Instrumentation

John Dunnicliff

Introduction

This is the twentieth episode of GIN. That means five years of trying to create something worthwhile for this 'column'. When I started, Helmut Bock, then President of Interfels in Germany, said "you will find it very hard to keep going, like the ticking of a clock"! Still ticking, but I need contributions from 'you out there'. If you think that GIN is worthwhile, please help me out by sending a contribution to the column, or an article. If you're thinking about an article, let me know, and I'll send you ground rules.

The following article, by Clairmont et al, was born on the 'optional fourth day' during the 1997 instrumentation course in Florida (see below). James Clairmont made a clear presentation of methods for lightning protection, something which I had never understood and which I had considered to be a black art. I asked for a written follow-up, and here it is.

Instrumentation Course in Florida

The next instrumentation course at Cocoa Beach, Florida will be on November 1-3, 1999, with an optional fourth day on November 4. Details are on page 36 of this issue of *Geotechnical News.* Come and join us on the beach.

Fifth International Symposium on Field Measurements in Geomechanics (FMGM - 99)

The symposium will be on December 1-3, 1999 in Singapore. Previous FMGMs, which are held every four years, have been in Zurich, Switzerland (1983), Kobe, Japan (1987), Oslo, Norway (1991) and Bergamo, Italy (1995), and have become established as the primary venues for those of us who work with geotechnical instrumentation. There will be the following sessions:

- New technology and developments in field measurements
- Management of instrumentation in geomechanics
- Deep and shallow foundations
- Deep excavations and retaining wall structures
- Soil and rock slopes, and dams
- Underground openings and tunneling
- Geo-environmental instrumentation
- Geosynthetics performance instrumentation
- Large-scale construction projects
- Land reclamation and related works

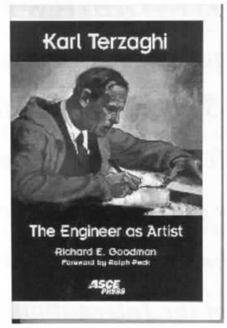
There will also be 'special lectures' by five invited speakers, and a half-day workshop on the afternoon of the day before the symposium. The available time during the workshop will be used in an interactive format, rather than for 'lecturing'. Attendees will select the workshop topics by democratic vote from a list prepared by the workshop leader and, if there is an adequate consensus, topics requested by an individual attendee will be discussed. This is an attempt to provide an alternative to the standard format of formal presentations, in the hope that it will lead to worthwhile interchanges of opinions and experiences which will 'continue in the bar afterwards'!

For more information, please contact the symposium Secretary, Harry Tan, e-mail cvetansa@nus.edu.sg or visit the symposium web-site http://www.eng.nus.edu.sg/civil/Conference/fmgm99.

Karl Terzaghi. The Engineer as Artist

Reviews of this wonderful new book by Dick Goodman are on pages 40 and 41. I started to read the book 'because I felt I should', but very soon found it hard to put down. It is a mammoth achievement.

Artist yes, but also philosopher and psychologist. In addition to all the recounting of engineering issues, the book tells about Terzaghi's numerous views



and suggestions 'about life and living' (this is the title of a 1923 lecture, but there is very much more here than quotations from the lecture). These parts of the book appealed to me even more than the parts about engineering, and were the ones that I read and re-read. Here is one example, after Terzaghi had given a lecture at Robert College in 1920 on 'religion, science, and life':

> *This talk must have particularly pleased President [of Robert College] Gates who later told Terzaghi that "without God's help such an institution as Robert College could not exist." Karl confessed his opinion of that attitude years later: "The continuous personal intervention of God in the lives and fates of us lowly parasites populating a third-class planet of His Universe gets decidedly on my nerves...[It is] unbearably arrogant." [Pages 89/90].*

There are numerous gems of this ilk. How many of us who have reviewed publications would love to write, as Terzaghi did when reviewing a publication by Bureau of Reclamation engineers?:

> *The only method I can think of for ameliorating the faults would be to change the author.*
> *[Page 231].*

Depending on your personal interests, experiences, and knowledge of the characters in the tale, I'm certain that all of you will find content that appeals especially to you. For me, having experienced both very comfortable and very uncomfortable interactions with Arthur Casagrande in the late 1960s, the many insights into his relationship with Terzaghi shed light on the makeup of A.C. How many of you know that A.C. "had been a violin prodigy as a child" [page 104]?

