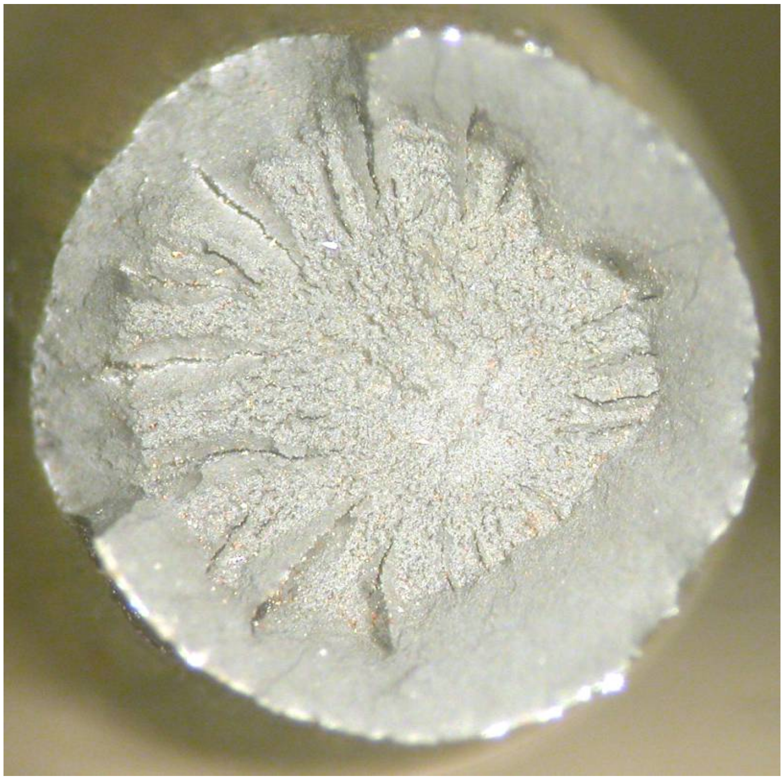


Fig. 61 Wire 9-1 surface (top) and fracture surface after tensile testing (bottom).

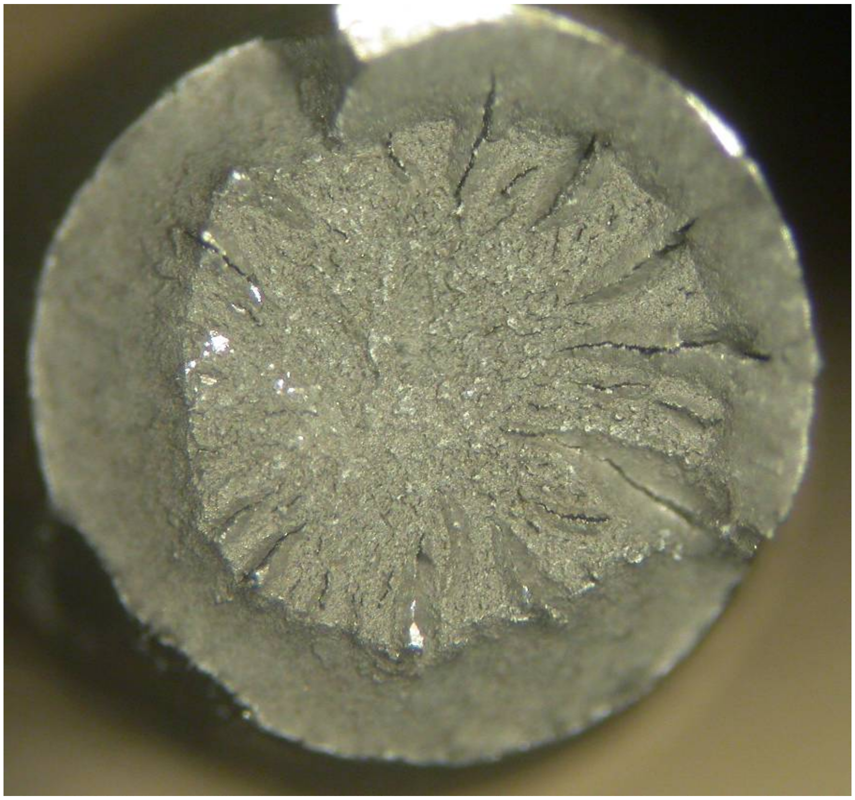


Fig. 62 Wire 9-2 surface (top) and fracture surface after tensile testing (bottom).

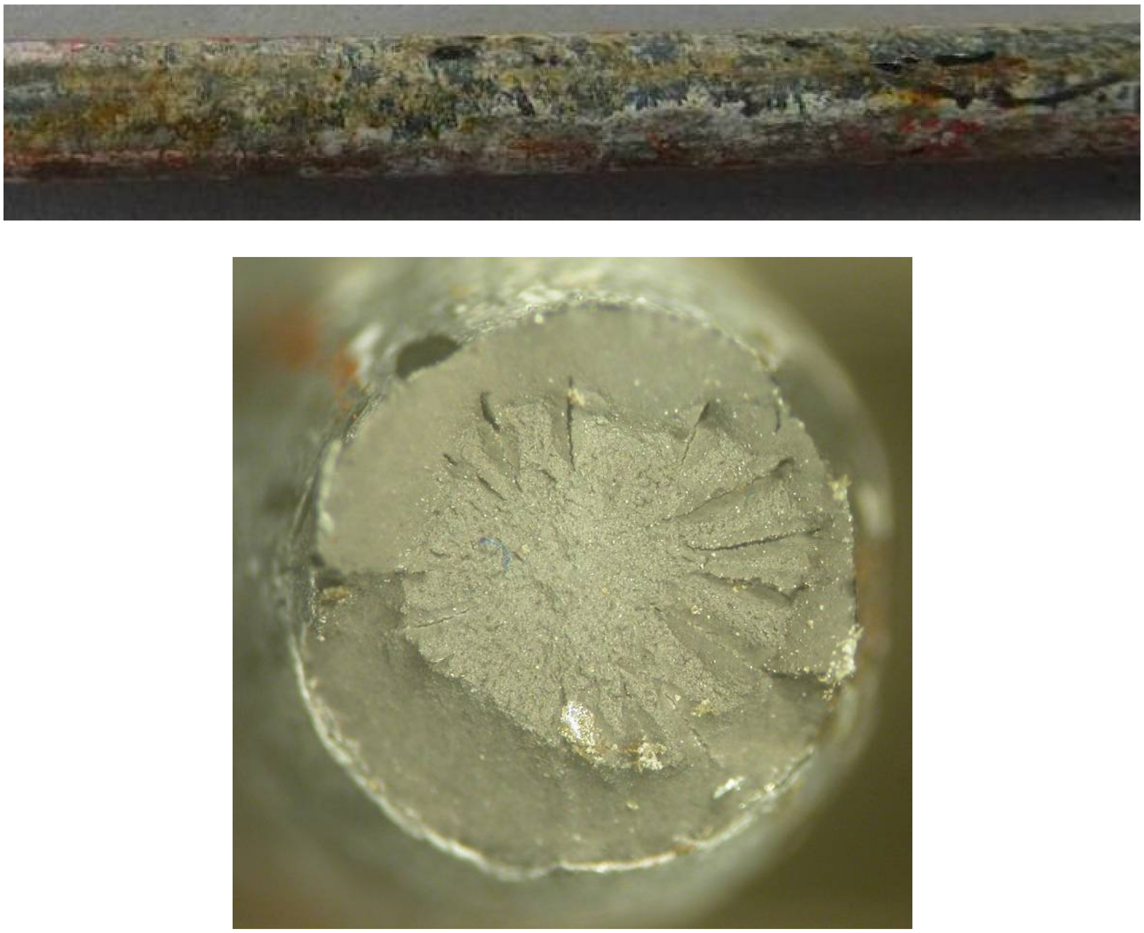


Fig. 63 Wire 9-3 surface (top) and fracture surface after tensile testing (bottom).

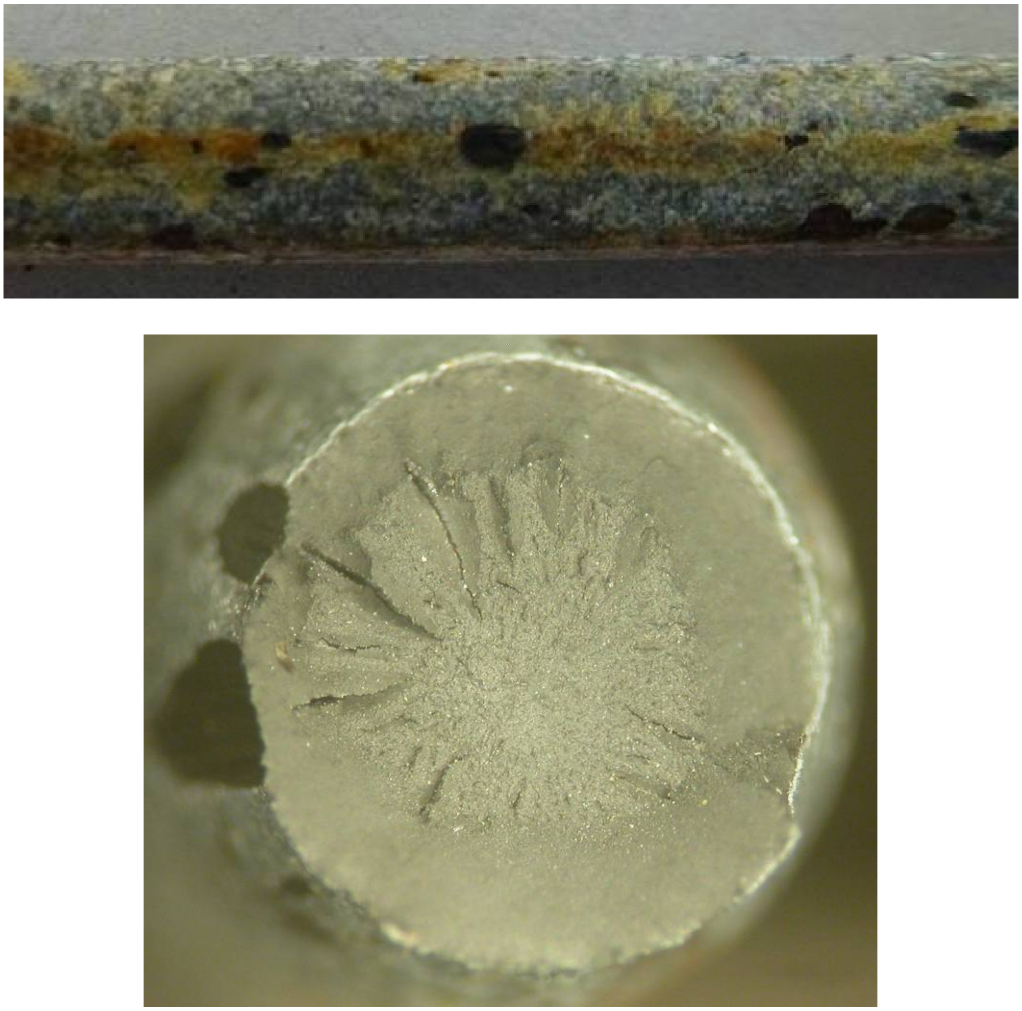


Fig. 64 Wire 9-4 surface (top) and fracture surface after tensile testing (bottom).

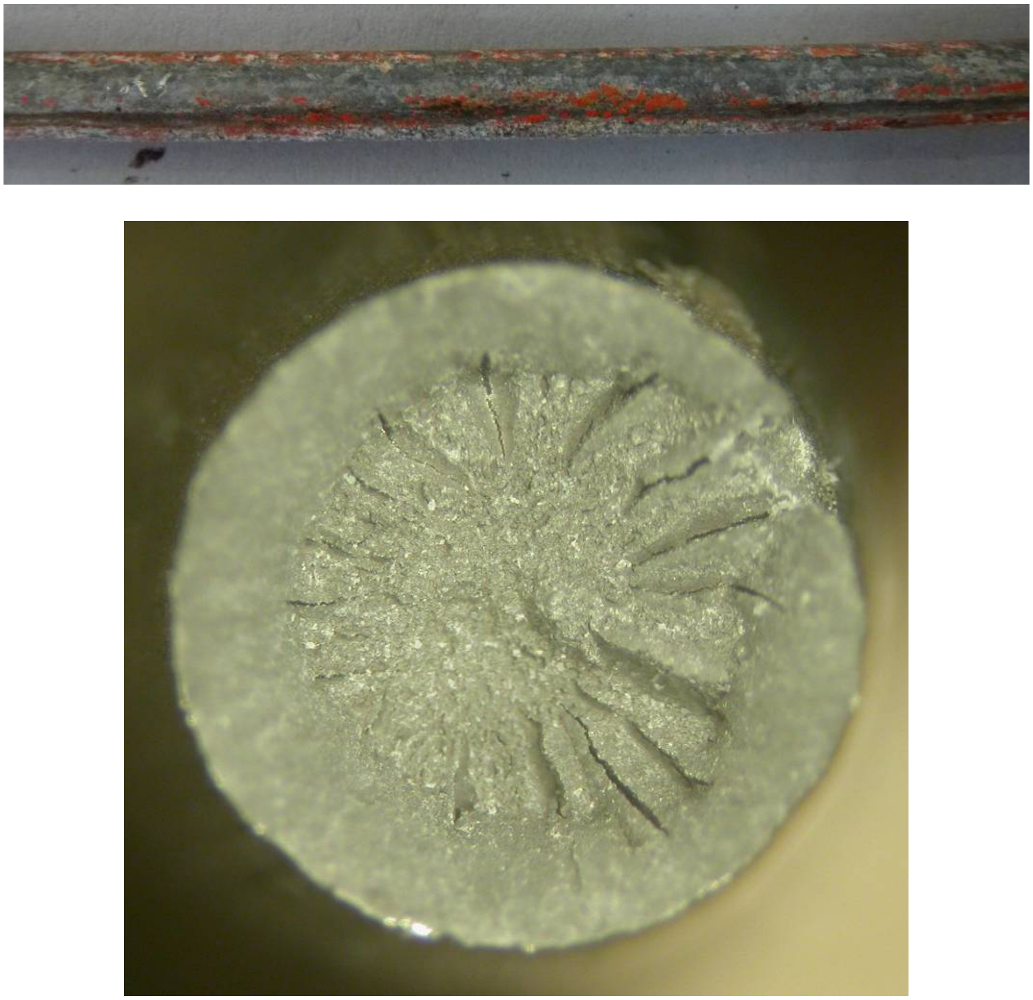


Fig. 65 Wire 9-5 surface (top) and fracture surface after tensile testing (bottom).

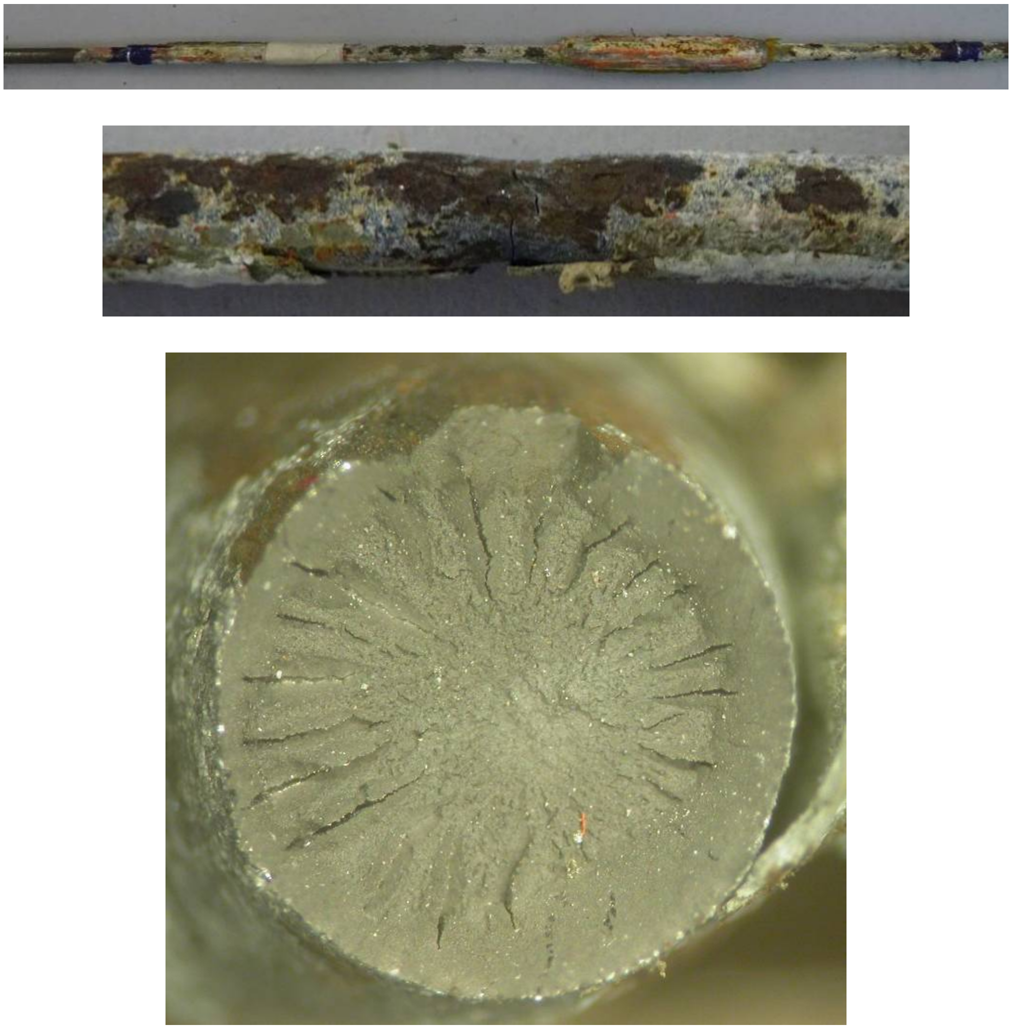


Fig. 66 Wire 9-6 surface (top) and fracture surface after tensile testing (bottom).

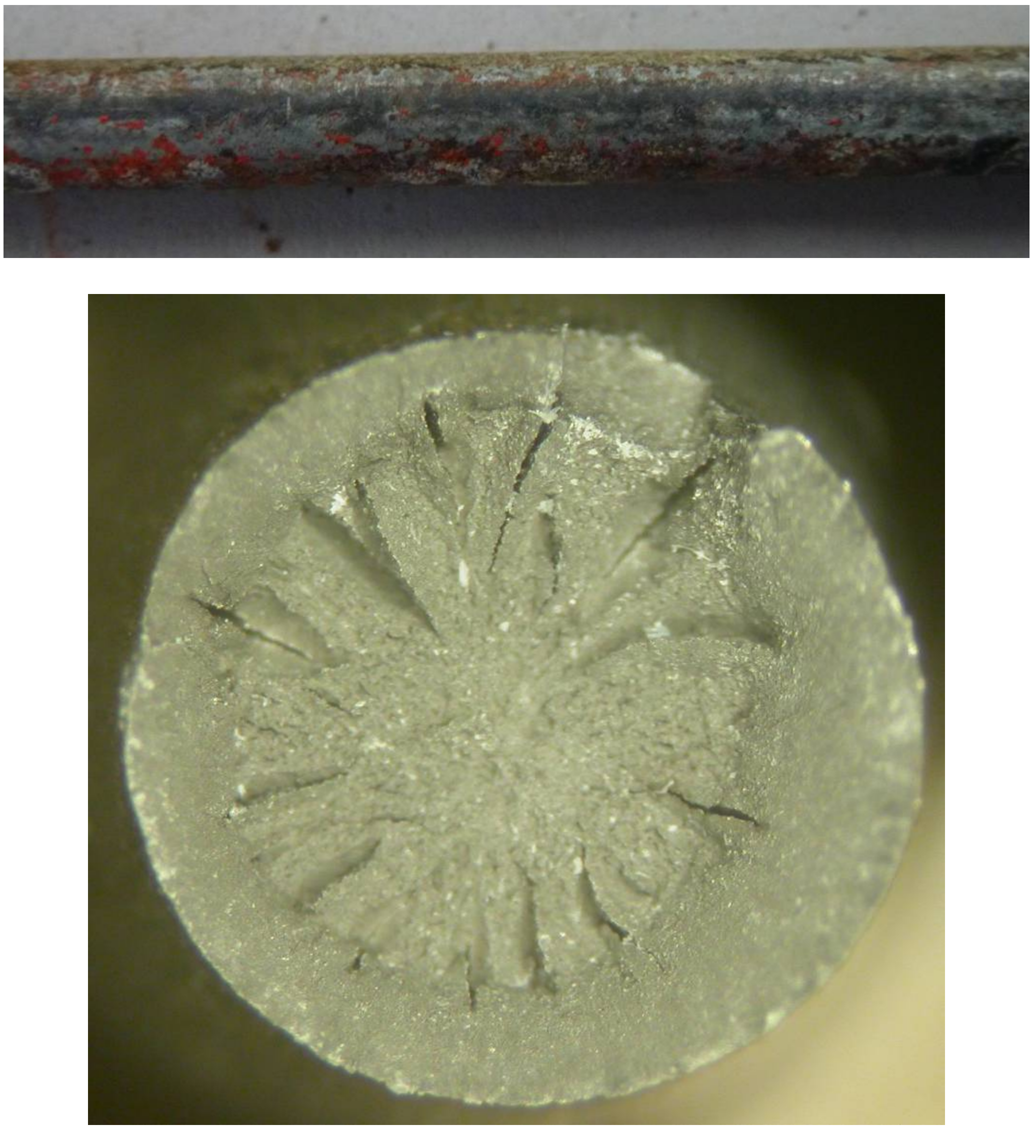


Fig. 67 Wire 10-1 surface (top) and fracture surface after tensile testing (bottom).

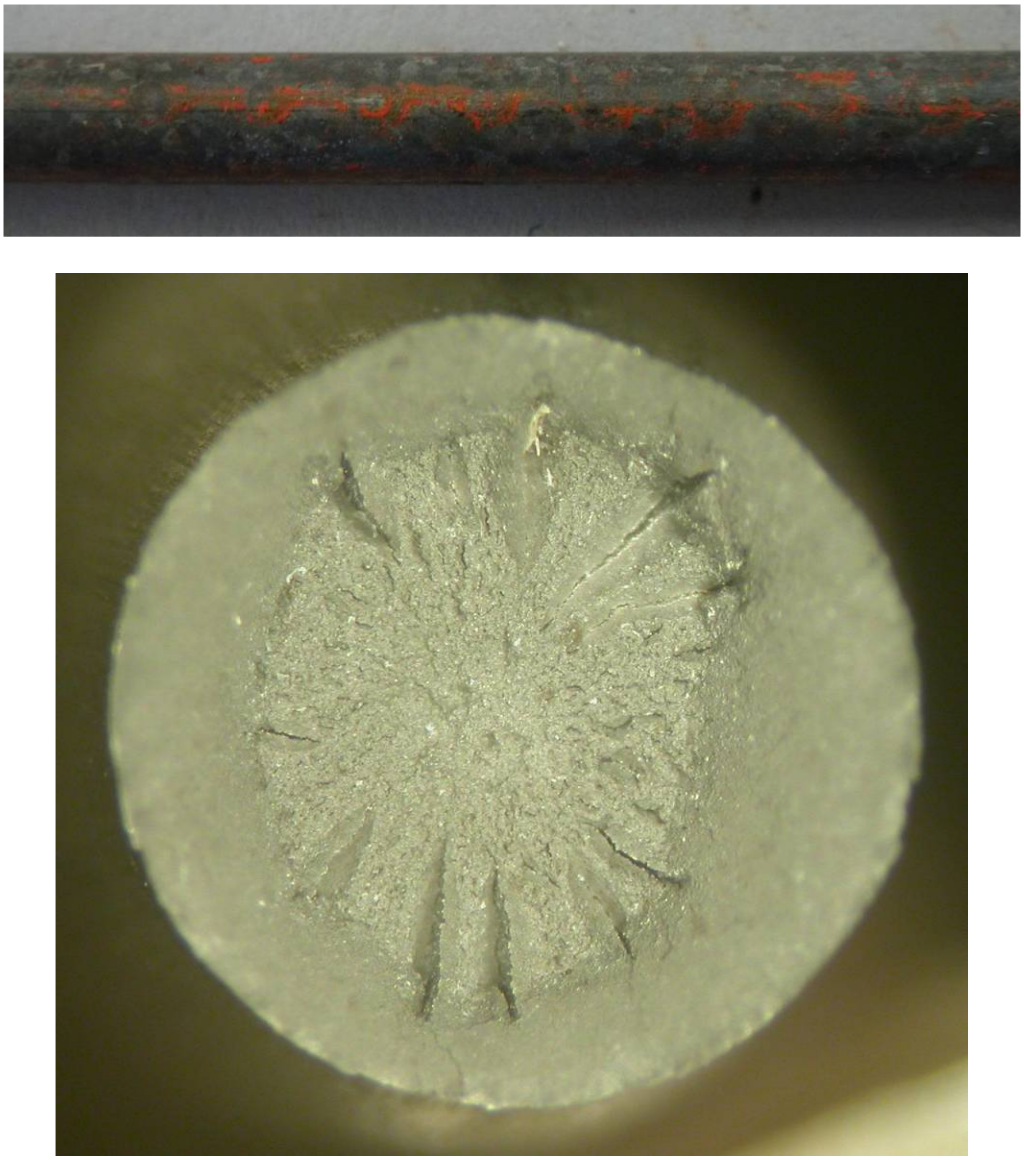


Fig. 68 Wire 10-2 surface (top) and fracture surface after tensile testing (bottom).

Fig. 69 Wire 10-3 surface (top) and fracture surface after tensile testing (bottom).

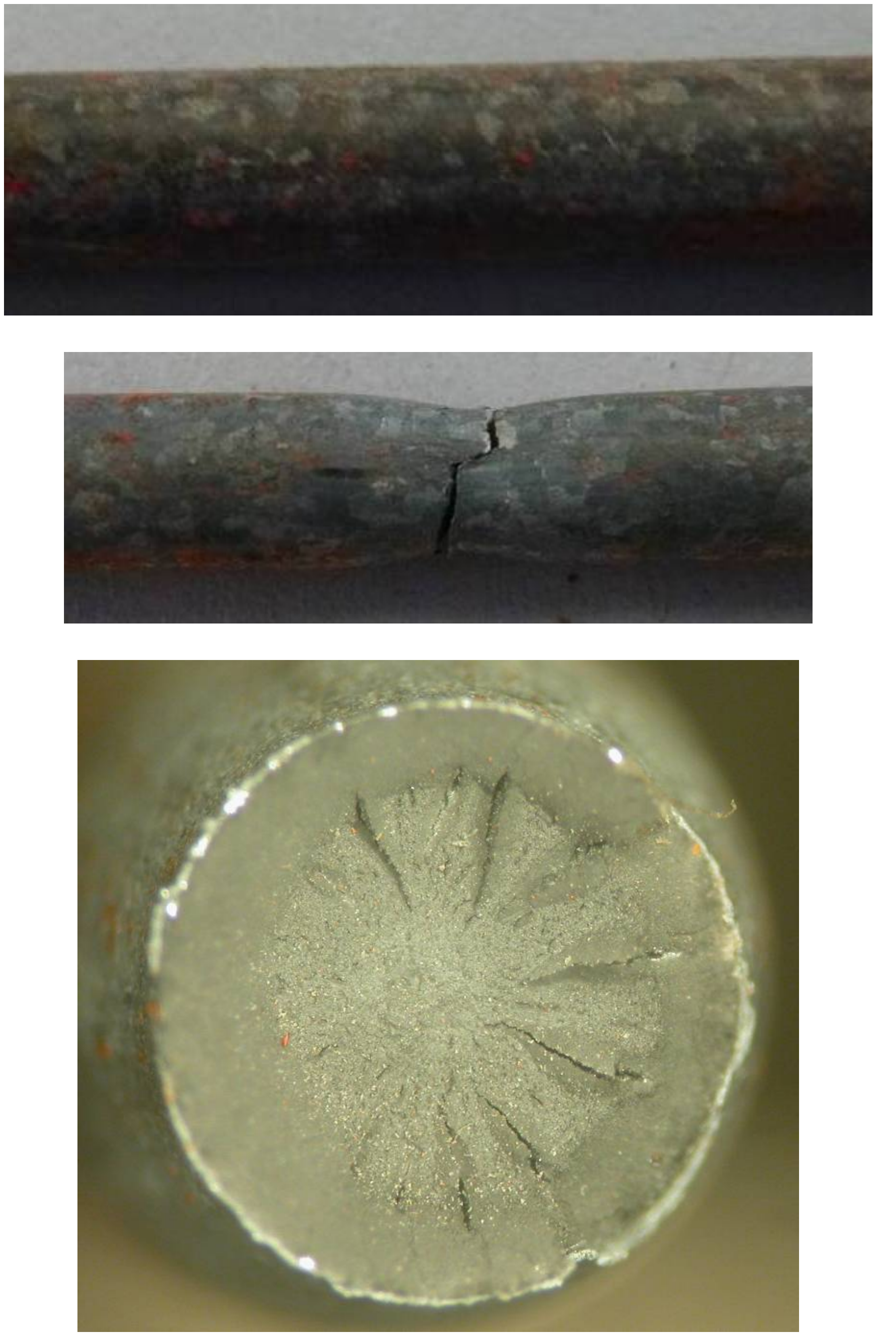


Fig. 70 Wire 10-4 surface (top) and fracture surface after tensile testing (bottom).

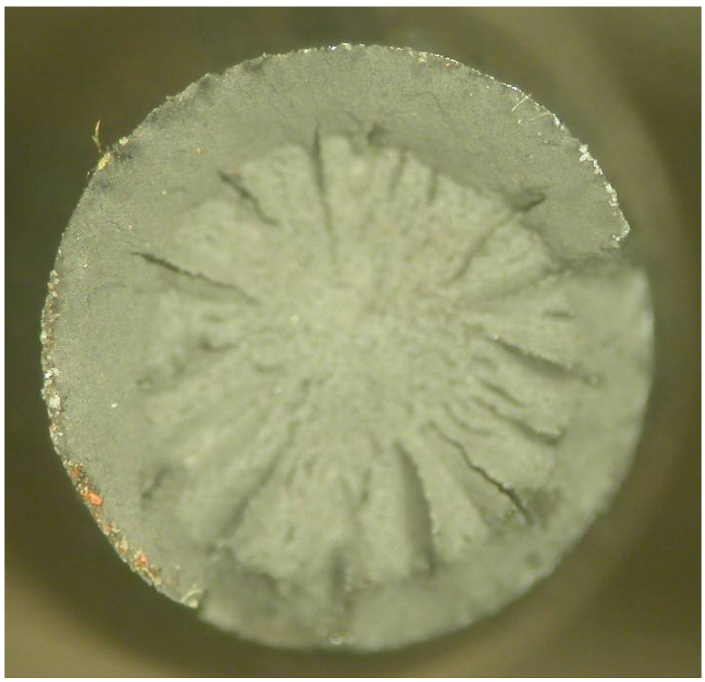


Fig. 71 Wire 10-5 surface (top) and fracture surface after tensile testing (bottom).

Fig. 72 Wire 10-6 surface (top) and fracture surface after tensile testing (bottom).

Fig. 73 Wire 10-7 surface (top) and fracture surface after tensile testing (bottom).

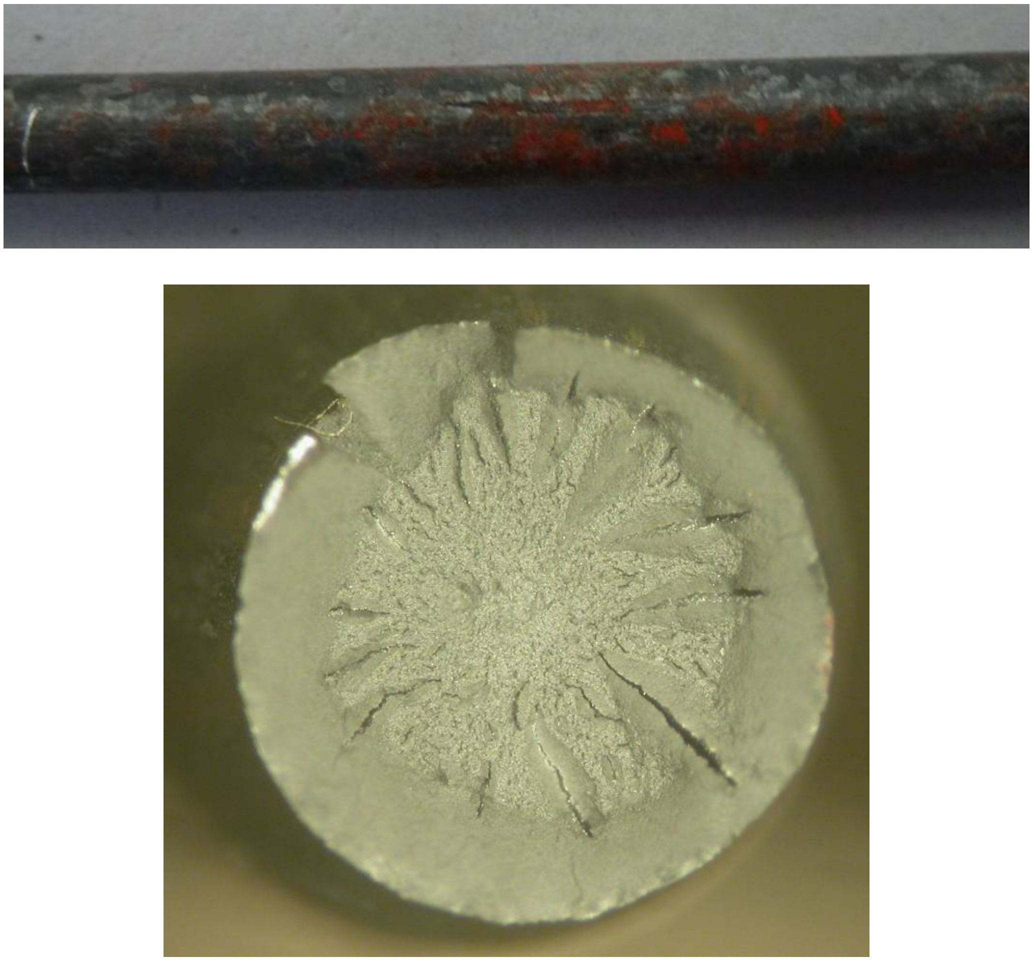
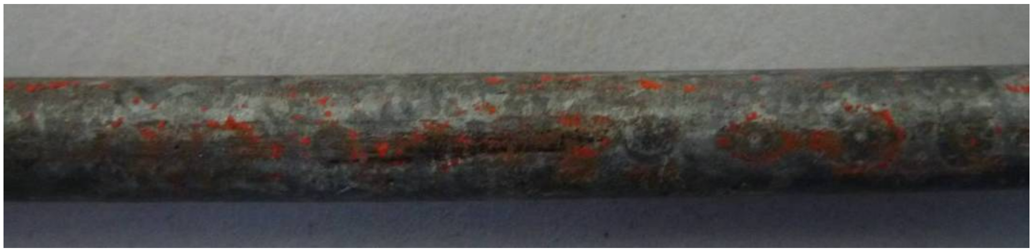


Fig. 74 Wire 10-8 surface (top) and fracture surface after tensile testing (bottom).



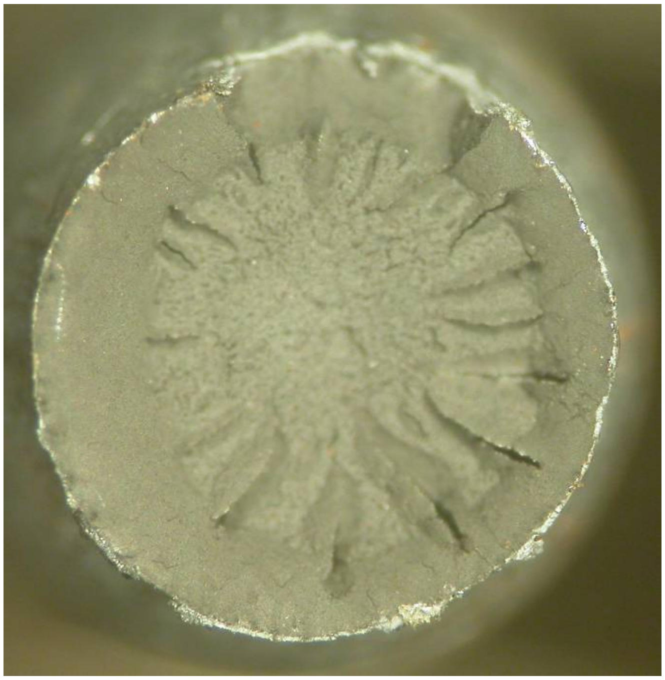


Fig. 75 Wire 10-9 surface (top) and fracture surface after tensile testing (bottom).

Fig. 76 Wire 10-10 surface (top) and fracture surface after tensile testing (bottom).

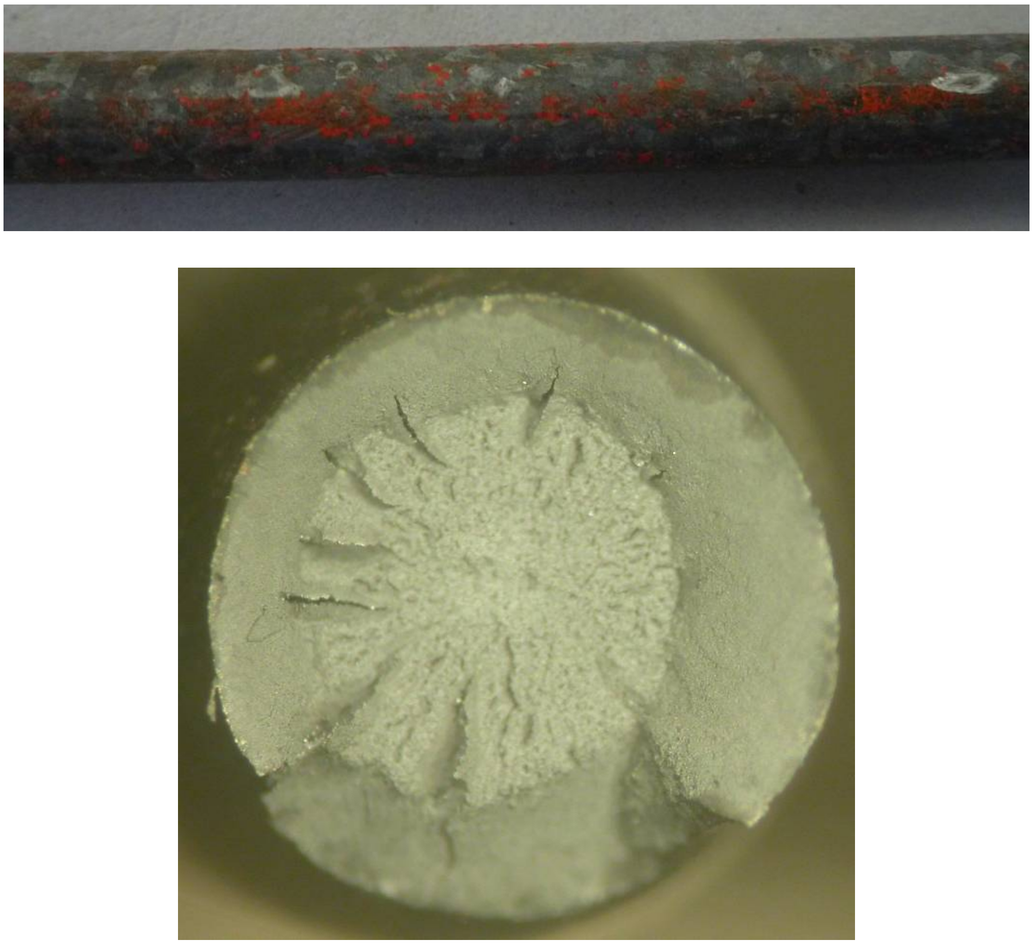


Fig. 77 Wire 10-11 surface (top) and fracture surface after tensile testing (bottom).

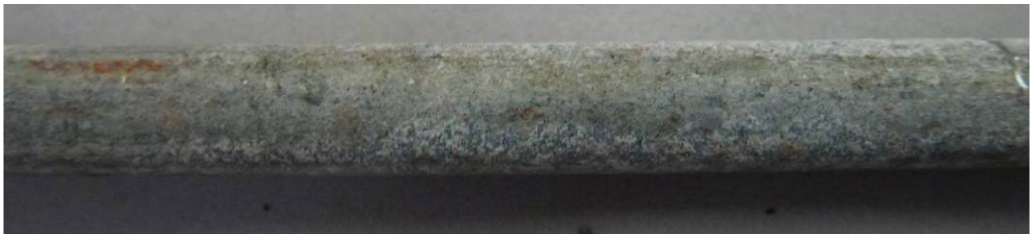
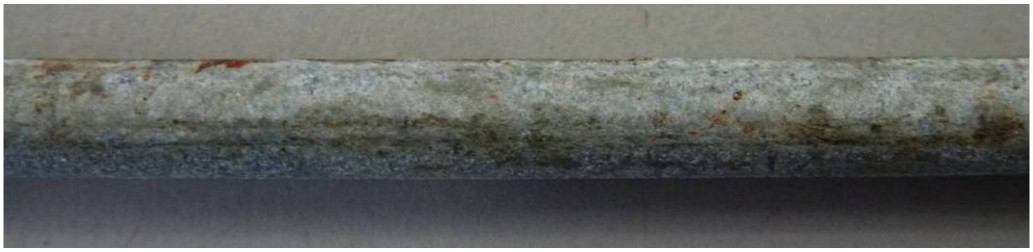


Fig. 78 Wire 11-1 surface (top) and fracture surface after tensile testing (bottom).



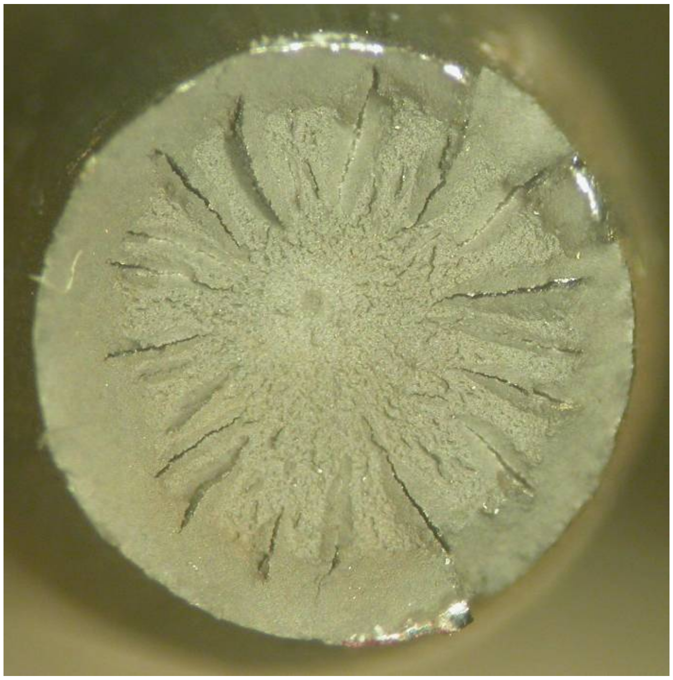


Fig. 79 Wire 11-2 surface (top) and fracture surface after tensile testing (bottom).

Fig. 80 Wire 11-3 surface (top) and fracture surface after tensile testing (bottom).

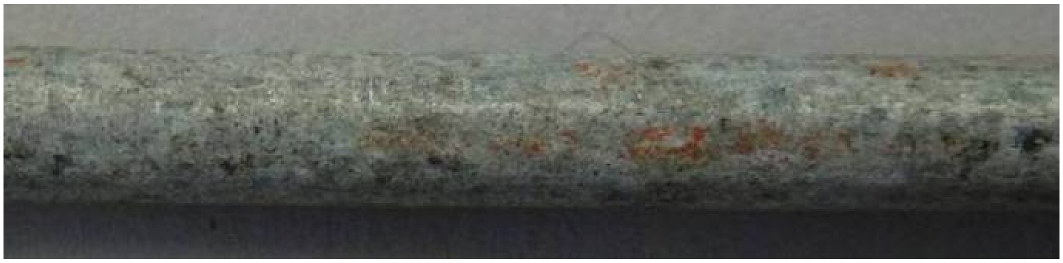


Fig. 81 Wire 11-4 surface (top) and fracture surface after tensile testing (bottom).

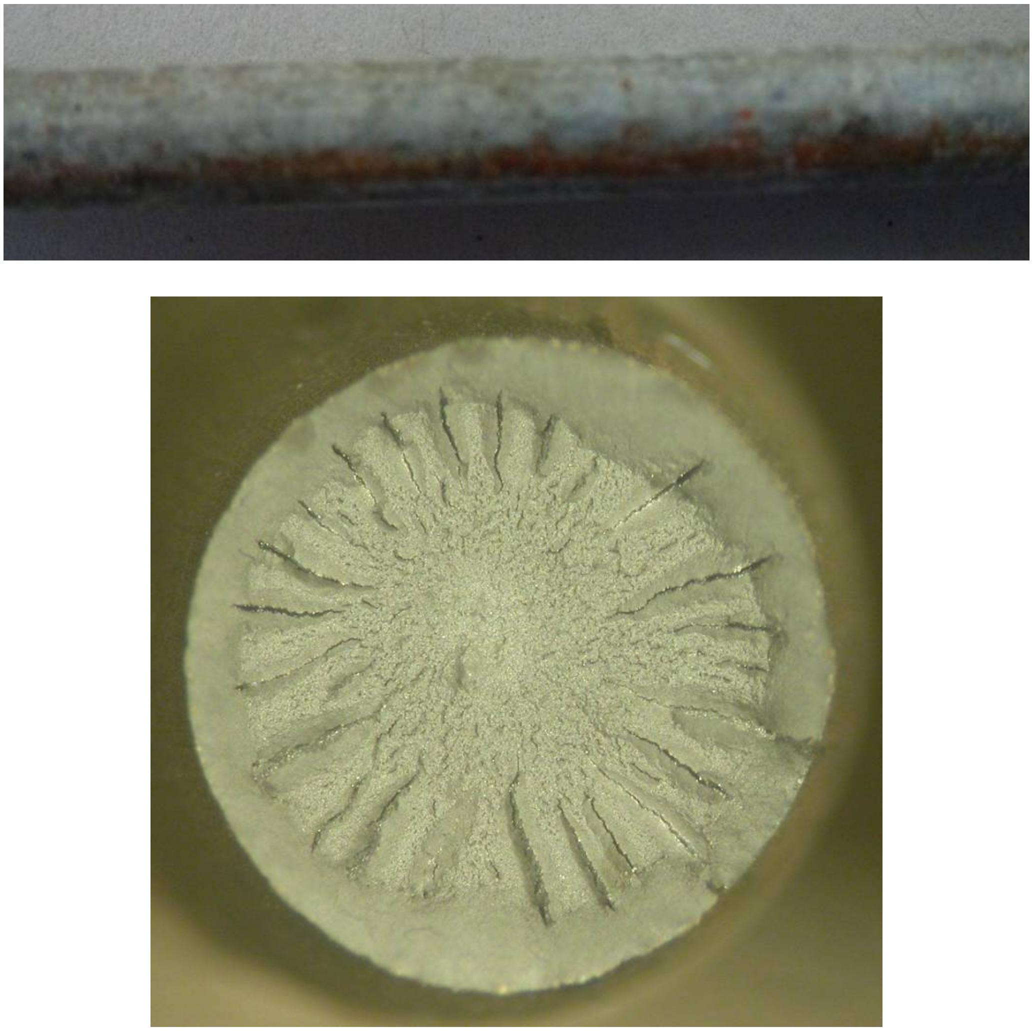


Fig. 82 Wire 11-5 surface (top) and fracture surface after tensile testing (bottom).

Fig. 83 Wire 11-6 surface (top) and fracture surface after tensile testing (bottom).

