INTRODUCTION:

360° had been retain to measure and/or characterize meaningful changes of electrical resistance of two supplied pipe samples as outlined below:

- Measuring the electrical resistance of the outer surface of a pipe
- Drill a small hole in a pipe surface and measure the electrical resistance of the outer surface of the pipe
- Increase the size of the hole in one direction (transverse to the pipe) to see the meaningful change in the electrical resistance of the pipe[1]
- Report the smallest size of the hole where meaningful change is observed.

For this purpose, two lengths of pipe approximately 12" long x 4.5" in diameter were supplied. Measurements were obtained by first attaching band electrodes to each pipe end to which the leads of an Agilent 4263B LCR meter were attached. The initial hole drilled in each pipe was 5mm, increasing in 5mm increments to 20mm; subsequent 20mm holes were drilled 15mm center-to-center either transversely or longitudinal to the pipe for a ~ 3" spread first to last.[2]

Figure 1: Test Configuration

[1] "For another pipe sample, please repeat the procedure just the hole orientation would be longitudinal to the pipe this time."

[2] "Please ensure the size of the drill bit is from 1 mm size with 0.5 mm diameter incremental till you see significant resistance measurement differences. Since the value would fluctuate, please ensure three readings per hole size are done with an average and st. dev. reported." UPDATED per call of ..., drill sizes: 5, 10, 15, 20 mm with 3-4" separation.

Findings:

Hole	R (KΩ)	R (KΩ)	R (KΩ)	Avg Ω	Std Dev
none	1.1953	1.1948	1.1944	1194.83	1.150
5mm	1.2457	1.2461	1.2464	1246.07	0.351
10mm	1.3227	1.3032	1.2756	1300.50	23.666
15mm	1.2352	1.2337	1.2328	1233.90	1.212
20mm	1.1956	1.1948	1.1944	1194.93	0.611
#2	1.4741	1.4299	1.3857	1429.90	44.200
#3	1.3386	1.3356	1.3309	1335.03	3.881
#4	1.3918	1.3851	1.3762	1384.37	7.826
#5	1.4465	1.4453	1.4442	1445.33	1.150

Table 1: Transverse resistance measurements

Hole	R (KΩ)	R (KΩ)	R (KΩ)	Avg Ω	Std Dev
none	1.4427	1.4420	1.4418	1442.17	0.473
5mm	1.4577	1.4575	1.4569	1457.37	0.416
10mm	1.4495	1.4486	1.4478	1448.63	0.850
15mm	1.4285	1.4251	1.4212	1424.93	3.653
20mm	1.4282	1.4247	1.4210	1424.63	3.600
#2	1.3981	1.3962	1.3939	1396.07	2.103
#3	1.3861	1.3849	1.3838	1384.93	1.150
#4	1.3728	1.3719	1.3712	1371.97	0.802
#5	1.3599	1.3593	1.3574	1358.87	1.305

Table 2: Longitudinal resistance measurements

Figure 2: Longitudinally drilled pipe

Figure 3: Transversely drilled pipe

The pipes' resistance exhibited some instability; typically, trending downward gradually over time (< 50Ω / day), with occasional abrupt upward changes while at rest (of up to 300Ω that could persist for hours).[3,4]

[3] Agilent 4263B: 0.1% basic accuracy, 100 Hz - 100 kHz test frequencies, high-speed: measurement (25 ms) & contact check. [4] A lab reference resistor of similar value was subsequently put in the test circuit and did not exhibit similar instability.