Remembering that this is supposed to be a 'column' about instrumentation, what is there in the book about that subject? Few specifics, but of course frequent mention of observations and monitoring as an essential part of the design/construct process. But the following description of lab tests made in 1917 to determine the horizontal pressure at a given depth below the surface of a layer of sand is fascinating:

> *Terzaghi fashioned a thick-walled box from wood and filled it with sand in a reproducible manner to a certain density...To obtain the horizontal pressure without modern measuring equipment required ingenuity. Between one of the walls and the sand fill, Terzaghi placed three flat steel strips covered with paper. One of these strips was rigged to a string so that it could be pulled across the wall; the string was affixed to the laboratory balance in such a way that its tension could be measured. An indicator was provided to reveal the onset of relative motion between the sand and the steel strip. By pulling on the string he could cause the steel strip to slip past the sand. The tensile force in the string is required to pull the strip past the sand because of friction between the two, and, at the moment of initial slip between the sand and the strip, the tension force equals the maximum friction force between the sand and the wall. The normal force of the sand on the wall could therefore be calculated by introducing the known friction coefficient. Terzaghi succeeded in independently measuring the friction coefficient. Thus, he was able to establish the horizontal pressure of sand against a wall at any depth. [Page 65].*

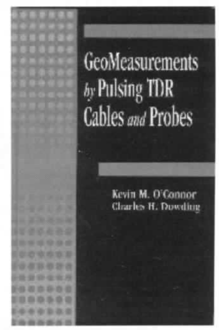
Today we would use miniature earth pressure cells to make such measurements in the lab. But in the field we have great difficulty in making adequately accurate measurements with earth pressure cells if the they are at locations where temperature changes, such as on the inside face of a thin retaining wall. Hydraulic earth pressure cells are very temperature sensitive, and we can't calibrate for this and apply a correction because the relationship between temperature change and change in cell reading depends on the boundary conditions at each individual cell — the less compressible the backfill, the more the temperature sensitivity (*Geotechnical News, Vol.15, No. 1, June 1997, page 42*). Next time that I have a need to make such measurements, perhaps I will use the diaphragm type of earth pressure cell (red book page 166), or perhaps Terzaghi's 1917 method will be the way to go. If the latter, that's quite remarkable, isn't it — no improvements in 82 years!

I have only one complaint about this extraordinary book, but I'm sure this is the responsibility of the ASCE Press rather than the author. There are numerous 'notes', which give very worthwhile background color commentary. But instead of appearing as footnotes on the appropriate page, they are at the back of the book, grouped by chapter number. You're happily reading, come across a superscript that indicates the existence of a note, you want to read it — you first have to turn back to find which chapter number you're reading, then turn to the back to find the note, read the note, and by then you've probably lost your place in the chapter. So perhaps you give up reading the notes! The solution — one of those little yellow stickers on the page of the last note read. But, in my view, footnotes would have been better.

New Book on Time Domain Reflectometry

The June 1996 issue of *Geotechnical News* (page 37) included an article by Kevin O'Connor of GeoTDR, Inc., *Geotechnical, Environmental and Infrastructure Applications of Metallic Time Domain Reflectometry.*

TDR is a technique developed by the telephone industry for locating cable breaks, and has been enhanced for use in the mining industry to determine locations of roof falls. TDR technology is now available for monitoring deformation in soil and rock (both axial and shear deformation) by grouting a coaxial cable in a borehole, water levels in a borehole, contaminant transport, and volumetric water content.



A new book, written by Kevin O'Connor of GeoTDR Inc. and Chuck Dowding of Northwestern University is now available from CRC Press, titled *GeoMeasurements by Pulsing TDR Cables and Probes.* (See inside back cover, this issue)

The book provides comprehensive guidance for practitioners who are interested in this exciting new technology. It begins with basic physics, and includes chapters on monitoring:

- Soil moisture
- Localized deformation in rock
- Soil deformation
- Structural deformation
- Air-liquid interfaces (such as the water level in open standpipe piezometers).

These chapters include ample information on field applications and installation considerations. The book concludes with chapters on electronics and software. There are several useful appendices, notably one providing practical guidelines on grouting TDR cables in boreholes, and another with a list of vendors of cable and other needed equipment.

This is undoubtedly a useful book, written for practitioners by practitioners.

ASCE Reprints Corps of Engineers Manual

The US Army Corps of Engineers engineering and design manual EM 1110-2-1908, dated 30 June 1995, *Instrumentation of Embankment Dams and Levees*, has recently been reprinted by ASCE and is available from ASCE Press, 1801 Alexander Bell Drive, Reston, VA 20191-4400. ASCE's web-site is http://www.asce.org.