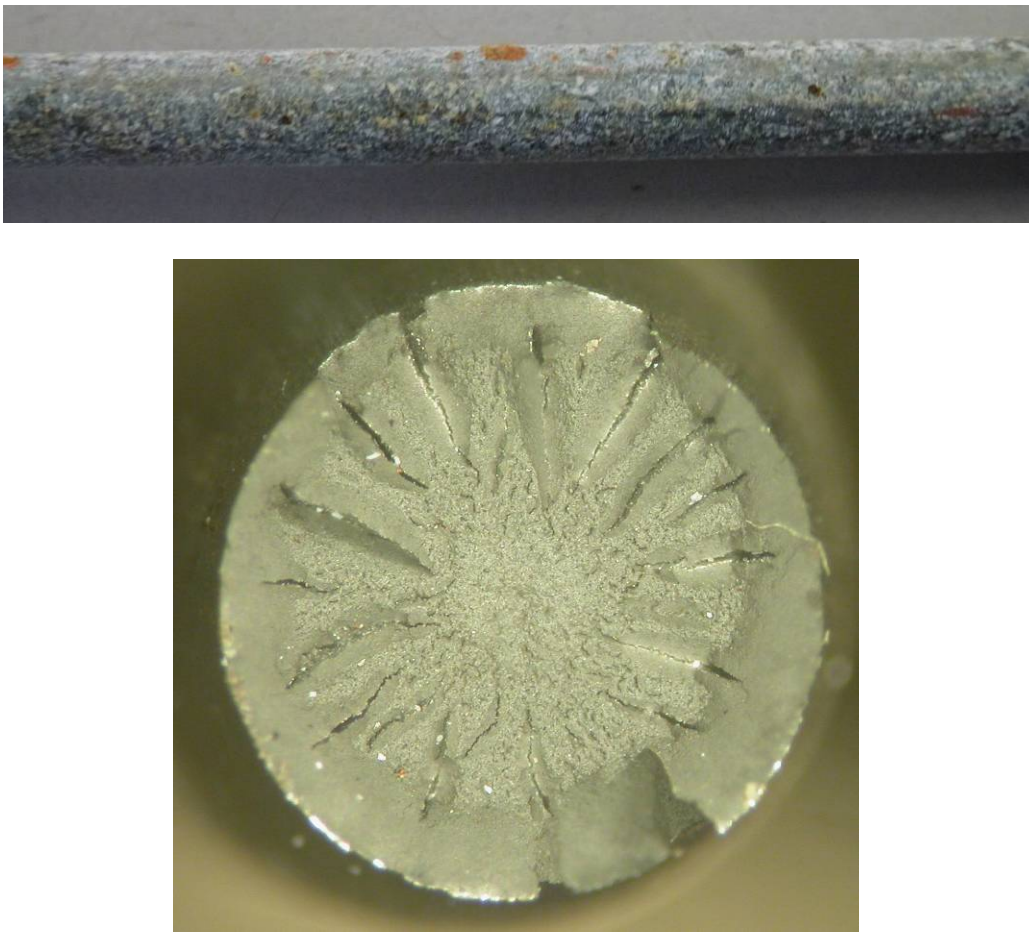


Fig. 84 Wire 12-1 surface (top) and fracture surface after tensile testing (bottom).

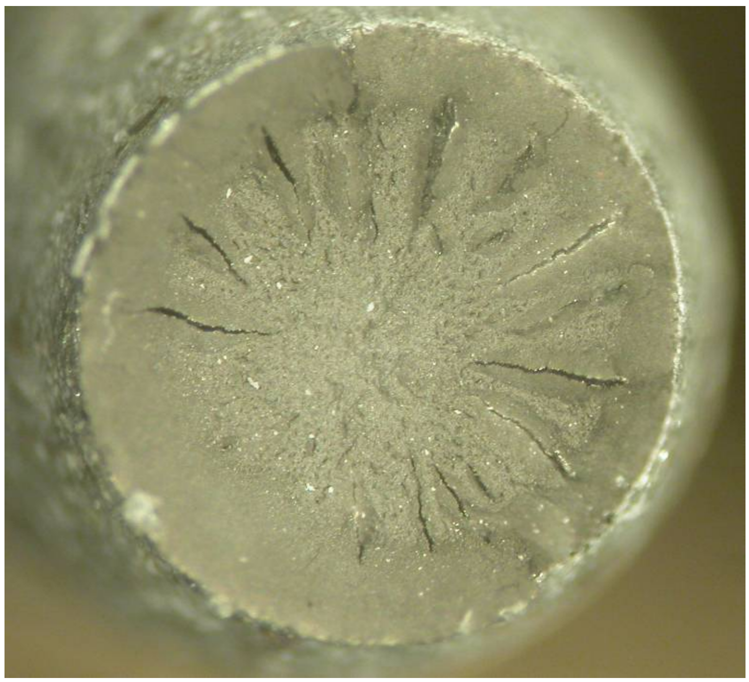


Fig. 85 Wire 12-2 surface (top) and fracture surface after tensile testing (bottom).

Fig. 86 Wire 12-3 surface (top) and fracture surface after tensile testing (bottom).

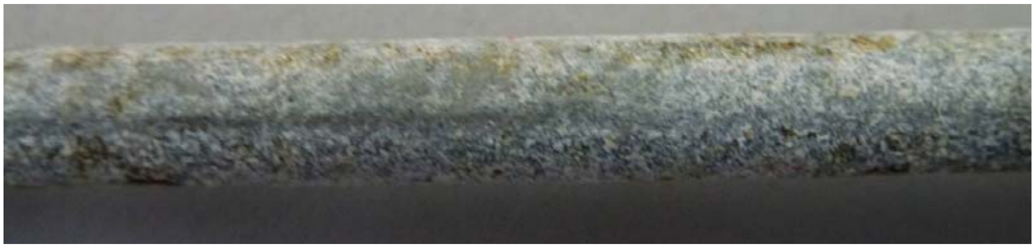


Fig. 87 Wire 12-4 surface (top) and fracture surface after tensile testing (bottom).

Fig. 88 Wire 12-5 surface (top) and fracture surface after tensile testing (bottom).

Fig. 89 Wire 12-6 surface (top) and fracture surface after tensile testing (bottom).

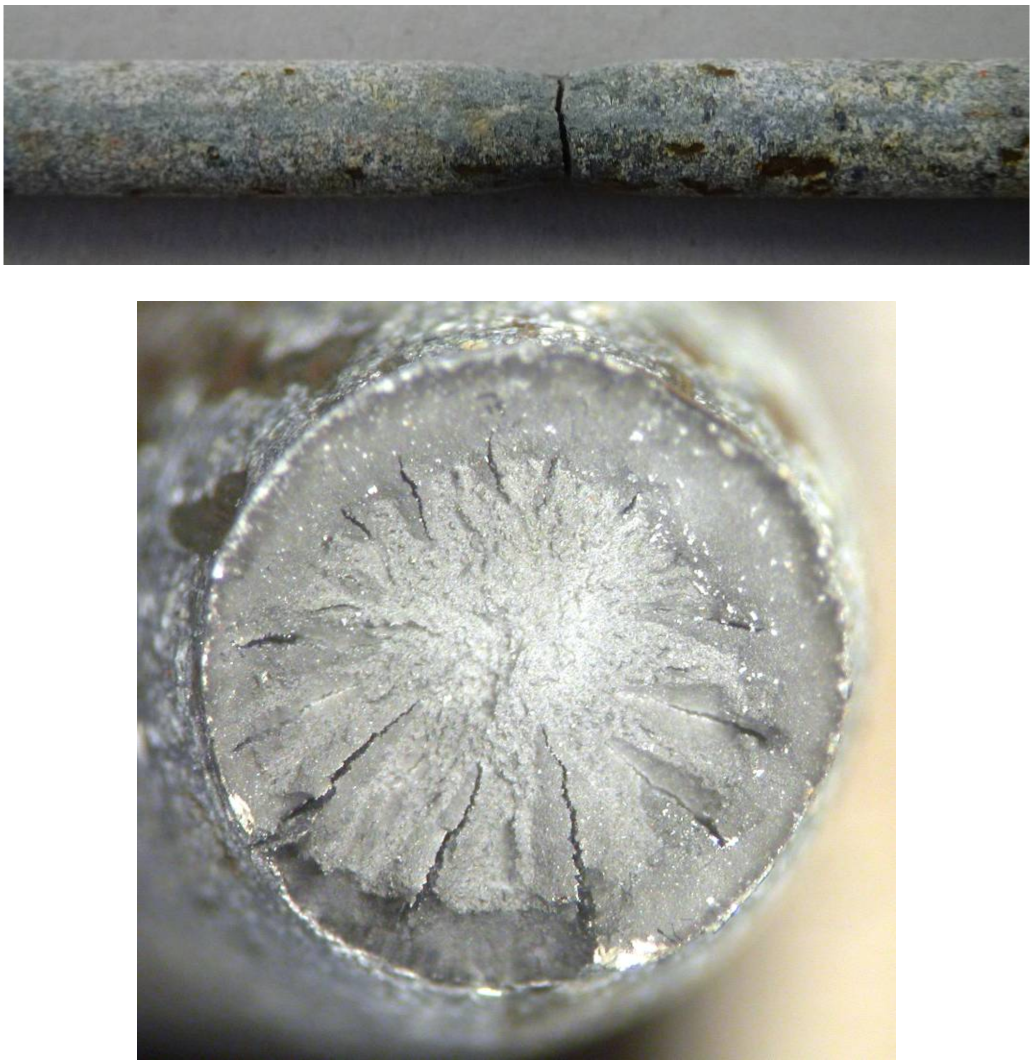


Fig. 90 Wire 12-7 surface (top) and fracture surface after tensile testing (bottom).

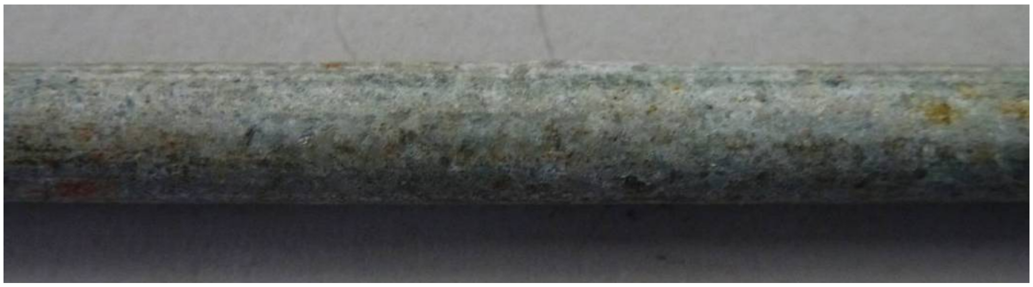


Fig. 91 Wire 13-1 surface (top) and fracture surface after tensile testing (bottom).

Fig. 92 Wire 13-2 surface (top) and fracture surface after tensile testing (bottom).

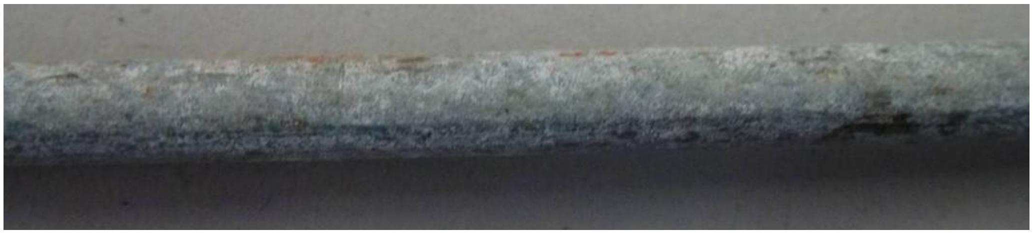


Fig. 93 Wire 13-3 surface (top) and fracture surface after tensile testing (bottom).

Fig. 94 Wire 13-4 surface (top) and fracture surface after tensile testing (bottom).

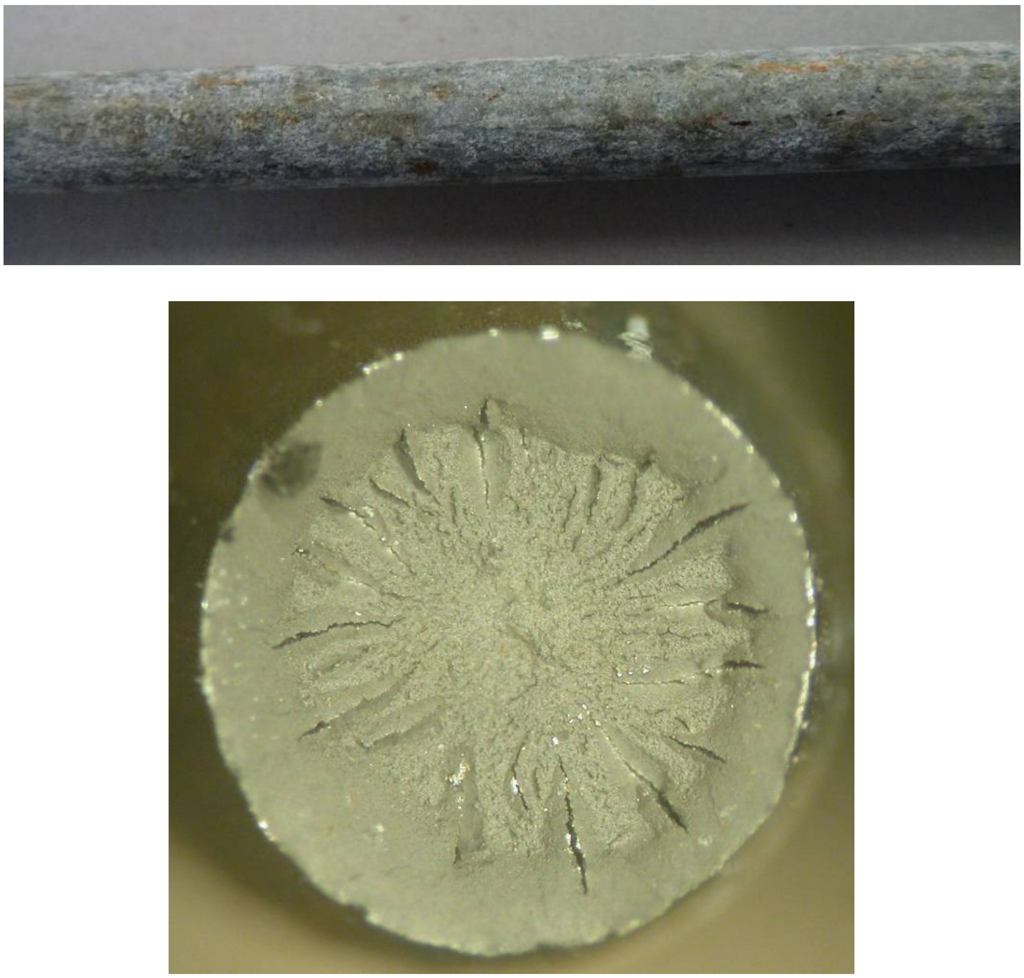
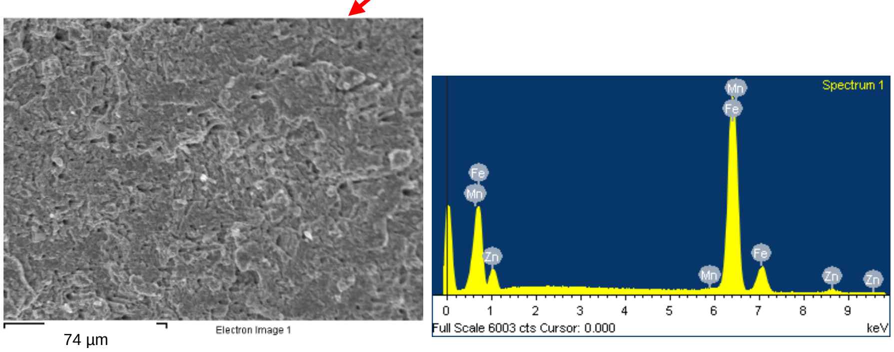


Fig. 95 Wire 13-5 surface (top) and fracture surface after tensile testing (bottom).

Fig. 96 Wire 13-6 surface (top) and fracture surface after tensile testing (bottom).



Element	Weight%
Spectrum 1	
Mn K	0.60
Fe K	Bal.
Zn K	4.17

Fig. 97 Scanning electron micrograph and EDS analysis of wire 1-2 fracture surface. Zinc in fine particulate form settled on the fracture surface after spalling from the outer surface during testing.

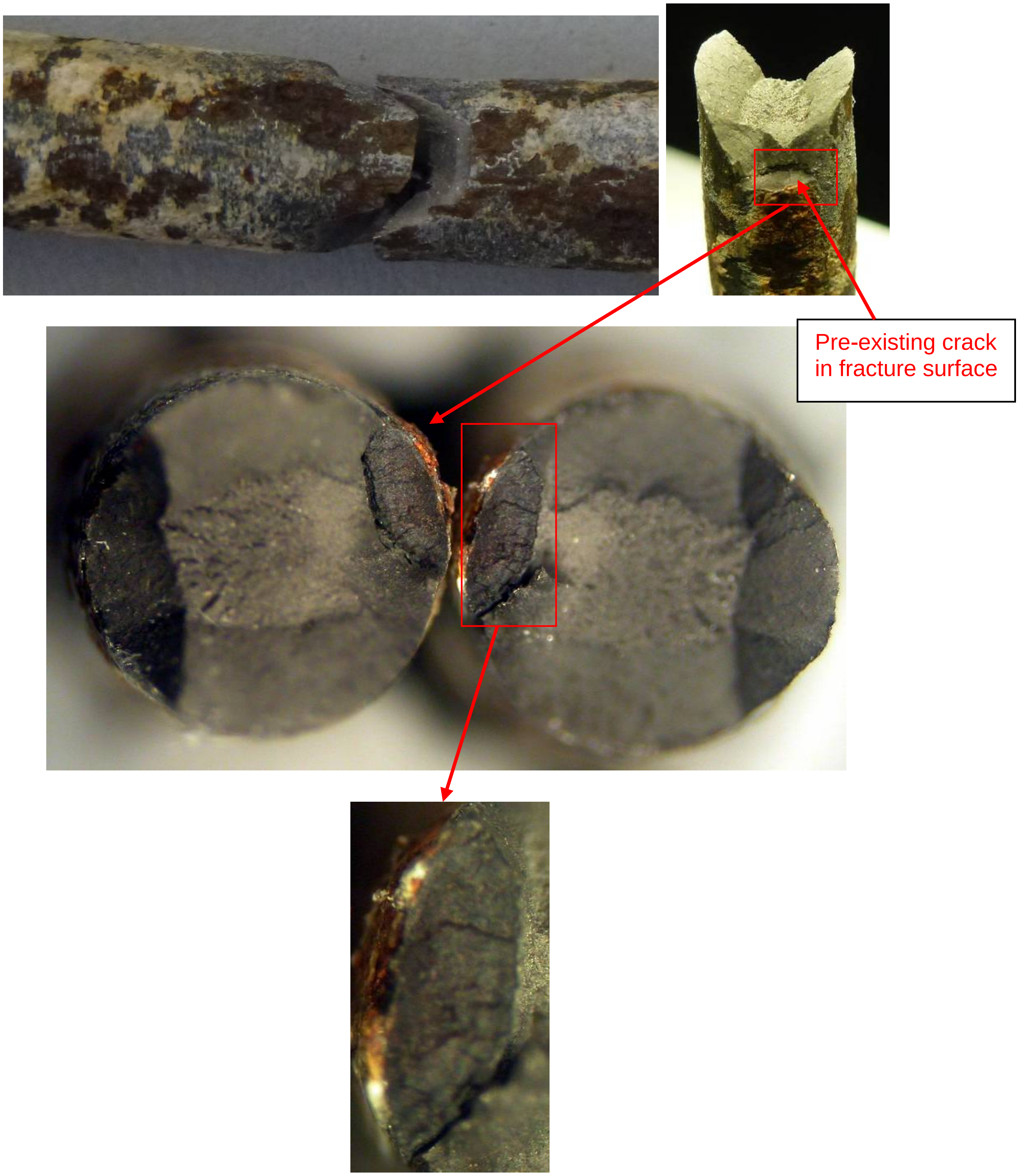
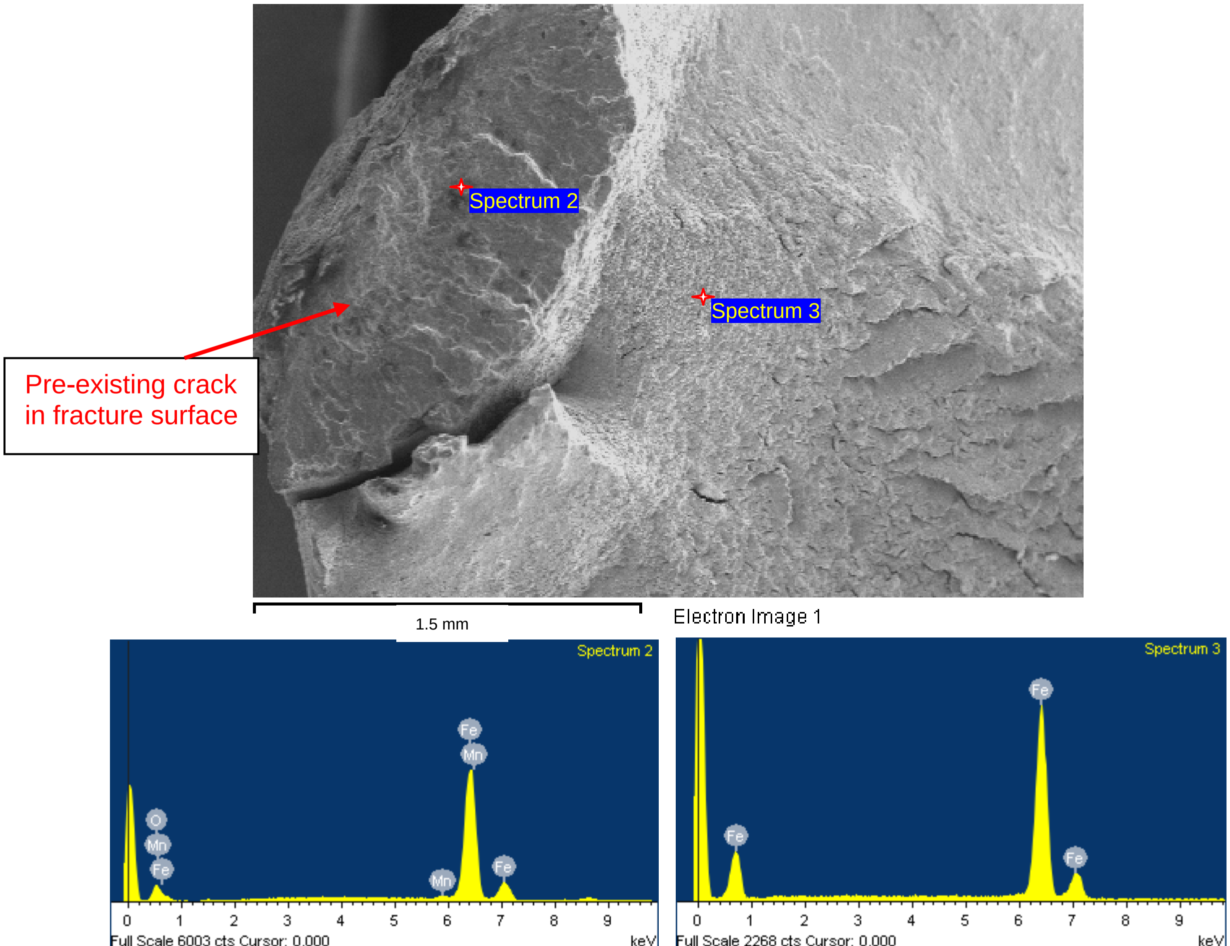


Fig. 98 Wire 3-3 fracture profile (top) and fracture surface (bottom).

Arcadis US, Inc.
Attention: Mr. Edward J. Adamczyk, PE.

January 25, 2013
Report No. F12454



Element	Weight%
Spectrum 2	
O K	8.29
Mn K	1.37
Fe K	Bal.

Fig. 99 Scanning electron micrograph and EDS analysis of wire 3-3 fracture surface.

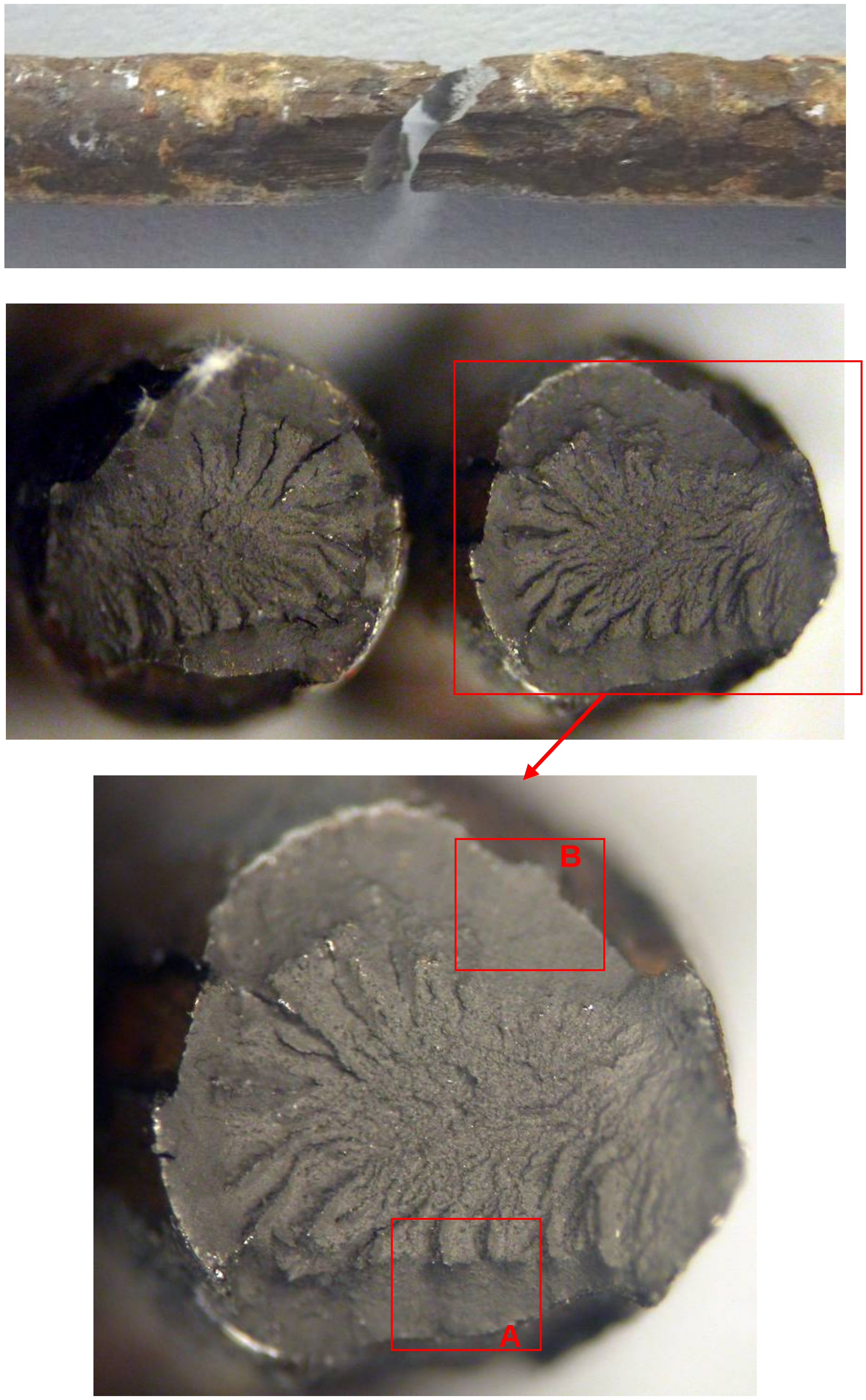


Fig. 100 Wire 5-4 fracture profile (top) and fracture surfaces (bottom).

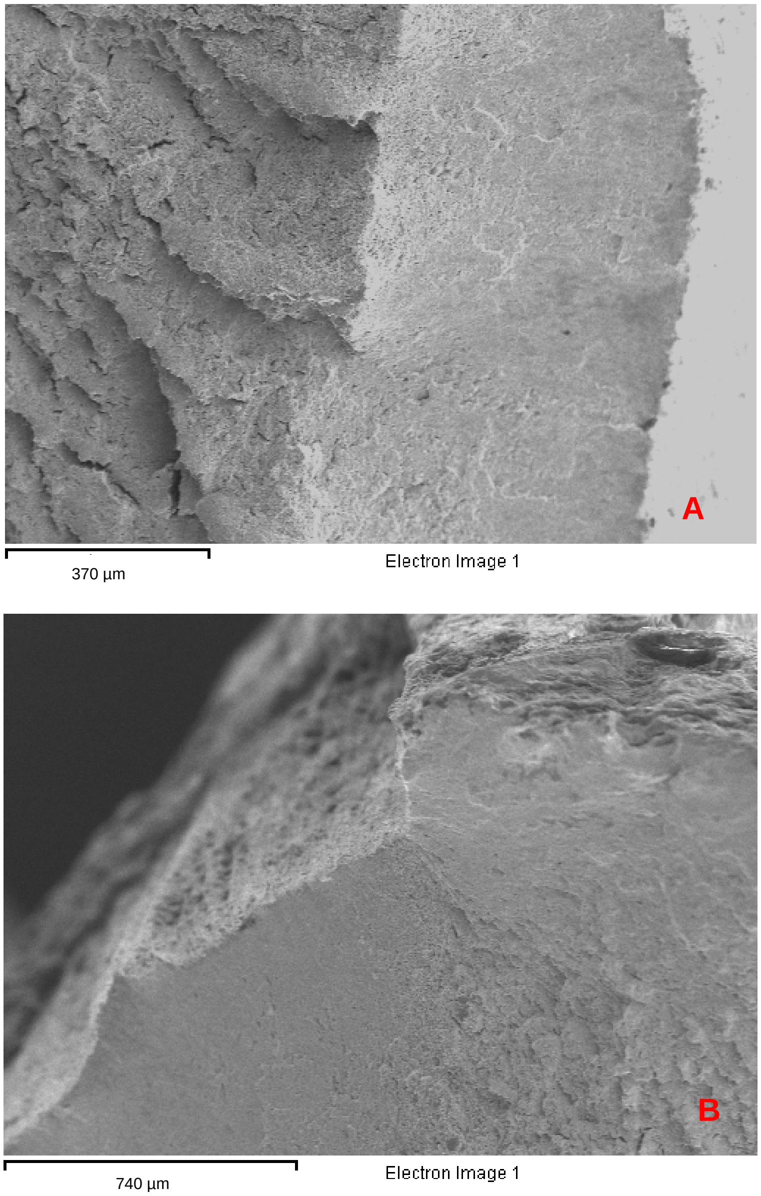


Fig. 101 Scanning electron micrograph of wire 5-4 fracture surface.

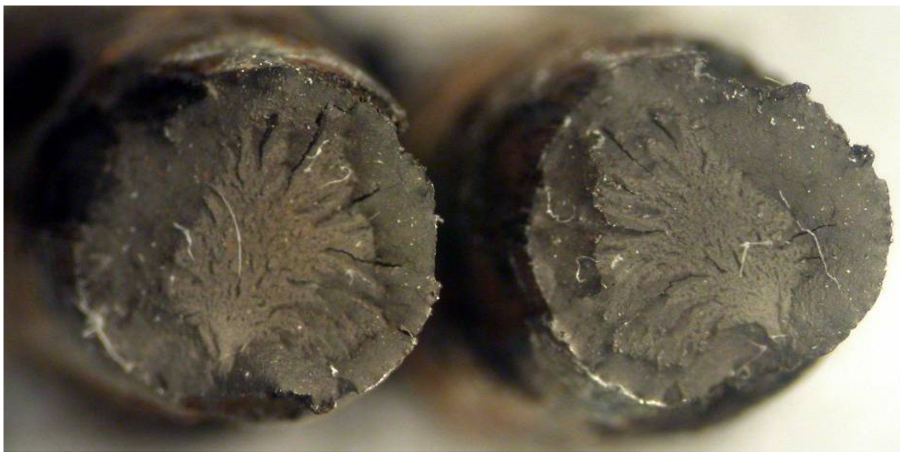


Fig. 102 Wire 5-7 fracture profile (top) and fracture surfaces (bottom).

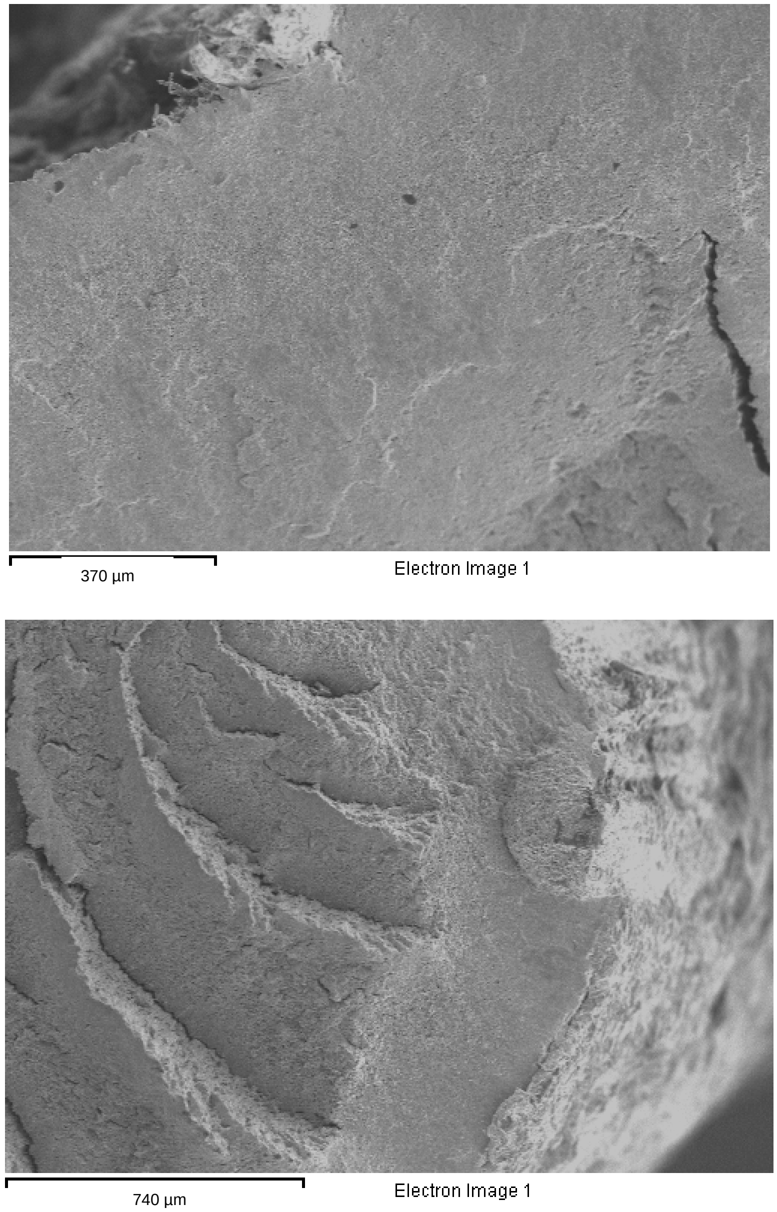


Fig. 103 Scanning electron micrograph of wire 5-7 fracture surface.

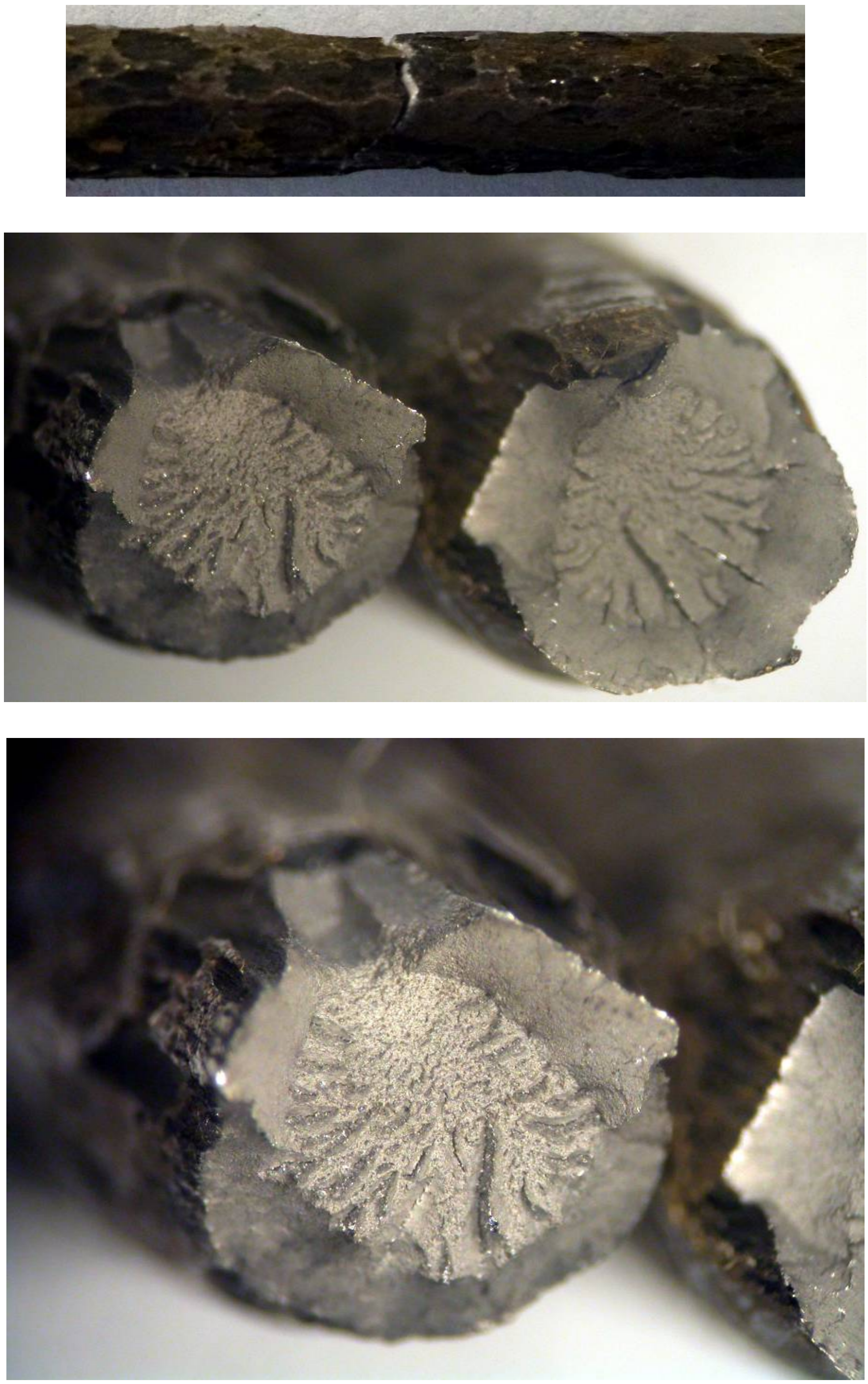
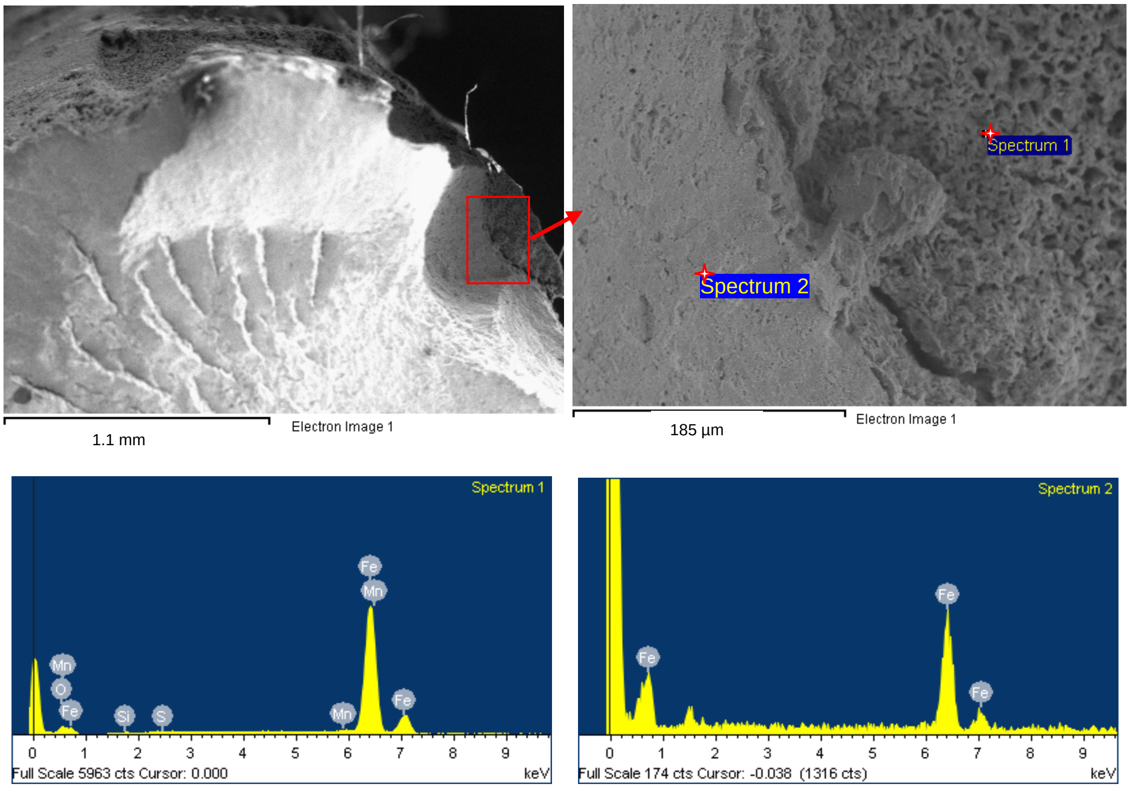


Fig. 104 Wire 7-4 fracture profile (top) and fracture surfaces (bottom).



Element	Weight%
Spectrum 1	
O K	3.35
Si K	0.23
S K	0.37
Mn K	1.01
Fe K	Bal.

Element	Weight%
Spectrum 2	
Fe K	100.00

Fig. 105 Scanning electron micrograph and EDS analysis of wire 7-4 fracture surface.

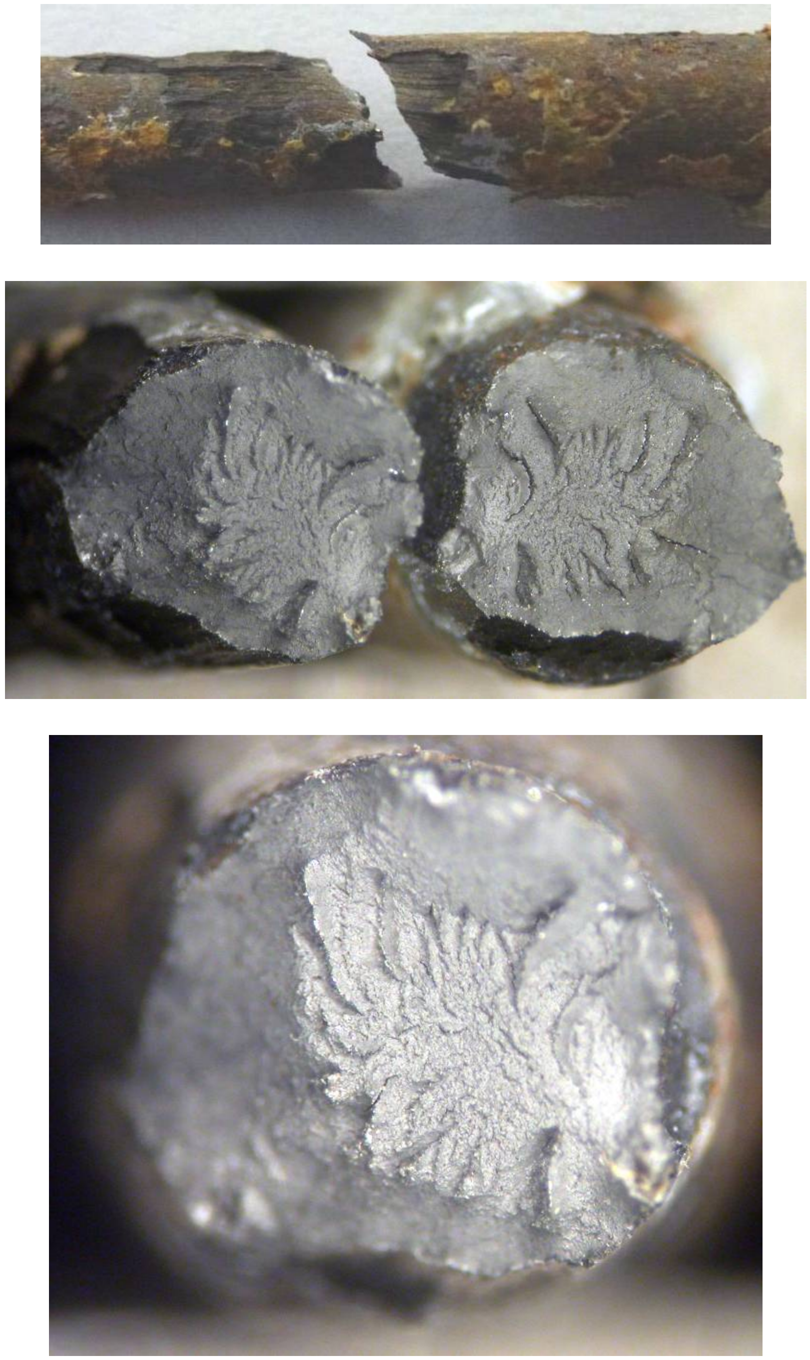


Fig. 106 Wire 7-5 fracture profile (top) and fracture surfaces (bottom).

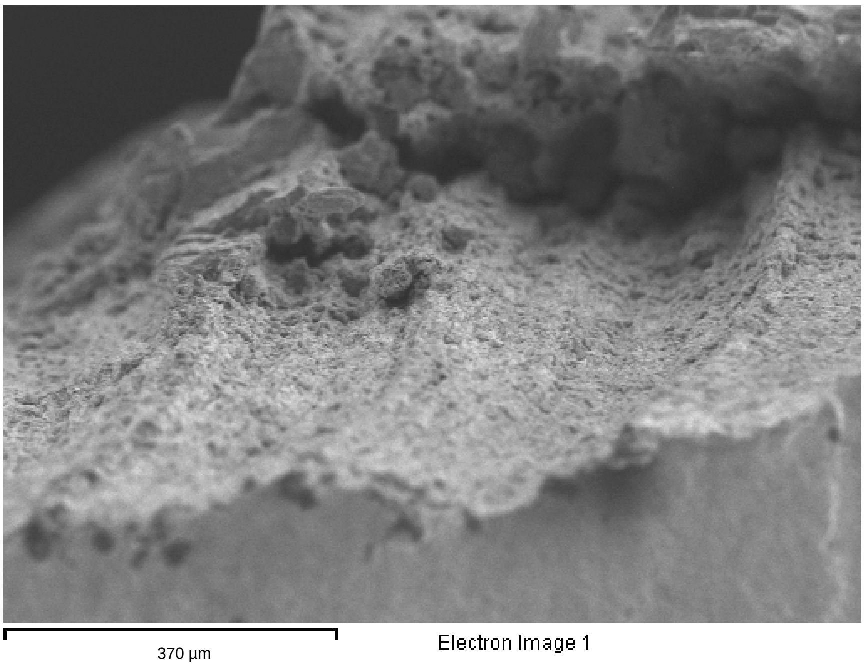


Fig. 107 Scanning electron micrograph of wire 7-5 fracture surface.