The manual is divided into the following nine chapters:

1. Introduction
2. Behavior of embankments and abutments
3. Basic concepts and design aspect of instrumentation
4. Summary of measurement methods
5. Automation considerations
6. Installation
7. Data management and analysis
8. Instrument maintenance
9. Continual reassessment for long-term monitoring

To match current trends, the manual focuses on existing dams and levees, and retrofitting existing instrumentation for long-term monitoring, whereas its predecessors focussed primarily on new dams. This is a very worthwhile document.

Change of Address

My new address is:
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For those of you on the other side of 'the pond' who don't know about leats (and they're not in Bill Gates's dictionary), a leat is Devon-speak for a stream.

Please send material for GIN to me by e-mail (as an attachment in ms-word please), or by fax.

Yam sing (the orient)

Lightning Protection and Shielding for Geotechnical Instruments and Data Acquisition Systems

James Clairmont, Martin Dupuis, Pierre Choquet and Romuald Budin

Introduction

The increased use of data acquisition systems to read, store and transfer data from geotechnical instruments raises the importance of discussing lightning protection and shielding issues. The reason is that a network scheme comprising instruments connected to one or more data acquisition systems is more prone to be affected by disturbances than a series of instruments taken individually.

Lightning is of course a natural phenomenon which cannot be avoided. Its effect is to generate electrical surges called transients, which can be as high as thousands of volts. Therefore, lightning strikes are the cause, and transients created by lightning strikes are what we want to be protected against.

Transient protection and shielding are two aspects that share the same goal: protection against external disturbances. For instance, surge arrestors are used to protect the instrument from being damaged due to massive surge current and high intensity electromagnetic fields. Shielding methods are used to protect the measurement signal coming from the instrument from being altered or distorted due to electrical or electromagnetic field.

The Importance of Grounding

Transient protection and shielding are intimately joined by a common point: grounding. Grounding is the ultimate consideration that needs to be carefully implemented and studied to make sure that lightning protection and shielding are efficient. Sophisticated transient and surge protection devices combined with a poor grounding system will be useless. Let's give a simple definition of ground: this is a conducting path intentional or accidental between an electric circuit or equipment and the earth.

Today's electronic devices are highly integrated and dielectric breakdown voltages within and between components are quite low, protection against lightning is becoming more and more important. There are three ways of minimizing the chances of lightning problems:

- Using proper type of electrical cable as per manufacturers recommendations, good quality connections compatible with environmental conditions of installation and normal care required by the nature of geotechnical instrumentation.
- Adequate temporary protection, implying that procedures described in this article must be implemented progressively in instrument installation, as soon as it becomes possible to use them. The worst practice would be to wait until all instruments are installed to start grounding and shielding the instruments.