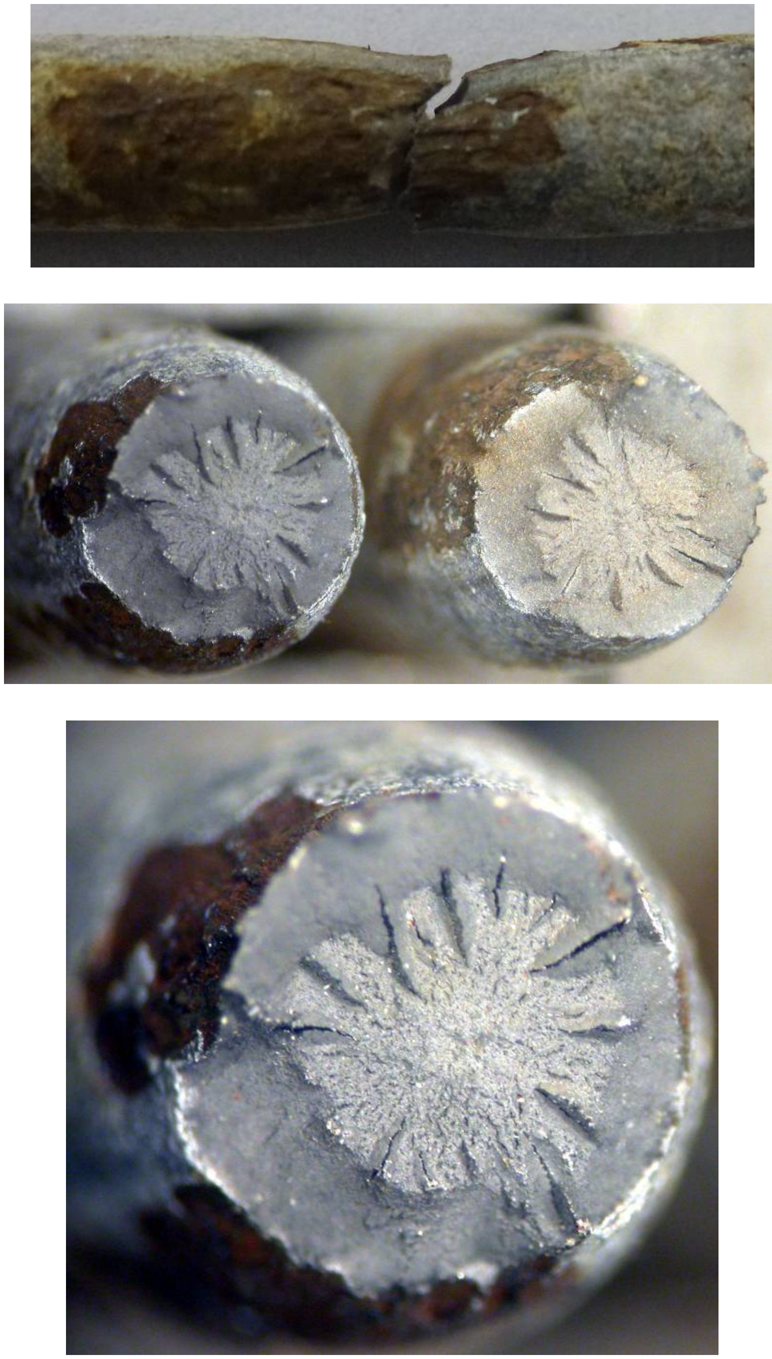


Fig. 108 Wire 6-4 fracture profile (top) and fracture surfaces (bottom).

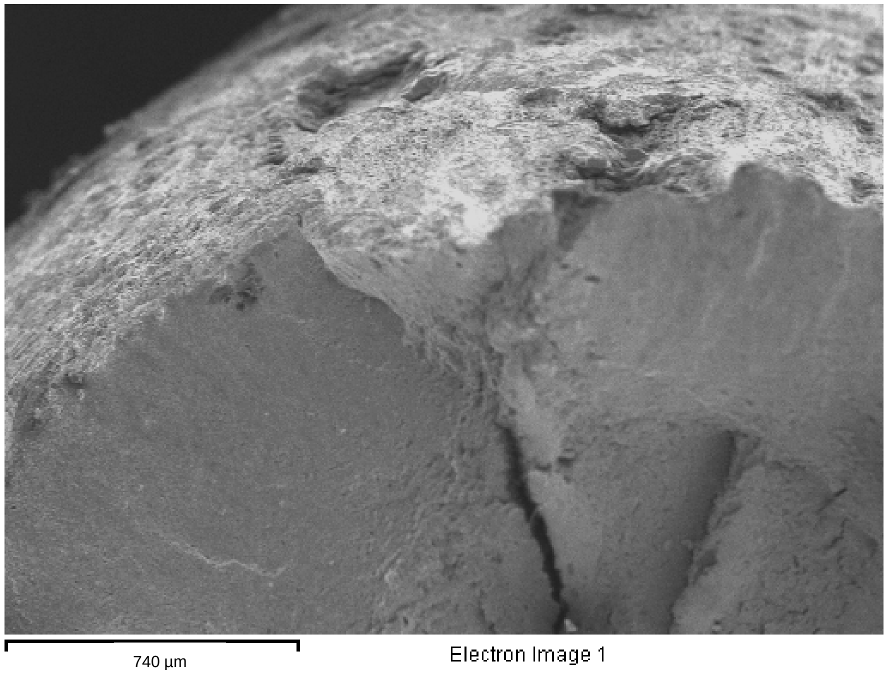


Fig. 109 Scanning electron micrograph of wire 6-4 fracture surface.

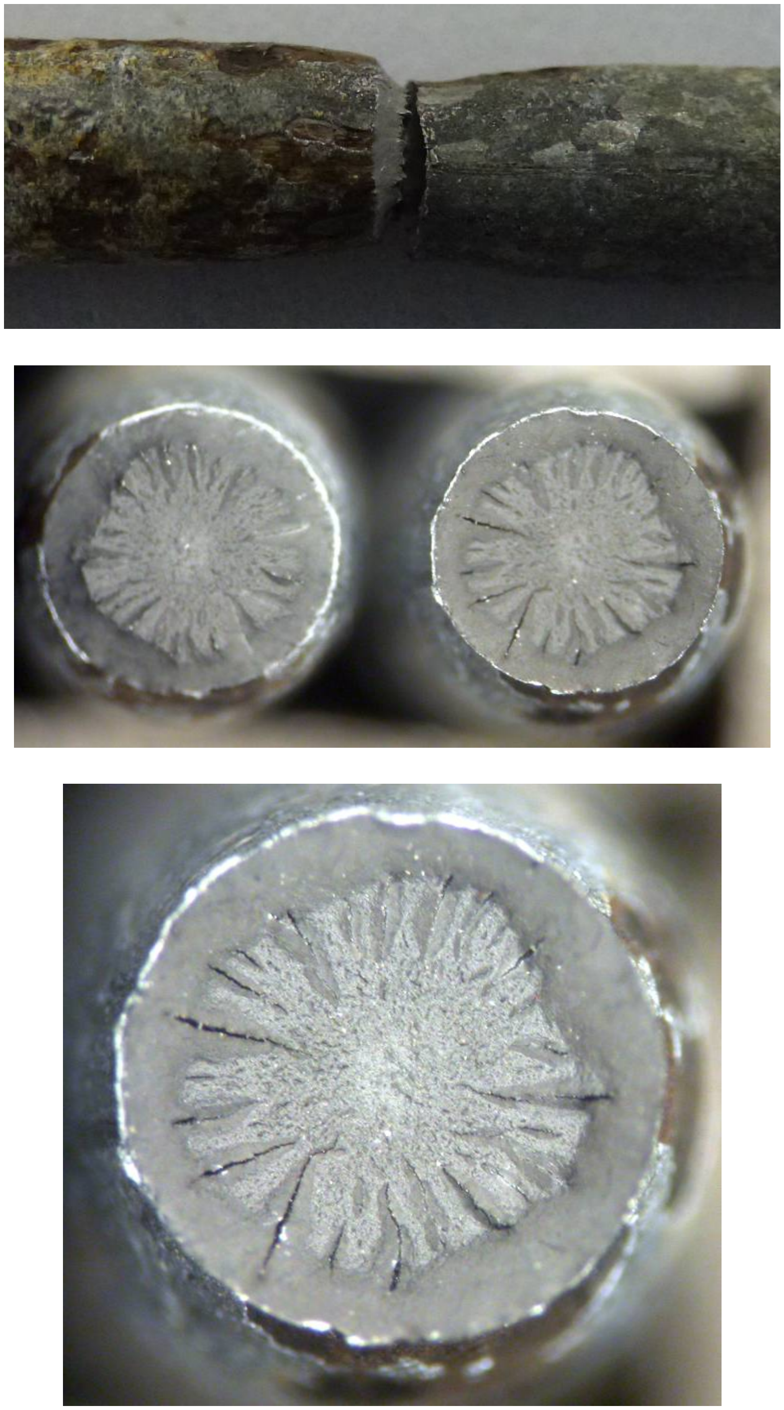
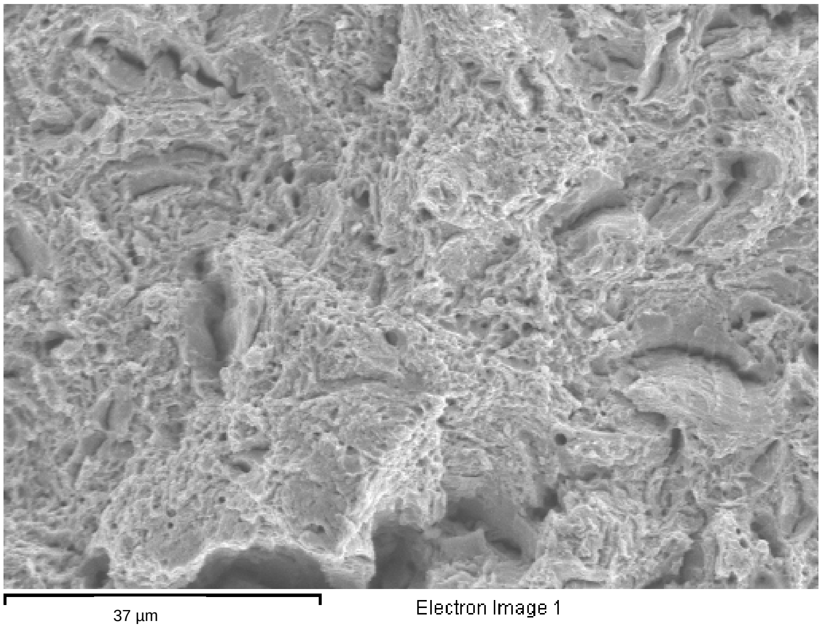


Fig. 110 Wire 8-1 fracture profile (top) and fracture surfaces (bottom).



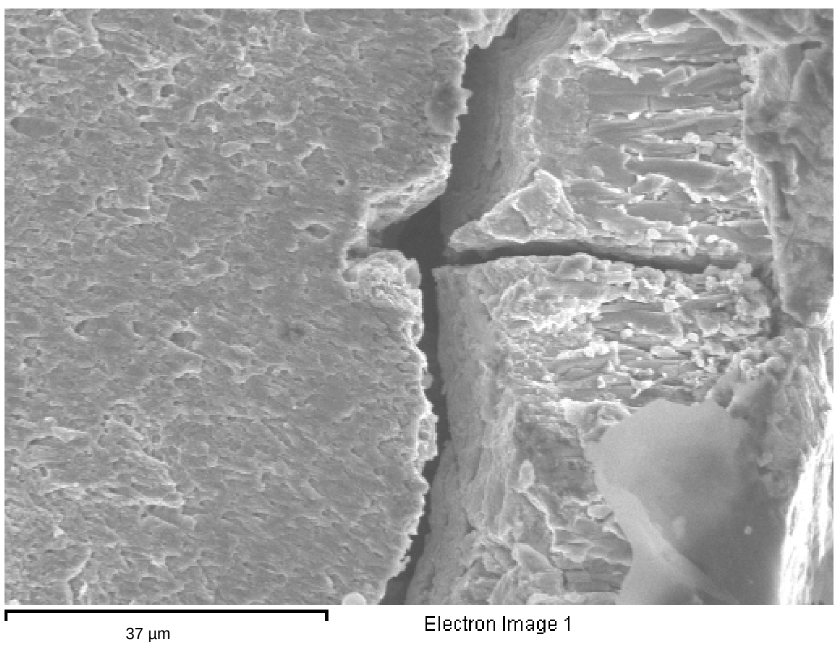


Fig. 111 Scanning electron micrograph of wire 8-1 fracture surface.

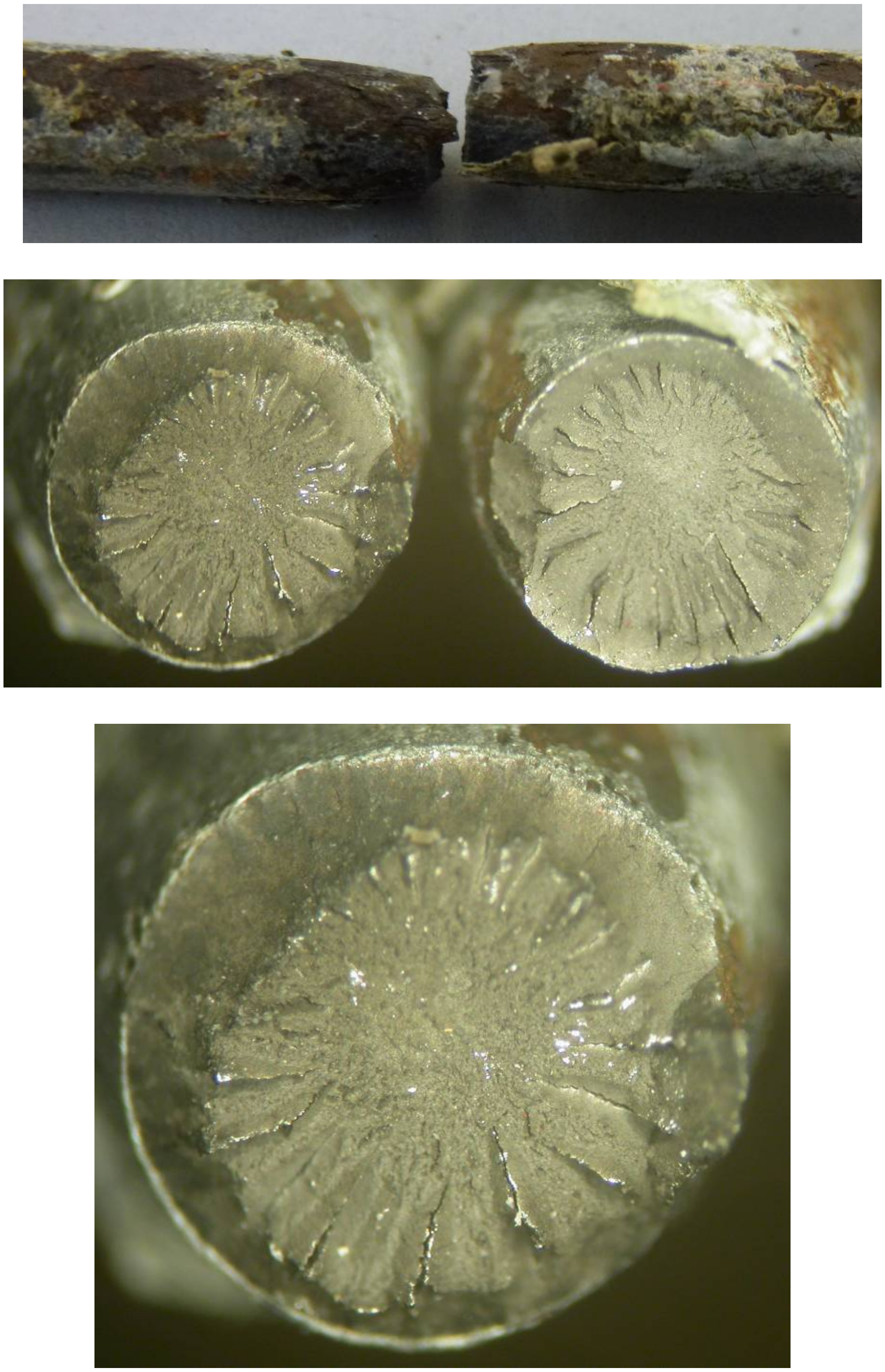
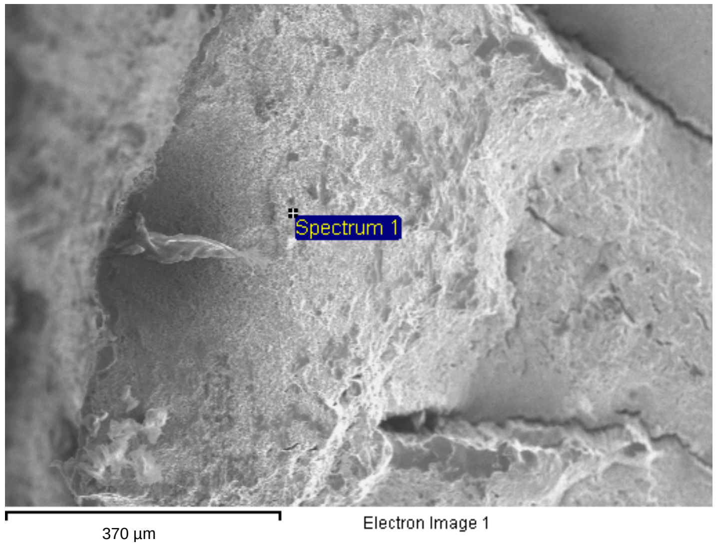
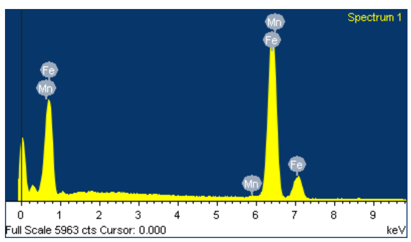


Fig. 112 Wire 9-6 fracture profile (top) and fracture surfaces (bottom).





Element	Weight%
Spectrum 1	
Mn K	0.73
Fe K	Bal.

Fig. 113 Scanning electron micrograph and EDS analysis of wire 9-6 fracture surface.

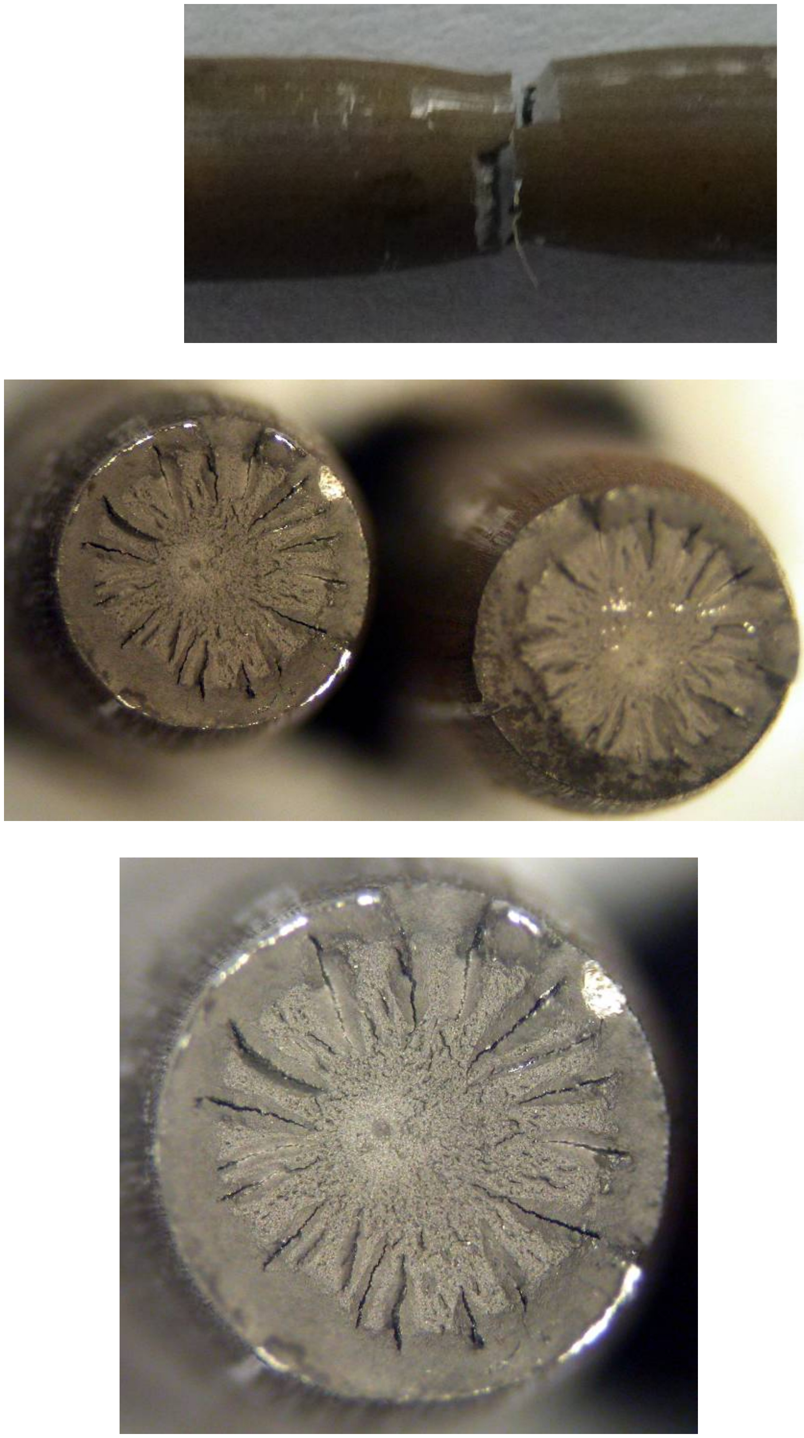
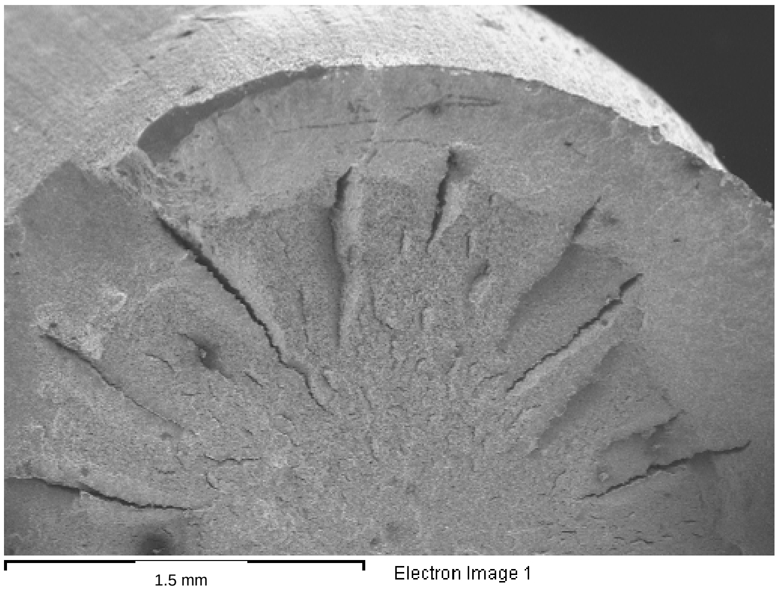


Fig. 114 Wire 11-2 fracture profile (top) and fracture surfaces (bottom).



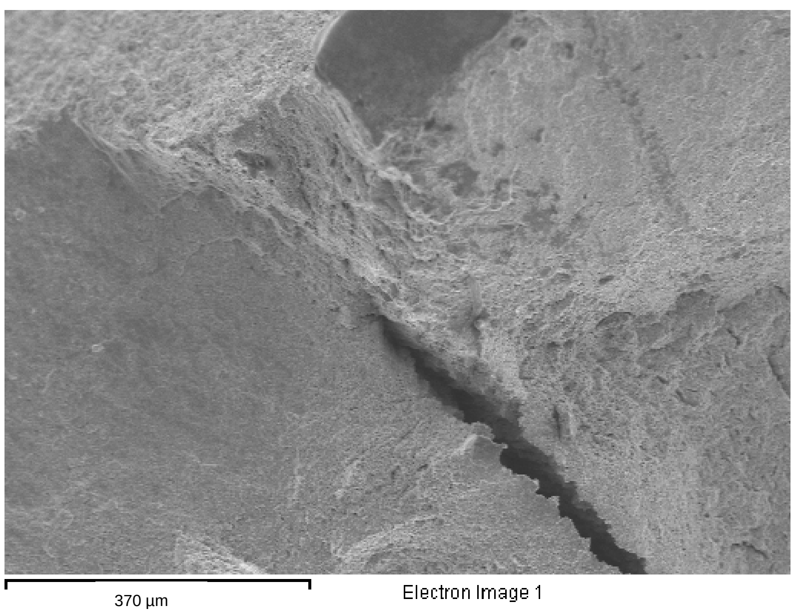


Fig. 115 Scanning electron micrograph of wire 11-2 fracture surface.

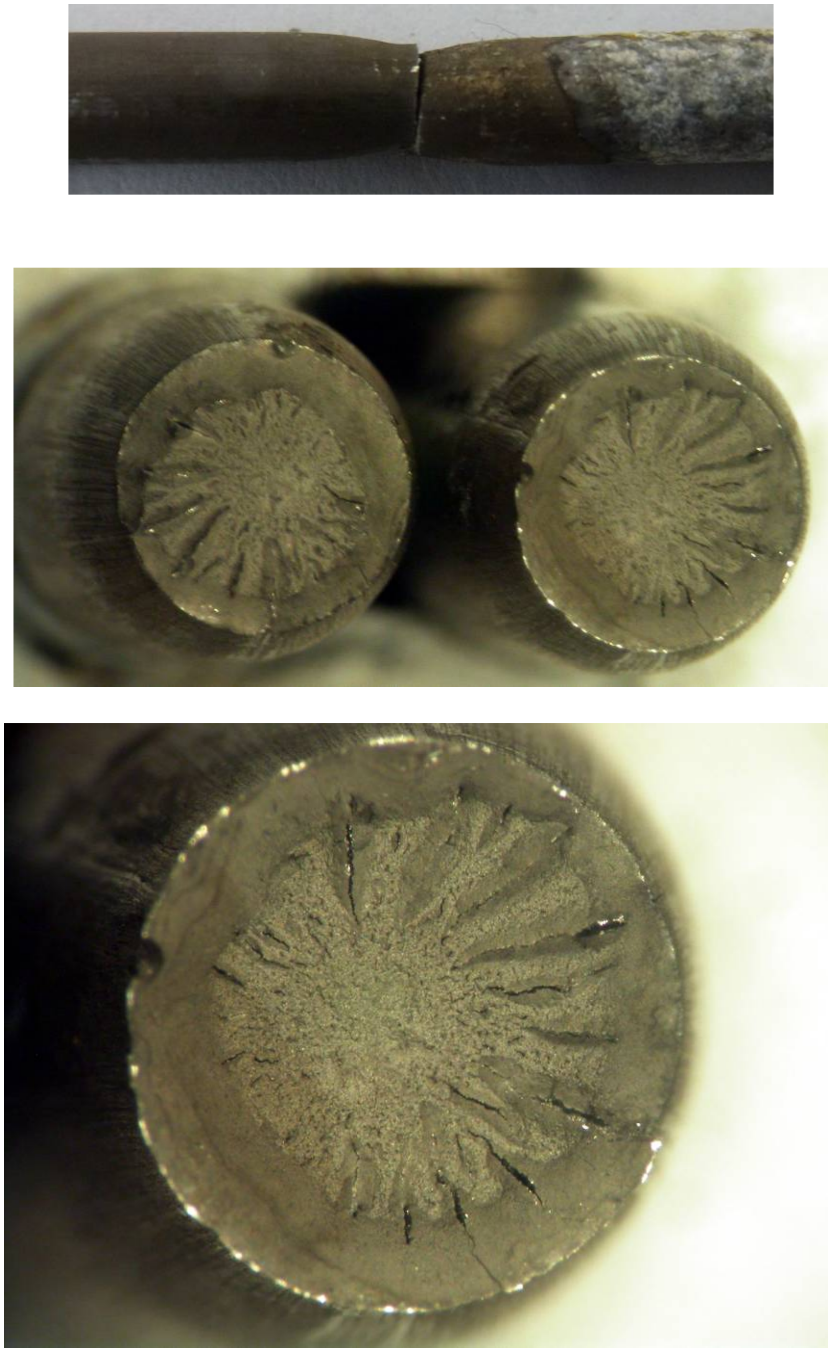


Fig. 116   Wire 12-4 fracture profile (top) and fracture surfaces (bottom).

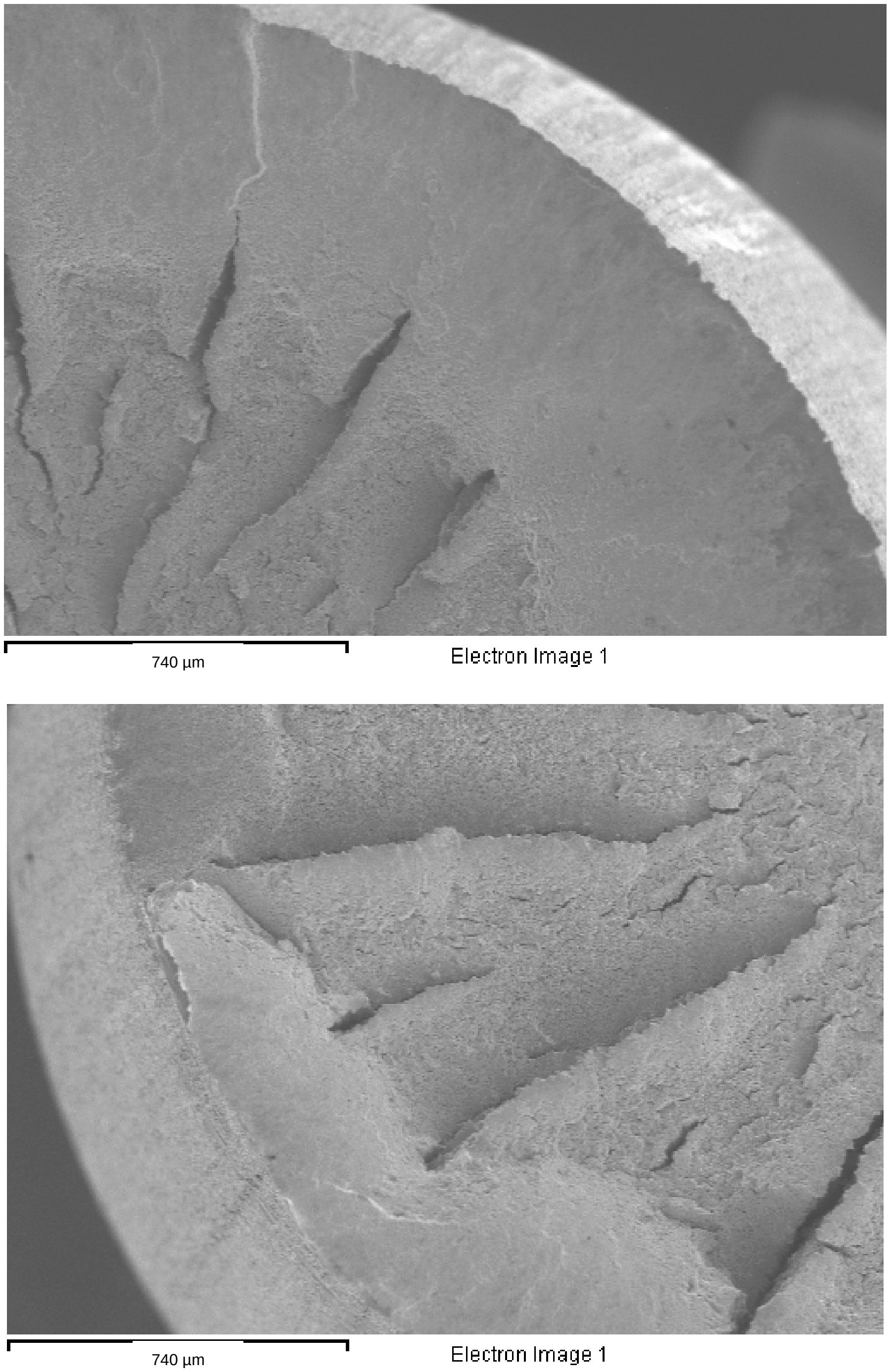


Fig. 117 Scanning electron micrograph of wire 12-4 fracture surface.

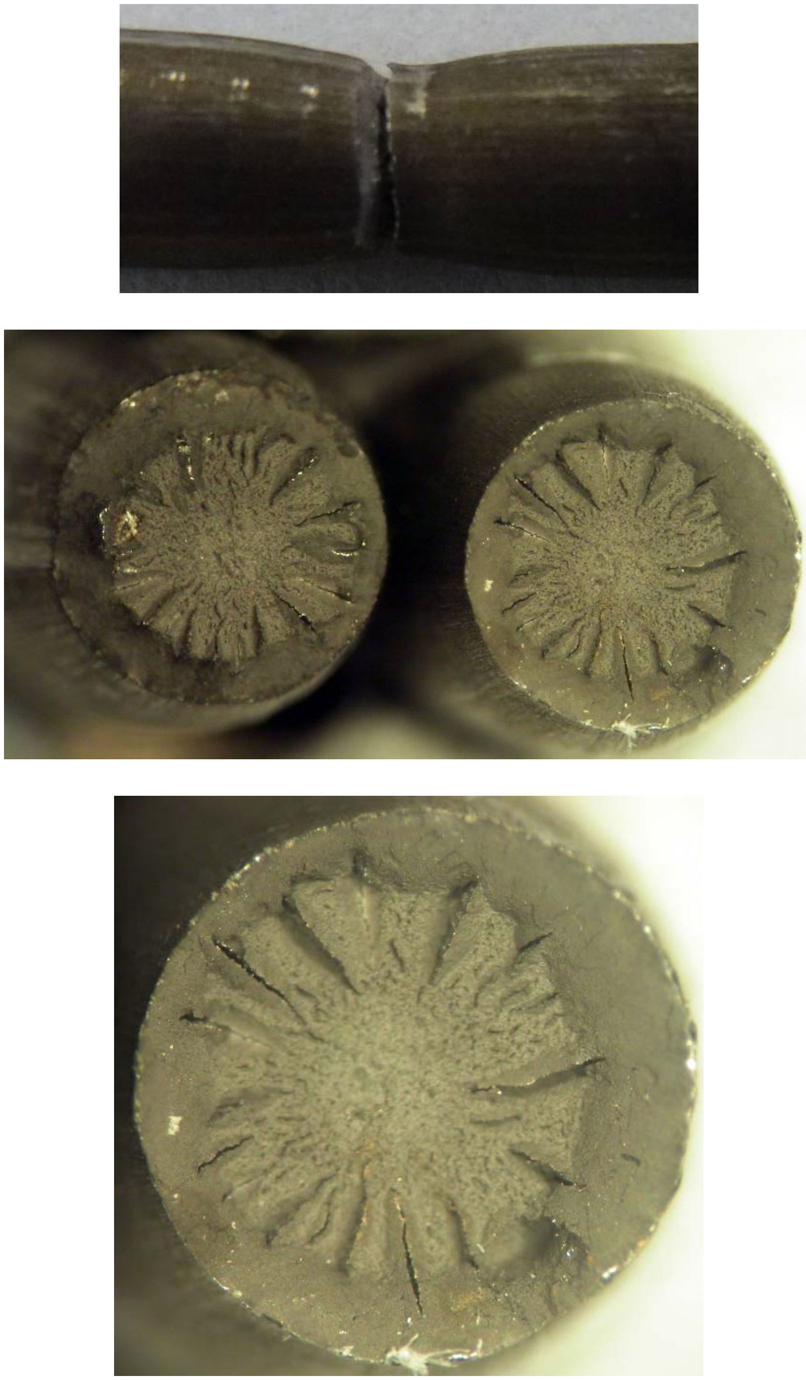


Fig. 118 Wire 13-6 fracture profile (top) and fracture surfaces (bottom).

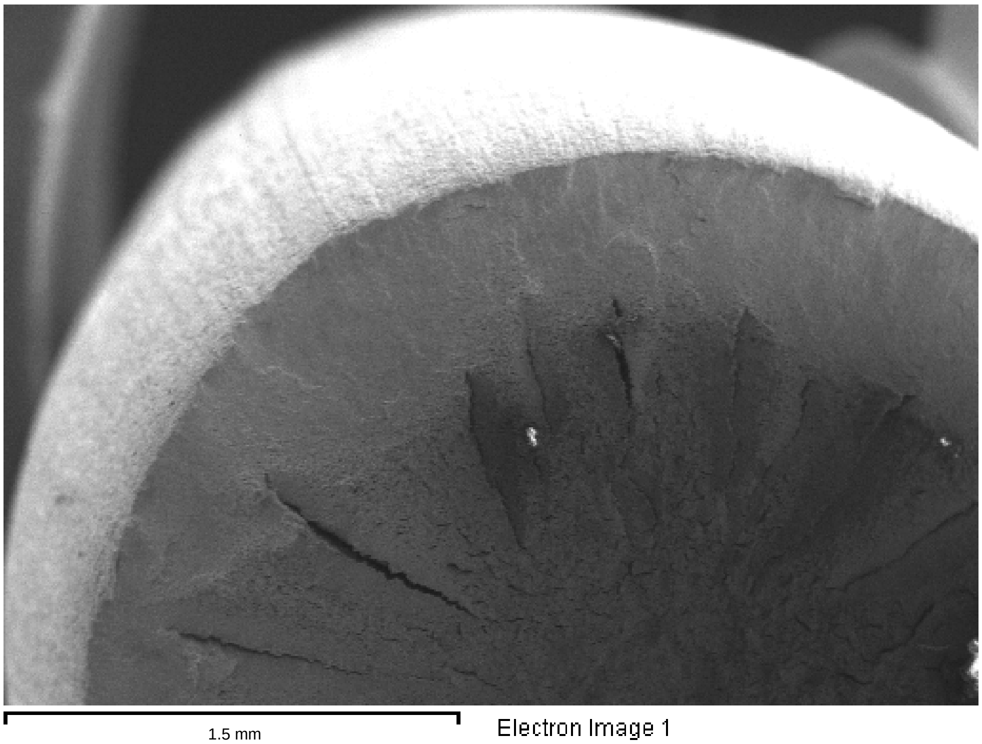
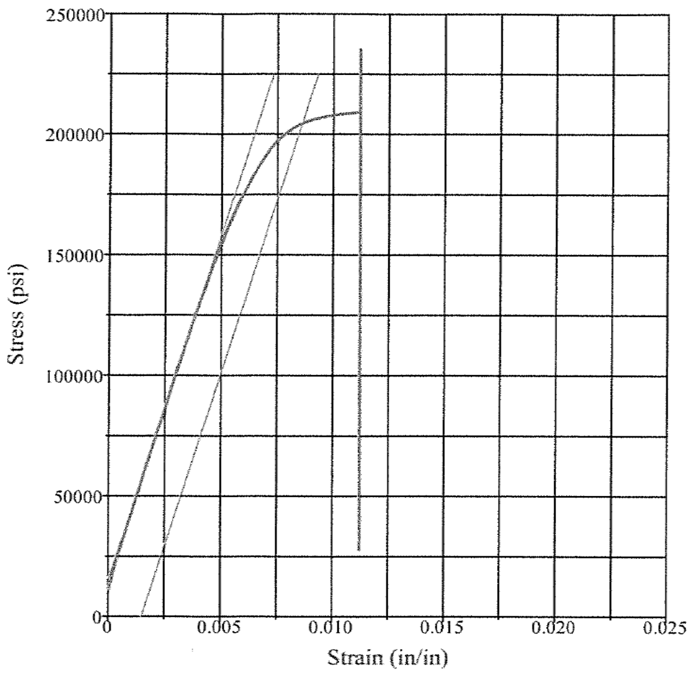


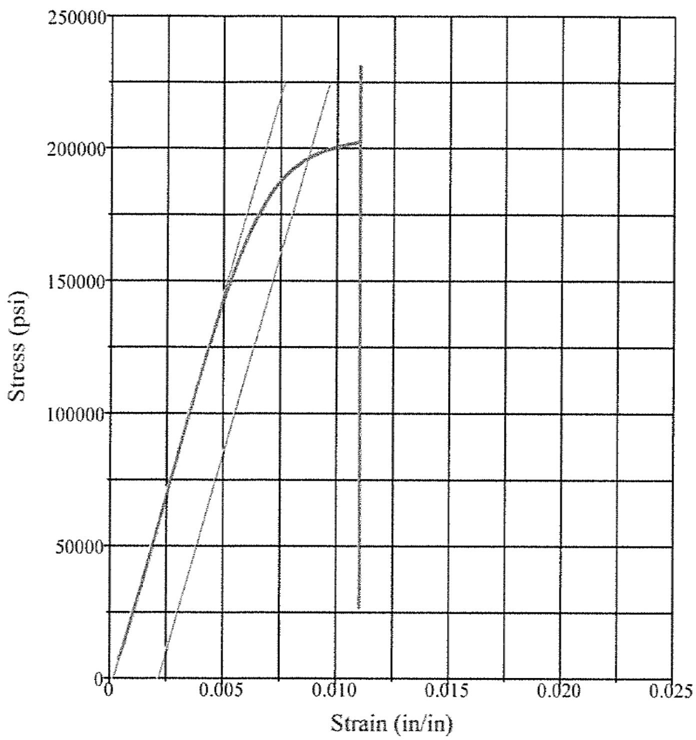
Fig. 119 Scanning electron micrograph of wire 13-6 fracture surface.

Wire Specimen Stress-Strain Curves



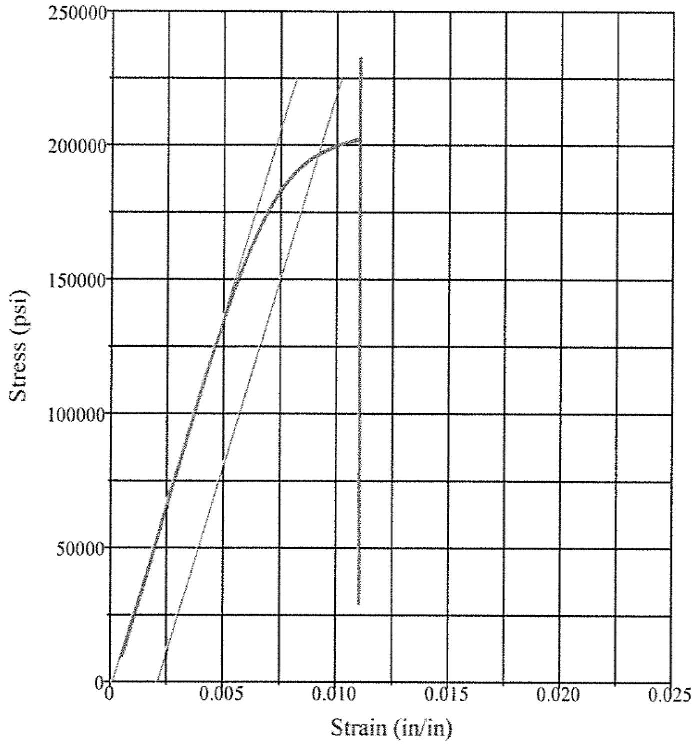
Test Results		
Specimen Gage Length:	**10.0000**	in
Diameter:	**0.1920**	in
After Test Diameter:	**0.1520**	in
Area:	**0.0290**	in^2
After Test Area:	**0.0181**	in^2
Correlation Coefficient:	**1.0000**	
Tangent Modulus:	**28583**	ksi
Tensile Strength:	**235**	ksi
Total Elongation:	**5**	%
Pretest Punch Length:	**10**	in
Posttest Punch Length:	**10.46**	in
Reduction of Area:	**38**	%
Peak Load:	**6821.7000**	lbf
Load at Offset:	**5930**	lbf
Stress at Offset:	**204**	ksi
Proportional Limit:	**4886.7000**	lbf

Specimen 1-1



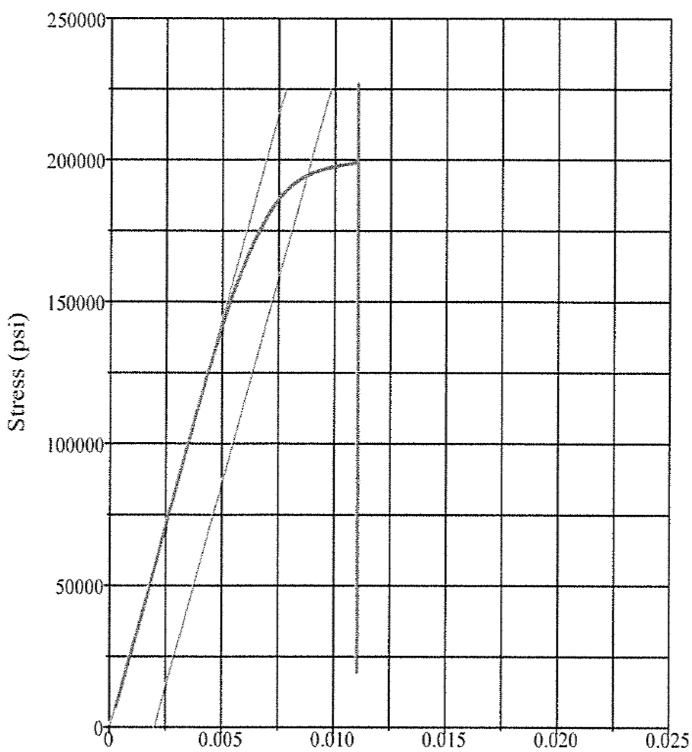
Test Results		
Specimen Gage Length:	**10.0000**	in
Diameter:	**0.1920**	in
After Test Diameter:	**0.1590**	in
Area:	**0.0290**	in^2
After Test Area:	**0.0199**	in^2
Correlation Coefficient:	**0.9999**	
Tangent Modulus:	**29765**	ksi
Tensile Strength:	**231**	ksi
Total Elongation:	**4**	%
Pretest Punch Length:	**10**	in
Posttest Punch Length:	**10.43**	in
Reduction of Area:	**31**	%
Peak Load:	**6702.8000**	lbf
Load at Offset:	**5689**	lbf
Stress at Offset:	**196**	ksi
Proportional Limit:	**4573.6000**	lbf

Specimen 1-2



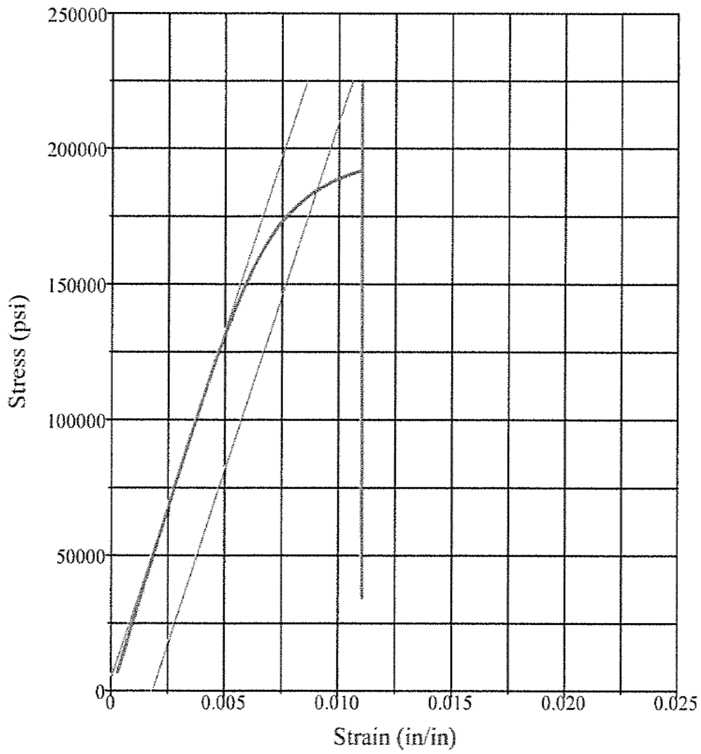
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1550** in
Area:	**0.0290** in^2
After Test Area:	**0.0189** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**27664** ksi
Tensile Strength:	**233** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.33** in
Reduction of Area:	**35** %
Peak Load:	**6743.0000** lbf
Stress at Offset:	**196** ksi
Load at Offset:	**5698** lbf
Proportional Limit:	**4595.6000** lbf

Specimen 1-3



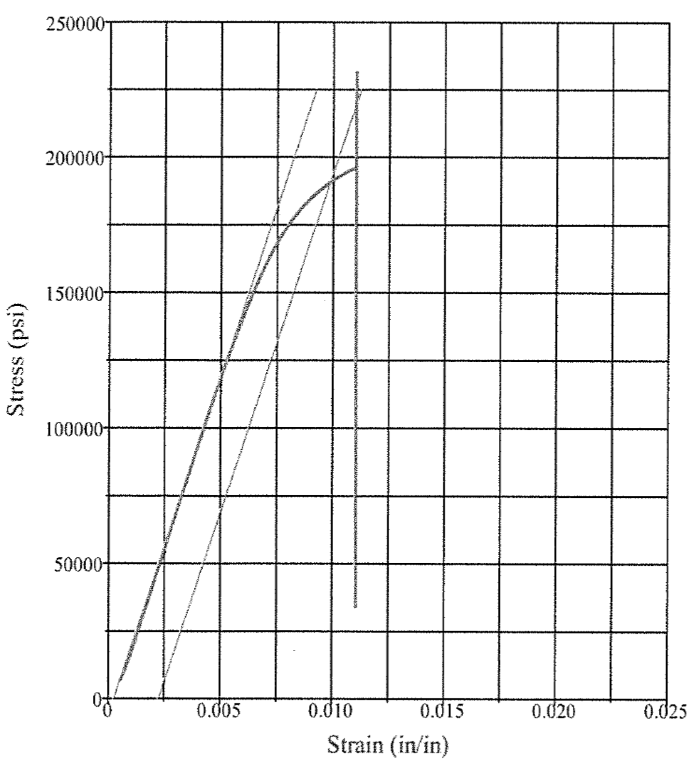
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1590** in
Area:	**0.0290** in^2
After Test Area:	**0.0199** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**28699** ksi
Tensile Strength:	**227** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.43** in
Reduction of Area:	**31** %
Peak Load:	**6578.5000** lbf
Load at Offset:	**5643** lbf
Stress at Offset:	**195** ksi
Proportional Limit:	**4583.7000** lbf