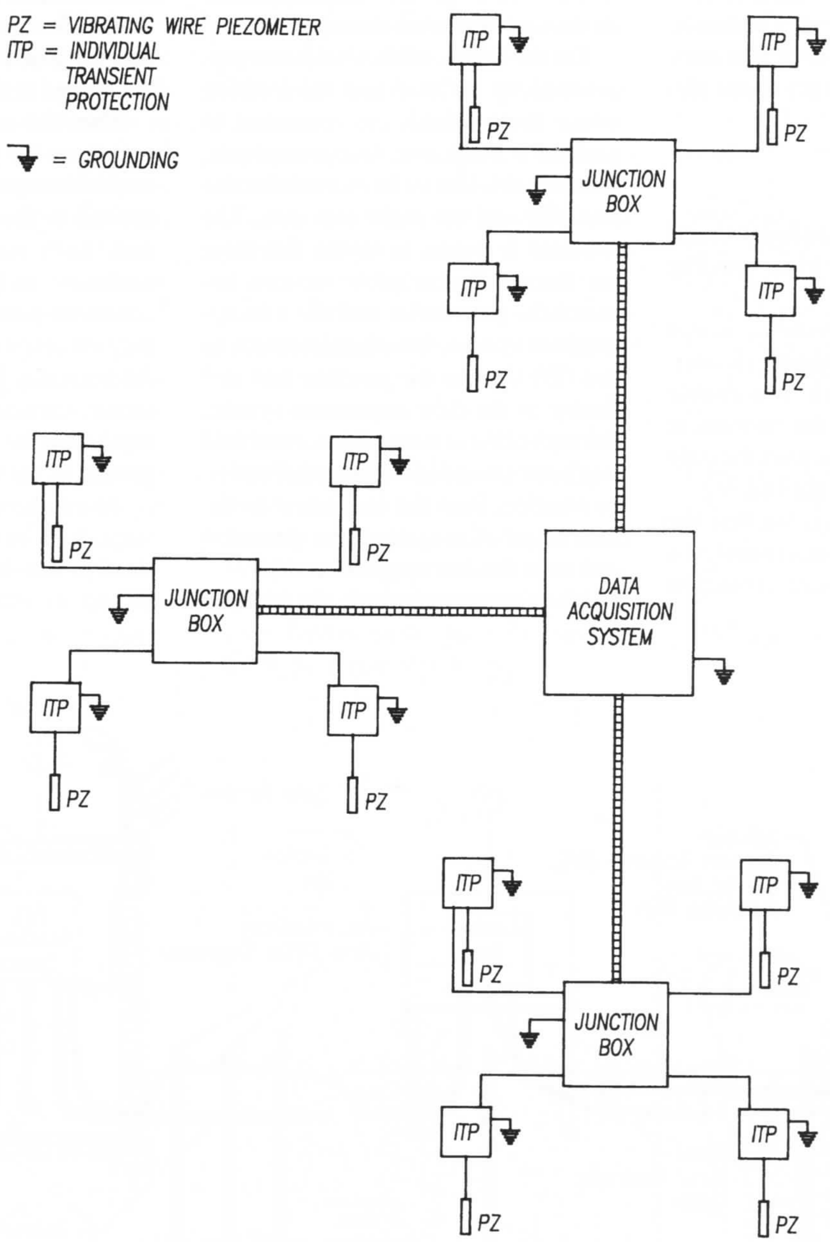

Figure: Example of plan view of a series of piezometers connected to a field data acquisition system.

- Using appropriate grounding, shielding and surge protection devices, which is the scope of the present article.

Let's take the example of a field situation where a number of piezometers are to be connected to a data acquisition system.

In order to minimize the cable quantities, we can use junction boxes to which the individual piezometers are connected, and which are then linked to the data acquisition system by a multi-conductor cable.

Such a situation is illustrated in Figure 1. On this figure, individual transient protections (ITP) and grounding locations are shown.

Figure 2 illustrates a cross-section of the same layout, with more details of the different grounding points.

Grounding involves the use of grounding rods as shown on the figure. These rods are installed at each borehole collar where ITPs are located, at the junction boxes and at the data acquisition system.

Although ITPs are occasionally omitted in some instrumentation layouts, the authors believe that they are very important. ITPs should be located on the ground surface and should be as close to borehole collars as possible, since lightning surcharges travel at the ground surface and not at depth.

Grounding rods should be a minimum of 3 meters long. As can be seen on Figure 2, it is good practice to use up to three rods at important locations, such as the data acquisition system, to provide a good ground network. Obviously, the soil resistivity is a factor that must be taken into account in the above recommendations.

The Final Protection: Shielding

Figure 3 illustrates the detailed path and components of the complete grounding and shielding points.

Starting from the piezometer, we can see that it normally incorporates its own transient protection, such as a double gas tube connected to the instrument housing. Note that at this level the only ground path available is the housing.

Coming to the surface, we find the ITP which normally incorporates a minimum of two transient protection levels, such as gas tube and suppressor diode, and very often three levels.

On the figure, cable shields are represented by an oval and the location where these shields are connected to grounds is illustrated. As a general rule, the cable shield must be grounded at one end only and not at the two ends. The situation is similar to saying that there are three different cable sections between the piezometer and the data acquisition system: from the piezometer to the ITP, then to the junction box and finally to the data acquisition system. For each of these three cables, one shield end is not grounded and the other end is. In practice, from the instrument to the data acquisition system, the grounded end is on the data acquisition side.

The next component is the junction box in which it can be seen that the shields from cables between the ITPs and the junction box are connected to the ground at the junction box.

Then the multiconductor cable that runs from the junction box to the data acquisition system is also shielded to the ground at the data acquisition system end. Such multiconductor cable has preferably an individual shield for each conductor pair and an overall shield and they are all grounded to the same point. Additionally, if the cable has a metallic armor, central or overall, this armor must also be connected to the same ground as the other shields.