Specimen 1-4



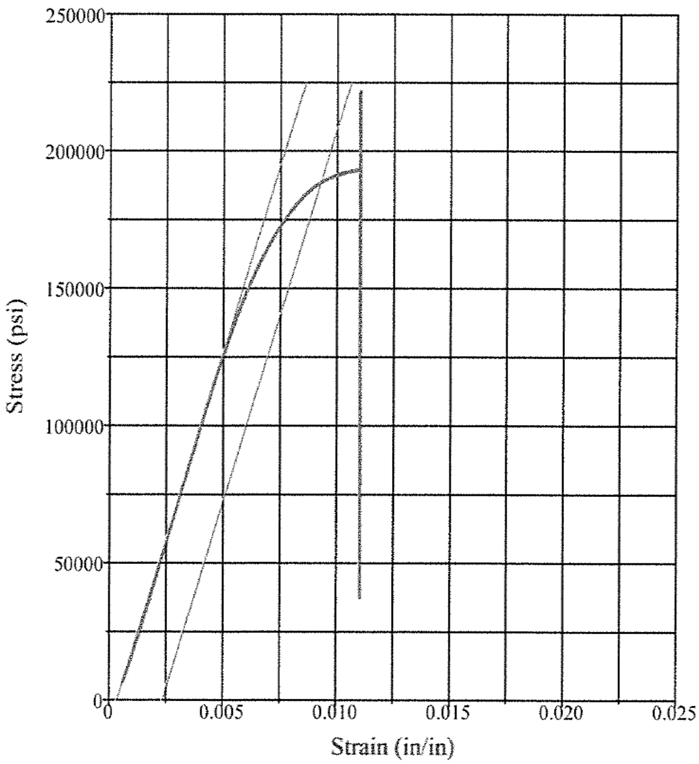
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1600** in
Area:	**0.0290** in^2
After Test Area:	**0.0201** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**25536** ksi
Tensile Strength:	**224** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.38** in
Reduction of Area:	**31** %
Peak Load:	**6494.6000** lbf
Stress at Offset:	**185** ksi
Load at Offset:	**5353** lbf
Proportional Limit:	**4352.6000** lbf

Specimen 1-5



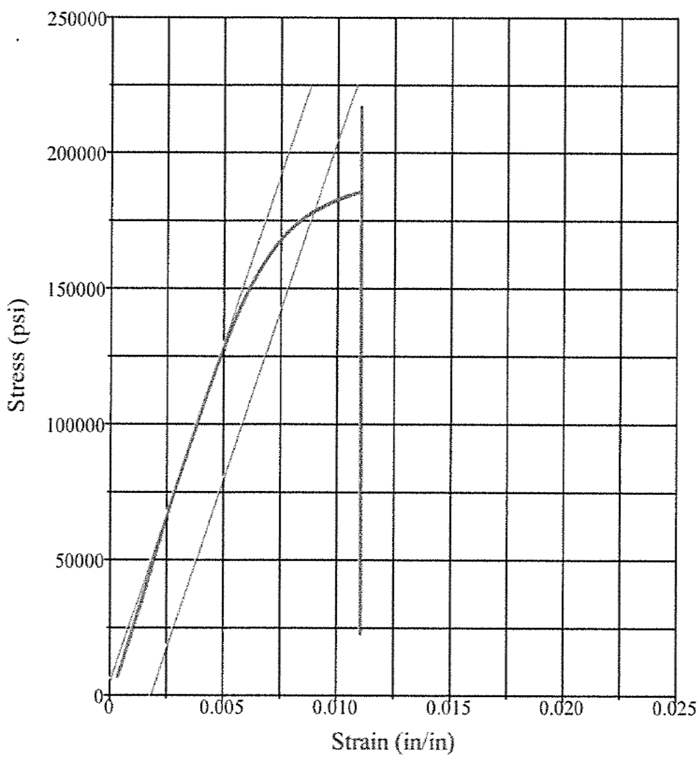
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1580** in
Area:	**0.0290** in^2
After Test Area:	**0.0196** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**24963** ksi
Tensile Strength:	**232** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.358** in
Reduction of Area:	**32** %
Peak Load:	**6715.1000** lbf
Load at Offset:	**5536** lbf
Stress at Offset:	**191** ksi
Proportional Limit:	**4501.7000** lbf

Specimen 1-6



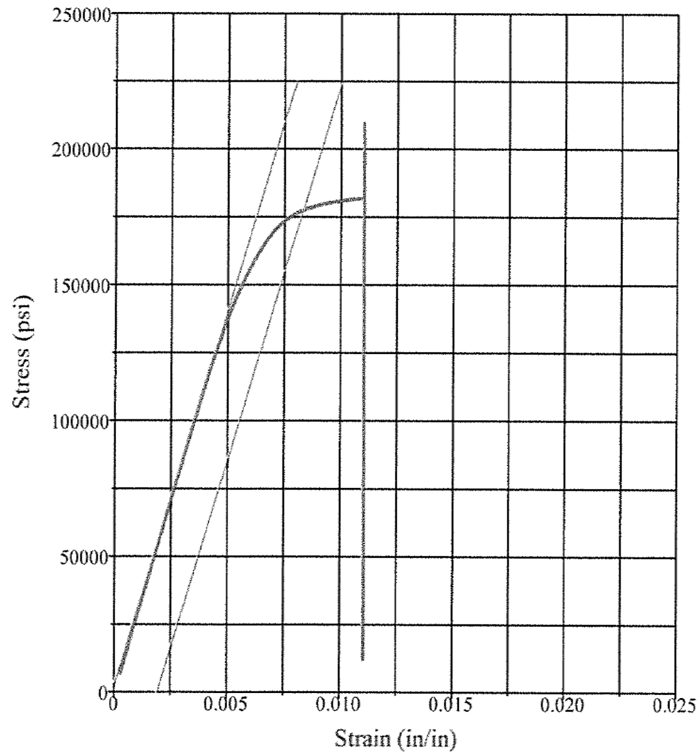
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1570** in
Area:	**0.0290** in^2
After Test Area:	**0.0194** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**27072** ksi
Tensile Strength:	**222** ksi
Total Elongation:	**6** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.57** in
Reduction of Area:	**33** %
Peak Load:	**6430.7000** lbf
Load at Offset:	**5468** lbf
Stress at Offset:	**189** ksi
Proportional Limit:	**4340.5000** lbf

Specimen 2-1



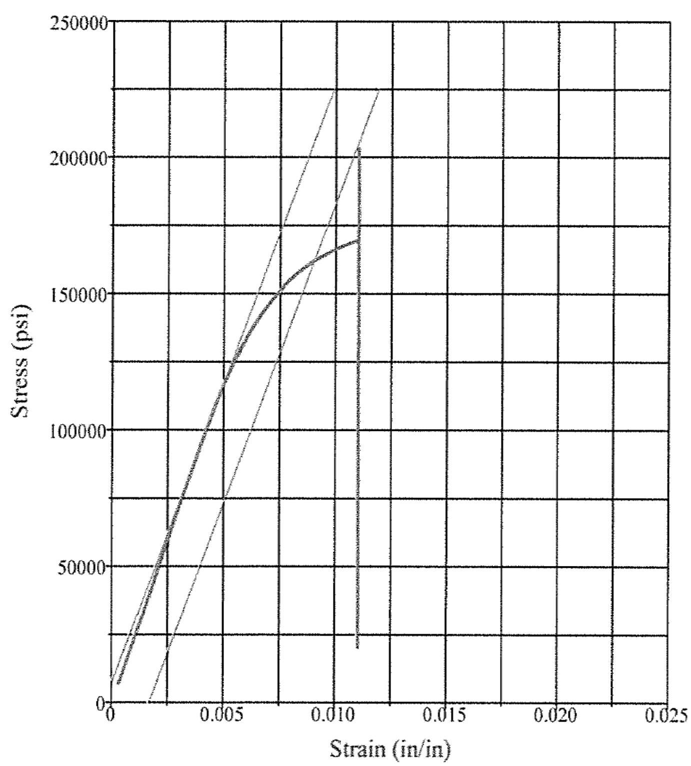
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1470** in
Area:	**0.0290** in^2
After Test Area:	**0.0170** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**24814** ksi
Tensile Strength:	**217** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.51** in
Reduction of Area:	**41** %
Peak Load:	**6292.6000** lbf
Load at Offset:	**5178** lbf
Stress at Offset:	**179** ksi
Proportional Limit:	**4236.2000** lbf

Specimen 2-2



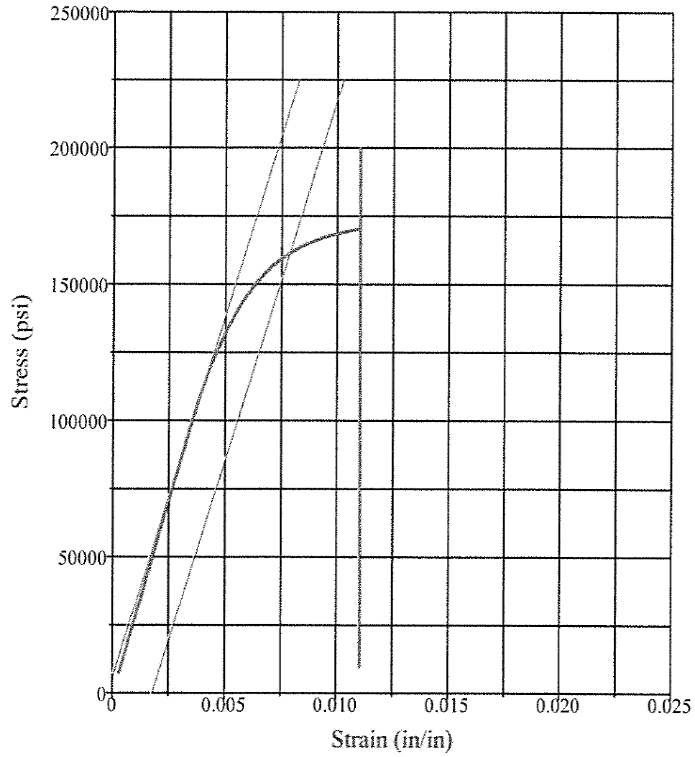
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1550** in
Area:	**0.0290** in^2
After Test Area:	**0.0189** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**27506** ksi
Tensile Strength:	**210** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.367** in
Reduction of Area:	**35** %
Peak Load:	**6078.0000** lbf
Load at Offset:	**5150** lbf
Stress at Offset:	**178** ksi
Proportional Limit:	**4251.7000** lbf

Specimen 2-3



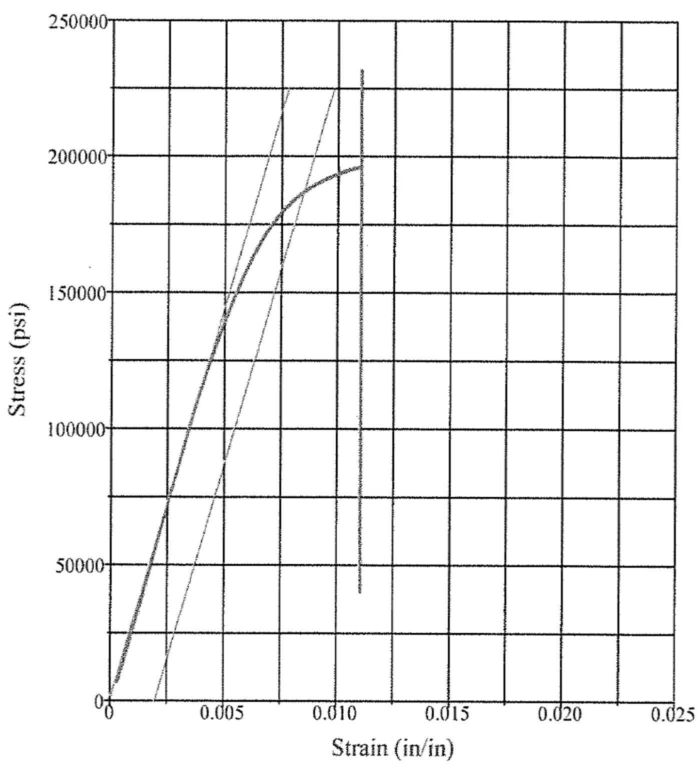
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1520** in
Area:	**0.0290** in^2
After Test Area:	**0.0181** in^2
Correlation Coefficient:	**0.9995**
Tangent Modulus:	**21899** ksi
Tensile Strength:	**203** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.475** in
Reduction of Area:	**38** %
Peak Load:	**5890.2000** lbf
Load at Offset:	**4700** lbf
Stress at Offset:	**162** ksi
Proportional Limit:	**3872.5000** lbf

Specimen 2-4



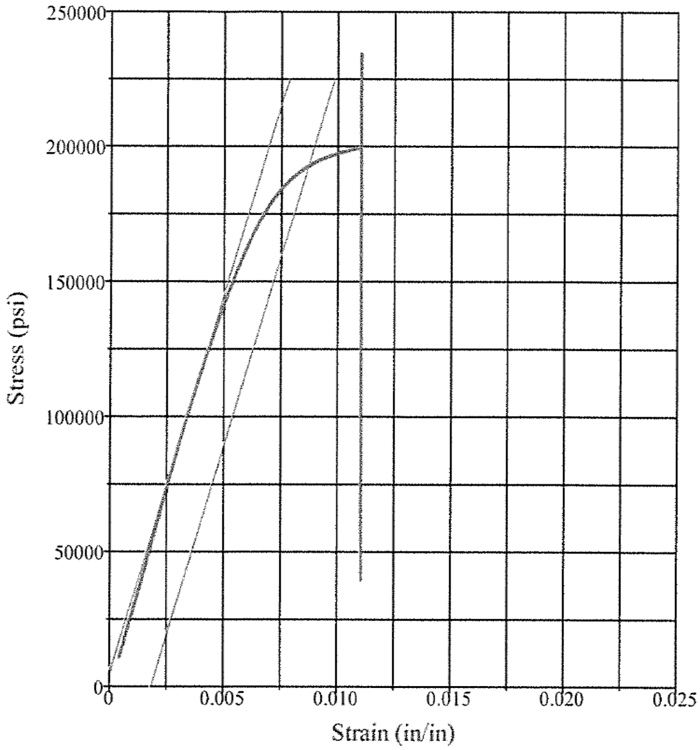
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1520** in
Area:	**0.0290** in^2
After Test Area:	**0.0181** in^2
Correlation Coefficient:	**0.9991**
Tangent Modulus:	**26351** ksi
Tensile Strength:	**200** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.52** in
Reduction of Area:	**38** %
Peak Load:	**5795.3000** lbf
Load at Offset:	**4683** lbf
Stress at Offset:	**161** ksi
Proportional Limit:	**3802.3000** lbf

Specimen 2-5



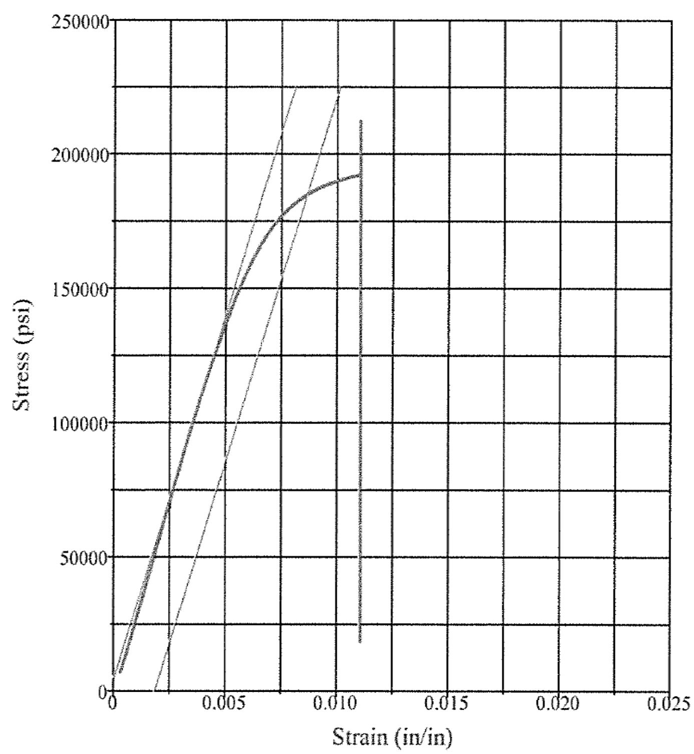
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1580** in
Area:	**0.0290** in^2
After Test Area:	**0.0196** in^2
Correlation Coefficient:	**0.9996**
Tangent Modulus:	**28621** ksi
Tensile Strength:	**232** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.27** in
Reduction of Area:	**32** %
Peak Load:	**6723.5000** lbf
Stress at Offset:	**187** ksi
Load at Offset:	**5424** lbf
Proportional Limit:	**4092.8000** lbf

Specimen 3-1



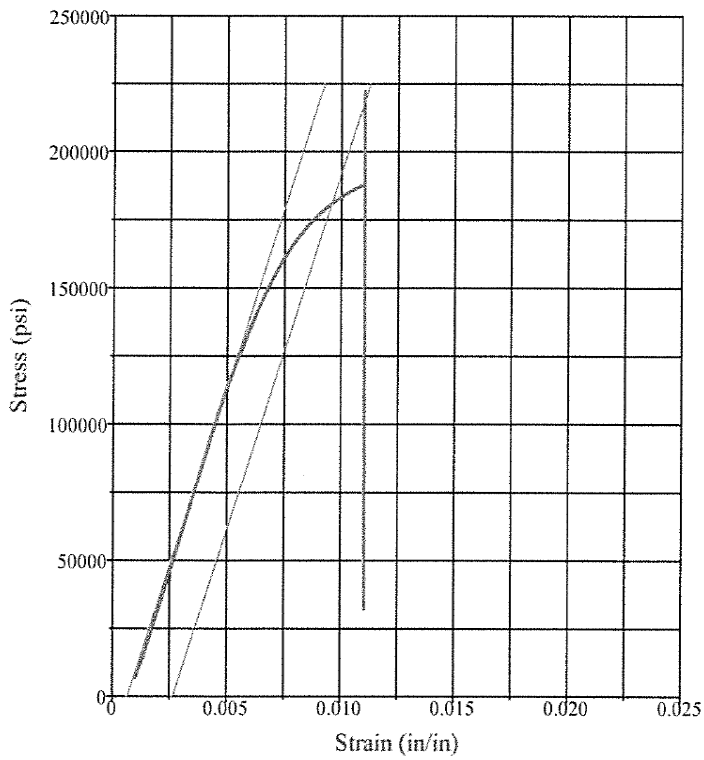
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1560** in
Area:	**0.0290** in^2
After Test Area:	**0.0191** in^2
Correlation Coefficient:	**0.9997**
Tangent Modulus:	**27875** ksi
Tensile Strength:	**235** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.46** in
Reduction of Area:	**34** %
Peak Load:	**6800.5000** lbf
Stress at Offset:	**193** ksi
Load at Offset:	**5593** lbf
Proportional Limit:	**4392.2000** lbf

Specimen 3-2



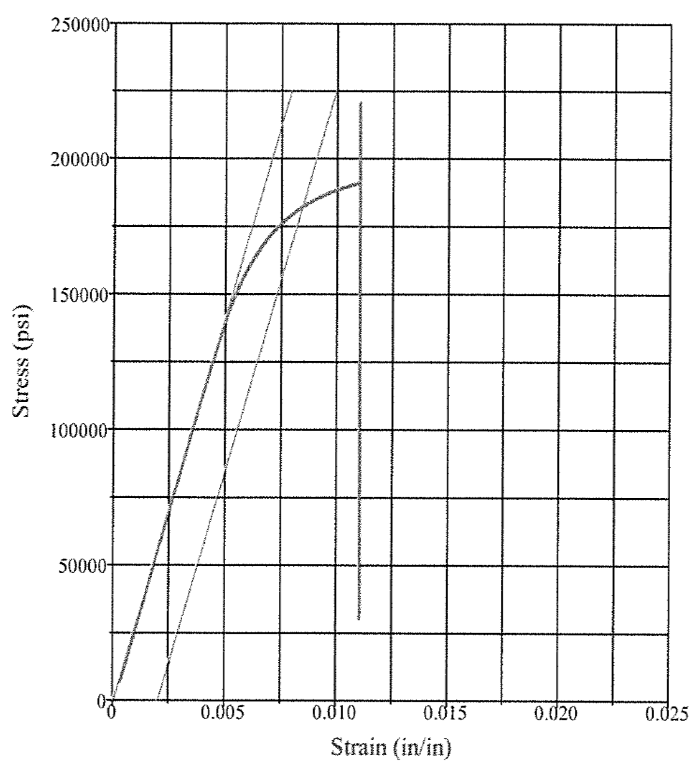
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1800** in
Area:	**0.0290** in^2
After Test Area:	**0.0254** in^2
Correlation Coefficient:	**0.9998**
Tangent Modulus:	**27116** ksi
Tensile Strength:	**212** ksi
Total Elongation:	**1** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.076** in
Reduction of Area:	**12** %
Peak Load:	**6159.8000** lbf
Stress at Offset:	**185** ksi
Load at Offset:	**5368** lbf
Proportional Limit:	**4301.8000** lbf

Specimen 3-3



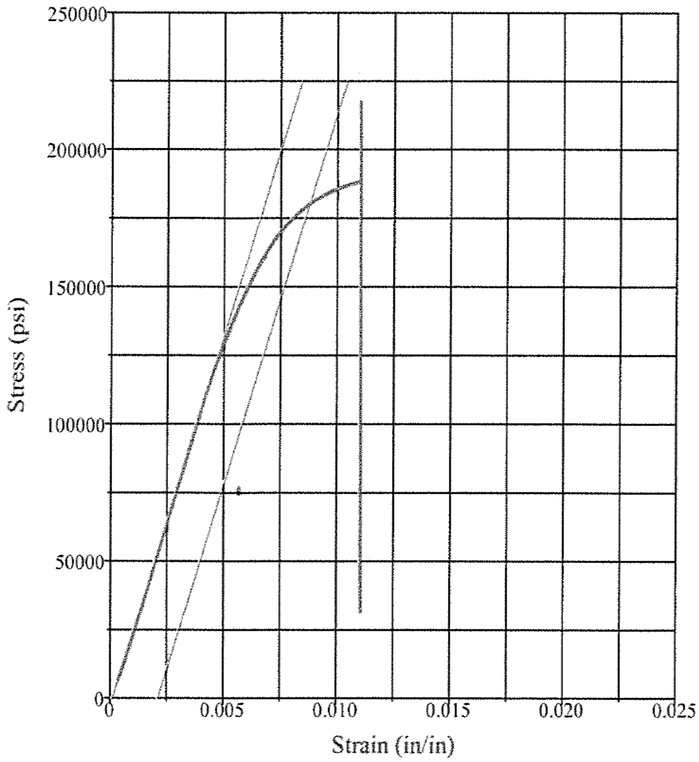
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1570** in
Area:	**0.0290** in²
After Test Area:	**0.0194** in²
Correlation Coefficient:	**0.9996**
Tangent Modulus:	**26036** ksi
Tensile Strength:	**222** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.372** in
Reduction of Area:	**33** %
Peak Load:	**6447.8000** lbf
Load at Offset:	**5250** lbf
Stress at Offset:	**181** ksi
Proportional Limit:	**4039.3000** lbf

Specimen 3-4



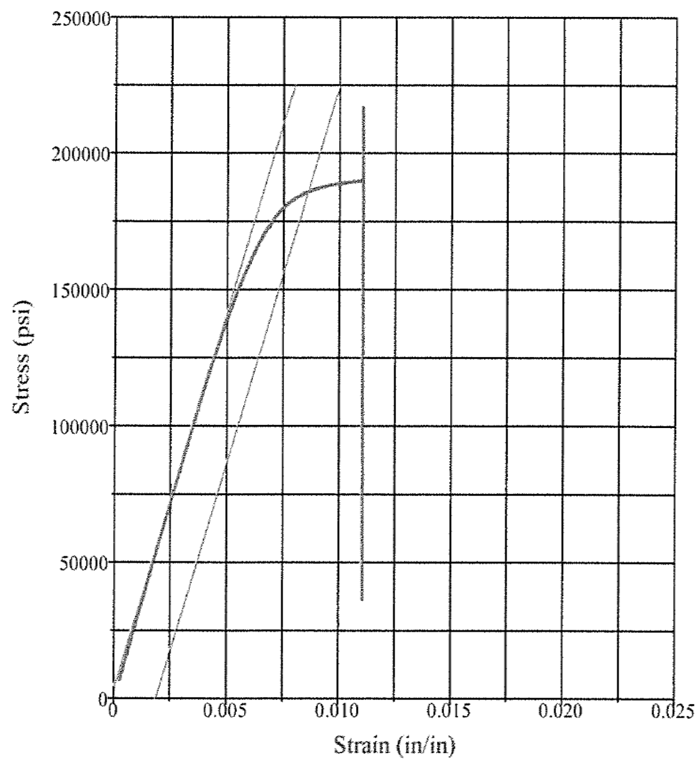
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1560** in
Area:	**0.0290** in²
After Test Area:	**0.0191** in²
Correlation Coefficient:	**1.0000**
Tangent Modulus:	**28251** ksi
Tensile Strength:	**221** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.30** in
Reduction of Area:	**34** %
Peak Load:	**6401.0000** lbf
Load at Offset:	**5291** lbf
Stress at Offset:	**182** ksi
Proportional Limit:	**4472.6000** lbf

Specimen 3-5



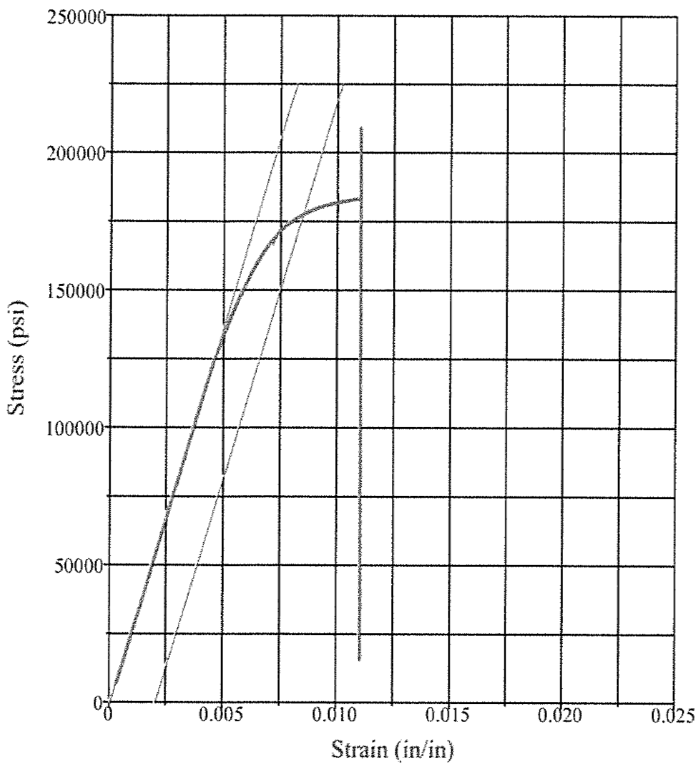
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1590** in
Area:	**0.0290** in^2
After Test Area:	**0.0199** in^2
Correlation Coefficient:	**0.9998**
Tangent Modulus:	**26945** ksi
Tensile Strength:	**218** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.38** in
Reduction of Area:	**31** %
Peak Load:	**6309.1000** lbf
Load at Offset:	**5228** lbf
Stress at Offset:	**180** ksi
Proportional Limit:	**4025.6000** lbf

Specimen 3-6



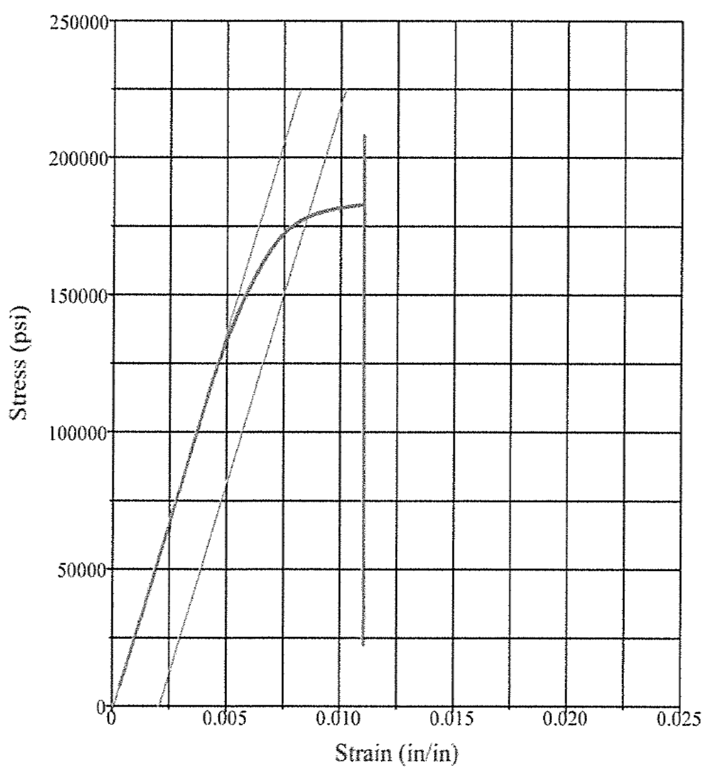
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1570** in
Area:	**0.0290** in^2
After Test Area:	**0.0194** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**27547** ksi
Tensile Strength:	**217** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.54** in
Reduction of Area:	**33** %
Peak Load:	**6296.2000** lbf
Load at Offset:	**5393** lbf
Stress at Offset:	**186** ksi
Proportional Limit:	**4421.5000** lbf

Specimen 4-1



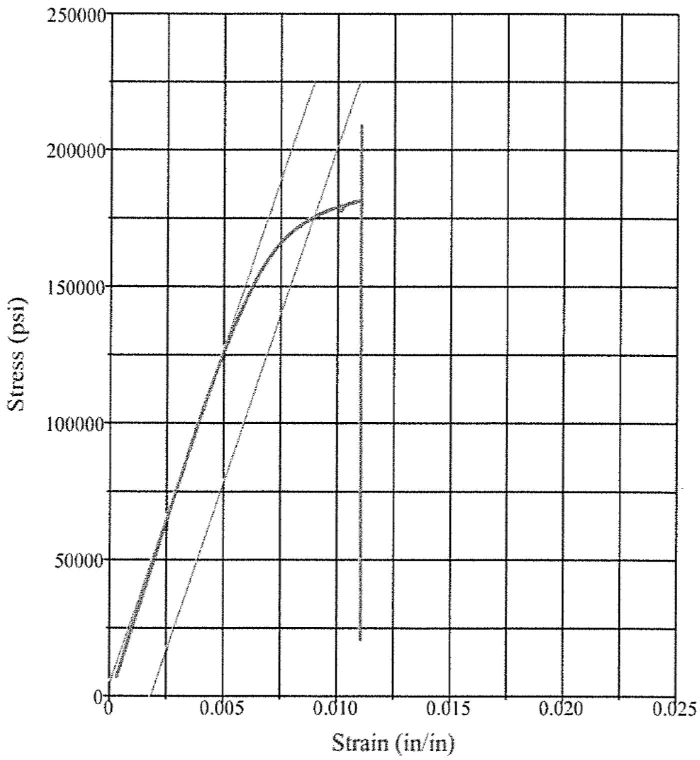
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1600** in
Area:	**0.0290** in^2
After Test Area:	**0.0201** in^2
Correlation Coefficient:	**1.0000**
Tangent Modulus:	**27407** ksi
Tensile Strength:	**209** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.30** in
Reduction of Area:	**31** %
Peak Load:	**6062.2000** lbf
Load at Offset:	**5154** lbf
Stress at Offset:	**178** ksi
Proportional Limit:	**4159.6000** lbf

Specimen 4-2



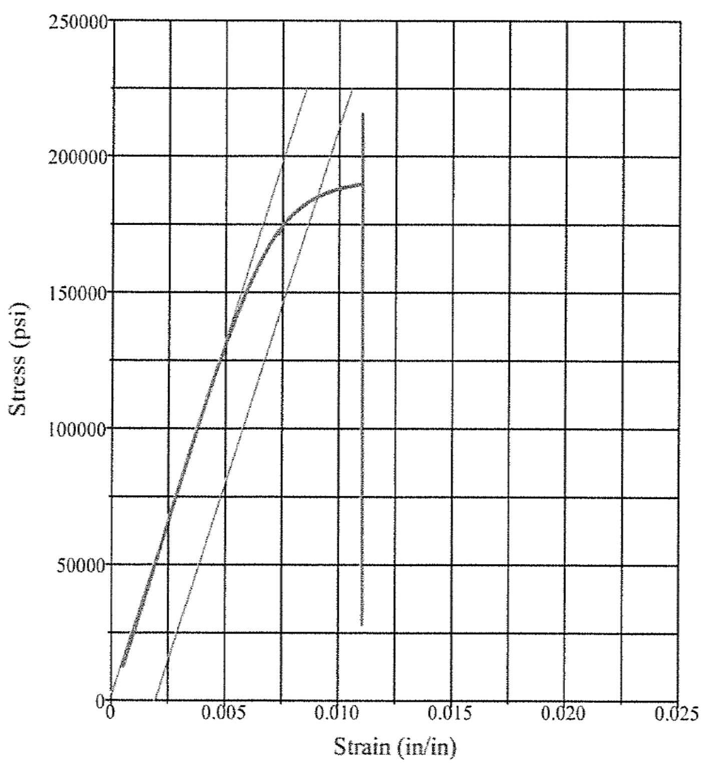
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1650** in
Area:	**0.0290** in^2
After Test Area:	**0.0214** in^2
Correlation Coefficient:	**1.0000**
Tangent Modulus:	**27508** ksi
Tensile Strength:	**208** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.264** in
Reduction of Area:	**26** %
Peak Load:	**6033.1000** lbf
Load at Offset:	**5175** lbf
Stress at Offset:	**178** ksi
Proportional Limit:	**4135.8000** lbf

Specimen 4-3



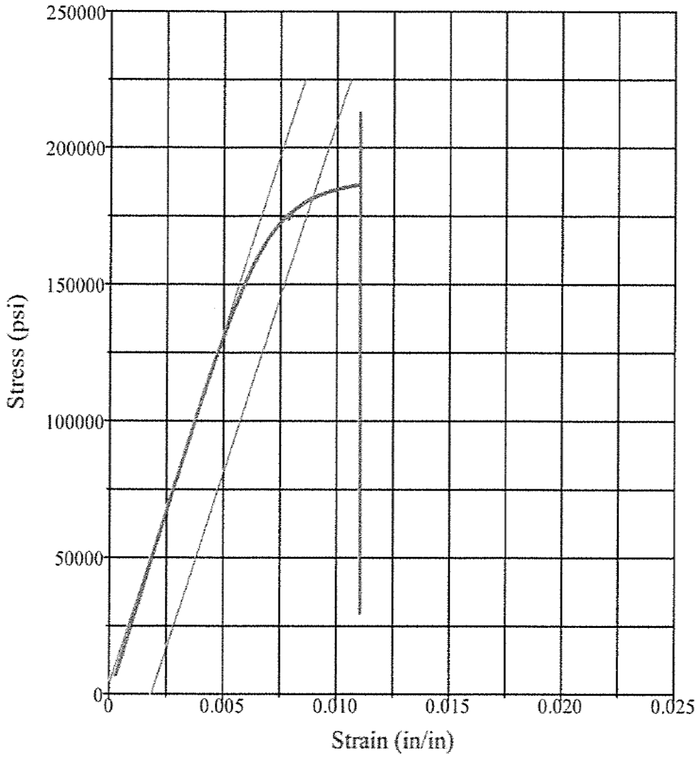
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in^2
After Test Area:	**0.0177** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**24477** ksi
Tensile Strength:	**209** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.32** in
Reduction of Area:	**39** %
Peak Load:	**6064.3000** lbf
Load at Offset:	**5091** lbf
Stress at Offset:	**176** ksi
Proportional Limit:	**4215.7000** lbf

Specimen 4-4



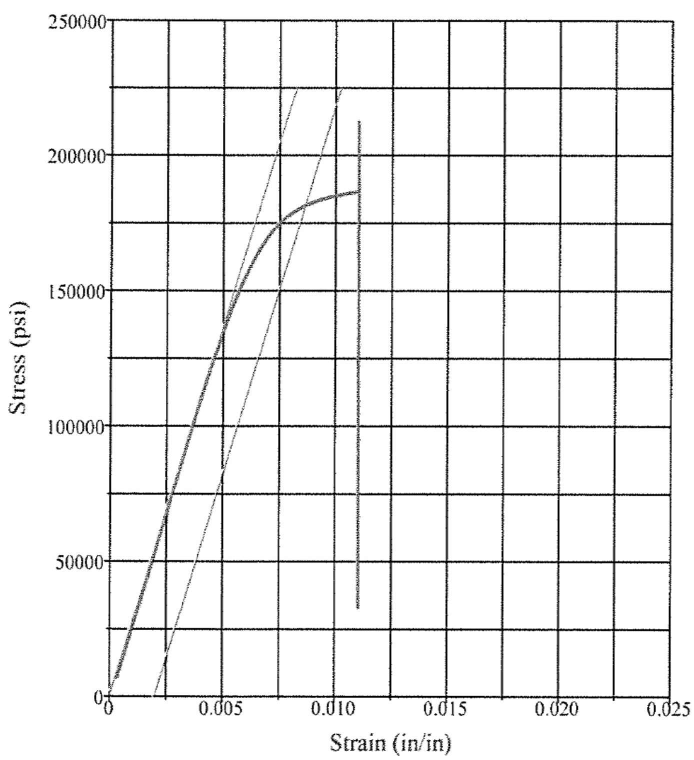
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1560** in
Area:	**0.0290** in^2
After Test Area:	**0.0191** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**26060** ksi
Tensile Strength:	**215** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.26** in
Reduction of Area:	**34** %
Peak Load:	**6247.2000** lbf
Stress at Offset:	**185** ksi
Load at Offset:	**5362** lbf
Proportional Limit:	**4377.9000** lbf

Specimen 4-5



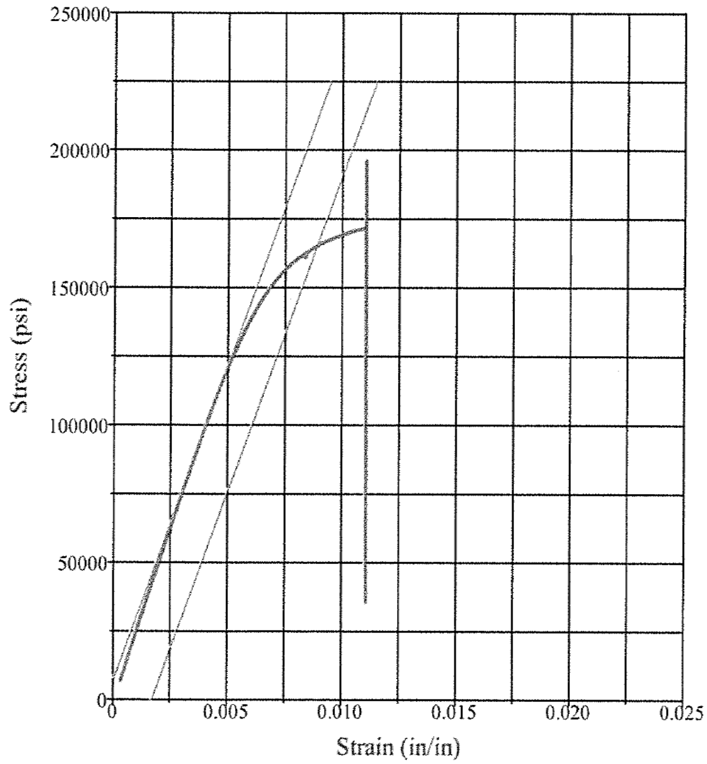
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1600** in
Area:	**0.0290** in^2
After Test Area:	**0.0201** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**25627** ksi
Tensile Strength:	**213** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.31** in
Reduction of Area:	**31** %
Peak Load:	**6167.0000** lbf
Stress at Offset:	**181** ksi
Load at Offset:	**5261** lbf
Proportional Limit:	**4347.1000** lbf

Specimen 4-6



Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1520** in
Area:	**0.0290** in^2
After Test Area:	**0.0181** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**27102** ksi
Tensile Strength:	**213** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.30** in
Reduction of Area:	**38** %
Peak Load:	**6168.4000** lbf
Load at Offset:	**5268** lbf
Stress at Offset:	**182** ksi
Proportional Limit:	**4356.9000** lbf

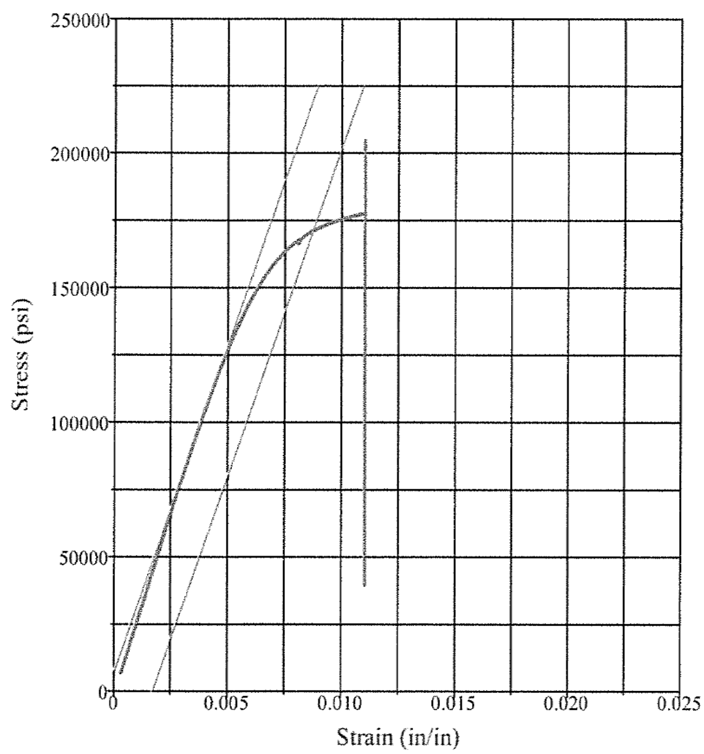
Specimen 5-1



Test Results

Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1650** in
Area:	**0.0290** in²
After Test Area:	**0.0214** in²
Correlation Coefficient:	**0.9998**
Tangent Modulus:	**22910** ksi
Tensile Strength:	**196** ksi
Total Elongation:	**2** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.162** in
Reduction of Area:	**26** %
Peak Load:	**5691.3000** lbf
Load at Offset:	**4795** lbf
Stress at Offset:	**165** ksi
Proportional Limit:	**4019.4000** lbf

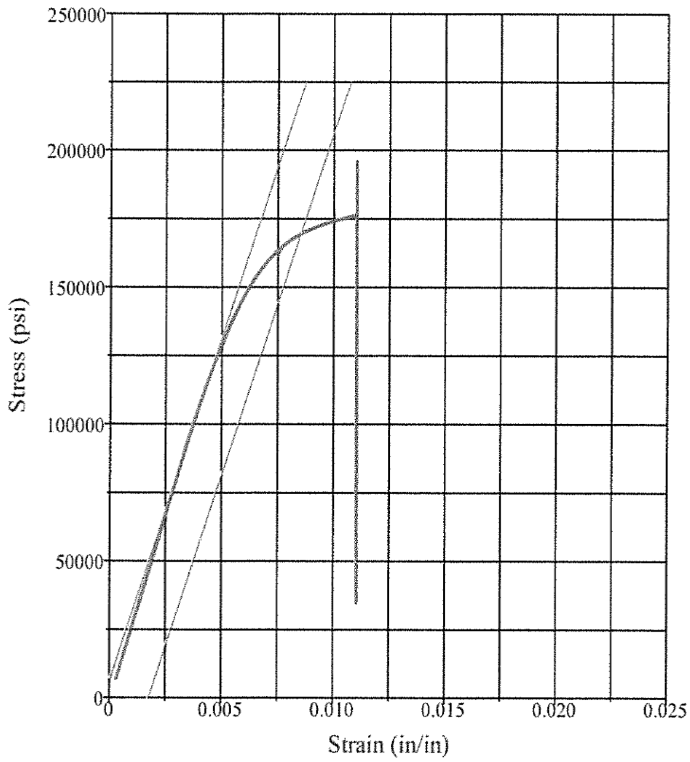
Specimen 5-2



Test Results

Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1640** in
Area:	**0.0290** in²
After Test Area:	**0.0211** in²
Correlation Coefficient:	**0.9998**
Tangent Modulus:	**24248** ksi
Tensile Strength:	**205** ksi
Total Elongation:	**2** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.24** in
Reduction of Area:	**27** %
Peak Load:	**5936.5000** lbf
Stress at Offset:	**171** ksi
Load at Offset:	**4965** lbf
Proportional Limit:	**4099.4000** lbf

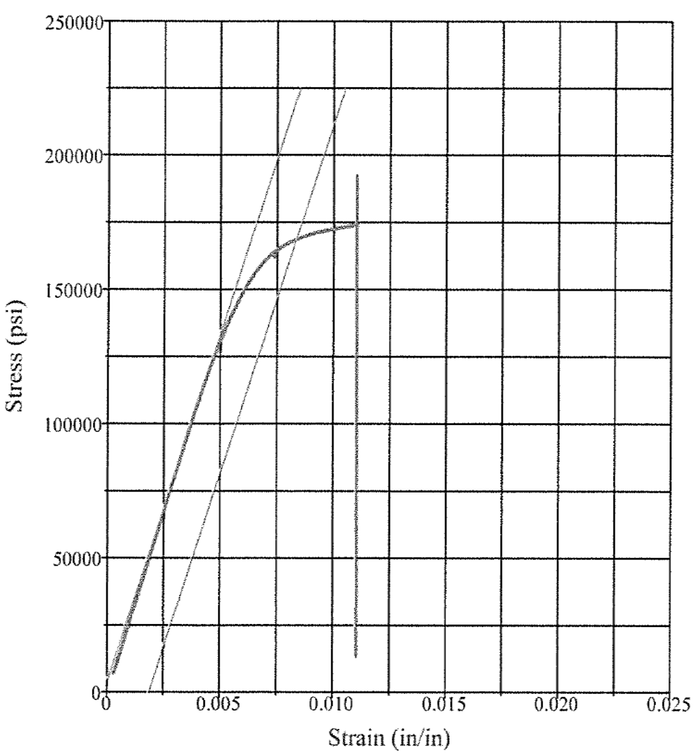
Specimen 5-3



Test Results

Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1780** in
Area:	**0.0290** in^2
After Test Area:	**0.0249** in^2
Correlation Coefficient:	**0.9995**
Tangent Modulus:	**24920** ksi
Tensile Strength:	**196** ksi
Total Elongation:	**1** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.14** in
Reduction of Area:	**14** %
Peak Load:	**5684.0000** lbf
Stress at Offset:	**169** ksi
Load at Offset:	**4914** lbf
Proportional Limit:	**4026.0000** lbf

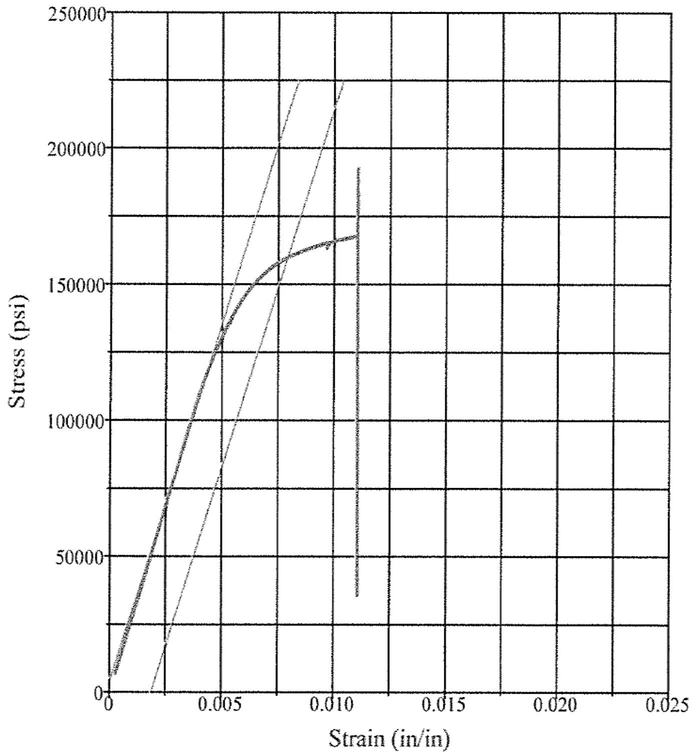
Specimen 5-4



Test Results

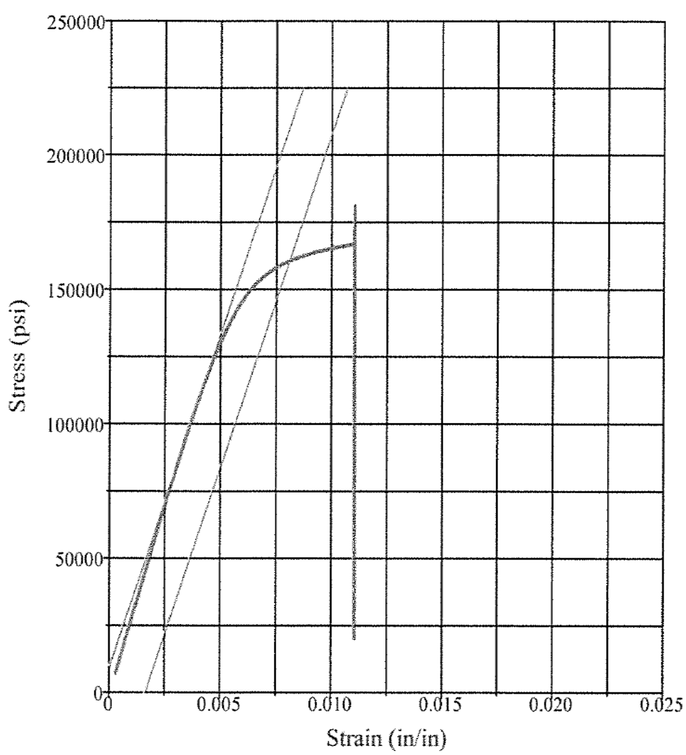
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1700** in
Area:	**0.0290** in^2
After Test Area:	**0.0227** in^2
Correlation Coefficient:	**0.9998**
Tangent Modulus:	**25842** ksi
Tensile Strength:	**192** ksi
Total Elongation:	**2** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.185** in
Reduction of Area:	**22** %
Peak Load:	**5576.0000** lbf
Stress at Offset:	**169** ksi
Load at Offset:	**4893** lbf
Proportional Limit:	**4085.9000** lbf

Specimen 5-5



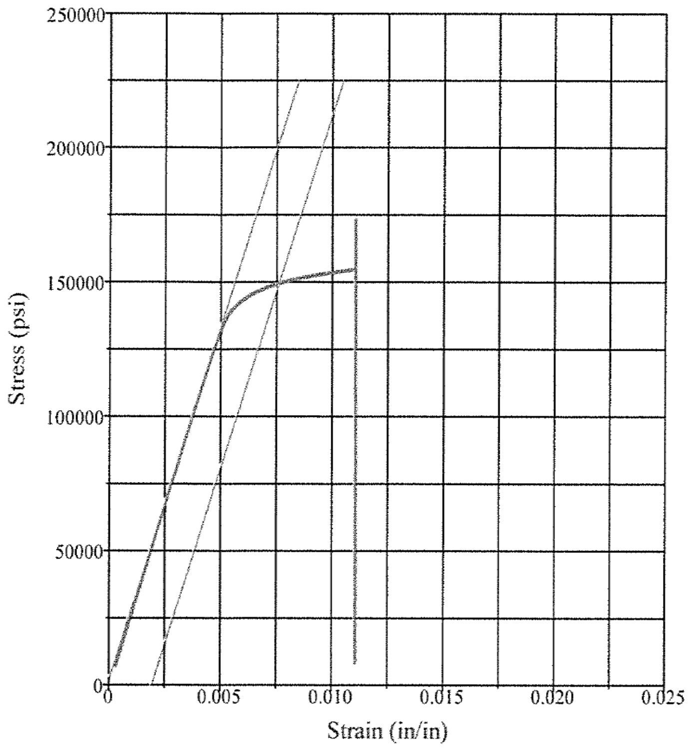
	Test Results	
Specimen Gage Length:	**10.0000**	in
Diameter:	**0.1920**	in
After Test Diameter:	**0.1600**	in
Area:	**0.0290**	in^2
After Test Area:	**0.0201**	in^2
Correlation Coefficient:	**0.9995**	
Tangent Modulus:	**26265**	ksi
Tensile Strength:	**193**	ksi
Total Elongation:	**2**	%
Pretest Punch Length:	**10**	in
Posttest Punch Length:	**10.23**	in
Reduction of Area:	**31**	%
Peak Load:	**5584.9000**	lbf
Load at Offset:	**4635**	lbf
Stress at Offset:	**160**	ksi
Proportional Limit:	**3818.9000**	lbf

Specimen 5-6



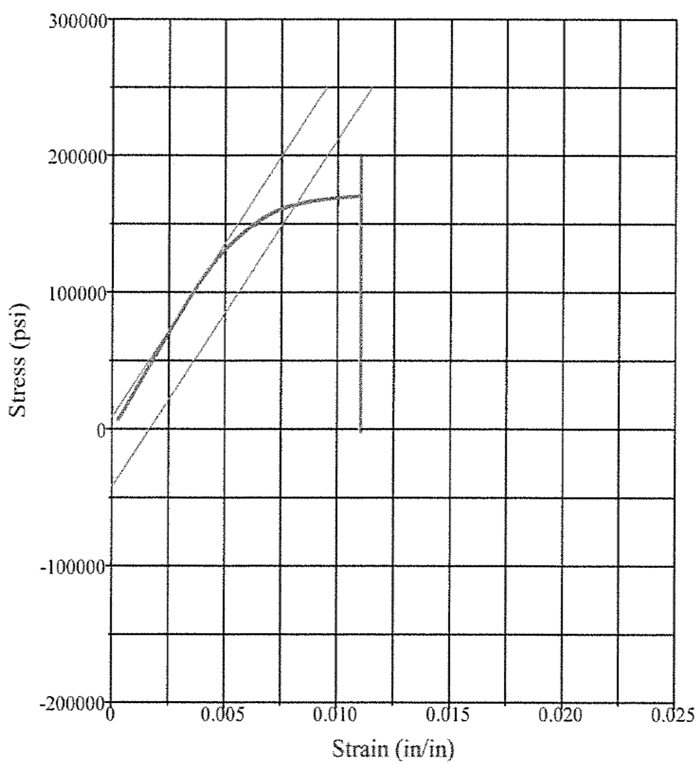
	Test Results	
Specimen Gage Length:	**10.0000**	in
Diameter:	**0.1920**	in
After Test Diameter:	**0.1720**	in
Area:	**0.0290**	in^2
After Test Area:	**0.0232**	in^2
Correlation Coefficient:	**0.9997**	
Tangent Modulus:	**24736**	ksi
Tensile Strength:	**181**	ksi
Total Elongation:	**2**	%
Pretest Punch Length:	**10**	in
Posttest Punch Length:	**10.246**	in
Reduction of Area:	**20**	%
Peak Load:	**5248.0000**	lbf
Load at Offset:	**4658**	lbf
Stress at Offset:	**161**	ksi
Proportional Limit:	**3964.0000**	lbf

Specimen 5-7



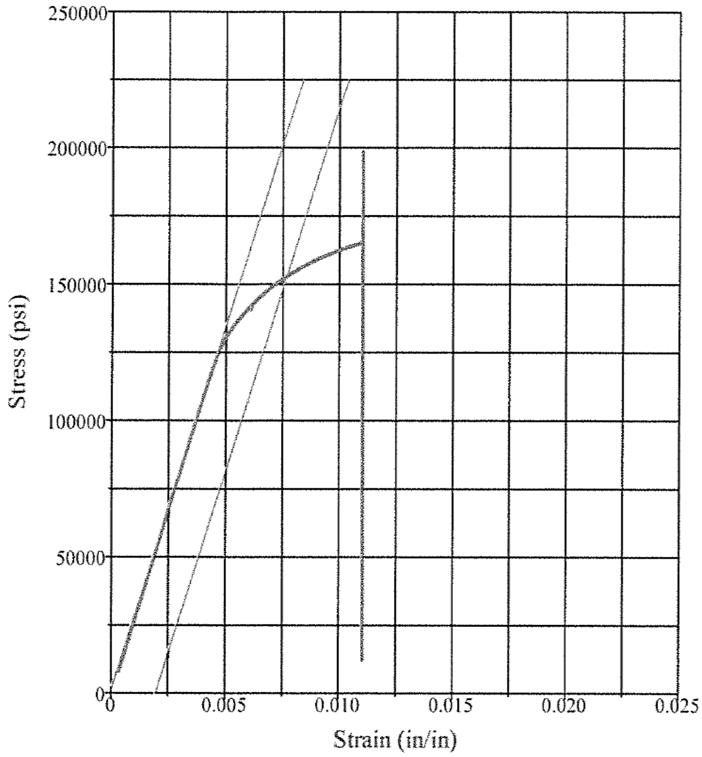
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1700** in
Area:	**0.0290** in²
After Test Area:	**0.0227** in²
Correlation Coefficient:	**1.0000**
Tangent Modulus:	**26193** ksi
Tensile Strength:	**173** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.254** in
Reduction of Area:	**22** %
Peak Load:	**5019.6000** lbf
Load at Offset:	**4336** lbf
Stress at Offset:	**150** ksi
Proportional Limit:	**4036.3000** lbf

Specimen 5-8



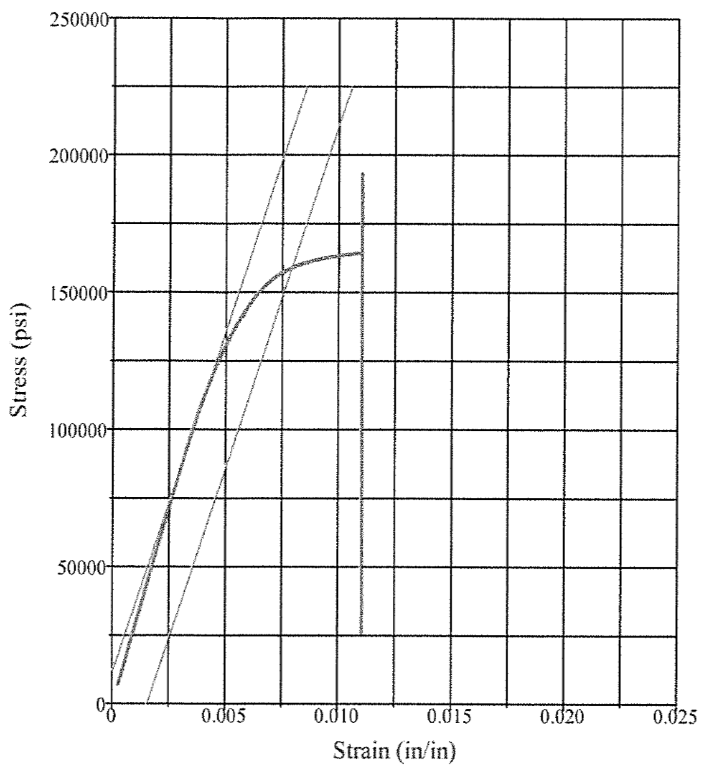
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1550** in
Area:	**0.0290** in²
After Test Area:	**0.0189** in²
Correlation Coefficient:	**0.9994**
Tangent Modulus:	**25336** ksi
Tensile Strength:	**199** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.45** in
Reduction of Area:	**35** %
Peak Load:	**5770.5000** lbf
Stress at Offset:	**164** ksi
Load at Offset:	**4762** lbf
Proportional Limit:	**3854.3000** lbf

Specimen 6-1



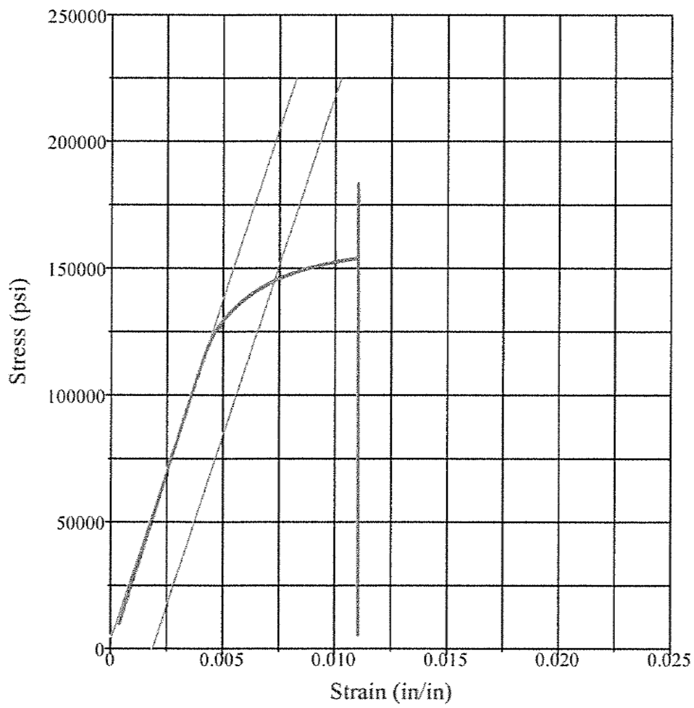
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1590** in
Area:	**0.0290** in^2
After Test Area:	**0.0199** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**26525** ksi
Tensile Strength:	**199** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.39** in
Reduction of Area:	**31** %
Peak Load:	**5761.9000** lbf
Stress at Offset:	**153** ksi
Load at Offset:	**4437** lbf
Proportional Limit:	**3822.8000** lbf

Specimen 6-2



	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1510** in
Area:	**0.0290** in^2
After Test Area:	**0.0179** in^2
Correlation Coefficient:	**0.9992**
Tangent Modulus:	**24873** ksi
Tensile Strength:	**193** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.43** in
Reduction of Area:	**38** %
Peak Load:	**5602.5000** lbf
Stress at Offset:	**159** ksi
Load at Offset:	**4610** lbf
Proportional Limit:	**3817.6000** lbf

Specimen 6-3

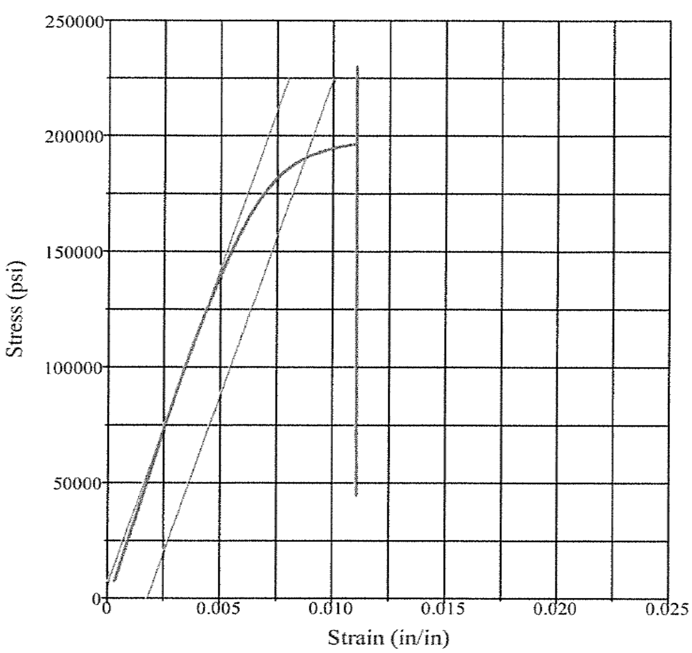


Test Results

Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1590** in
Area:	**0.0290** in^2
After Test Area:	**0.0199** in^2
Correlation Coefficient:	**0.9998**
Tangent Modulus:	**26705** ksi
Tensile Strength:	**183** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.35** in
Reduction of Area:	**31** %
Peak Load:	**5316.6000** lbf
Stress at Offset:	**145** ksi
Load at Offset:	**4207** lbf
Proportional Limit:	**3689.6000** lbf

Speci

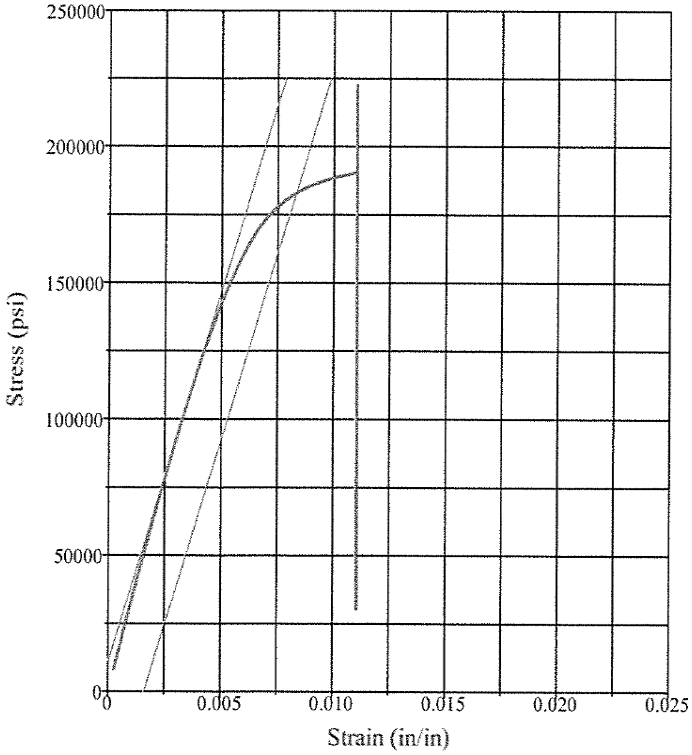
men 6-4



Test Results

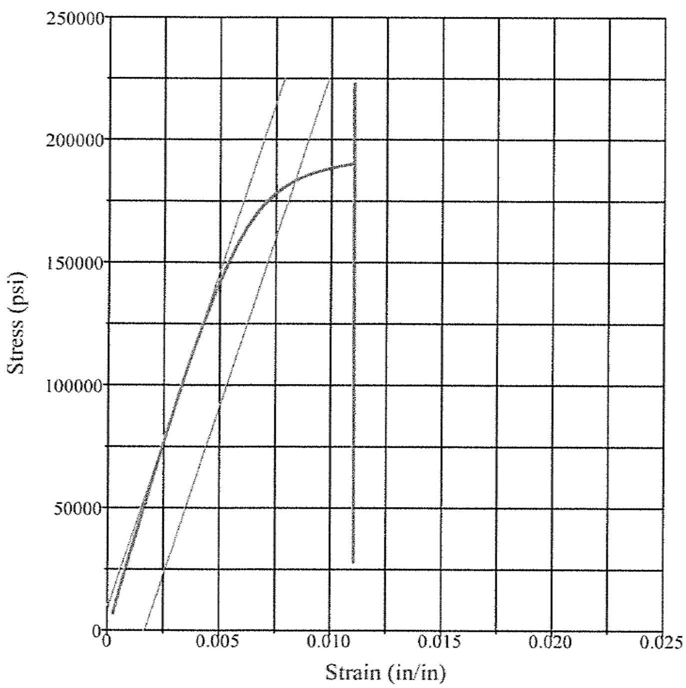
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1590** in
Area:	**0.0290** in^2
After Test Area:	**0.0199** in^2
Correlation Coefficient:	**0.9998**
Tangent Modulus:	**27189** ksi
Tensile Strength:	**230** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.36** in
Reduction of Area:	**31** %
Peak Load:	**6666.9000** lbf
Stress at Offset:	**191** ksi
Load at Offset:	**5525** lbf
Proportional Limit:	**4411.6000** lbf

Specimen 6-5



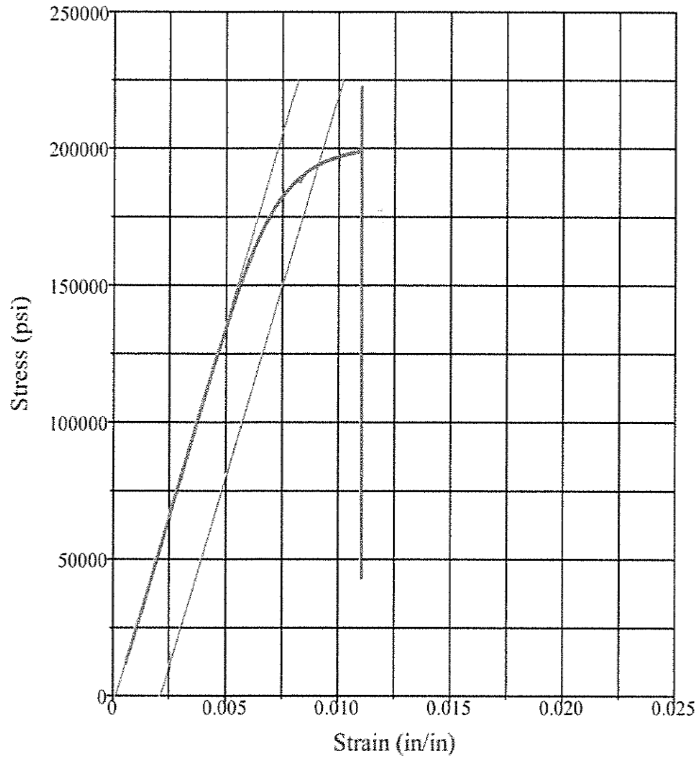
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1580** in
Area:	**0.0290** in^2
After Test Area:	**0.0196** in^2
Correlation Coefficient:	**0.9998**
Tangent Modulus:	**27214** ksi
Tensile Strength:	**222** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.33** in
Reduction of Area:	**32** %
Peak Load:	**6445.4000** lbf
Load at Offset:	**5300** lbf
Stress at Offset:	**183** ksi
Proportional Limit:	**4248.5000** lbf

Specimen 7-1



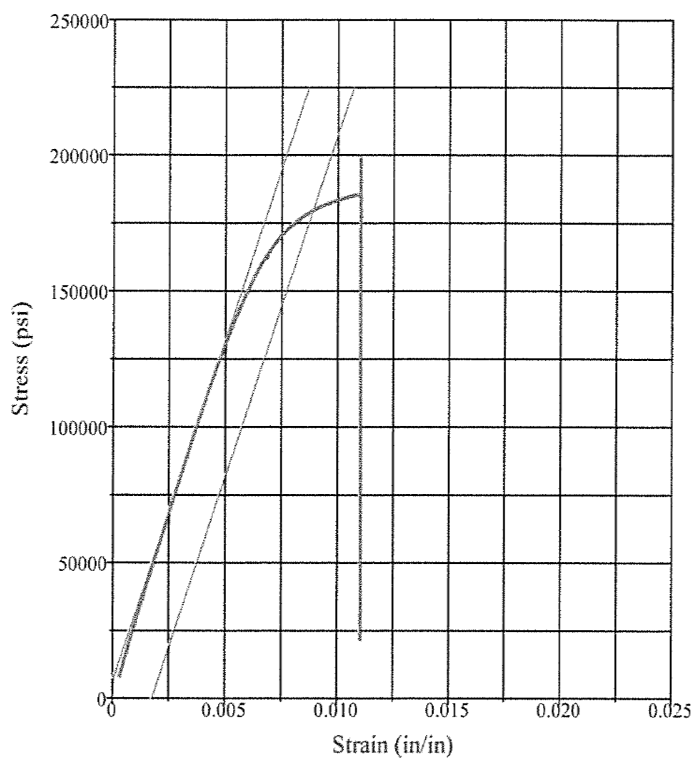
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1550** in
Area:	**0.0290** in^2
After Test Area:	**0.0189** in^2
Correlation Coefficient:	**0.9998**
Tangent Modulus:	**27292** ksi
Tensile Strength:	**223** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.42** in
Reduction of Area:	**35** %
Peak Load:	**6468.5000** lbf
Stress at Offset:	**183** ksi
Load at Offset:	**5318** lbf
Proportional Limit:	**4300.8000** lbf

Specimen 7-2



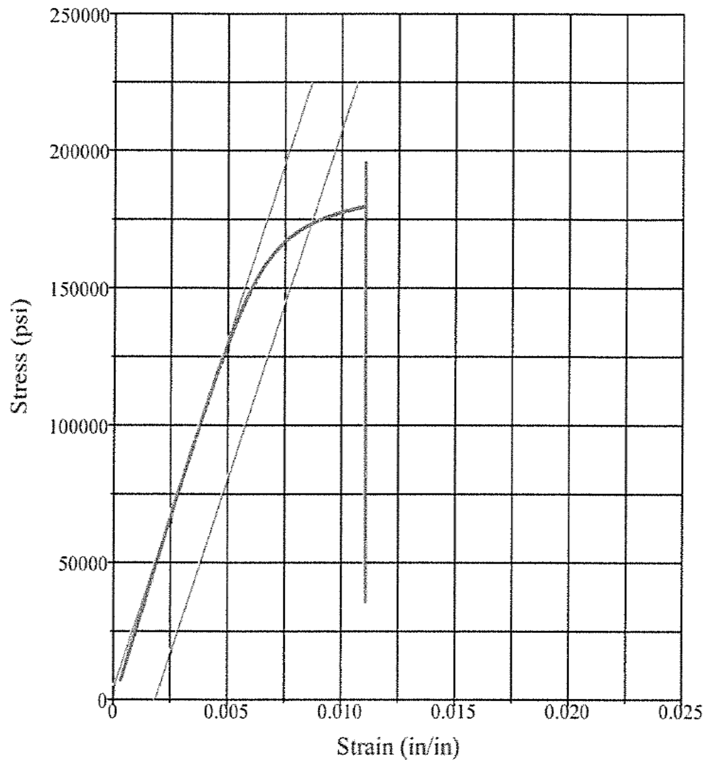
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1650** in
Area:	**0.0290** in^2
After Test Area:	**0.0214** in^2
Correlation Coefficient:	**1.0000**
Tangent Modulus:	**27786** ksi
Tensile Strength:	**222** ksi
Total Elongation:	**2** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.21** in
Reduction of Area:	**26** %
Peak Load:	**6449.7000** lbf
Stress at Offset:	**194** ksi
Load at Offset:	**5628** lbf
Proportional Limit:	**4714.2000** lbf

Specimen 7-3



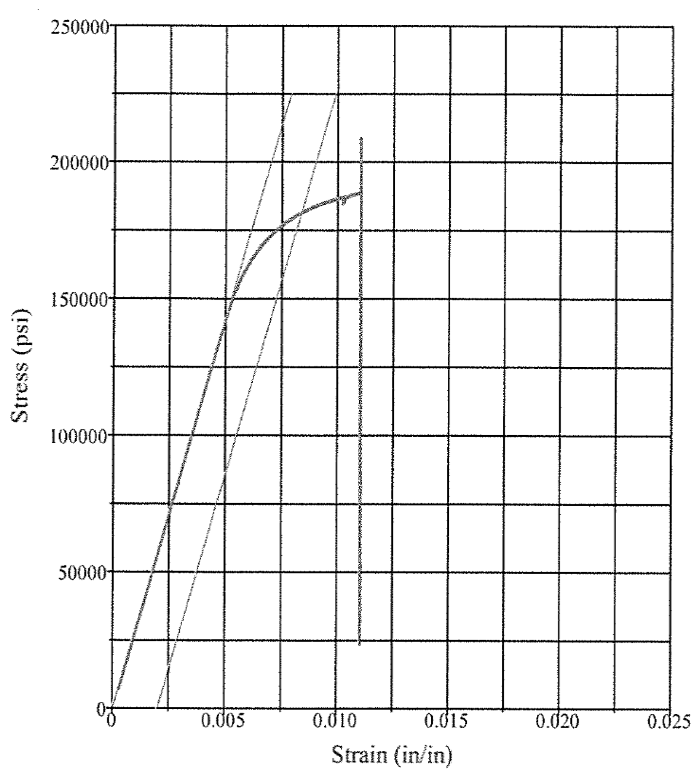
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1740** in
Area:	**0.0290** in^2
After Test Area:	**0.0238** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**25037** ksi
Tensile Strength:	**199** ksi
Total Elongation:	**0** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.045** in
Reduction of Area:	**18** %
Peak Load:	**5767.6000** lbf
Stress at Offset:	**180** ksi
Load at Offset:	**5214** lbf
Proportional Limit:	**4303.2000** lbf

Specimen 7-4



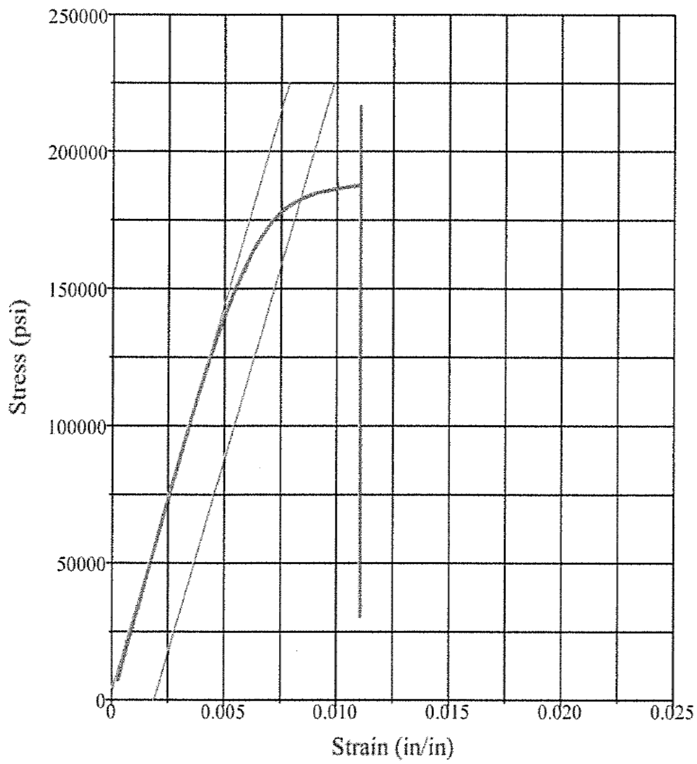
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1700** in
Area:	**0.0290** in^2
After Test Area:	**0.0227** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**25374** ksi
Tensile Strength:	**196** ksi
Total Elongation:	**1** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.10** in
Reduction of Area:	**22** %
Peak Load:	**5682.3000** lbf
Stress at Offset:	**173** ksi
Load at Offset:	**5030** lbf
Proportional Limit:	**4251.6000** lbf

Specimen 7-5



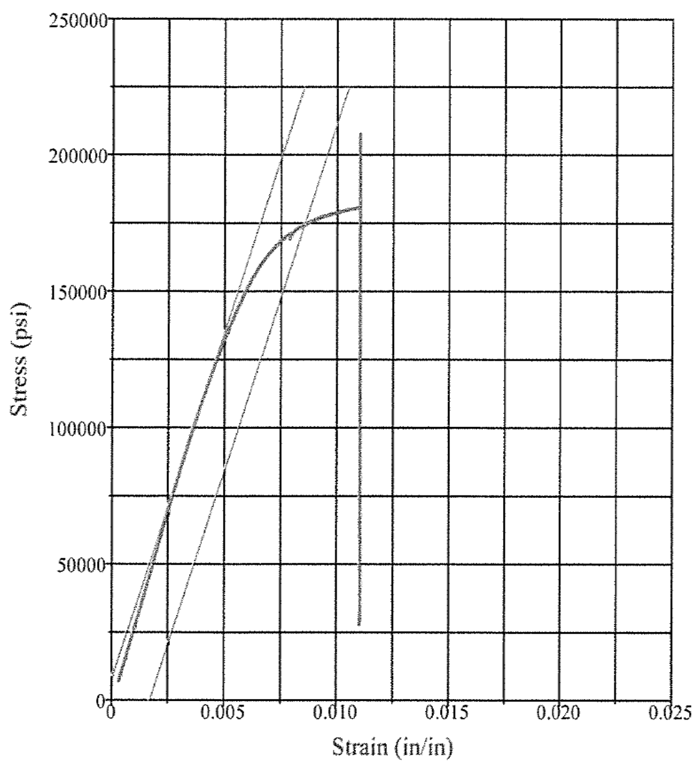
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1610** in
Area:	**0.0290** in^2
After Test Area:	**0.0204** in^2
Correlation Coefficient:	**1.0000**
Tangent Modulus:	**28337** ksi
Tensile Strength:	**208** ksi
Total Elongation:	**1** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.14** in
Reduction of Area:	**30** %
Peak Load:	**6046.1000** lbf
Load at Offset:	**5259** lbf
Stress at Offset:	**181** ksi
Proportional Limit:	**4628.0000** lbf

Specimen 7-6



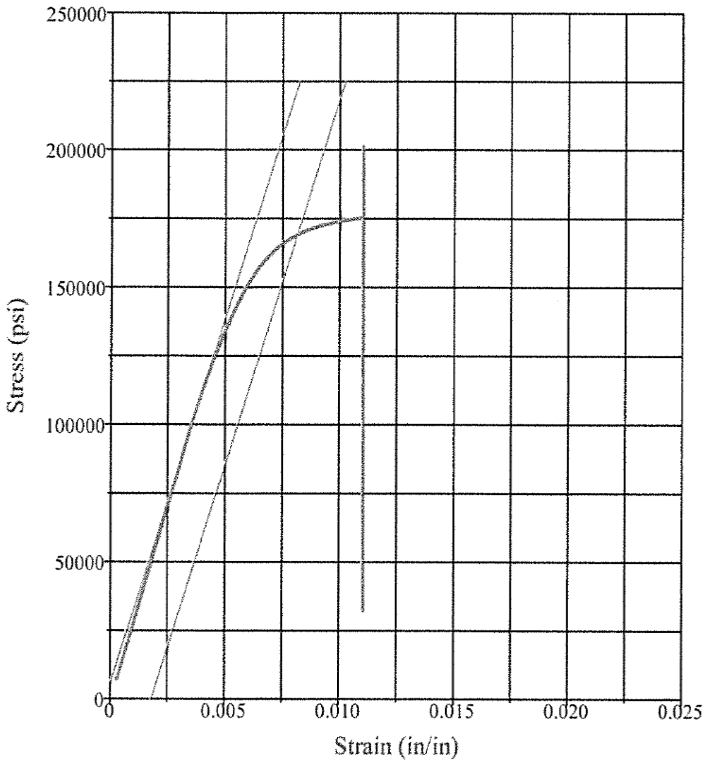
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1550** in
Area:	**0.0290** in^2
After Test Area:	**0.0189** in^2
Correlation Coefficient:	**0.9998**
Tangent Modulus:	**28080** ksi
Tensile Strength:	**217** ksi
Total Elongation:	**6** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.57** in
Reduction of Area:	**35** %
Peak Load:	**6280.1000** lbf
Stress at Offset:	**183** ksi
Load at Offset:	**5297** lbf
Proportional Limit:	**4208.2000** lbf

Specimen 8-1



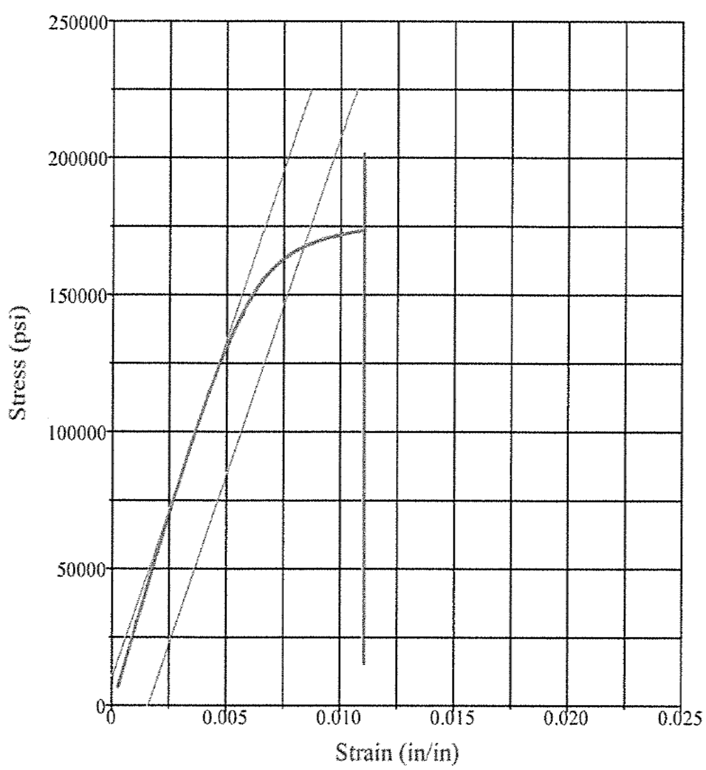
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1580** in
Area:	**0.0290** in^2
After Test Area:	**0.0196** in^2
Correlation Coefficient:	**0.9997**
Tangent Modulus:	**25334** ksi
Tensile Strength:	**208** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.325** in
Reduction of Area:	**32** %
Peak Load:	**6026.7000** lbf
Stress at Offset:	**175** ksi
Load at Offset:	**5065** lbf
Proportional Limit:	**4187.4000** lbf

Specimen 8-2



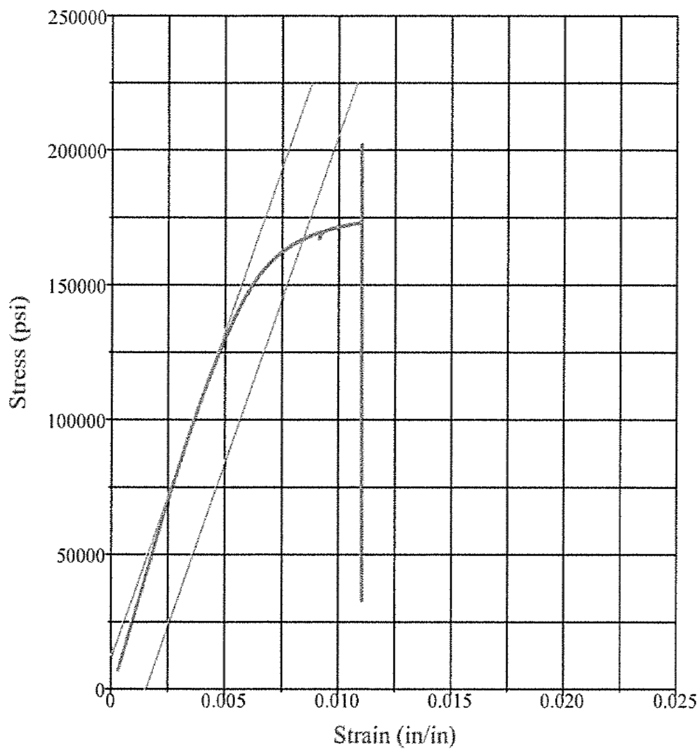
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1560** in
Area:	**0.0290** in^2
After Test Area:	**0.0191** in^2
Correlation Coefficient:	**0.9992**
Tangent Modulus:	**26540** ksi
Tensile Strength:	**202** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.32** in
Reduction of Area:	**34** %
Peak Load:	**5843.6000** lbf
Load at Offset:	**4911** lbf
Stress at Offset:	**169** ksi
Proportional Limit:	**3988.2000** lbf

Specimen 8-3



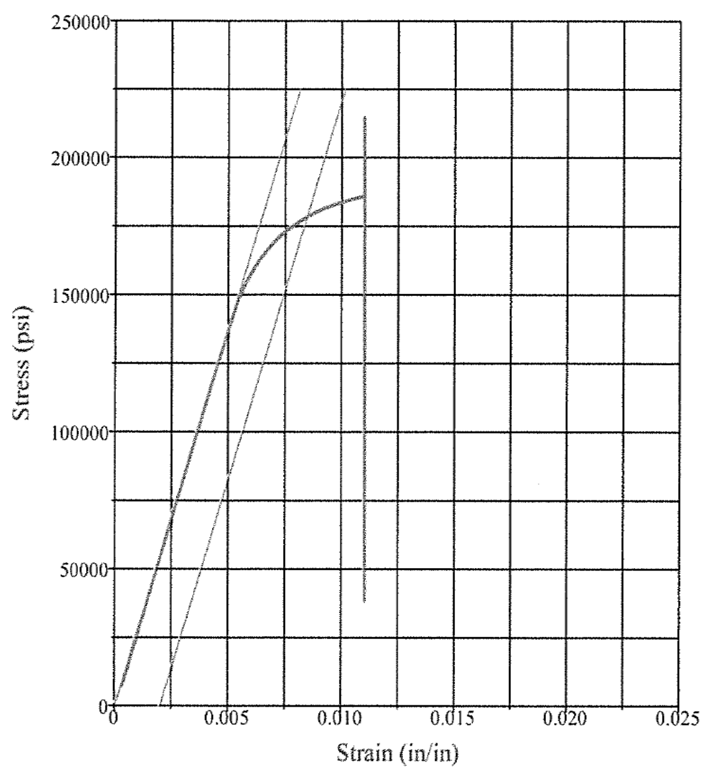
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1600** in
Area:	**0.0290** in^2
After Test Area:	**0.0201** in^2
Correlation Coefficient:	**0.9997**
Tangent Modulus:	**24647** ksi
Tensile Strength:	**202** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.32** in
Reduction of Area:	**31** %
Peak Load:	**5848.1000** lbf
Stress at Offset:	**168** ksi
Load at Offset:	**4863** lbf
Proportional Limit:	**4065.9000** lbf

Specimen 8-4



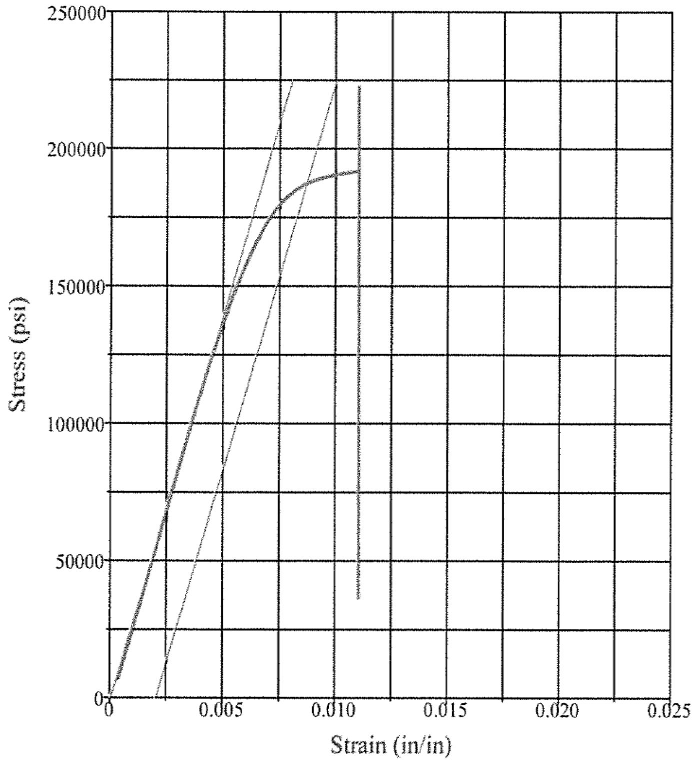
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1600** in
Area:	**0.0290** in^2
After Test Area:	**0.0201** in^2
Correlation Coefficient:	**0.9996**
Tangent Modulus:	**24152** ksi
Tensile Strength:	**202** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.37** in
Reduction of Area:	**31** %
Peak Load:	**5863.8000** lbf
Stress at Offset:	**167** ksi
Load at Offset:	**4846** lbf
Proportional Limit:	**4080.7000** lbf

Specimen 8-5



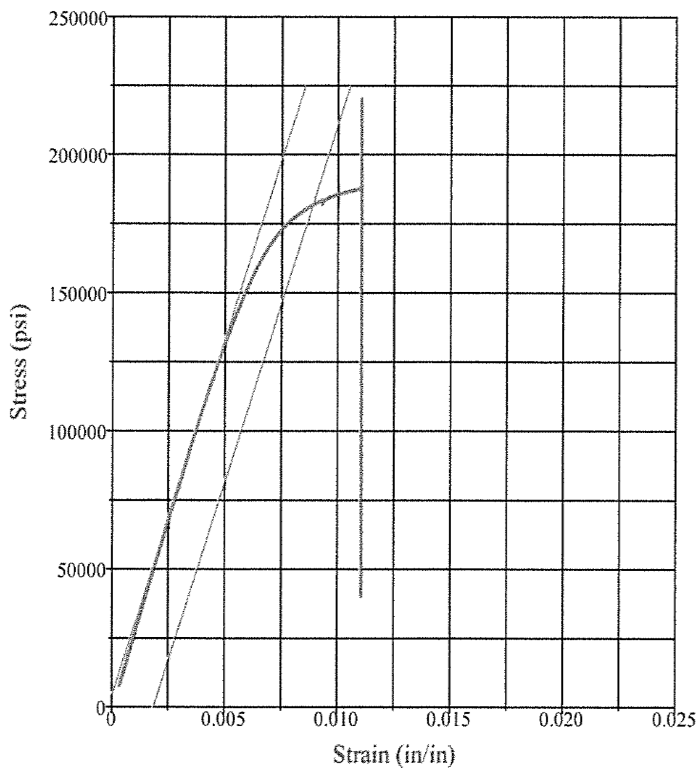
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1550** in
Area:	**0.0290** in^2
After Test Area:	**0.0189** in^2
Correlation Coefficient:	**1.0000**
Tangent Modulus:	**27484** ksi
Tensile Strength:	**215** ksi
Total Elongation:	**2** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.20** in
Reduction of Area:	**35** %
Peak Load:	**6228.7000** lbf
Stress at Offset:	**179** ksi
Load at Offset:	**5179** lbf
Proportional Limit:	**4554.3000** lbf

Specimen 8-6



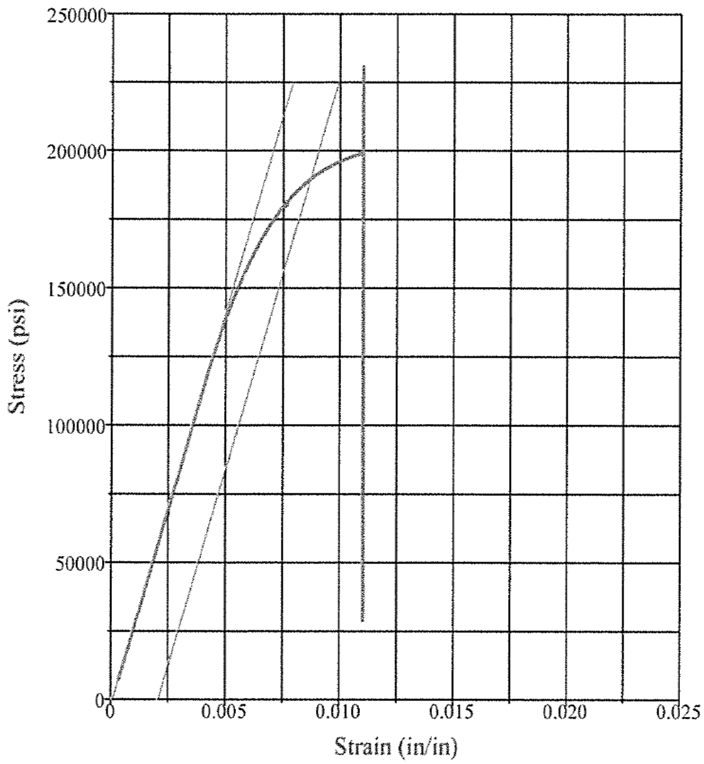
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1580** in
Area:	**0.0290** in^2
After Test Area:	**0.0196** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**27958** ksi
Tensile Strength:	**223** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.45** in
Reduction of Area:	**32** %
Peak Load:	**6460.6000** lbf
Stress at Offset:	**187** ksi
Load at Offset:	**5437** lbf
Proportional Limit:	**4360.7000** lbf

Specimen 9-1



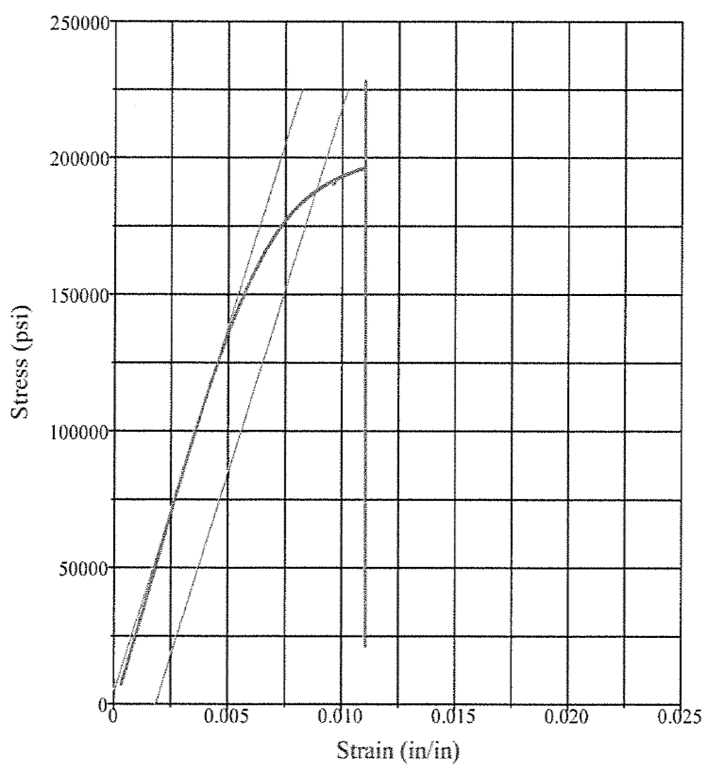
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1520** in
Area:	**0.0290** in^2
After Test Area:	**0.0181** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**25805** ksi
Tensile Strength:	**220** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.375** in
Reduction of Area:	**38** %
Peak Load:	**6392.7000** lbf
Stress at Offset:	**182** ksi
Load at Offset:	**5279** lbf
Proportional Limit:	**4349.8000** lbf