As can be seen on the figure, multistage transient protection is incorporated in the data acquisition system to protect its entries from transients that

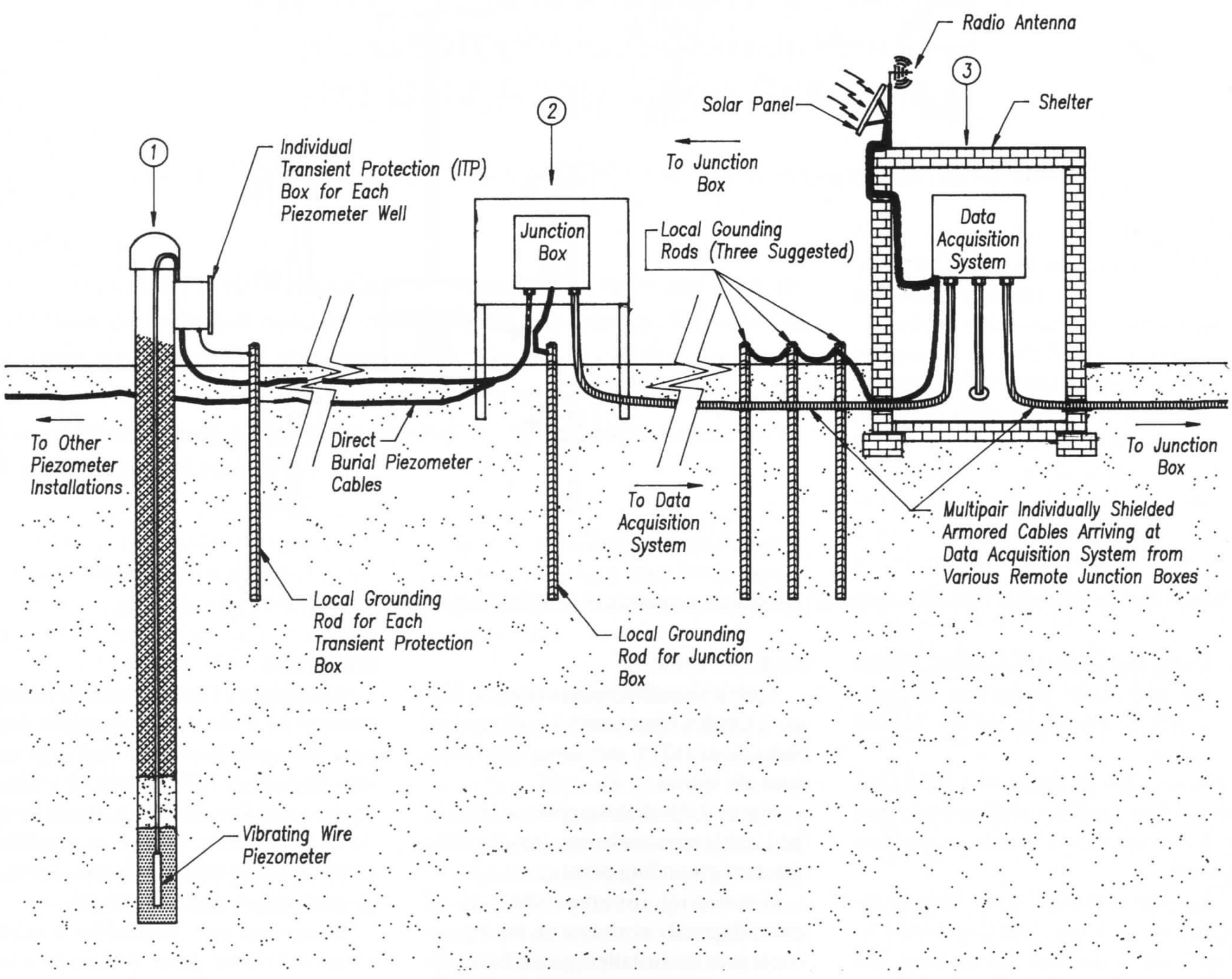

Figure 2: Sectional view of the same installation as in Figure 1

would come along the connection cables.

Finally, a few last recommendations:

- It is also essential to use a good quality cable to connect instruments to the data acquisition system. Good quality refers to mechanical and electrical characteristics of the cable, such as waterproof overall jacket, armoring and individual or overall shielding of electrical conductors.
- Radio links should also be adequately protected using standard RF (radio frequency) surge protections.
- Whenever AC power is used for the data acquisition system or for any instrument or accessory, AC arrestors should be used.
- Solar power equipment should also be grounded.
- If a phone line is used, it also requires adequate protection.