Specimen 9-2



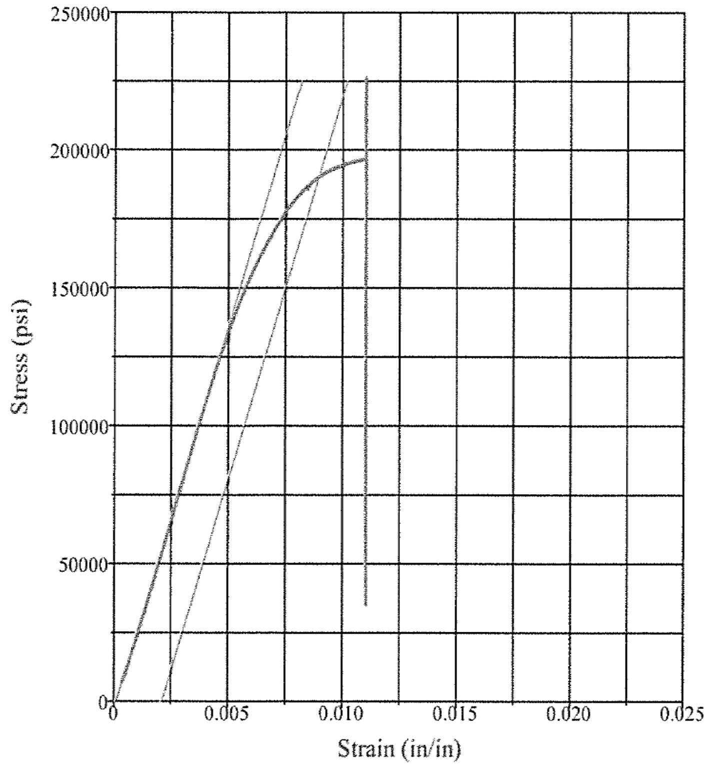
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1520** in
Area:	**0.0290** in^2
After Test Area:	**0.0181** in^2
Correlation Coefficient:	**1.0000**
Tangent Modulus:	**28490** ksi
Tensile Strength:	**231** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.43** in
Reduction of Area:	**38** %
Peak Load:	**6693.7000** lbf
Stress at Offset:	**190** ksi
Load at Offset:	**5507** lbf
Proportional Limit:	**4373.6000** lbf

Specimen 9-3



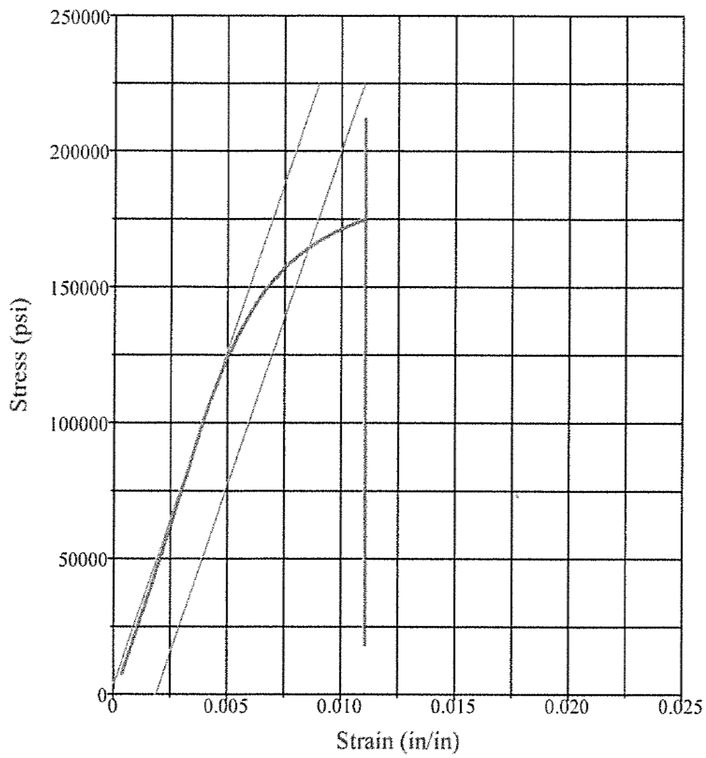
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in^2
After Test Area:	**0.0177** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**26672** ksi
Tensile Strength:	**228** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.43** in
Reduction of Area:	**39** %
Peak Load:	**6618.7000** lbf
Load at Offset:	**5450** lbf
Stress at Offset:	**188** ksi
Proportional Limit:	**4293.3000** lbf

Specimen 9-4



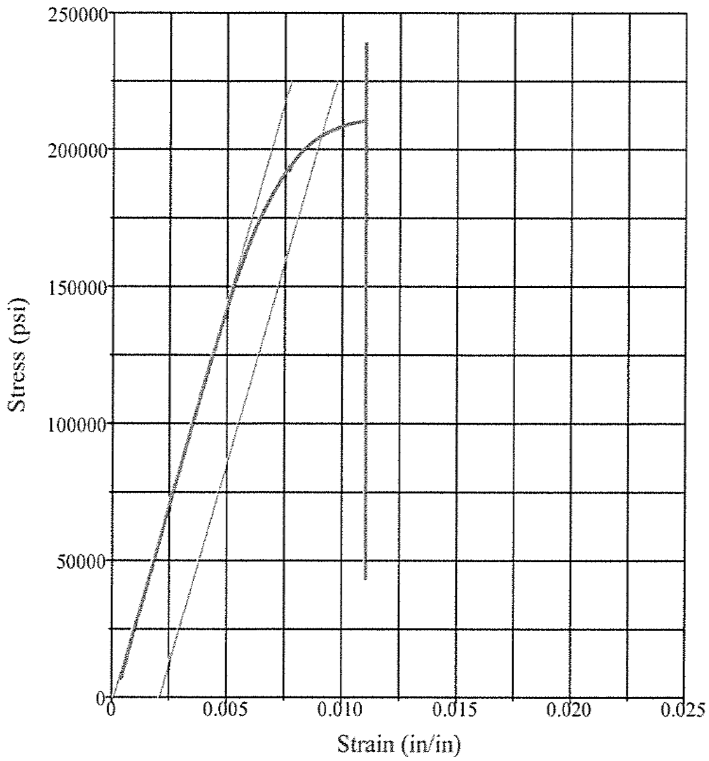
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1480** in
Area:	**0.0290** in^2
After Test Area:	**0.0172** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**27594** ksi
Tensile Strength:	**226** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.375** in
Reduction of Area:	**41** %
Peak Load:	**6564.3000** lbf
Stress at Offset:	**190** ksi
Load at Offset:	**5521** lbf
Proportional Limit:	**4307.2000** lbf

Specimen 9-5



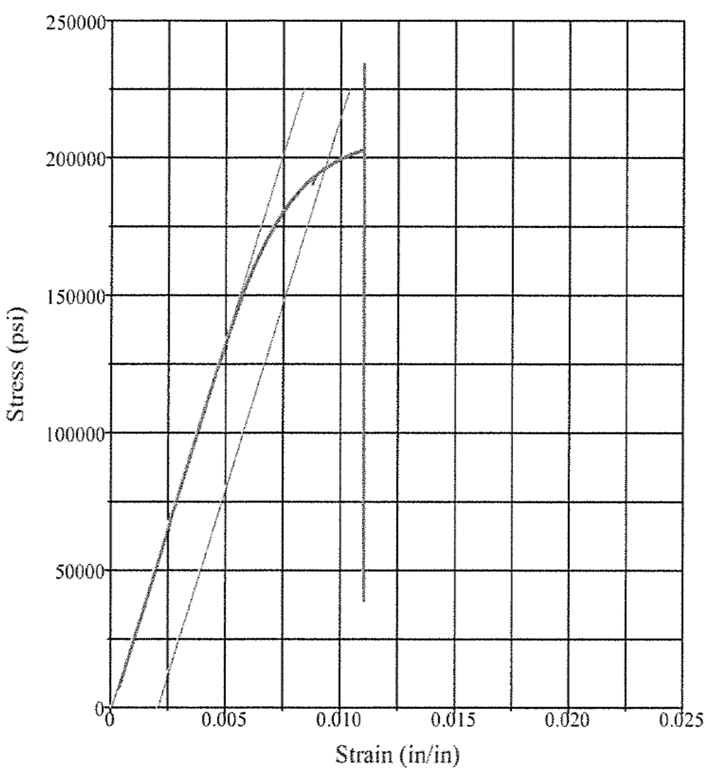
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1540** in
Area:	**0.0290** in^2
After Test Area:	**0.0186** in^2
Correlation Coefficient:	**0.9988**
Tangent Modulus:	**24587** ksi
Tensile Strength:	**212** ksi
Total Elongation:	**2** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.21** in
Reduction of Area:	**36** %
Peak Load:	**6145.6000** lbf
Stress at Offset:	**165** ksi
Load at Offset:	**4772** lbf
Proportional Limit:	**3838.3000** lbf

Specimen 9-6



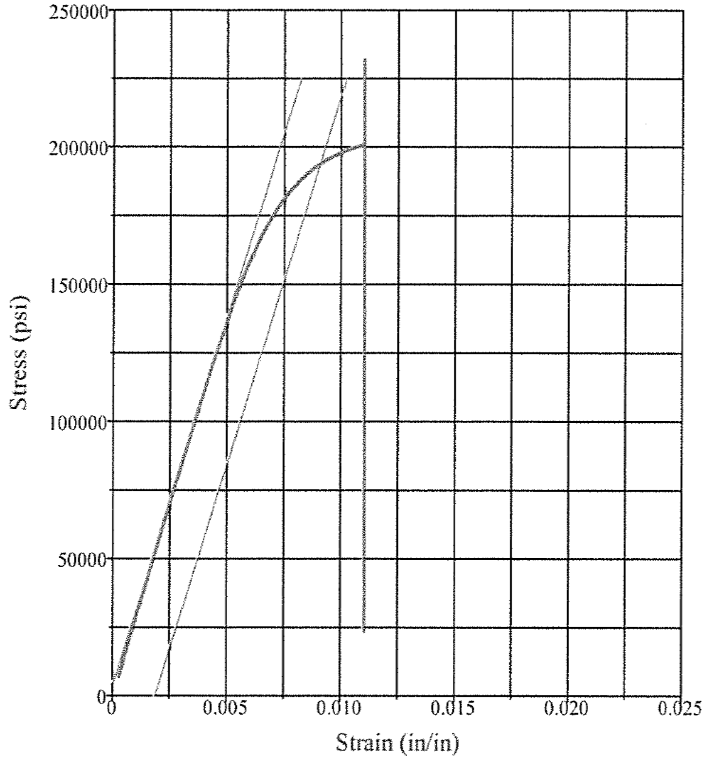
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in^2
After Test Area:	**0.0177** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**29091** ksi
Tensile Strength:	**239** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.492** in
Reduction of Area:	**39** %
Peak Load:	**6929.5000** lbf
Stress at Offset:	**205** ksi
Load at Offset:	**5948** lbf
Proportional Limit:	**4875.2000** lbf

Specimen 10-1



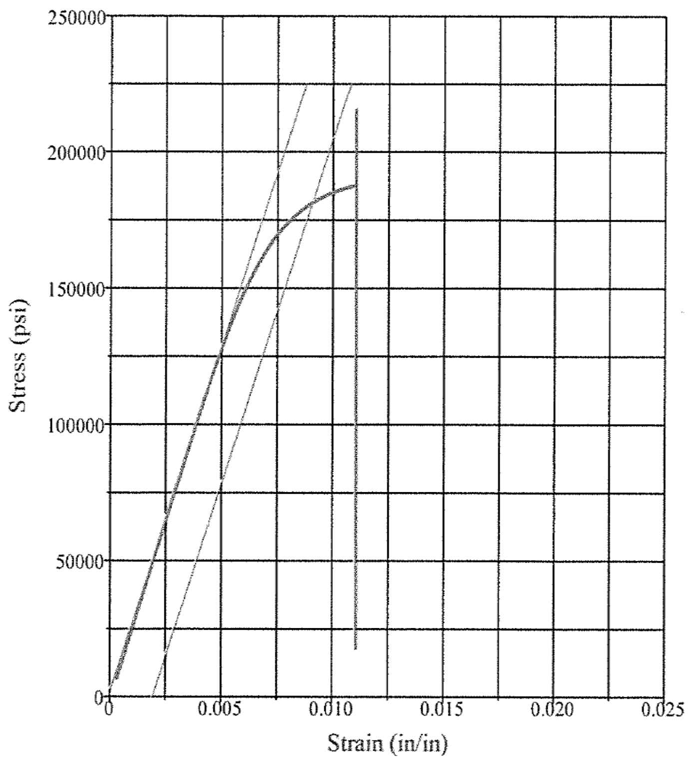
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in^2
After Test Area:	**0.0177** in^2
Correlation Coefficient:	**1.0000**
Tangent Modulus:	**26891** ksi
Tensile Strength:	**234** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.350** in
Reduction of Area:	**39** %
Peak Load:	**6794.6000** lbf
Stress at Offset:	**196** ksi
Load at Offset:	**5695** lbf
Proportional Limit:	**4668.4000** lbf

Specimen 10-2



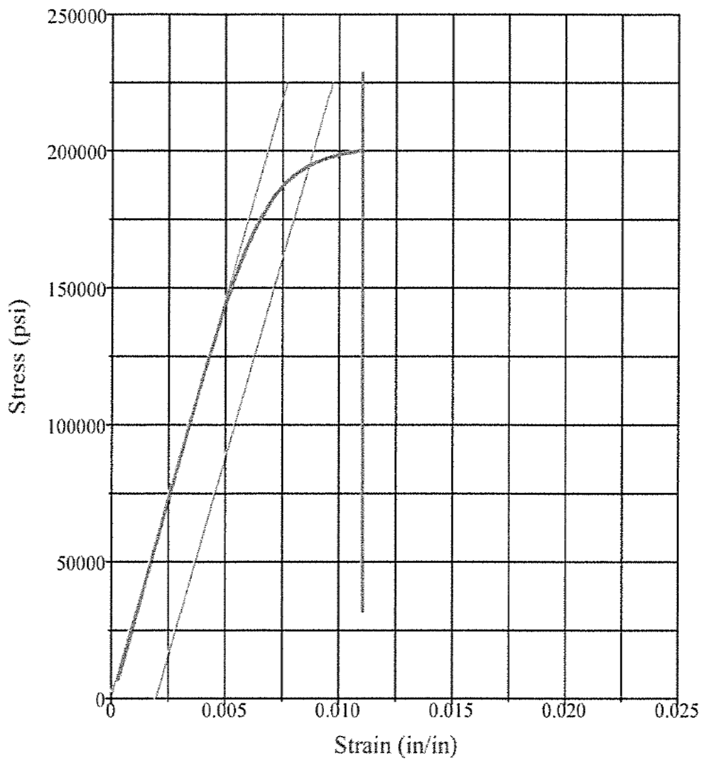
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1520** in
Area:	**0.0290** in^2
After Test Area:	**0.0181** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**26755** ksi
Tensile Strength:	**232** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.33** in
Reduction of Area:	**38** %
Peak Load:	**6731.8000** lbf
Stress at Offset:	**194** ksi
Load at Offset:	**5625** lbf
Proportional Limit:	**4602.0000** lbf

Specimen 10-3



	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1980** in
After Test Diameter:	**0.1550** in
Area:	**0.0308** in^2
After Test Area:	**0.0189** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**25284** ksi
Tensile Strength:	**216** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.475** in
Reduction of Area:	**39** %
Peak Load:	**6637.8000** lbf
Load at Offset:	**5588** lbf
Stress at Offset:	**181** ksi
Proportional Limit:	**4584.3000** lbf

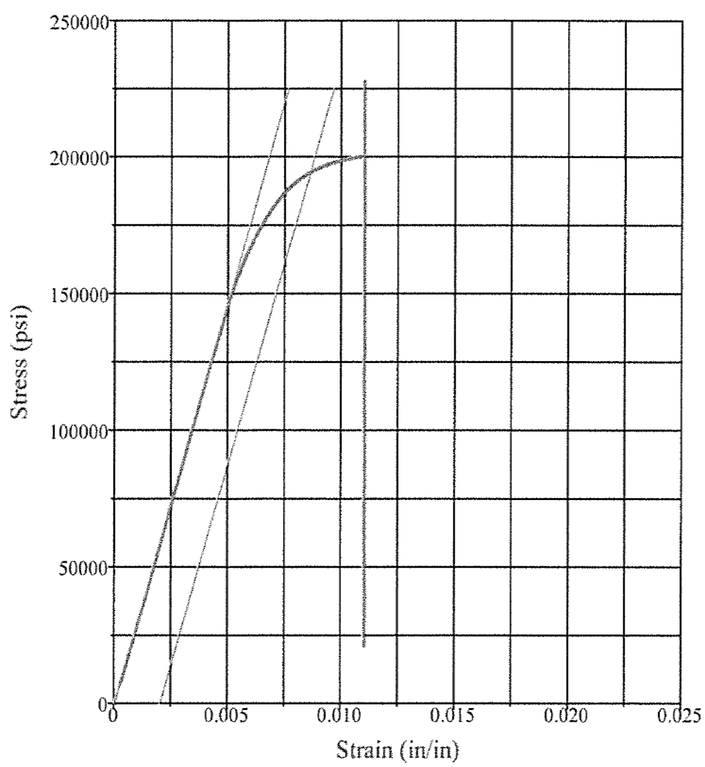
Specimen 10-4



Test Results

Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in^2
After Test Area:	**0.0177** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**28832** ksi
Tensile Strength:	**229** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.357** in
Reduction of Area:	**39** %
Peak Load:	**6631.2000** lbf
Stress at Offset:	**195** ksi
Load at Offset:	**5648** lbf
Proportional Limit:	**4682.2000** lbf

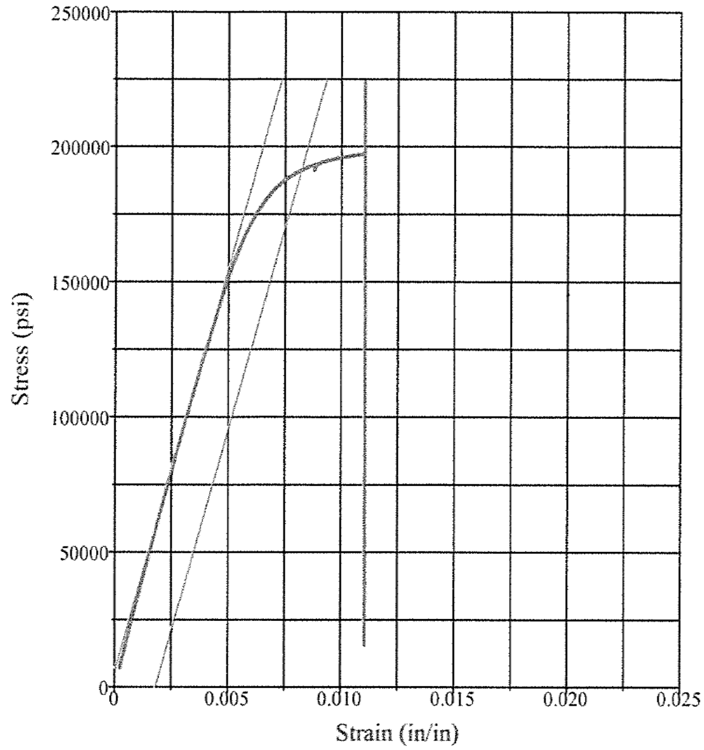
Specimen 10-5



Test Results

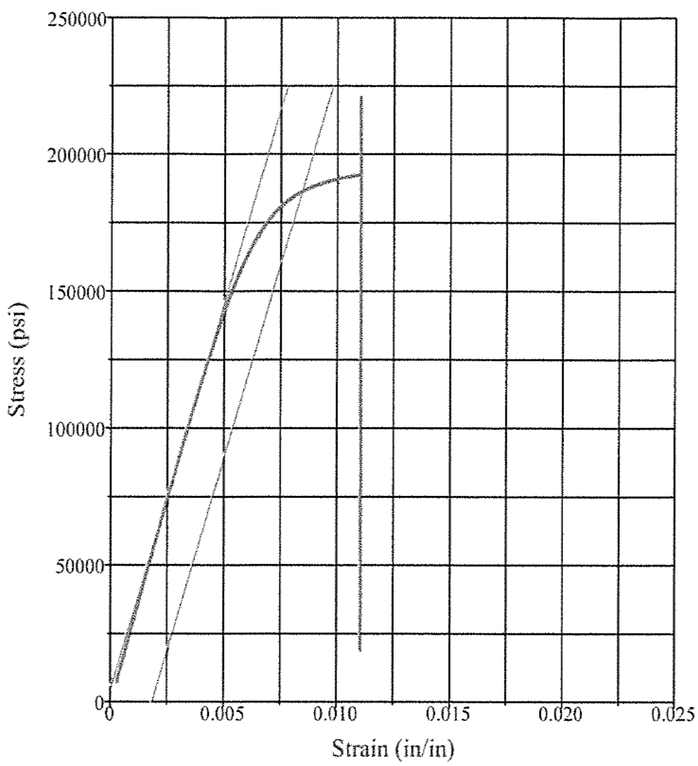
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in^2
After Test Area:	**0.0177** in^2
Correlation Coefficient:	**1.0000**
Tangent Modulus:	**29373** ksi
Tensile Strength:	**228** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.340** in
Reduction of Area:	**39** %
Peak Load:	**6612.6000** lbf
Stress at Offset:	**194** ksi
Load at Offset:	**5639** lbf
Proportional Limit:	**4753.1000** lbf

Specimen 10-6



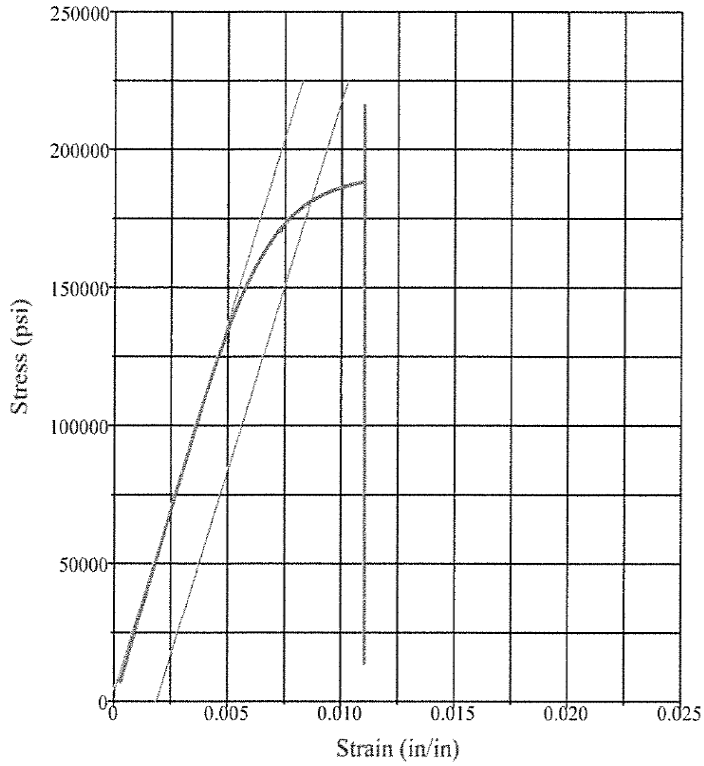
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1480** in
Area:	**0.0290** in^2
After Test Area:	**0.0172** in^2
Correlation Coefficient:	**1.0000**
Tangent Modulus:	**29658** ksi
Tensile Strength:	**224** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.40** in
Reduction of Area:	**41** %
Peak Load:	**6494.9000** lbf
Load at Offset:	**5550** lbf
Stress at Offset:	**191** ksi
Proportional Limit:	**4697.7000** lbf

Specimen 10-7



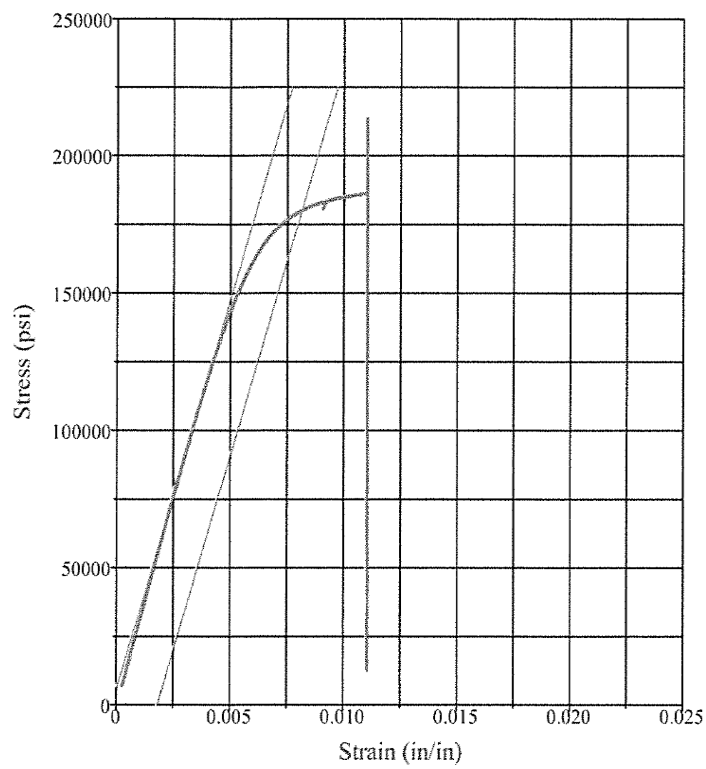
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in^2
After Test Area:	**0.0177** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**28070** ksi
Tensile Strength:	**221** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.45** in
Reduction of Area:	**39** %
Peak Load:	**6407.3000** lbf
Stress at Offset:	**187** ksi
Load at Offset:	**5410** lbf
Proportional Limit:	**4445.8000** lbf

Specimen 10-8



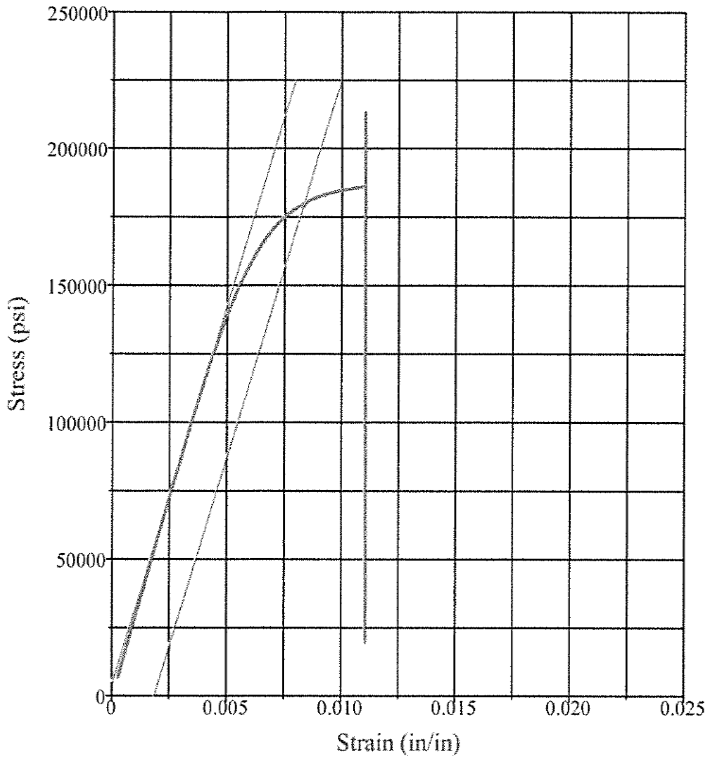
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1520** in
Area:	**0.0290** in^2
After Test Area:	**0.0181** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**26682** ksi
Tensile Strength:	**216** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.30** in
Reduction of Area:	**38** %
Peak Load:	**6262.2000** lbf
Stress at Offset:	**181** ksi
Load at Offset:	**5260** lbf
Proportional Limit:	**4249.3000** lbf

Specimen 10-9



	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in^2
After Test Area:	**0.0177** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**28283** ksi
Tensile Strength:	**214** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.48** in
Reduction of Area:	**39** %
Peak Load:	**6198.5000** lbf
Stress at Offset:	**180** ksi
Load at Offset:	**5228** lbf
Proportional Limit:	**4315.4000** lbf

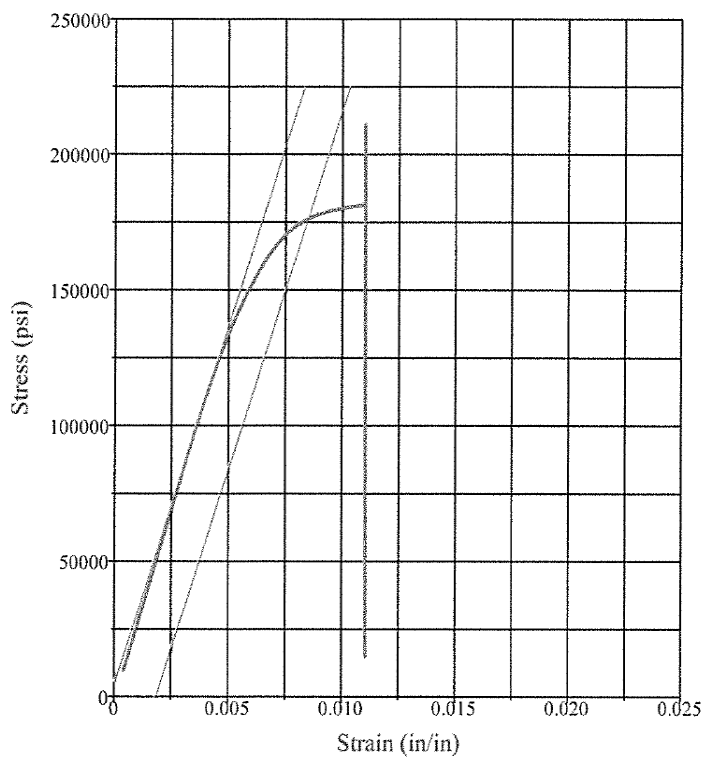
Specimen 10-10



Test Results

Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in^2
After Test Area:	**0.0177** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**27563** ksi
Tensile Strength:	**213** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.40** in
Reduction of Area:	**39** %
Peak Load:	**6183.1000** lbf
Stress at Offset:	**179** ksi
Load at Offset:	**5188** lbf
Proportional Limit:	**4252.6000** lbf

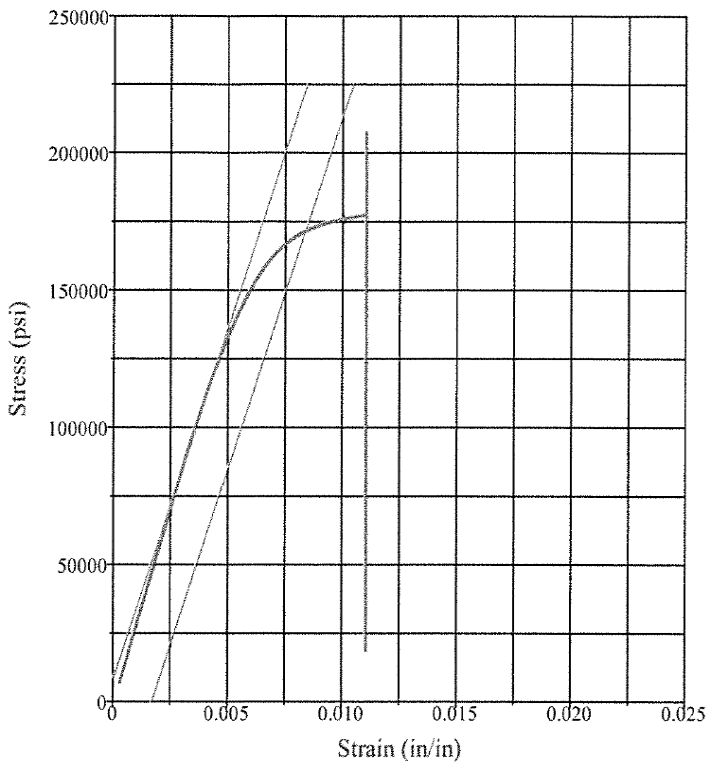
Specimen 10-11



Test Results

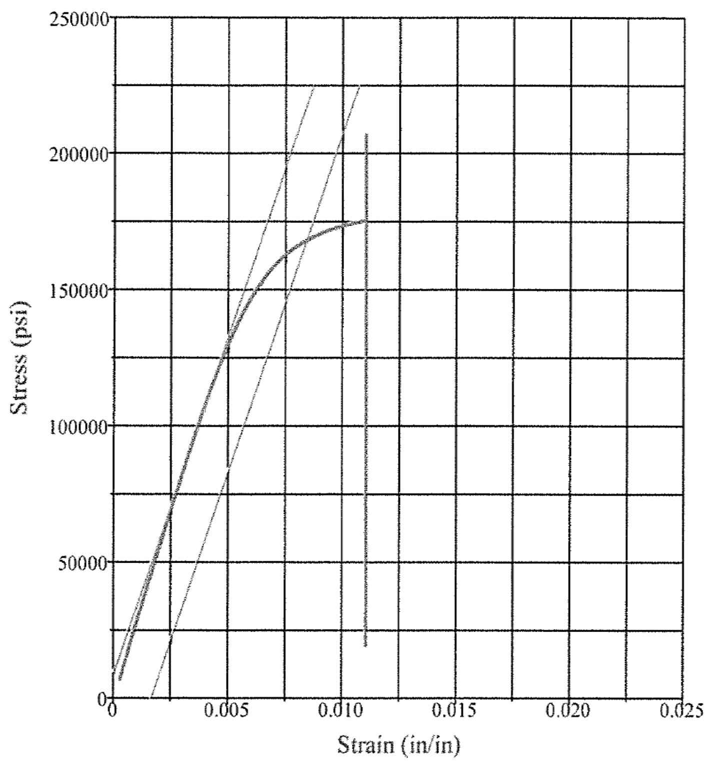
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in^2
After Test Area:	**0.0177** in^2
Correlation Coefficient:	**0.9997**
Tangent Modulus:	**26343** ksi
Tensile Strength:	**211** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.35** in
Reduction of Area:	**39** %
Peak Load:	**6124.0000** lbf
Stress at Offset:	**176** ksi
Load at Offset:	**5118** lbf
Proportional Limit:	**4122.3000** lbf

Specimen 11-1



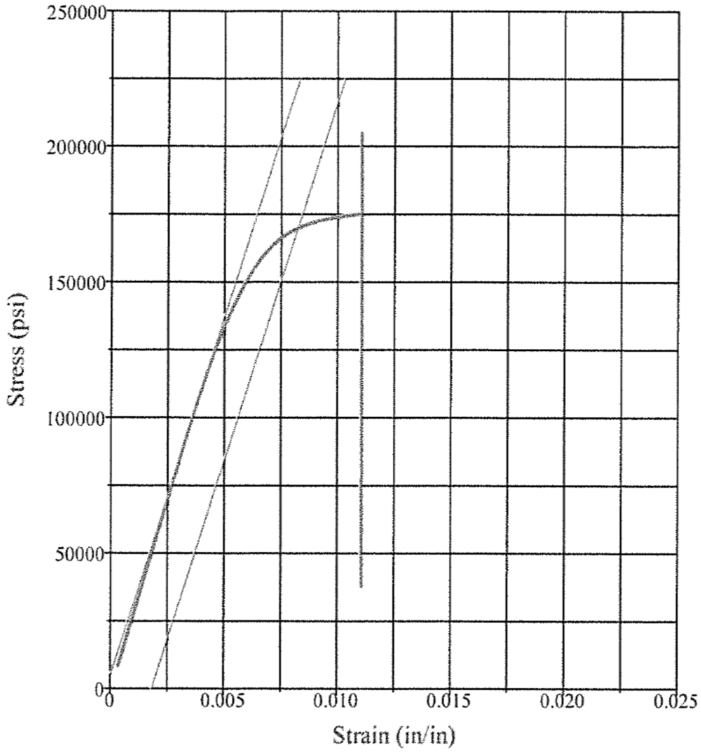
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1530** in
Area:	**0.0290** in²
After Test Area:	**0.0184** in²
Correlation Coefficient:	**0.9997**
Tangent Modulus:	**25595** ksi
Tensile Strength:	**208** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.32** in
Reduction of Area:	**37** %
Peak Load:	**6020.1000** lbf
Stress at Offset:	**172** ksi
Load at Offset:	**4979** lbf
Proportional Limit:	**4089.6000** lbf

Specimen 11-2



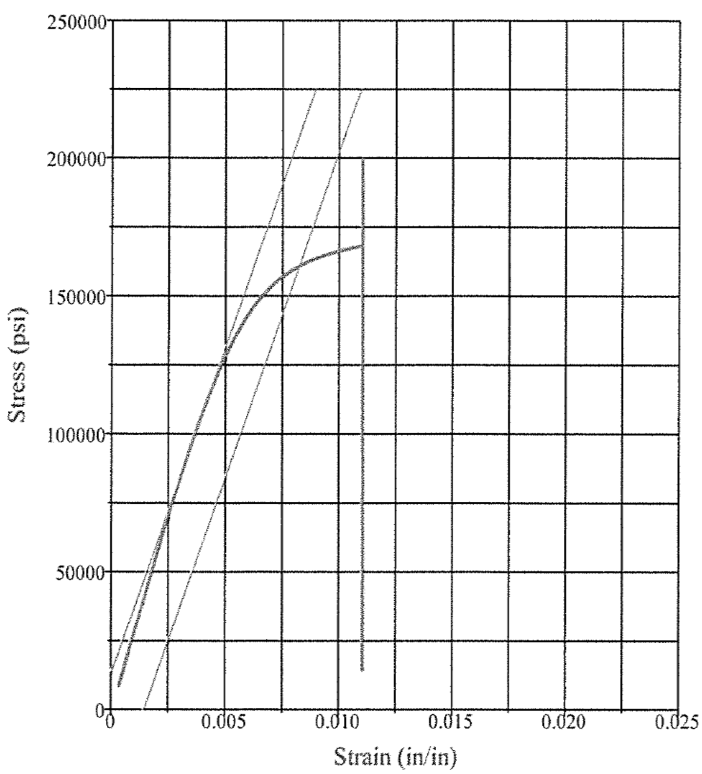
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1460** in
Area:	**0.0290** in²
After Test Area:	**0.0167** in²
Correlation Coefficient:	**0.9997**
Tangent Modulus:	**24746** ksi
Tensile Strength:	**207** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.35** in
Reduction of Area:	**42** %
Peak Load:	**6005.1000** lbf
Stress at Offset:	**168** ksi
Load at Offset:	**4883** lbf
Proportional Limit:	**4026.8000** lbf

Specimen 11-3



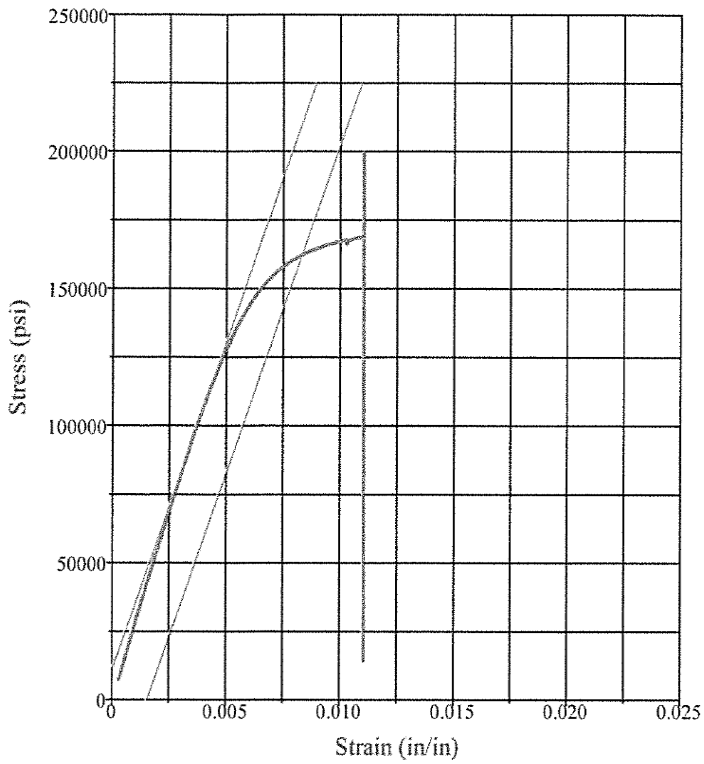
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1570** in
Area:	**0.0290** in²
After Test Area:	**0.0194** in²
Correlation Coefficient:	**0.9998**
Tangent Modulus:	**26384** ksi
Tensile Strength:	**205** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.42** in
Reduction of Area:	**33** %
Peak Load:	**5948.4000** lbf
Stress at Offset:	**170** ksi
Load at Offset:	**4933** lbf
Proportional Limit:	**4074.0000** lbf

Specimen 11-4



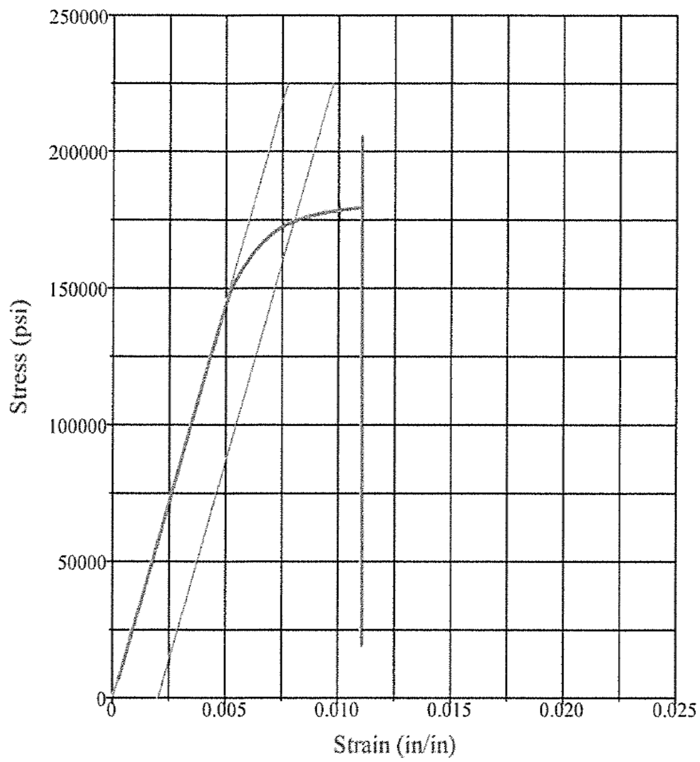
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in²
After Test Area:	**0.0177** in²
Correlation Coefficient:	**0.9995**
Tangent Modulus:	**23512** ksi
Tensile Strength:	**200** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.38** in
Reduction of Area:	**39** %
Peak Load:	**5792.6000** lbf
Stress at Offset:	**161** ksi
Load at Offset:	**4672** lbf
Proportional Limit:	**3918.6000** lbf

Specimen 11-5



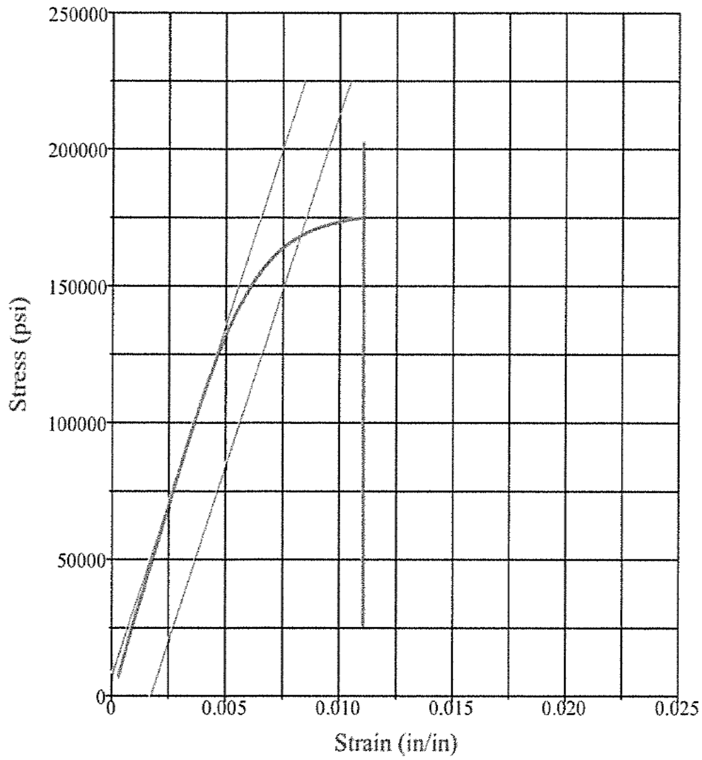
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in^2
After Test Area:	**0.0177** in^2
Correlation Coefficient:	**0.9995**
Tangent Modulus:	**23858** ksi
Tensile Strength:	**200** ksi
Total Elongation:	**3** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.345** in
Reduction of Area:	**39** %
Peak Load:	**5792.1000** lbf
Stress at Offset:	**163** ksi
Load at Offset:	**4714** lbf
Proportional Limit:	**3956.8000** lbf

Specimen 11-6



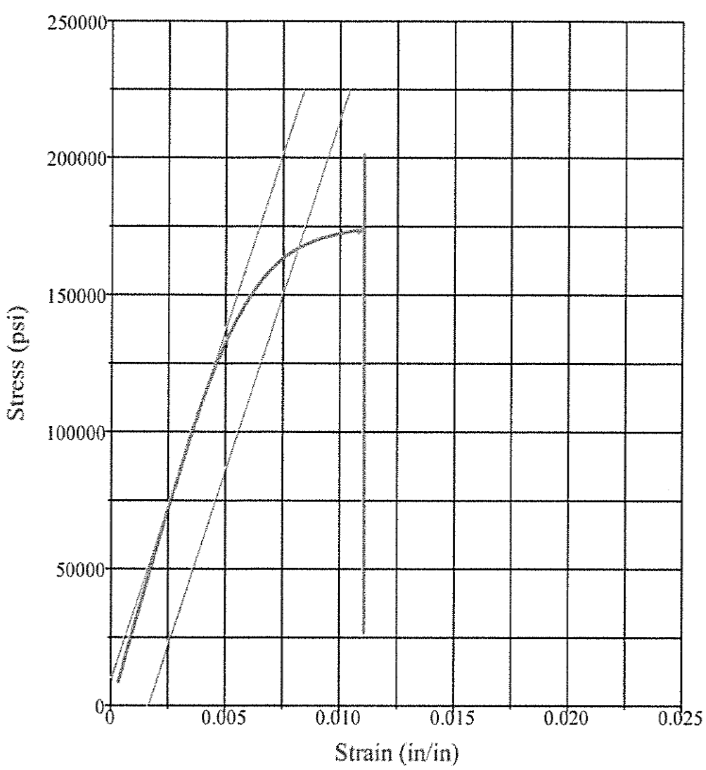
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in^2
After Test Area:	**0.0177** in^2
Correlation Coefficient:	**1.0000**
Tangent Modulus:	**28975** ksi
Tensile Strength:	**206** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.52** in
Reduction of Area:	**39** %
Peak Load:	**5961.0000** lbf
Stress at Offset:	**175** ksi
Load at Offset:	**5065** lbf
Proportional Limit:	**4490.5000** lbf

Specimen 12-1



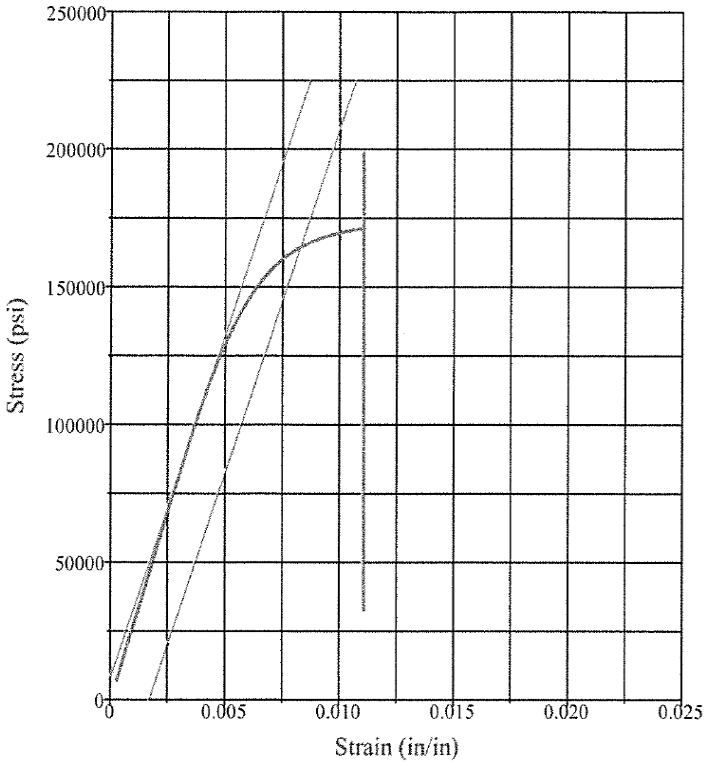
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1480** in
Area:	**0.0290** in^2
After Test Area:	**0.0172** in^2
Correlation Coefficient:	**0.9997**
Tangent Modulus:	**25544** ksi
Tensile Strength:	**202** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.390** in
Reduction of Area:	**41** %
Peak Load:	**5867.4000** lbf
Stress at Offset:	**168** ksi
Load at Offset:	**4885** lbf
Proportional Limit:	**4018.4000** lbf

Specimen 12-2



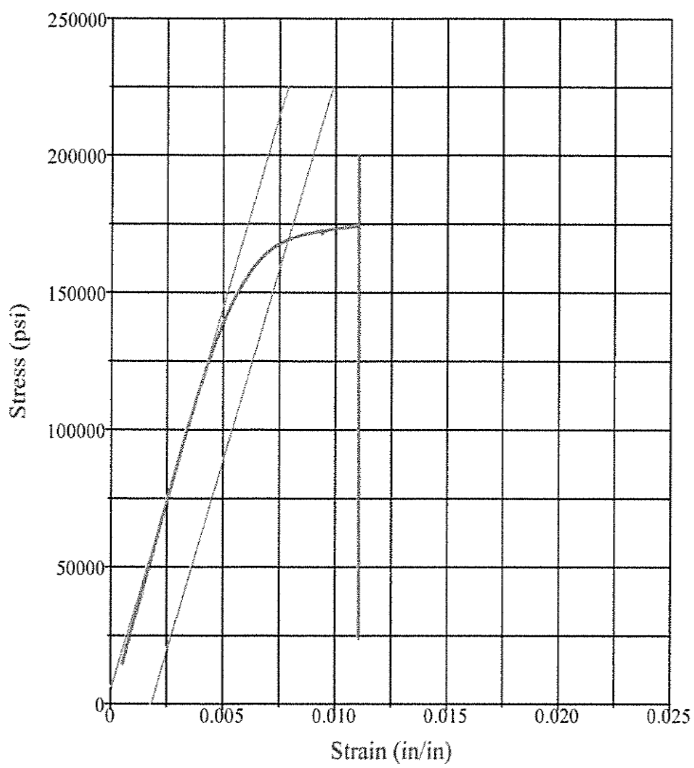
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1470** in
Area:	**0.0290** in^2
After Test Area:	**0.0170** in^2
Correlation Coefficient:	**0.9995**
Tangent Modulus:	**25567** ksi
Tensile Strength:	**201** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.47** in
Reduction of Area:	**41** %
Peak Load:	**5832.3000** lbf
Stress at Offset:	**167** ksi
Load at Offset:	**4849** lbf
Proportional Limit:	**3936.1000** lbf

Specimen 12-3



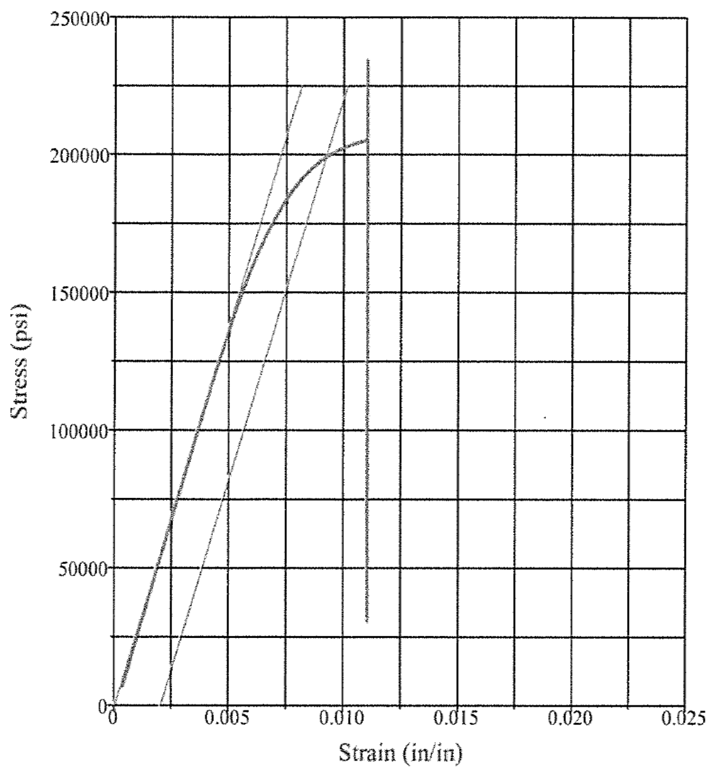
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in^2
After Test Area:	**0.0177** in^2
Correlation Coefficient:	**0.9996**
Tangent Modulus:	**24904** ksi
Tensile Strength:	**199** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.415** in
Reduction of Area:	**39** %
Peak Load:	**5769.4000** lbf
Stress at Offset:	**165** ksi
Load at Offset:	**4774** lbf
Proportional Limit:	**3930.5000** lbf

Specimen 12-4



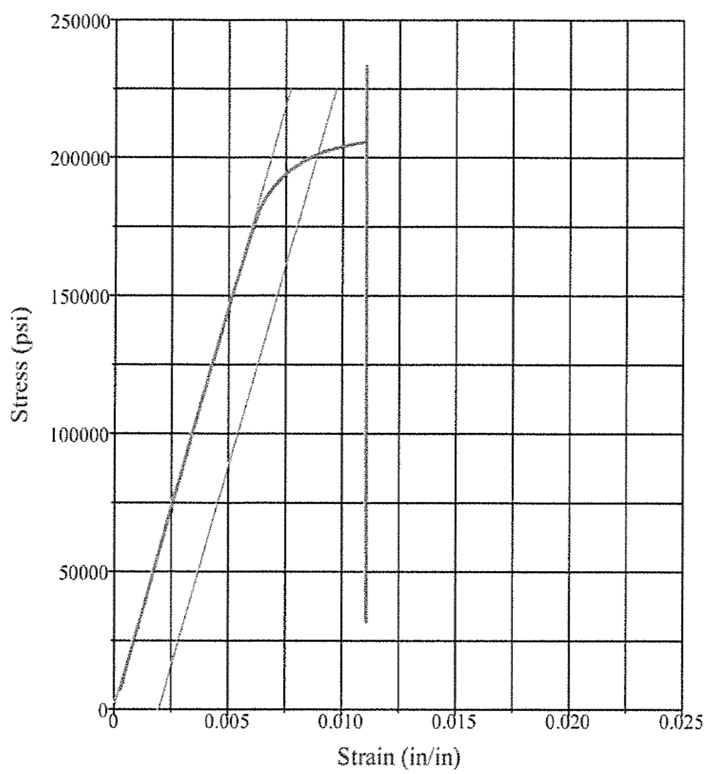
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in^2
After Test Area:	**0.0177** in^2
Correlation Coefficient:	**0.9998**
Tangent Modulus:	**27777** ksi
Tensile Strength:	**200** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.45** in
Reduction of Area:	**39** %
Peak Load:	**5811.9000** lbf
Load at Offset:	**4913** lbf
Stress at Offset:	**169** ksi
Proportional Limit:	**4053.7000** lbf

Specimen 12-5



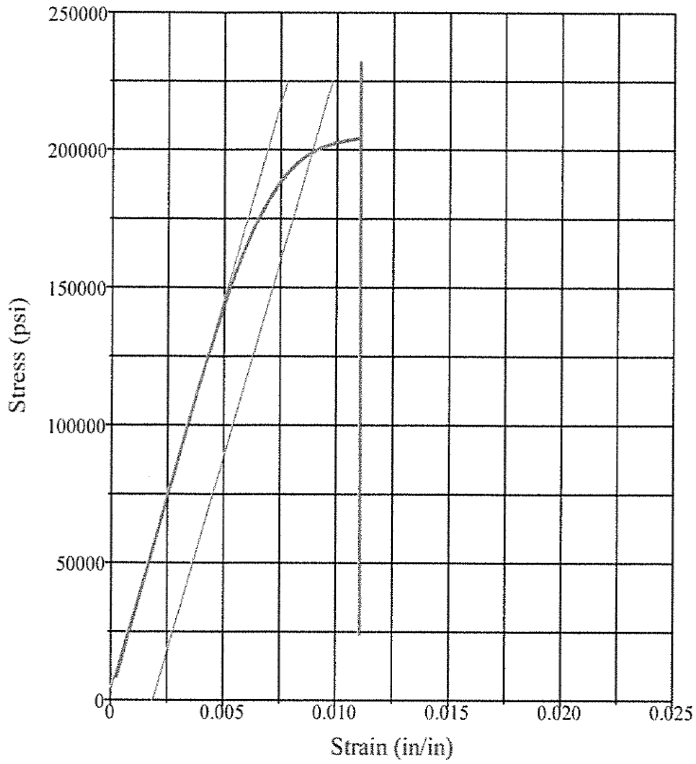
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1490** in
Area:	**0.0290** in²
After Test Area:	**0.0174** in²
Correlation Coefficient:	**1.0000**
Tangent Modulus:	**27575** ksi
Tensile Strength:	**235** ksi
Total Elongation:	**6** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.558** in
Reduction of Area:	**40** %
Peak Load:	**6806.3000** lbf
Stress at Offset:	**199** ksi
Load at Offset:	**5779** lbf
Proportional Limit:	**4684.1000** lbf

Specimen 12-6



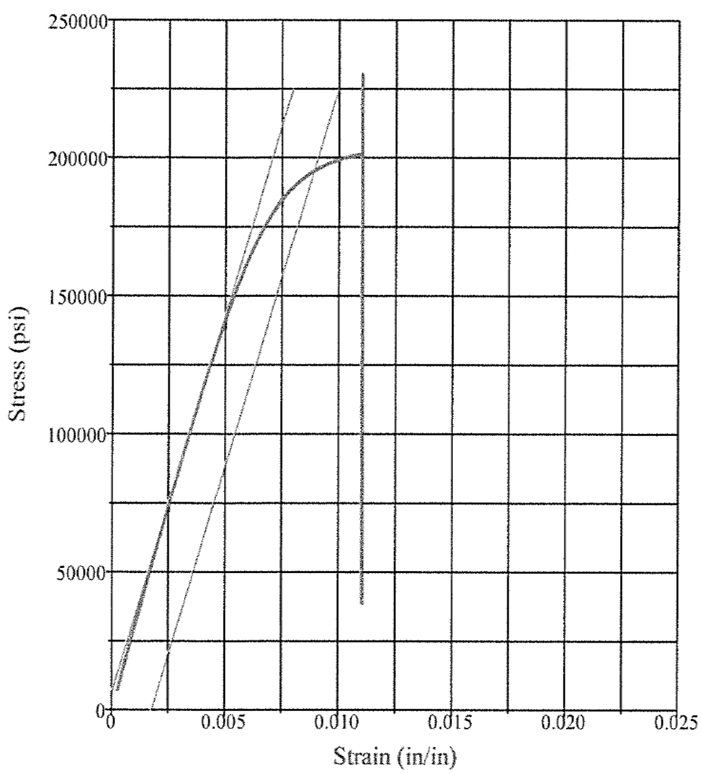
	Test Results
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1520** in
Area:	**0.0290** in²
After Test Area:	**0.0181** in²
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**28864** ksi
Tensile Strength:	**233** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.460** in
Reduction of Area:	**38** %
Peak Load:	**6766.6000** lbf
Stress at Offset:	**201** ksi
Load at Offset:	**5839** lbf
Proportional Limit:	**5401.1000** lbf

Specimen 12-7



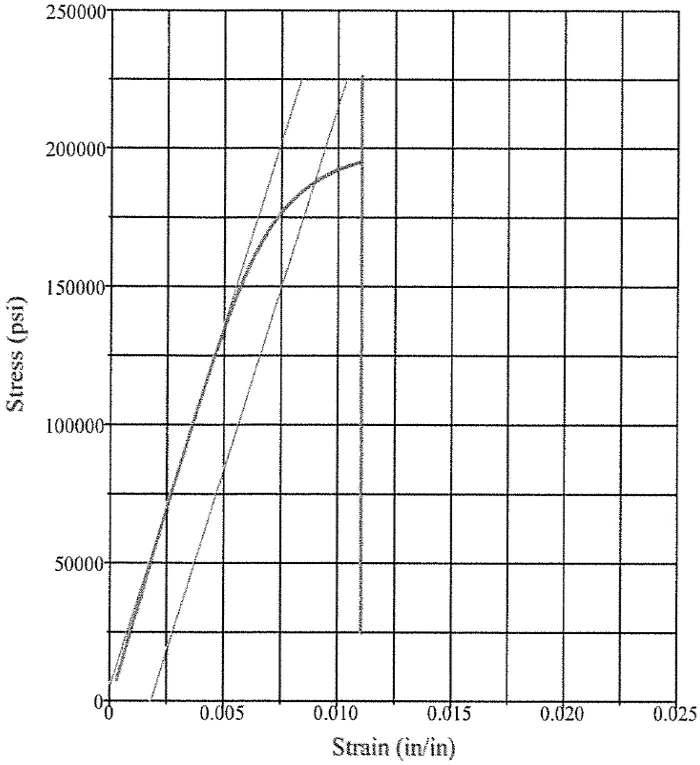
Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1640** in
Area:	**0.0290** in^2
After Test Area:	**0.0211** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**28291** ksi
Tensile Strength:	**232** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.51** in
Reduction of Area:	**27** %
Peak Load:	**6722.0000** lbf
Stress at Offset:	**199** ksi
Load at Offset:	**5771** lbf
Proportional Limit:	**4679.5000** lbf

Specimen 13-1



Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1540** in
Area:	**0.0290** in^2
After Test Area:	**0.0186** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**27312** ksi
Tensile Strength:	**230** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.42** in
Reduction of Area:	**36** %
Peak Load:	**6674.5000** lbf
Stress at Offset:	**195** ksi
Load at Offset:	**5657** lbf
Proportional Limit:	**4633.0000** lbf

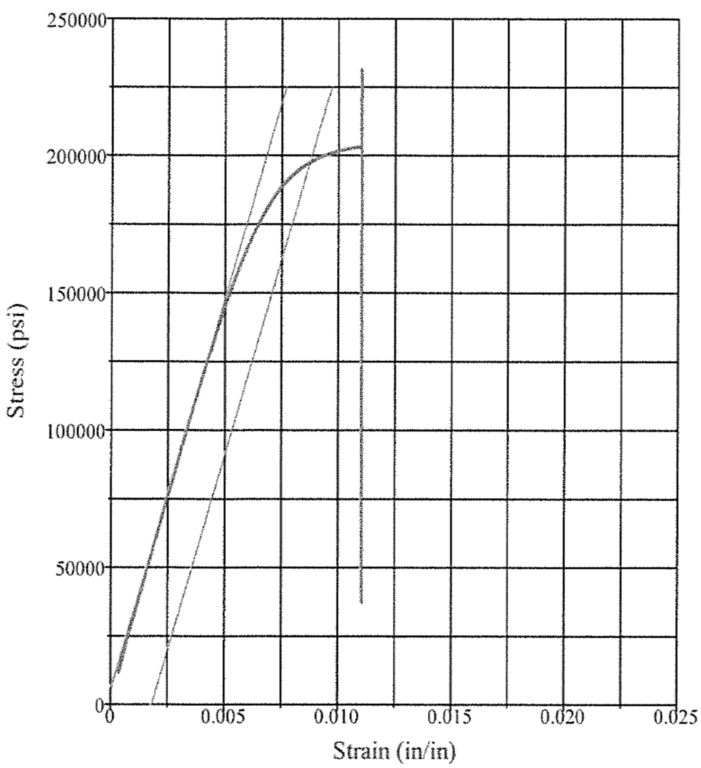
Specimen 13-2



Test Results

Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1540** in
Area:	**0.0290** in^2
After Test Area:	**0.0186** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**26127** ksi
Tensile Strength:	**226** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.351** in
Reduction of Area:	**36** %
Peak Load:	**6547.6000** lbf
Stress at Offset:	**187** ksi
Load at Offset:	**5434** lbf
Proportional Limit:	**4446.4000** lbf

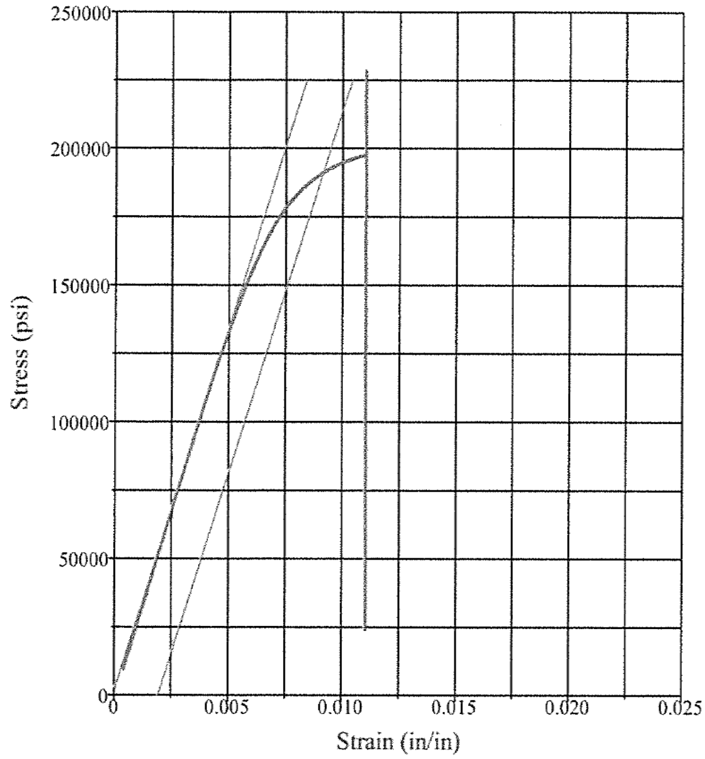
Specimen 13-3



Test Results

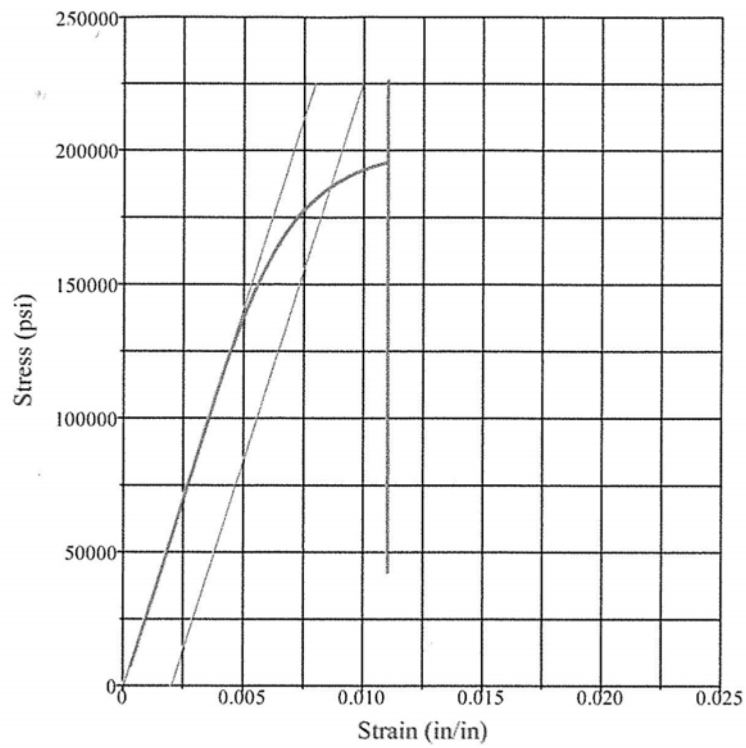
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in^2
After Test Area:	**0.0177** in^2
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**28355** ksi
Tensile Strength:	**231** ksi
Total Elongation:	**5** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.52** in
Reduction of Area:	**39** %
Peak Load:	**6707.8000** lbf
Stress at Offset:	**197** ksi
Load at Offset:	**5726** lbf
Proportional Limit:	**4611.0000** lbf

Specimen 13-4



Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1520** in
Area:	**0.0290** in²
After Test Area:	**0.0181** in²
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**26376** ksi
Tensile Strength:	**228** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.40** in
Reduction of Area:	**38** %
Peak Load:	**6620.5000** lbf
Stress at Offset:	**191** ksi
Load at Offset:	**5540** lbf
Proportional Limit:	**4522.7000** lbf

Specimen 13-5



Test Results	
Specimen Gage Length:	**10.0000** in
Diameter:	**0.1920** in
After Test Diameter:	**0.1500** in
Area:	**0.0290** in²
After Test Area:	**0.0177** in²
Correlation Coefficient:	**0.9999**
Tangent Modulus:	**28187** ksi
Tensile Strength:	**226** ksi
Total Elongation:	**4** %
Pretest Punch Length:	**10** in
Posttest Punch Length:	**10.378** in
Reduction of Area:	**39** %
Peak Load:	**6551.2000** lbf
Load at Offset:	**5398** lbf
Stress at Offset:	**186** ksi
Proportional Limit:	**4242.1000** lbf

Specimen 13-6

APPENDIX D –SUMMARY CABLE STRENGTH CALCULATIONS

Sample ID	Wire Type	Location	Cable	Wire Gap
				(inch)
1	Sample Wire	PP 3 - PP 4	South	0.625
2	Sample Wire	PP 3 - PP 4	South	0.5625
3	Sample Wire	PP 3 - PP 4	South	0.50
			Average:	0.563

Sample ID	Wire Type	Location	Cable	Wire Gap
				(inch)
4	Sample Wire	PP 58 - PP 59	South	0.50
5	Sample Wire	PP 58 - PP 59	South	0.50
6	Sample Wire	PP 58 - PP 59	South	0.50
			Average:	0.50

Sample ID	Wire Type	Location	Cable	Wire Gap
				(inch)
7	Sample Wire	PP 65 - East	North	0.50
8	Sample Wire	PP 65 - East	North	0.5625
9	Sample Wire	PP 65 - East	North	0.625
			Average:	0.563

Sample ID	Wire Type	Location	Cable	Wire Gap
				(inch)
10	Sample Wire	PP 31 - PP 32	North	0.4375
11	Sample Wire	PP 31 - PP 32	North	0.50
12	Sample Wire	PP 31 - PP 32	North	0.5625
13	Sample Wire	PP 31 - PP 32	North	0.4375
			Average:	0.484

This sheet is used to :

1. Determine the Weibull coefficients of the ultimate strength and ultimate strain of the different groups. The average and standard deviation of each group are inputted and Solver is used to determine the corresponding coefficients.

   The wires are divided into 4 groups based on their condition:
   - Group 2 : Stage 1 and 2 wires
   - Group 3 : Stage 3 wires
   - Group 4 : Stage 4 wires
   - Group 5 : Cracked wires

2. Calculate the percentage of cracked Stage 3 and Stage 4 wires based on the percentage of cracked wires in the sample population. These are treated seperately as Group 5 wires.

3. Determine the Ramberg-Osgood function variables to approximate the average stress-strain curve of the wires.

Summary of Wire Sample Test Results

		Group					
		2	3	4	*5		
	n	23	23	26	12	total n =	84
σ_{ult}	mean	210	193	196	199		
	Std dev.	13.54	22.65	17.52	12.79		
ε_{max}	mean	N/A	N/A	N/A	N/A		
	Std dev.	N/A	N/A	N/A	N/A		

*Only the Stage 4 cracked wires (2 total) were included in the calculation of the wire properties for Group 5.

Ultimate Strength Weibull Coefficient Calculation - For Brittle Wire Model

	Group				
	2	3	4	5	
mean strength (ksi), μ	210	193	196	199	
standard deviation (ksi), σ	13.54	22.65	17.52	12.79	
m	**19.216**	**10.243**	**13.675**	**19.278**	excel parameter - α
$\Gamma(1+2/m)$	0.9497	0.9194	0.9343	0.9499	
$\Gamma(1+1/m)$	0.9725	0.9523	0.9628	0.9726	
$\Gamma(1+2/m)/\Gamma^{-2}(1+1/m)$	1.0042	1.0138	1.0080	1.0041	
σ^2	183.29	513.22	306.91	163.60	
μ^2	44160	37103	38437	39661	
σ^2/μ^2	0.004151	0.013832	0.007985	0.004125	
σ/μ	0.064	0.118	0.089	0.064	
$\Gamma(1+2/m)/\Gamma^{-2}(1+1/m)-1-\sigma^2/\mu^2$	0.00000	0.00000	0.00000	0.00000	Use solver to set = 0 by varying m
$\nu = \mu/\Gamma(1+1/m)$	**216**	**202**	**204**	**205**	excel parameter - β

Cracked wires - Both Models   Report 534 Section 4.4.2

	sample	cracked	$p_{c,k}$	
Stage 3	4	0	0.0000	includes 0.33 factor
Stage 4	6	2	0.3333	

The 0.33 factor accounts for the fact that the sample wires will be from the outer region of the cable, where the Stage 3 wires are more likely to be cracked. Stage 3 wires deeper within the cable are rarely cracked.

Average Stress-Strain Curve for Limited Ductility Model

Average Stress-strain Curve

ε	Calc'd σ
0.000	0
0.002	57
0.004	111
0.006	153
0.008	178
0.010	190
0.012	196
0.014	200
0.016	203
0.018	205
0.020	207
0.022	209
0.024	211
0.026	213
0.028	215
0.030	217
0.032	219
0.034	220
0.036	222
0.038	224
0.040	226
0.042	228
0.044	229
0.046	231
0.048	233
0.050	235

Modified Ramberg-Osgood function

$$f_p = E\varepsilon_{pf}\left[A + \frac{1-A}{\left[1+(B\varepsilon_{pf})^C\right]^{1/C}}\right]$$

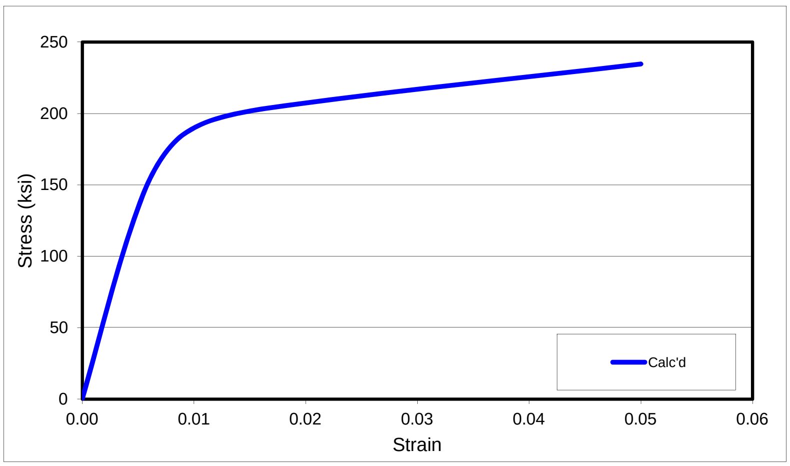
E : 28,500 ksi

Vary A, B, and C to match average curve

A : 0.031

B : 145

C : 4



This sheet is used to :

1. Determine the Weibull coefficients of the ultimate strength and ultimate strain of the different groups. The average and standard deviation of each group are inputted and Solver is used to determine the corresponding coefficients.

The wires are divided into 4 groups based on their condition:

Group 2 : Stage 1 and 2 wires
Group 3 : Stage 3 wires
Group 4 : Stage 4 wires
Group 5 : Cracked wires

2. Calculate the percentage of cracked Stage 3 and Stage 4 wires based on the percentage of cracked wires in the sample population. These are treated seperately as Group 5 wires.

3. Determine the Ramberg-Osgood function variables to approximate the average stress-strain curve of the wires.

Summary of Wire Sample Test Results

		Group					
		2	3	4	*5		
	n	23	23	26	12	total n =	84
σ_{ult}	mean	205	182	189	190		
	Std dev.	14.86	28.01	20.43	15.08		
ε_{max}	mean	N/A	N/A	N/A	N/A		
	Std dev.	N/A	N/A	N/A	N/A		

*Only the Stage 4 cracked wires (2 total) were included in the calculation of the wire properties for Group 5.

Ultimate Strength Weibull Coefficient Calculation - For Brittle Wire Model

	Group				
	2	3	4	5	
mean strength (ksi), μ	205	182	189	190	
standard deviation (ksi), σ	14.86	28.01	20.43	15.08	
m	**17.050**	**7.705**	**11.229**	**15.468**	excel parameter - α
$\Gamma(1+2/m)$	0.9446	0.9045	0.9243	0.9402	
$\Gamma(1+1/m)$	0.9694	0.9400	0.9559	0.9666	
$\Gamma(1+2/m)/\Gamma^{-2}(1+1/m)$	1.0052	1.0236	1.0116	1.0063	
σ^2	220.75	784.79	417.28	227.40	
μ^2	42222	33233	35899	36062	
σ^2/μ^2	0.005228	0.023615	0.011624	0.006306	
σ/μ	0.072	0.154	0.108	0.079	
$\Gamma(1+2/m)/\Gamma^{-2}(1+1/m)-1-\sigma^2/\mu^2$	0.00000	0.00000	0.00000	0.00000	Use solver to set = 0 by varying m
$\nu = \mu/\Gamma(1+1/m)$	**212**	**194**	**198**	**196**	excel parameter - β

Cracked wires - Both Models   Report 534 Section 4.4.2

	sample	cracked	$p_{c,k}$	
Stage 3	4	0	0.0000	includes 0.33 factor
Stage 4	6	2	0.3333	

The 0.33 factor accounts for the fact that the sample wires will be from the outer region of the cable, where the Stage 3 wires are more likely to be cracked. Stage 3 wires deeper within the cable are rarely cracked.

Average Stress-Strain Curve for Limited Ductility Model

Average Stress-strain Curve

ε	Calc'd σ
0.000	0
0.002	57
0.004	111
0.006	153
0.008	178
0.010	190
0.012	196
0.014	200
0.016	203
0.018	205
0.020	207
0.022	209
0.024	211
0.026	213
0.028	215
0.030	217
0.032	219
0.034	220
0.036	222
0.038	224
0.040	226
0.042	228
0.044	229
0.046	231
0.048	233
0.050	235

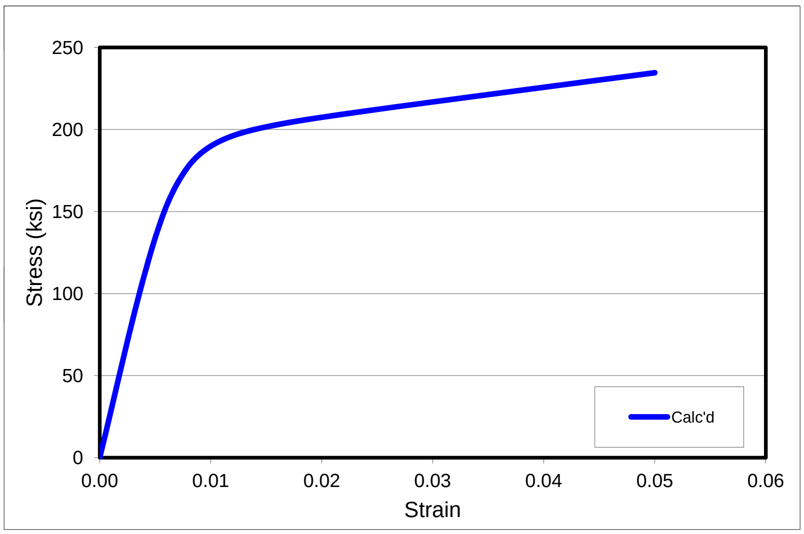
Modified Ramberg-Osgood function

$$f_p = E\varepsilon_{pf}\left[A + \frac{1-A}{\left[1+(B\varepsilon_{pf})^C\right]^{1/C}}\right]$$

E : 28,500 ksi

Vary A, B, and C to match average curve

A :	0.031
B :	145
C :	4



Location : PP3-PP4

Cable : South **Panel :** PP3-PP4

Max. Cable Force = 6,241 kips

Simplified Strength Model*
Cable Strength = 12,600 kips **F.S. = 2.02**

Brittle Wire Model
Cable Strength = 15,200 kips **F.S. = 2.44**

Limited Ductility Model
Cable Strength = N/A kips **F.S. = N/A**

Wires at each Stage of Corrosion

	No.	% total
Stage 1 :	0	0.0%
Stage 2 :	11	0.3%
Stage 3 :	2931	82.9%
Stage 4 :	593	16.8%
Total :	3534	100%

Broken Wires

Surface wires :	0
Internal wires :	0
Total broken wires :	0

This spreadsheet is used to calculate the strength of a cable section per NCHRP Report 534, based on the following :
- Degree of corrosion
- Broken wires
- Tensile tests of sample wires

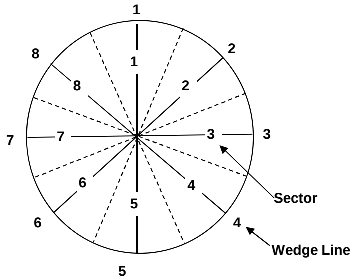
The Brittle Wire Model is used, which assumes all wires have the same stress-strain curve

Degree of corrosion - wires are grouped into the following stages
- Stage 1 : Start of zinc deterioration
- Stage 2 : Wires covered with "white rust"
- Stage 3 : 0 to 30% of wire surface corroded
- Stage 4 : Over 30% of wire surface corroded

Steps
1. Fill in Corrosion information on sheet "Corrosion-6" or "Corrosion-8" - depending on the number of wedges used for inspection
2. Fill in broken wire information on sheet "Broken-6" or "Broken-8"
3. Fill in results of wire sample tests and number of cracked wires on sheet "WirePropsTyp"
4. Determine the Weibull coefficients and average wire stress-strain curve on sheet "WirePropsTyp"
   The remaining steps are carried out on sheet "Strength"
5. Calculate Development Coefficient and Redevelopment Length
6. Determine Number of Broken Wires in Development Length
7. Calculate Number of Cracked Wires in Development Length and Fraction of Wires in each Group
8. Calculate Cable Strength

Values in cells preceded by "=" are calculated by the spreadsheet. Those in cells preceded by ":" are inputted. Values in boxed cells may vary at each panel point.

* may underestimate strength by up to 20%



Cable Cross-Section - looking West

This sheet is used to approximate the number of wires at each stage of corrosion in the cable.
per NCHRP 534 Article 4.3.2.

The corrosion stages of the inspected wires are inputted in the boxed cells of the table

No. of wires : 3534
No. of rings = 35
Wire diamter: 0.196 in
Wire diameter: 0.192 in (before galvanizing)
Eff. wire diameter : 0.1829 in

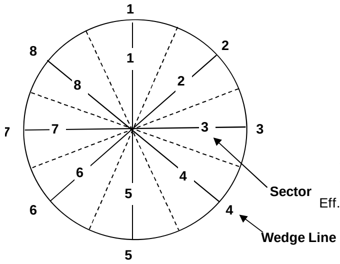
**** Only 6 wedge lines were driven, lines 2 and 8 were not driven (See NCHRP Report 534 - Section 2.4.2.1).**
Lines 4 and 8 were assumed to have the same corrosion as the adjacent wedge lines
unless noted otherwise.

L is to the left of the wedge when viewed with cable surface at top (counterclockwise from wedge)

		1		2		3		4 **		5		6		7		8 **		Estimated Total Observed Wires				
Ring	No.	0.0625		0.0625		0.0625		0.0625		0.0625		0.0625		0.0625		0.0625		Stage				
No.	Wires	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	1	2	3	4	
1	196	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	0	196	
2	191	4	4	3	3	3	3	3	4	4	4	4	4	4	4	4	4	0	0	60	131	
3	185	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	3	0	0	93	93	
4	179	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	3	0	0	90	90	
5	174	3	3	3	3	3	3	3	3	3	3	4	4	4	3	3	3	0	0	141	33	
6	168	3	3	3	3	3	3	3	3	3	3	4	4	3	3	3	3	0	0	147	21	
7	163	3	3	3	3	3	3	3	3	3	3	3	4	3	3	3	3	0	0	152	10	
8	157	3	3	3	3	3	3	3	3	3	4	3	3	3	3	3	3	0	0	147	10	
9	151	3	3	3	3	3	3	3	3	3	4	3	3	3	3	3	3	0	0	142	9	
10	146	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	146	0	
11	140	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	140	0	
12	135	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	135	0	
13	129	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	129	0	
14	123	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	123	0	
15	118	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	118	0	
16	112	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	112	0	
17	107	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	107	0	
18	101	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	101	0	
19	95	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	95	0	
20	90	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	90	0	
21	84	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	84	0	
22	79	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	79	0	
23	73	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	73	0	
24	67	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	67	0	
25	62	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	62	0	
26	56	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	56	0	
27	50	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	50	0	
28	45	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	45	0	
29	39	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	39	0	
30	34	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	34	0	
31	28	3	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	0	4	25	0	
32	22	3	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	0	3	20	0	
33	17	3	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	0	2	15	0	
34	11	3	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	0	1	10	0	
35	6	3	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	0	1	5	0	
36	1	3	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	0	0	1	0	
	3534.0																	0	11	2931	593	3534
																		0%	0%	83%	17%	100%

Projects Anthony Wayne Bridge
Subject Cable Strength Investigation - Primary Location PP3-PP4, South Cable
Broken Wire Data

Made By MJS 11/2012 Date
Checked By TS 12/2012 Date
Sheet No. of



Cable Cross-Section - looking West

This sheet is used to approximate the number of broken wires in the cable per NCHRP 534 Article 4.3.3. Broken wires are treated as surface wires, and entered into the cells below, or interior wires, which are entered into the boxed cells of the table. If both are present, zero's should be entered into the cells in the table corresponding to the surface wires.

No. of wires = 3534
No. of rings = 35
Wire diameter = 0.196 in
Wire diameter = 0.192 in (before galvanizing)
Eff. wire diameter = 0.1829 in

Surface Wires - 4.3.3.2
n_{b1} : 0 broken wires in outer ring
d_0 : 0 depth to which no broken wires are found
Surface Broken Wires, n_{bi} = 0 broken wires

Internal Wires - 4.3.3.1
Internal Broken Wires = 0
Total Broken Wires = 0

- Calculation of Interior Broken Wires - Shaded region accounted for in Surface Wire calc's above - should be all zero's

			1		2		3		4		5		6		7		8									
Est. Depth	Ring	No.	0.125		0.125		0.125		0.125		0.125		0.125		0.125		0.125		$0.5n_ja_j$							
(in)	No.	Wires	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	1	2	3	4	5	6	7	8
0.091	1	196	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.274	2	191	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.457	3	185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.640	4	179	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.823	5	174	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.006	6	168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.189	7	163	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.372	8	157	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.555	9	151	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.738	10	146	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.921	11	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.104	12	135	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.286	13	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.469	14	123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.652	15	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.835	16	112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.018	17	107	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.201	18	101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.384	19	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.567	20	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.750	21	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.933	22	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.116	23	73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.298	24	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.481	25	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.664	26	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.847	27	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.030	28	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.213	29	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.396	30	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.579	31	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.762	32	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.945	33	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.128	34	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.311	35	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.493	36	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		3534.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		USF	0.50		0.50		0.50		0.50		0.50		0.50		0.50		0.50									
		USF n_{bm}																	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

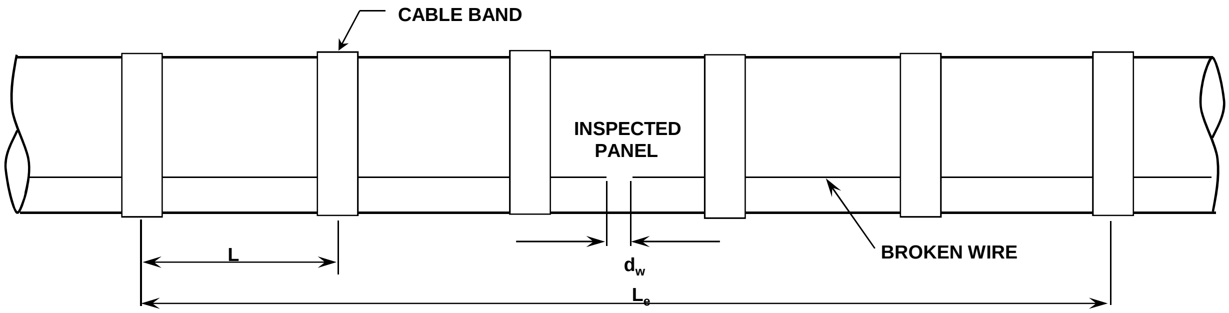
0.0

0.0

This sheet is used to :

Calculate the Development Coefficient and Redevelopement length
Determine the number of broken wires in the effective development length
Calculate the number of cracked wires in the effective development length and fraction of wires in each group
Calculate the cable strength - 3 models are considered:

1. Simplified Strength model - neglects cracked and redeveloped wires - used only where fraction of cracked wires < 10%
2. Brittle Wire Model - based on strength properties of sampled wires
3. Limited Ductility Model - based on strain properties of sampled wires



Total wires in cable =	3534			T =	1.82	kips	wire tension at Service
L :	20.9686	ft.	wire length between bands	wire stress =	63	ksi	at service
Cable Service Force :	6,418	kips		d_w :	0.563	in	average broken wire gap
E :	28500	ksi					
a_w :	0.0290	in^2	wire area				

Calculate Development Coefficient and Redevelopment Length

4.5 Wire Redevelopment

μ_{s2} =	210	ksi	Group 2 sample mean tensile strength
d_e =	0.554	in	elastic def. over L due to T
N_T =	1		number of panels in which wire tension < T - service force in wire
N_B =	4		number of bands to redevelop wire - at stress of $0.95\mu_{s2}$
L_e =	7		effective development length
C_d =	0.250	min	redevelopment coefficient
	0.333	max	
F =	1.445	kips - min	Force developed at each cable band
	1.927	kips - max	

Determine Number of Broken Wires in Development Length

n_{bi} =	0	number of broken wires in panel
n_{ri} :	0	number of repaired wires in panel
N_b =	0	number of broken wires over development length, = $n_{bi} \times L_e$
N_r =	0	number of repaired wires over development length, = n_{ri}
$N_b - N_r$ =	0	

Calculate Number of Cracked Wires in Development Length and Fraction of Wires in each Group

Number of wires at each corrosion stage

N_{s1}	N_{s2}	N_{s3}	N_{s4}
0	11	2931	593

				cracked		redeveloped		
Group	N_{0k}	$p_{c,k}$	$N_{c,k}/N_{0k}$	$N_{c,k}$	$N_{cr,k}/N_{0k}$	$N_{cr,k}$	N_k	p_k
2	11		0	0	0	0	11	0.00
3	2931	0.000	0.000	0	0.000	0	2931	0.83
4	593	0.333	0.939	557	0.231	137	36	0.01
5							557	0.16
N_{eff} =	3534				N_{cr} =	137	3534	1.00

where :

N_{0k} = Number of unbroken stage k wires in the evaluated panel - Eq. 5.3.2.3-1 through Eq. 5.3.2.3-6

$p_{c,k}$ = Fraction of stage k wires that are cracked

$N_{c,k}/N_{0k}$ = Fraction of discrete cracked wires in the effective development length - $\Sigma p_{c,k}(1-p_{c,k})^{i-1}$ or from Figure 5.3.2.4.1-1

$N_{c,k}$ = Number of discrete cracked wires in the effective development length

$N_{cr,k}/N_{0k}$ = Fraction of redeveloped cracked wires that break - $\Sigma C_{Di} p_{c,k}(1-p_{c,k})^{i-1}$ or from Figure 5.3.2.4.2-1

$N_{cr,k}$ = Effective number of stage k broken cracked wires that can be redeveloped

N_k = Number of Group k wires in evaluated panel

p_k = Fraction of unbroken wires in the evaluated panel

Summary of Wire Test Results (see Spreadsheet "WirePropsTyp")

Ultimate Stress

Group	μ_{sk}	σ_{sk}	μ^2	$\sigma^2+\mu^2$	m (α)	ν (β)
2	210	13.54	44,160	44,343	19.216	216
3	193	22.65	37,103	37,616	10.243	202
4	196	17.52	38,437	38,744	13.675	204
5	199	12.79	39,661	39,824	19.278	205

Calculate Cable Strength

5.3.3.1 Simplified Strength Model

Applied to cables with very few (<10% of total) cracked wires
Based on the Brittle Wire Model, with cracked and broken wires reduced accordingly
Strength may be underestimated by up to 20%
Useful for locating controlling location

Percentage of cracked wires = 16% Simplified Model NA

			p_{uk}
μ_s =	193	2	0.004
σ_s =	22.60	3	0.984
Coeff of Var, σ_s/μ_s =	0.1173	4	0.01214

N_{eff} - N_5 = 2977 a_w = 0.0290 in^2

R = 12,627 kips K : 0.76 from Figure 5.3.3.1.2-1

5.3.3.2 Brittle Wire Model

Used where > 10% of wires are cracked.
Assumes all wires have the same stress-strain diagram

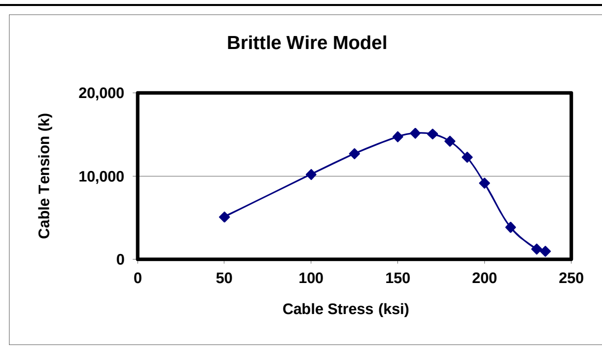
cable stress, s = 163.8 ksi
Use solver to solve for s that maximizes T

Group	p_k	$F3_k(s)$	$p_kF3_k(s)$	failed	remaining	Force
2	0.003	0.0049	0.00001	0	11	50 kips
3	0.829	0.1088	0.09020	319	2612	12,386 kips
4	0.010	0.0496	0.00051	2	34	163 kips
5	0.157	0.0134	0.00211	7	549	2,604 kips
		$F_C(s)$ =	0.09284	328	3206	15,203 kips

$F3_k(s)$ = Weibull cumulative distribution of ultimate stress of Group k wires - fraction of Group k wires that have failed
$F_C(s)$ = Compound cumulative distribution of the tensile strength

			wires		
Force in unbroken wires	T_u =	4.74 kips/wire x	3206 ($N_{eff}(1-F_C(s))$)	15,203	kips
Force in redeveloped cracked wires that break	T_{cr} =	5.78 ($0.95\mu_{s2}a_w$)	2 ($N_{cr}F3_5(s)$)	11	kips
Force in redeveloped broken wires	R_b =	5.78	0 ($n_{bi}0.5(L_e-1)$)	-	kips
Total Cable Force	T =			15,213	kips

s	T	failed	%
50	5,116	0	0%
100	10,226	2	0%
125	12,713	21	1%
150	14,760	136	4%
160	15,173	260	7%
170	15,088	473	13%
180	14,225	817	23%
190	12,292	1330	38%
200	9,186	2012	57%
215	3,867	3030	86%
230	1,264	3463	98%
235	983	3506	99%



Location : PP58-PP59 South

Cable : South **Panel :** PP58-PP59

Max. Cable Force = 6,422 kips

Simplified Strength Model*
Cable Strength = 6,700 kips F.S. = 1.04

Brittle Wire Model
Cable Strength = 16,000 kips F.S. = 2.49

Limited Ductility Model
Cable Strength = N/A kips F.S. = N/A

Wires at each Stage of Corrosion

	No.	% total
Stage 1 :	0	0.0%
Stage 2 :	0	0.0%
Stage 3 :	1454	41.1%
Stage 4 :	2080	58.9%
Total :	3534	100%

Broken Wires

Surface wires :	0
Internal wires :	0
Total broken wires :	0

This spreadsheet is used to calculate the strength of a cable section per NCHRP Report 534, based on the following :
- Degree of corrosion
- Broken wires
- Tensile tests of sample wires

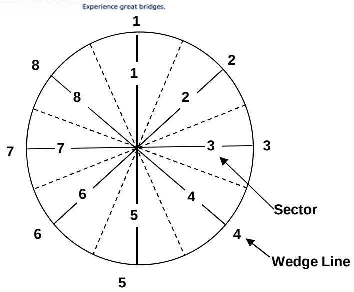
The Brittle Wire Model is used, which assumes all wires have the same stress-strain curve

Degree of corrosion - wires are grouped into the following stages
- Stage 1 : Start of zinc deterioration
- Stage 2 : Wires covered with "white rust"
- Stage 3 : 0 to 30% of wire surface corroded
- Stage 4 : Over 30% of wire surface corroded

Steps
1. Fill in Corrosion information on sheet "Corrosion-6" or "Corrosion-8" - depending on the number of wedges used for inspection
2. Fill in broken wire information on sheet "Broken-6" or "Broken-8"
3. Fill in results of wire sample tests and number of cracked wires on sheet "WirePropsTyp"
4. Determine the Weibull coefficients and average wire stress-strain curve on sheet "WirePropsTyp"
   The remaining steps are carried out on sheet "Strength"
5. Calculate Development Coefficient and Redevelopment Length
6. Determine Number of Broken Wires in Development Length
7. Calculate Number of Cracked Wires in Development Length and Fraction of Wires in each Group
8. Calculate Cable Strength

Values in cells preceded by "=" are calculated by the spreadsheet. Those in cells preceded by ":" are inputted. Values in boxed cells may vary at each panel point.