Conclusion

Lightning protection cannot be treated as a general recipe. The authors recognize that each site and each instrumentation scheme require adaptation to the general rules presented in this article. It is believed that the various procedures detailed in this article correspond to sound engineering practice. It should, however, be recognized that no lightning protection can guarantee 100% effectiveness due to unknown and large scale effects of lightning in close vicinity of an instrumentation site. This observation explains, incidentally, the strong interest in novel fiber-optic sensors which hold the promise of being completely immune to lightning and other interferences. Such sensors have been recently introduced to the market and will certainly be adapted and find applications in the field of geotechnical instrumentation in the foreseeable future.

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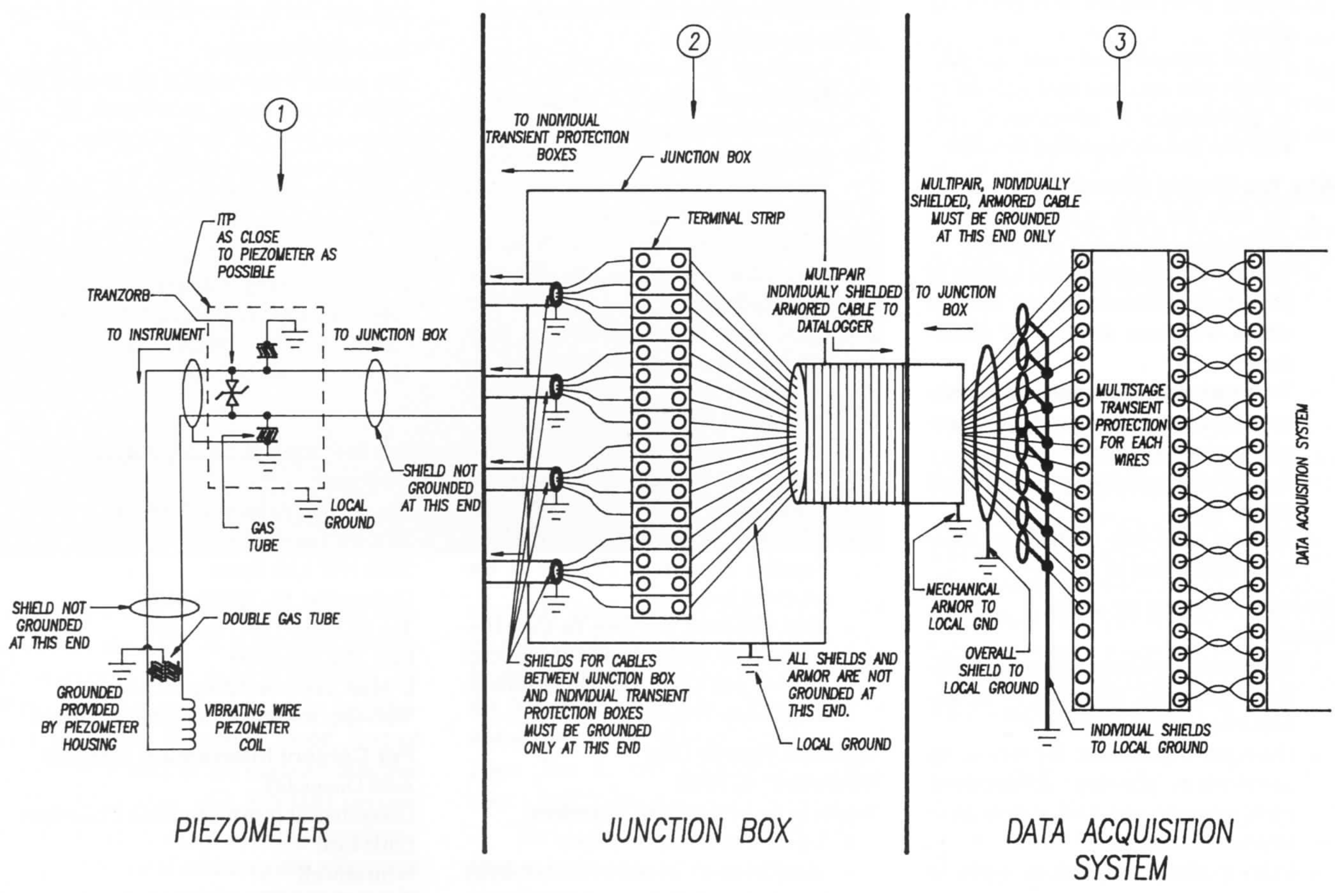

Figure 3: Example of detailed path and components of the complete grounding and shielding points, at locations 1, 2 and 3, shown in Figure 2