* may underestimate strength by up to 20%



Cable Cross-Section - looking West

This sheet is used to approximate the number of wires at each stage of corrosion in the cable.
per NCHRP 534 Article 4.3.2.

The corrosion stages of the inspected wires are inputted in the boxed cells of the table

No. of wires : 3534
No. of rings = 35
Wire diamter: 0.196 in
Wire diameter: 0.192 in (before galvanizing)
Eff. wire diameter : 0.1829 in

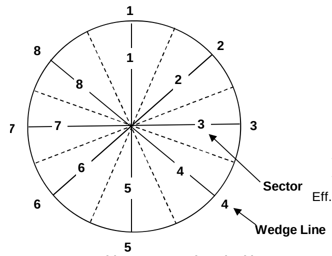
**** Only 7 wedge lines were driven, line 8 was not driven (See NCHRP Report 534 - Section 2.4.2.1).**
Line 8 was assumed to have the same corrosion as the adjacent wedge lines
unless noted otherwise.

L is to the left of the wedge when viewed with cable surface at top (counterclockwise from wedge)

		1		2		3		4		5		6		7		8 **		Estimated Total Observed Wires				
Ring	No.	0.0625		0.0625		0.0625		0.0625		0.0625		0.0625		0.0625		0.0625		Stage				
No.	Wires	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	1	2	3	4	
1	196	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	0	196	
2	191	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	0	191	
3	185	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	0	185	
4	179	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	0	179	
5	174	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	0	174	
6	168	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	0	168	
7	163	4	4	4	4	4	4	4	4	4	4	3	4	4	3	3	4	0	0	30	132	
8	157	4	4	4	4	4	4	3	4	4	4	3	4	4	3	3	4	0	0	39	118	
9	151	4	4	3	4	3	4	3	3	4	4	3	4	4	3	3	4	0	0	66	85	
10	146	4	4	3	4	3	4	3	4	4	4	3	4	4	3	3	4	0	0	55	91	
11	140	4	4	3	3	3	4	3	4	3	3	3	4	4	3	3	4	0	0	79	61	
12	135	4	3	4	3	3	4	4	4	3	3	3	4	3	3	3	4	0	0	76	59	
13	129	4	3	4	3	3	4	4	3	3	3	4	3	4	3	3	4	0	0	73	56	
14	123	3	3	4	3	4	4	3	4	3	3	3	3	4	4	4	3	0	0	69	54	
15	118	3	4	3	3	4	4	3	3	3	3	3	3	4	3	3	3	0	0	88	29	
16	112	4	4	3	4	4	4	3	3	4	4	3	3	4	3	3	4	0	0	49	63	
17	107	4	4	3	3	4	4	3	3	4	3	3	3	4	3	3	4	0	0	60	47	
18	101	4	3	3	3	3	4	3	3	4	3	4	3	4	3	3	4	0	0	63	38	
19	95	3	3	3	3	3	4	3	3	3	3	4	3	3	3	3	3	0	0	83	12	
20	90	3	4	3	4	4	4	3	3	4	3	4	3	3	3	3	3	0	0	56	34	
21	84	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	84	0	
22	79	3	4	3	4	3	3	3	3	3	3	4	4	3	3	3	3	0	0	59	20	
23	73	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	73	0	
24	67	3	4	3	4	3	4	3	3	3	4	3	4	3	3	3	3	0	0	46	21	
25	62	4	3	3	3	3	3	3	3	3	3	4	3	4	3	3	4	0	0	46	15	
26	56	4	3	3	3	3	3	3	3	3	3	4	3	3	3	3	4	0	0	46	11	
27	50	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	4	0	0	41	9	
28	45	4	3	3	4	4	3	3	3	3	3	3	3	4	3	3	4	0	0	31	14	
29	39	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	39	0	
30	34	3	3	4	3	4	4	3	3	3	3	3	3	3	4	4	3	0	0	23	11	
31	28	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	3	0	0	25	4	
32	22	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	3	0	0	21	1	
33	17	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	3	0	0	16	1	
34	11	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	11	0	
35	6	3	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	5	0	
36	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	1	0	
	3534.0																	0	0	1454	2080	3534
																		0%	0%	41%	59%	100%

Projects Anthony Wayne Bridge
Subject Cable Strength Investigation - Optional Location PP58-PP59, South Cable
Broken Wire Data

Made By MJS 11/2012 Date
Checked By TS 12/2012 Date
Sheet No. of



Cable Cross-Section - looking West

This sheet is used to approximate the number of broken wires in the cable per NCHRP 534 Article 4.3.3. Broken wires are treated as surface wires, and entered into the cells below, or interior wires, which are entered into the boxed cells of the table. If both are present, zero's should be entered into the cells in the table corresponding to the surface wires.

No. of wires = 3534
No. of rings = 35
Wire diameter = 0.196 in
Wire diameter = 0.192 in (before galvanizing)
Eff. wire diameter = 0.1829 in

Surface Wires - 4.3.3.2
n_{b1} : 0 broken wires in outer ring
d_0 : 0 depth to which no broken wires are found
Surface Broken Wires, n_{bi} = 0 broken wires

Internal Wires - 4.3.3.1
Internal Broken Wires = 0
Total Broken Wires = 0

- Calculation of Interior Broken Wires - Shaded region accounted for in Surface Wire calc's above - should be all zero's

			1		2		3		4		5		6		7		8									
Est. Depth	Ring	No.	0.125		0.125		0.125		0.125		0.125		0.125		0.125		0.125		0.5$n_j a_j$							
(in)	No.	Wires	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	1	2	3	4	5	6	7	8
0.091	1	196	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.274	2	191	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.457	3	185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.640	4	179	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.823	5	174	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.006	6	168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.189	7	163	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.372	8	157	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.555	9	151	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.738	10	146	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.921	11	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.104	12	135	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.286	13	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.469	14	123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.652	15	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.835	16	112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.018	17	107	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.201	18	101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.384	19	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.567	20	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.750	21	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.933	22	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.116	23	73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.298	24	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.481	25	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.664	26	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.847	27	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.030	28	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.213	29	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.396	30	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.579	31	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.762	32	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.945	33	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.128	34	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.311	35	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.493	36	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		3534.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		USF	0.50		0.50		0.50		0.50		0.50		0.50		0.50		0.50									
		USF n_{bm}																	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

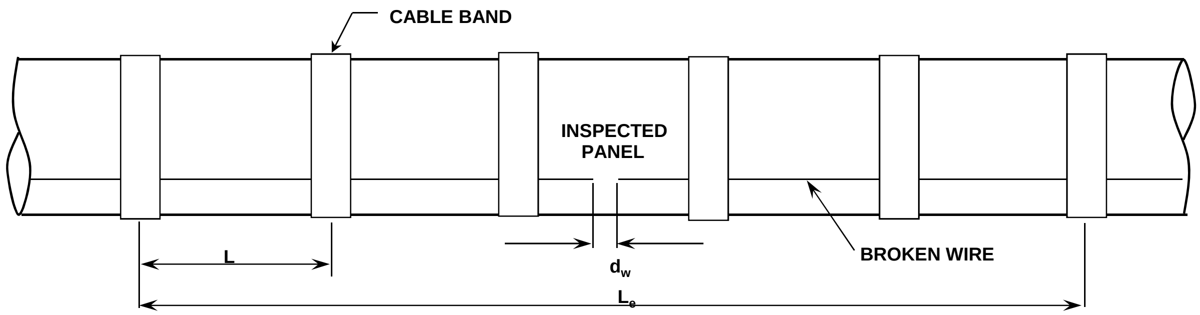
0.0

0.0

This sheet is used to :

Calculate the Development Coefficient and Redevelopement length
Determine the number of broken wires in the effective development length
Calculate the number of cracked wires in the effective development length and fraction of wires in each group
Calculate the cable strength - 3 models are considered:

1. Simplified Strength model - neglects cracked and redeveloped wires - used only where fraction of cracked wires < 10%
2. Brittle Wire Model - based on strength properties of sampled wires
3. Limited Ductility Model - based on strain properties of sampled wires



Total wires in cable =	3534			T =	1.87	kips	wire tension at Service
L :	21.5737	ft.	wire length between bands	wire stress =	65	ksi	at service
Cable Service Force :	6,604	kips		d_w :	0.5	in	average broken wire gap
E :	28500	ksi					
a_w :	0.0290	in^2	wire area				

Calculate Development Coefficient and Redevelopment Length

4.5 Wire Redevelopment

μ_{s2} =	210	ksi	Group 2 sample mean tensile strength
d_e =	0.586	in	elastic def. over L due to T
N_T =	0		number of panels in which wire tension < T - service force in wire
N_B =	4		number of bands to redevelop wire - at stress of $0.95\mu_{s2}$
L_e =	7		effective development length
C_d =	0.250	min	redevelopment coefficient
	0.333	max	
F =	1.445	kips - min	Force developed at each cable band
	1.927	kips - max	

Determine Number of Broken Wires in Development Length

n_{bi} =	0	number of broken wires in panel
n_{ri} :	0	number of repaired wires in panel
N_b =	0	number of broken wires over development length, = n_{bi} x L_e
N_r =	0	number of repaired wires over development length, = n_{ri}
N_b - N_r =	0	

Calculate Number of Cracked Wires in Development Length and Fraction of Wires in each Group

Number of wires at each corrosion stage

N_{s1}	N_{s2}	N_{s3}	N_{s4}
0	0	1454	2080

Group	N_{0k}	$p_{c,k}$	$N_{c,k}/N_{0k}$	cracked $N_{c,k}$	$N_{cr,k}/N_{0k}$	redeveloped $N_{cr,k}$	N_k	p_k
2	0		0	0	0	0	0	0.00
3	1454	0.000	0.000	0	0.000	0	1454	0.41
4	2080	0.333	0.939	1953	0.231	480	127	0.04
5							1953	0.55
N_{eff} =	3534				N_{cr} =	480	3534	1.00

where :

N_{0k} = Number of unbroken stage k wires in the evaluated panel - Eq. 5.3.2.3-1 through Eq. 5.3.2.3-6

$p_{c,k}$ = Fraction of stage k wires that are cracked

$N_{c,k}/N_{0k}$ = Fraction of discrete cracked wires in the effective development length - $\Sigma p_{c,k}(1-p_{c,k})^{i-1}$ or from Figure 5.3.2.4.1-1

$N_{c,k}$ = Number of discrete cracked wires in the effective development length

$N_{cr,k}/N_{0k}$ = Fraction of redeveloped cracked wires that break - $\Sigma C_{Di} p_{c,k}(1-p_{c,k})^{i-1}$ or from Figure 5.3.2.4.2-1

$N_{cr,k}$ = Effective number of stage k broken cracked wires that can be redeveloped

N_k = Number of Group k wires in evaluated panel

p_k = Fraction of unbroken wires in the evaluated panel

Summary of Wire Test Results (see Spreadsheet "WirePropsTyp")

Ultimate Stress

Group	μ_{sk}	σ_{sk}	μ^2	$\sigma^2+\mu^2$	m (α)	ν (β)
2	210	13.54	44,160	44,343	19.216	216
3	193	22.65	37,103	37,616	10.243	202
4	196	17.52	38,437	38,744	13.675	204
5	199	12.79	39,661	39,824	19.278	205

Calculate Cable Strength

5.3.3.1 Simplified Strength Model

Applied to cables with very few (<10% of total) cracked wires
Based on the Brittle Wire Model, with cracked and broken wires reduced accordingly
Strength may be underestimated by up to 20%
Useful for locating controlling location

Percentage of cracked wires = 55% Simplified Model NA

			p_{uk}
μ_s =	193	2	0.000
σ_s =	22.31	3	0.920
Coeff of Var, σ_s/μ_s =	0.1156	4	0.08025

N_{eff} - N_5 = 1581 a_w = 0.0290 in^2
R = 6,720 kips K : 0.761 from Figure 5.3.3.1.2-1

5.3.3.2 Brittle Wire Model

Used where > 10% of wires are cracked.
Assumes all wires have the same stress-strain diagram

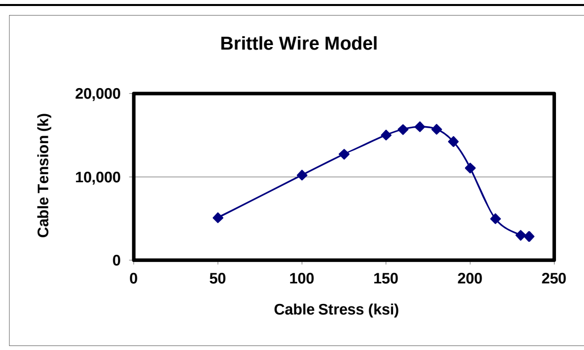
cable stress, s = 171.2 ksi
Use solver to solve for s that maximizes T

Group	p_k	$F3_k(s)$	$p_kF3_k(s)$	failed	remaining	Force
2	0.000	0.0113	0.00000	0	0	0 kips
3	0.411	0.1656	0.06814	241	1213	6,014 kips
4	0.036	0.0889	0.00319	11	116	573 kips
5	0.553	0.0312	0.01722	61	1892	9,378 kips
		$F_C(s)$ =	0.08856	313	3221	15,964 kips

$F3_k(s)$ = Weibull cumulative distribution of ultimate stress of Group k wires - fraction of Group k wires that have failed
$F_C(s)$ = Compound cumulative distribution of the tensile strength

			wires		
Force in unbroken wires	T_u =	4.96 kips/wire x	3221 ($N_{eff}(1-F_C(s))$)	15,964	kips
Force in redeveloped cracked wires that break	T_{cr} =	5.78 ($0.95\mu_{s2}a_w$)	15 ($N_{cr}F3_5(s)$)	87	kips
Force in redeveloped broken wires	R_b =	5.78	0 ($n_{bi}0.5(L_e-1)$)	-	kips
Total Cable Force	T =			16,051	kips

s	T	failed	%
50	5,116	0	0%
100	10,229	1	0%
125	12,751	11	0%
150	15,037	73	2%
160	15,712	147	4%
170	16,046	289	8%
180	15,734	558	16%
190	14,263	1047	30%
200	11,087	1845	52%
215	4,993	3143	89%
230	3,014	3498	99%
235	2,871	3520	100%



Location : PP65 - East

Cable : North **Panel :** PP65 - East

Max. Cable Force (Existing Condition) = **6,243 kips**
ax. Cable Force (Rehabilitated, No FWS) = **5,984 kips**

Simplified Strength Model*
Cable Strength = **10,000 kips** **F.S. =** **1.67**

Brittle Wire Model
F.S. = **2.31** (Existing Cond.)
Cable Strength = **14,400 kips** **F.S. =** **2.41** (Rehab. Cond., No FWS)

Limited Ductility Model
Cable Strength = **N/A kips** **F.S. =** **N/A**

Wires at each Stage of Corrosion

	No.	% total
Stage 1 :	0	0.0%
Stage 2 :	567	16.0%
Stage 3 :	1901	53.8%
Stage 4 :	1066	30.2%
Total :	3534	100%

Broken Wires

Surface wires :	0
Internal wires :	0
Total broken wires :	0

This spreadsheet is used to calculate the strength of a cable section per NCHRP Report 534, based on the following :
- Degree of corrosion
- Broken wires
- Tensile tests of sample wires

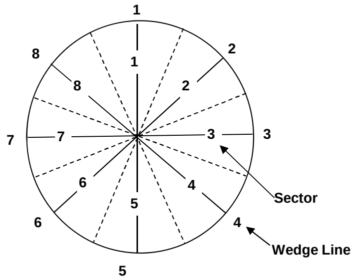
The Brittle Wire Model is used, which assumes all wires have the same stress-strain curve

Degree of corrosion - wires are grouped into the following stages
- Stage 1 : Start of zinc deterioration
- Stage 2 : Wires covered with "white rust"
- Stage 3 : 0 to 30% of wire surface corroded
- Stage 4 : Over 30% of wire surface corroded

Steps
1. Fill in Corrosion information on sheet "Corrosion-6" or "Corrosion-8" - depending on the number of wedges used for inspection
2. Fill in broken wire information on sheet "Broken-6" or "Broken-8"
3. Fill in results of wire sample tests and number of cracked wires on sheet "WirePropsTyp"
4. Determine the Weibull coefficients and average wire stress-strain curve on sheet "WirePropsTyp"
   The remaining steps are carried out on sheet "Strength"
5. Calculate Development Coefficient and Redevelopment Length
6. Determine Number of Broken Wires in Development Length
7. Calculate Number of Cracked Wires in Development Length and Fraction of Wires in each Group
8. Calculate Cable Strength

Values in cells preceded by "=" are calculated by the spreadsheet. Those in cells preceded by ":" are inputted. Values in boxed cells may vary at each panel point.

* may underestimate strength by up to 20%



Cable Cross-Section - looking West

This sheet is used to approximate the number of wires at each stage of corrosion in the cable.
per NCHRP 534 Article 4.3.2.

The corrosion stages of the inspected wires are inputted in the boxed cells of the table

No. of wires : 3534
No. of rings = 35
Wire diamter: 0.196 in
Wire diamter: 0.192 in (before galvanizing)
Eff. wire diameter : 0.1829 in

**** Only 6 wedge lines were driven, lines 2 and 6 were not driven (See NCHRP Report 534 - Section 2.4.2.1).**
Lines 2 and 6 were assumed to have the same corrosion as the adjacent wedge lines
unless noted otherwise.

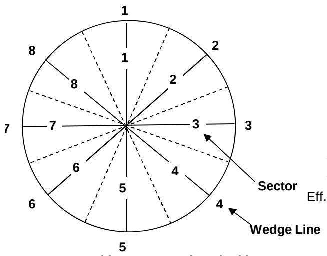
L is to the left of the wedge when viewed with cable surface at top (counterclockwise from wedge)

Ring	No.	1		2 **		3		4		5		6 **		7		8		Estimated Total Observed Wires				
		0.0625		0.0625		0.0625		0.0625		0.0625		0.0625		0.0625		0.0625		Stage				
No.	Wires	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	1	2	3	4	
1	196	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	0	196	
2	191	4	4	4	4	4	4	3	3	4	4	4	4	4	4	4	4	0	0	24	167	
3	185	4	4	4	4	4	4	3	3	4	4	4	4	4	4	3	3	0	0	46	139	
4	179	4	4	4	4	4	4	3	3	4	4	4	4	4	4	3	3	0	0	45	135	
5	174	4	4	4	4	4	4	3	3	4	4	4	4	4	4	3	3	0	0	43	130	
6	168	4	4	4	4	4	4	3	3	4	4	4	4	4	4	3	3	0	0	42	126	
7	163	4	4	4	4	4	4	3	3	3	3	3	4	4	4	3	3	0	0	71	91	
8	157	3	4	4	4	4	3	3	3	3	3	3	4	4	3	3	3	0	0	98	59	
9	151	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	151	0	
10	146	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	146	0	
11	140	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	131	9	
12	135	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	135	0	
13	129	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	0	8	121	0	
14	123	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	0	8	116	0	
15	118	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	0	7	110	0	
16	112	3	3	3	2	2	2	3	3	3	3	3	4	4	3	3	3	0	21	77	14	
17	107	3	3	3	3	3	2	3	3	3	3	3	2	2	3	3	3	0	20	87	0	
18	101	3	3	3	3	3	2	3	3	2	2	2	2	2	3	3	3	0	38	63	0	
19	95	3	3	3	3	3	2	3	3	2	2	2	2	2	3	3	3	0	36	60	0	
20	90	3	3	3	2	2	2	3	2	3	2	2	2	2	3	3	3	0	45	45	0	
21	84	3	3	3	2	2	2	3	2	2	2	2	2	2	3	3	3	0	47	37	0	
22	79	3	3	3	3	3	2	3	3	2	2	2	2	2	3	3	3	0	29	49	0	
23	73	3	3	3	2	2	2	3	2	2	2	2	2	2	3	2	3	0	46	27	0	
24	67	3	3	3	3	3	2	3	2	2	2	2	2	2	3	2	2	0	38	29	0	
25	62	3	3	3	2	2	2	3	2	2	2	2	3	3	2	3	2	0	35	27	0	
26	56	3	3	3	2	2	2	3	2	2	2	2	2	2	2	3	3	0	35	21	0	
27	50	3	3	3	3	3	2	2	3	2	2	2	3	3	2	3	3	0	19	32	0	
28	45	3	3	3	2	2	2	2	2	2	3	3	2	2	2	3	3	0	25	20	0	
29	39	3	3	3	2	2	3	2	2	2	2	2	2	2	2	2	2	0	29	10	0	
30	34	3	3	3	2	2	2	2	2	2	2	2	3	3	2	3	3	0	19	15	0	
31	28	3	3	3	2	2	2	3	2	2	2	2	2	2	2	2	2	0	21	7	0	
32	22	3	3	3	2	2	2	3	2	2	2	2	2	2	2	2	3	0	15	7	0	
33	17	3	3	3	2	2	3	2	2	2	2	2	2	2	2	2	2	0	13	4	0	
34	11	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	0	9	2	0	
35	6	3	3	3	3	3	3	2	3	2	3	3	2	2	2	2	2	0	2	3	0	
36	1	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	0	1	0	0	
	3534.0																	0	567	1901	1066	3534
																		0%	16%	54%	30%	100%

MODJESKI and MASTERS
Experience great bridges.

Projects Anthony Wayne Bridge
Subject Cable Strength Investigation - Primary Location PP65 -East, North Cable
Broken Wire Data

Made By MJS 11/2012 Date
Checked By TS 12/2012 Date
Sheet No. of



Cable Cross-Section - looking West

This sheet is used to approximate the number of broken wires in the cable per NCHRP 534 Article 4.3.3. Broken wires are treated as surface wires, and entered into the cells below, or interior wires, which are entered into the boxed cells of the table. If both are present, zero's should be entered into the cells in the table corresponding to the surface wires.

No. of wires = 3534
No. of rings = 35
Wire diameter = 0.196 in
Wire diameter = 0.192 in (before galvanizing)
Eff. wire diameter = 0.1829 in

Surface Wires - 4.3.3.2
n_{b1} : 0 broken wires in outer ring
d_0 : 0 depth to which no broken wires are found
Surface Broken Wires, n_{bi} = 0 broken wires

Internal Wires - 4.3.3.1
Internal Broken Wires = 0
Total Broken Wires = 0
Length Inspected = 20 ft

- Calculation of Interior Broken Wires - Shaded region accounted for in Surface Wire calc's above - should be all zero's

			1		2		3		4		5		6		7		8									
Est. Depth	Ring	No.	0.125		0.125		0.125		0.125		0.125		0.125		0.125		0.125		$0.5n_ja_j$							
(in)	No.	Wires	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	1	2	3	4	5	6	7	8
0.091	1	196	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.274	2	191	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.457	3	185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.640	4	179	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.823	5	174	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.006	6	168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.189	7	163	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.372	8	157	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.555	9	151	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.738	10	146	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.921	11	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.104	12	135	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.286	13	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.469	14	123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.652	15	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.835	16	112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.018	17	107	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.201	18	101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.384	19	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.567	20	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.750	21	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.933	22	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.116	23	73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.298	24	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.481	25	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.664	26	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.847	27	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.030	28	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.213	29	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.396	30	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.579	31	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.762	32	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.945	33	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.128	34	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.311	35	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.493	36	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		3534.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		USF	0.50		0.50		0.50		0.50		0.50		0.50		0.50		0.50									
		USF n_{bm}																	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

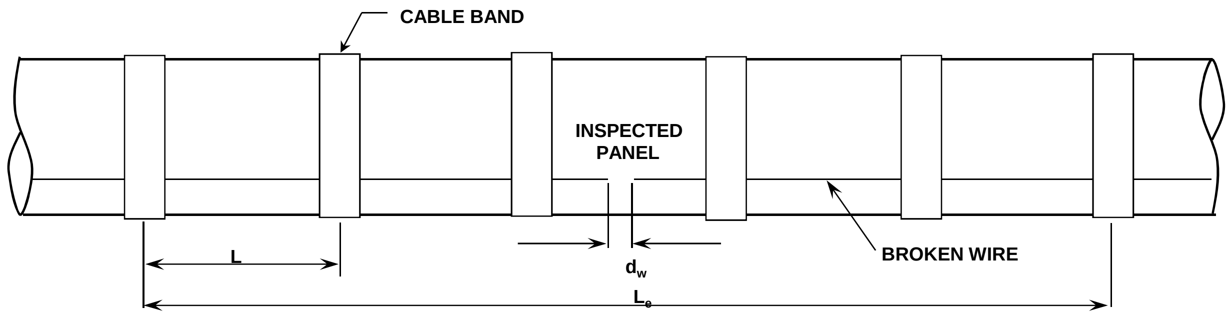
0.0

0.0

This sheet is used to :

Calculate the Development Coefficient and Redevelopement length
Determine the number of broken wires in the effective development length
Calculate the number of cracked wires in the effective development length and fraction of wires in each group
Calculate the cable strength - 3 models are considered:

1 Simplified Strength model - neglects cracked and redeveloped wires - used only where fraction of cracked wires < 10%
2 Brittle Wire Model - based on strength properties of sampled wires
3 Limited Ductility Model - based on strain properties of sampled wires



Total wires in cable =	3534			T =	1.74	kips	wire tension at Service
L :	213.477	ft.	wire length between bands	wire stress =	60	ksi	at service
Cable Service Force :	6,154	kips		d_w :	0.5625	in	average broken wire gap
E :	28500	ksi		No. of Side Span Panels =	3		
a_w :	0.0290	in^2	wire area	No. of Back Stay Panels =	1		

Calculate Development Coefficient and Redevelopment Length

4.5 Wire Redevelopment

μ_{s2} =	205	ksi	Group 2 sample mean tensile strength
d_e =	5.406	in	elastic def. over L due to T
N_T =	0		number of panels in which wire tension < T - service force in wire
N_B =	4		number of bands to redevelop wire - at stress of $0.95\mu_{s2}$
Le =	4		effective development length (back stay panel + side span panels)
L_e =	7		effective development length assuming cable is uniform-used for fraction of wires that redevelop
C_d =	0.250	min	redevelopment coefficient
	0.333	max	
F =	1.413	kips - min	Force developed at each cable band
	1.884	kips - max	

Determine Number of Broken Wires in Development Length

n_{bi} =	0	number of broken wires in panel = number broken over inspected length x panel length / inspected length
n_{ri} :	0	number of repaired wires in panel
N_b =	0	number of broken wires over development length, = n_{bi} x L_e
N_r =	0	number of repaired wires over development length, = n_{ri}
N_b - N_r =	0	

Calculate Number of Cracked Wires in Development Length and Fraction of Wires in each Group

Number of wires at each corrosion stage

N_{s1}	N_{s2}	N_{s3}	N_{s4}
0	567	1901	1066

Group	N_{0k}	$p_{c,k}$	$N_{c,k}/N_{0k}$	cracked $N_{c,k}$	$N_{cr,k}/N_{0k}$	redeveloped $N_{cr,k}$	N_k	p_k
2	567		0	0	0	0	567	0.16
3	1901	0.000	0.000	0	0.000	0	1901	0.54
4	1066	0.333	0.939	1001	0.231	246	65	0.02
5							1001	0.28
N_{eff} =	3534				N_{cr} =	246	3534	1.00

where :

N_{0k} = Number of unbroken stage k wires in the evaluated panel - Eq. 5.3.2.3-1 through Eq. 5.3.2.3-6

$p_{c,k}$ = Fraction of stage k wires that are cracked

$N_{c,k}/N_{0k}$ = Fraction of discrete cracked wires in the effective development length - $\Sigma p_{c,k}(1-p_{c,k})^{i-1}$ or from Figure 5.3.2.4.1-1

$N_{c,k}$ = Number of discrete cracked wires in the effective development length

$N_{cr,k}/N_{0k}$ = Fraction of redeveloped cracked wires that break - $\Sigma C_{Di} p_{c,k}(1-p_{c,k})^{i-1}$ or from Figure 5.3.2.4.2-1

$N_{cr,k}$ = Effective number of stage k broken cracked wires that can be redeveloped

N_k = Number of Group k wires in evaluated panel

p_k = Fraction of unbroken wires in the evaluated panel

Summary of Wire Test Results (see Spreadsheet "WirePropsTyp")

Ultimate Stress

Group	μ_{sk}	σ_{sk}	μ^2	$\sigma^2+\mu^2$	m (α)	ν (β)
2	205	14.86	42,222	42,443	17.05	212
3	182	28.01	33,233	34,018	7.70	194
4	189	20.43	35,899	36,316	11.23	198
5	190	15.08	36,062	36,290	15.47	196

Calculate Cable Strength

5.3.3.1 Simplified Strength Model

Applied to cables with very few (<10% of total) cracked wires
Based on the Brittle Wire Model, with cracked and broken wires reduced accordingly
Strength may be underestimated by up to 20%
Useful for locating controlling location

Percentage of cracked wires = 28% Simplified Model NA

			p_{uk}
μ_s =	188	2	0.224
σ_s =	27.24	3	0.751
Coeff of Var, σ_s/μ_s =	0.1451	4	0.02568

$N_{eff} - N_5$ = 2533 a_w = 0.0290 in^2

R = 10,005 kips K : 0.727 from Figure 5.3.3.1.2-1

5.3.3.2 Brittle Wire Model

Used where > 10% of wires are cracked.
Assumes all wires have the same stress-strain diagram

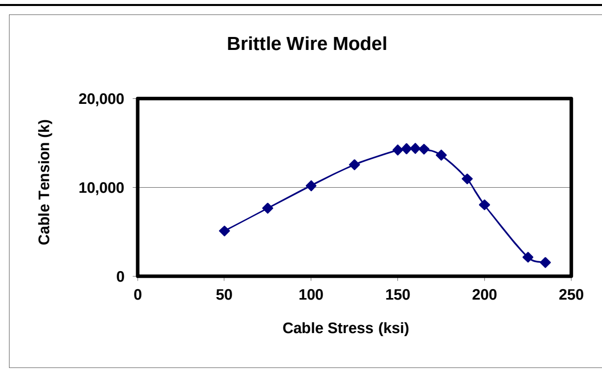
cable stress, s = 159.2 ksi
Use solver to solve for s that maximizes T

Group	p_k	$F3_k(s)$	$p_kF3_k(s)$	failed	remaining	Force	
2	0.160	0.0076	0.00122	4	562	2,592	kips
3	0.538	0.1967	0.10584	374	1527	7,042	kips
4	0.018	0.0820	0.00151	5	60	275	kips
5	0.283	0.0381	0.01079	38	963	4,440	kips
		$F_C(s)$ =	0.11936	422	3112	14,349	kips

$F3_k(s)$ = Weibull cumulative distribution of ultimate stress of Group k wires - fraction of Group k wires that have failed
$F_C(s)$ = Compound cumulative distribution of the tensile strength

			wires			
Force in unbroken wires	T_u =	4.61 kips/wire x	3112	$(N_{eff}(1-F_C(s)))$	14,349	kips
Force in redeveloped cracked wires that break	T_{cr} =	5.65 $(0.95\mu_{s2}a_w)$	9	$(N_{cr}F3_5(s))$	53	kips
Force in redeveloped broken wires	R_b =	5.65	0	$(n_{bi}0.5(L_e-1))$	-	kips
Total Cable Force	T =				14,402	kips

s	T	failed	%
50	5,116	0	0%
75	7,671	1	0%
100	10,198	12	0%
125	12,557	65	2%
150	14,218	265	7%
155	14,361	342	10%
160	14,401	438	12%
165	14,315	556	16%
175	13,650	882	25%
190	10,974	1653	47%
200	8,058	2318	66%
225	2,167	3415	97%
235	1,564	3509	99%



Location : PP31-PP32

Cable : North **Panel :** PP31-PP32

Max. Cable Force =	**5,712 kips**			
Simplified Strength Model* **Cable Strength =**	**15,100 kips**		**F.S. =**	**2.64**
Brittle Wire Model **Cable Strength =**	**16,600 kips**		**F.S. =**	**2.91**
Limited Ductility Model **Cable Strength =**	**N/A kips**		**F.S. =**	**N/A**

Wires at each Stage of Corrosion

	No.	% total
Stage 1 :	37	1.0%
Stage 2 :	2179	61.6%
Stage 3 :	985	27.9%
Stage 4 :	334	9.4%
Total :	3534	100%

Broken Wires

Surface wires :	0
Internal wires :	0
Total broken wires :	0

This spreadsheet is used to calculate the strength of a cable section per NCHRP Report 534, based on the following :

- Degree of corrosion
- Broken wires
- Tensile tests of sample wires

The Brittle Wire Model is used, which assumes all wires have the same stress-strain curve

Degree of corrosion - wires are grouped into the following stages

- Stage 1 : Start of zinc deterioration
- Stage 2 : Wires covered with "white rust"
- Stage 3 : 0 to 30% of wire surface corroded
- Stage 4 : Over 30% of wire surface corroded

Steps

1. Fill in Corrosion information on sheet "Corrosion-6" or "Corrosion-8" - depending on the number of wedges used for inspection
2. Fill in broken wire information on sheet "Broken-6" or "Broken-8"
3. Fill in results of wire sample tests and number of cracked wires on sheet "WirePropsTyp"
4. Determine the Weibull coefficients and average wire stress-strain curve on sheet "WirePropsTyp"
   The remaining steps are carried out on sheet "Strength"
5. Calculate Development Coefficient and Redevelopment Length
6. Determine Number of Broken Wires in Development Length
7. Calculate Number of Cracked Wires in Development Length and Fraction of Wires in each Group
8. Calculate Cable Strength

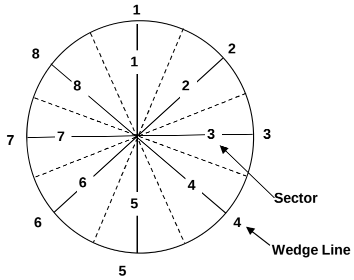
Values in cells preceded by "=" are calculated by the spreadsheet. Those in cells preceded by ":" are inputted. Values in boxed cells may vary at each panel point.

* may underestimate strength by up to 20%

MODJESKI and MASTERS
Experience great bridges.

Projects Anthony Wayne Bridge
Subject Cable Strength Investigation - Optional Location PP31 to PP32, North Cable
Corrosion Data

Made By MJS 11/2012 Date
Checked By TS 12/2012 Date
Sheet No. of



Cable Cross-Section - looking West

This sheet is used to approximate the number of wires at each stage of corrosion in the cable. per NCHRP 534 Article 4.3.2.

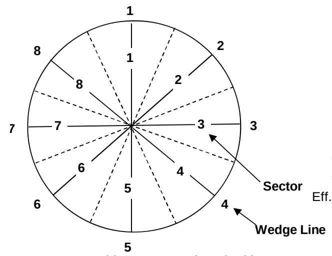
The corrosion stages of the inspected wires are inputted in the boxed cells of the table

No. of wires : 3534
No. of rings = 35
Wire diamter: 0.196 in
Wire diamter: 0.192 in (before galvanizing)
Eff. wire diameter : 0.1829 in

**** Only 6 wedge lines were driven, lines 4 and 8 were not driven (See NCHRP Report 534 - Section 2.4.2.1).**
Lines 4 and 8 were assumed to have the same corrosion as the adjacent wedge lines unless noted otherwise.

L is to the left of the wedge when viewed with cable surface at top (counterclockwise from wedge)

		1		2		3		4 **		5		6		7		8 **		Estimated Total Observed Wires				
Ring	No.	0.0625		0.0625		0.0625		0.0625		0.0625		0.0625		0.0625		0.0625		Stage				
No.	Wires	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	1	2	3	4	
1	196	1	1	4	3	4	4	4	4	4	4	4	4	4	4	4	1	37	0	12	147	
2	191	2	2	3	4	4	4	4	4	4	4	3	4	3	3	3	2	0	36	60	95	
3	185	2	2	3	4	4	3	3	4	4	4	3	3	3	2	2	2	0	58	69	58	
4	179	2	2	3	3	4	3	3	3	3	4	3	3	3	2	2	2	0	56	101	22	
5	174	2	2	2	3	3	3	3	3	3	4	3	3	2	2	2	2	0	76	87	11	
6	168	2	2	2	3	2	3	3	3	3	3	3	3	2	2	2	2	0	84	84	0	
7	163	2	2	2	3	2	2	2	3	3	3	3	3	2	2	2	2	0	102	61	0	
8	157	2	2	3	2	2	2	2	3	3	3	3	3	2	2	2	2	0	98	59	0	
9	151	2	2	3	2	2	2	2	3	3	3	3	3	2	2	2	2	0	95	57	0	
10	146	2	2	2	2	2	2	2	3	3	3	2	3	2	2	2	2	0	109	36	0	
11	140	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	0	105	35	0	
12	135	2	2	2	2	2	3	3	3	3	3	3	2	2	2	2	2	0	84	50	0	
13	129	2	2	2	2	3	2	2	3	3	3	3	3	2	2	2	2	0	81	48	0	
14	123	2	2	2	2	3	2	2	3	3	3	3	2	2	2	2	2	0	85	39	0	
15	118	2	2	2	2	3	2	2	3	3	3	3	3	2	2	2	2	0	74	44	0	
16	112	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	0	56	56	0	
17	107	2	2	2	3	2	2	2	3	3	3	2	2	2	2	2	2	0	80	27	0	
18	101	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	0	95	6	0	
19	95	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	0	89	6	0	
20	90	2	2	2	2	2	2	2	3	3	2	2	3	2	2	2	2	0	73	17	0	
21	84	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	84	0	0	
22	79	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	0	74	5	0	
23	73	2	2	3	2	2	2	2	2	2	2	3	2	2	2	2	2	0	64	9	0	
24	67	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	67	0	0	
25	62	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	0	58	4	0	
26	56	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	0	53	4	0	
27	50	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	0	47	3	0	
28	45	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	0	42	3	0	
29	39	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	39	0	0	
30	34	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	34	0	0	
31	28	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	28	0	0	
32	22	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	22	0	0	
33	17	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	0	16	1	0	
34	11	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	0	11	1	0	
35	6	2	2	2	3	3	2	2	2	2	2	2	2	2	2	2	2	0	5	1	0	
36	1	2	2	2	2	3	3	3	3	3	3	2	2	2	2	2	2	0	1	0	0	
	3534.0																	37	2179	985	334	3534
																		1%	62%	28%	9%	100%



Cable Cross-Section - looking West

This sheet is used to approximate the number of broken wires in the cable per NCHRP 534 Article 4.3.3. Broken wires are treated as surface wires, and entered into the cells below, or interior wires, which are entered into the boxed cells of the table. If both are present, zero's should be entered into the cells in the table corresponding to the surface wires.

No. of wires = 3534
No. of rings = 35
Wire diameter = 0.196 in
Wire diameter = 0.192 in (before galvanizing)
Eff. wire diameter = 0.1829 in

Surface Wires - 4.3.3.2
n_{b1} : 0 broken wires in outer ring
d_0 : 0 depth to which no broken wires are found
Surface Broken Wires, n_{bi} = 0 broken wires

Internal Wires - 4.3.3.1
Internal Broken Wires = 0
Total Broken Wires = 0

- Calculation of Interior Broken Wires - Shaded region accounted for in Surface Wire calc's above - should be all zero's

			1		2		3		4		5		6		7		8									
Est. Depth	Ring	No.	0.125		0.125		0.125		0.125		0.125		0.125		0.125		0.125		$0.5n_ja_j$							
(in)	No.	Wires	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	1	2	3	4	5	6	7	8
0.091	1	196	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.274	2	191	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.457	3	185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.640	4	179	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.823	5	174	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.006	6	168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.189	7	163	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.372	8	157	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.555	9	151	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.738	10	146	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.921	11	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.104	12	135	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.286	13	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.469	14	123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.652	15	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.835	16	112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.018	17	107	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.201	18	101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.384	19	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.567	20	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.750	21	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.933	22	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.116	23	73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.298	24	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.481	25	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.664	26	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.847	27	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.030	28	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.213	29	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.396	30	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.579	31	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.762	32	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.945	33	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.128	34	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.311	35	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.493	36	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		3534.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		USF	0.50		0.50		0.50		0.50		0.50		0.50		0.50		0.50									
		USF n_{bm}																	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

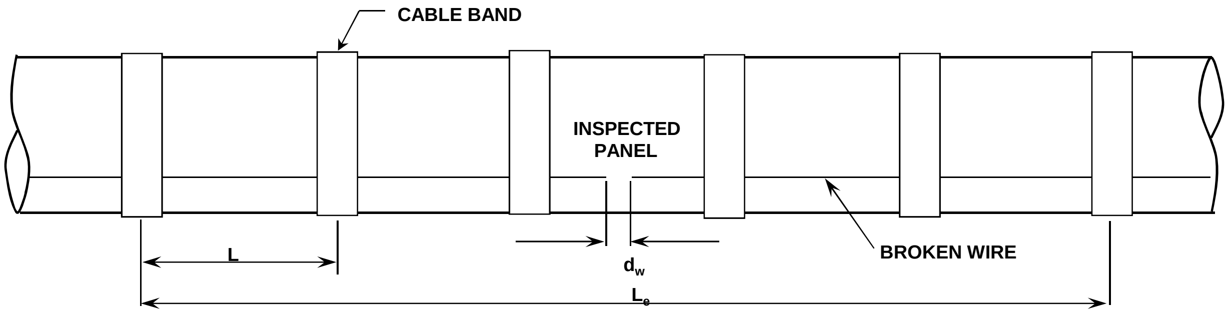
0.0

0.0

This sheet is used to :

Calculate the Development Coefficient and Redevelopement length
Determine the number of broken wires in the effective development length
Calculate the number of cracked wires in the effective development length and fraction of wires in each group
Calculate the cable strength - 3 models are considered:

1. Simplified Strength model - neglects cracked and redeveloped wires - used only where fraction of cracked wires < 10%
2. Brittle Wire Model - based on strength properties of sampled wires
3. Limited Ductility Model - based on strain properties of sampled wires



Total wires in cable =	3534			T =	1.66	kips	wire tension at Service
L :	19.9599	ft.	wire length between bands	wire stress =	57	ksi	at service
Cable Service Force :	5,874	kips		d_w :	0.484	in	average broken wire gap
E :	28500	ksi					
a_w :	0.0290	in^2	wire area				

Calculate Development Coefficient and Redevelopment Length

4.5 Wire Redevelopment

μ_{s2} =	210	ksi	Group 2 sample mean tensile strength
d_e =	0.482	in	elastic def. over L due to T
N_T =	1		number of panels in which wire tension < T - service force in wire
N_B =	4		number of bands to redevelop wire - at stress of $0.95\mu_{s2}$
L_e =	7		effective development length
C_d =	0.250	min	redevelopment coefficient
	0.333	max	
F =	1.445	kips - min	Force developed at each cable band
	1.927	kips - max	

Determine Number of Broken Wires in Development Length

n_{bi} =	0	number of broken wires in panel
n_{ri} :	0	number of repaired wires in panel
N_b =	0	number of broken wires over development length, = n_{bi} x L_e
N_r =	0	number of repaired wires over development length, = n_{ri}
N_b - N_r =	0	

Calculate Number of Cracked Wires in Development Length and Fraction of Wires in each Group

Number of wires at each corrosion stage

N_{s1}	N_{s2}	N_{s3}	N_{s4}
37	2179	985	334

Group	N_{0k}	$p_{c,k}$	$N_{c,k}/N_{0k}$	cracked $N_{c,k}$	$N_{cr,k}/N_{0k}$	redeveloped $N_{cr,k}$	N_k	p_k
2	2215		0	0	0	0	2215	0.63
3	985	0.000	0.000	0	0.000	0	985	0.28
4	334	0.333	0.939	313	0.231	77	20	0.01
5							313	0.09
N_{eff} =	3534				N_{cr} =	77	3534	1.00

where :

N_{0k} = Number of unbroken stage k wires in the evaluated panel - Eq. 5.3.2.3-1 through Eq. 5.3.2.3-6

$p_{c,k}$ = Fraction of stage k wires that are cracked

$N_{c,k}/N_{0k}$ = Fraction of discrete cracked wires in the effective development length - $\Sigma p_{c,k}(1-p_{c,k})^{i-1}$ or from Figure 5.3.2.4.1-1

$N_{c,k}$ = Number of discrete cracked wires in the effective development length

$N_{cr,k}/N_{0k}$ = Fraction of redeveloped cracked wires that break - $\Sigma C_{Di} p_{c,k}(1-p_{c,k})^{i-1}$ or from Figure 5.3.2.4.2-1

$N_{cr,k}$ = Effective number of stage k broken cracked wires that can be redeveloped

N_k = Number of Group k wires in evaluated panel

p_k = Fraction of unbroken wires in the evaluated panel

Summary of Wire Test Results (see Spreadsheet "WirePropsTyp")

Ultimate Stress

Group	μ_{sk}	σ_{sk}	μ^2	$\sigma^2+\mu^2$	m (α)	ν (β)
2	210	13.54	44,160	44,343	19.22	216.08
3	193	22.65	37,103	37,616	10.24	202.27
4	196	17.52	38,437	38,744	13.67	203.64
5	199	12.79	39,661	39,824	19.28	204.76

Calculate Cable Strength

5.3.3.1 Simplified Strength Model

Applied to cables with very few (<10% of total) cracked wires
Based on the Brittle Wire Model, with cracked and broken wires reduced accordingly
Strength may be underestimated by up to 20%
Useful for locating controlling location

Percentage of cracked wires = 9%

			p_{uk}
μ_s =	205	2	0.688
σ_s =	18.72	3	0.306
Coeff of Var, σ_s/μ_s =	0.0915	4	0.00632

N_{eff} - N_5 = 3221 a_w = 0.0290 in^2

R = 15,117 kips K : 0.792 from Figure 5.3.3.1.2-1

5.3.3.2 Brittle Wire Model

Used where > 10% of wires are cracked.
Assumes all wires have the same stress-strain diagram

cable stress, s = 177.3 ksi
Use solver to solve for s that maximizes T

Group	p_k	$F3_k(s)$	$p_kF3_k(s)$	failed	remaining	Force
2	0.627	0.0221	0.01384	49	2167	11,121 kips
3	0.279	0.2283	0.06364	225	760	3,901 kips
4	0.006	0.1396	0.00080	3	18	90 kips
5	0.089	0.0603	0.00535	19	294	1,511 kips
		$F_C(s)$ =	0.08363	296	3238	16,623 kips

$F3_k(s)$ = Weibull cumulative distribution of ultimate stress of Group k wires - fraction of Group k wires that have failed
$F_C(s)$ = Compound cumulative distribution of the tensile strength

			wires	
Force in unbroken wires	T_u =	5.13 kips/wire x	3238 ($N_{eff}(1-F_C(s))$)	16,623 kips
Force in redeveloped cracked wires that break	T_{cr} =	5.78 ($0.95\mu_{s2}a_w$)	5 ($N_{cr}F3_5(s)$)	27 kips
Force in redeveloped broken wires	R_b =	5.78	0 ($n_{bi}0.5(L_e-1)$)	- kips
Total Cable Force	T =			16,650 kips

s	T	failed	%
50	5,116	0	0%
100	10,230	1	0%
125	12,764	7	0%
150	15,140	48	1%
160	15,932	96	3%
170	16,496	185	5%
180	16,624	351	10%
190	15,930	655	19%
200	13,795	1188	34%
215	7,085	2462	70%
230	1,138	3430	97%
235	610	3510	99%