Air Pollution Grant:

**Nitrogen Dioxide Determination in Air via the Palmes Diffusion Tube Method** -
An air pollution monitoring kit for schools and colleges

D.B. Short

**Nitrogen Dioxide:** Nitrogen dioxide (NO\textsubscript{2}) is one of a group of highly reactive gases known as "oxides of nitrogen," or "nitrogen oxides (NOx)." Other nitrogen oxides include nitrous acid and nitric acid. While EPA’s National Ambient Air Quality Standard covers this entire group of NOx, NO\textsubscript{2} is the component of greatest interest and the indicator for the larger group of nitrogen oxides. NO\textsubscript{2} forms quickly from emissions from cars, trucks and buses, power plants, and off-road equipment. In addition to contributing to the formation of ground-level ozone, and fine particle pollution, NO\textsubscript{2} is linked with a number of adverse effects on the respiratory system. (From EPAs web site)

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Summary

Nitrogen dioxide (NO₂) is a pollutant gas which is measured routinely by state and local agencies. Continuous measurement requires the use of an approximately $15,000 electrical chemiluminescent analyzer which is usually located at one fixed site. NO₂ concentrations may be determined much more cost effectively and at many more locations with a more portable and simpler chemical method. The passive diffusion tube method described here is a much more cost effective way to introduce students to the study of atmospheric science. The procedure is a wet chemical spectroscopic based technique used extensively in Europe but is used less frequently in the United States.

We propose this project to introduce high school students to the science of air pollution monitoring. The project seeks to outfit schools with the materials and methods to measure the concentration of NO₂ in the atmosphere. It is the objective of this project that the beneficiaries will develop a more comprehensive understanding of surrounding local air quality issues.
Environmental Effects of Nitrogen Dioxide

Nitrogen Dioxide (NO₂) is a reddish-brown gas that belongs to a family of highly reactive gases called nitrogen oxides (NOₓ). These gases form primarily when fuel is burned at high temperatures, and come principally from motor vehicle exhaust and other anthropogenic combustion sources. NO₂ plays a major role in the atmospheric reactions that produce ground-level ozone or smog [1]. NO₂ is also a strong oxidizing agent that reacts in the atmosphere to form nitric acid, a key component of acid rain/deposition [2]. In addition to these negative effects on our atmosphere, the amounts of NO₂ that are being produced today can have dire consequences on human respiratory health and so they must be monitored to ensure safe living conditions.

Perhaps the most important environmental issue resulting from NO₂ is photochemical smog. Smog itself is simply airborne pollution which may obscure vision and cause various health conditions. It is caused by the man-made emission of reactive gases which become concentrated in the air for a variety of reasons. Photochemical smog is a unique type of air pollution which is caused by reactions between sunlight and pollutants like hydrocarbons and nitrogen dioxide [3]. Photochemical smog forms through a series of chemical reactions among compounds in the atmosphere. When nitric oxide (NO), a component of the exhaust from cars and power plants, enters the atmosphere, it reacts with oxygen to produce NO₂. The sun's UV rays can break nitrogen dioxide down. This process initiates other chemical reactions that lead to the formation of low-level ozone (O₃) [4]. Ozone's presence at the ground level poses a serious health risk. Although photochemical smog is often invisible, it can be extremely harmful, leading to irritations of the respiratory tract and eyes.

Another problem associated with elevated levels of NO₂ in the atmosphere is Acid deposition. Acid deposition (can be wet or dry), is formed primarily from sulfur oxides (SOₓ) and NOₓ reacting with water in the atmosphere to form sulfuric acid and nitric acid, it's two major components. When the newly acidified precipitation reaches the ground it can have several negative effects on the local biosphere. Perhaps one of the better known effects is acidification, a condition in which lakes and streams have a low pH level due to the acid deposition, resulting in the death of fish and other animal and plant life that cannot survive in the new conditions. Soils are also affected by acid deposition, particularly in areas with highly siliceous bedrock (granite, gneisses, quartzite, and quartz sandstone) that is already slightly acidic. When acid deposition occurs on acidic soils, important cations including potassium, calcium, magnesium, and sodium are readily leached out, making them unavailable to plants as nutrients. This phenomenon, termed soil depletion, reduces the fertility of the soil. Similarly, in areas with old, highly leached soils, acid deposition depletes the small amounts of cations present, and the soil soon becomes unable to support plant life.
The elevated levels of NO$_2$ in our atmosphere and environment has led to some major human health concerns. First and foremost are the health effects associated with breathing ground level ozone caused by photochemical smog. Studies have shown that O$_3$ can cause negative pulmonary function responses and alterations in lung function and breathing patterns of otherwise healthy test subjects [5]. These effects are compounded when suffering from a multitude of other respiratory issues (i.e., asthma, COPD, etc.). Similar health problems exist when dealing with NO$_2$ alone. For instance, "studies have shown that bronchitic symptoms of asthmatic children increase in association with annual NO$_2$ concentration, and that reduced lung function growth in children is linked to elevated NO$_2$ concentrations within communities already at current North American and European urban ambient air levels" [6].
Past Measurements of NO$_2$ in Pittsburgh and the Surrounding Area

The US EPAs National Ambient Air Quality Standard for NO$_2$ is an annual mean value of 53 ppb and all areas meet this standard. Currently, the annual average NO$_2$ concentrations range from 10 - 20 ppb [7]. NO$_2$ does fluctuate throughout the day and can reach levels as high as 70 ppb. Data for EPA’s State and Local Monitoring Stations (SLAM) network is collected from a number of continuous chemiluminescent monitors throughout the country. Chemiluminescence is a chemical technique which measures the intensity of light emission from a reaction between NO with ozone generated by an instrument:

\[
O_3 + NO \rightarrow NO_2^* + O_2
\]

\[
NO_2^* \rightarrow NO_2 + h\nu \quad \text{(emission from 590 to 2800 nm)}
\]

The concentration of the light emitting species is proportional to the emitted infrared light intensity and proportional to the precursors. NO$_2$ is calculated as the difference between the concentrations of NOx and NO.

Measurements are currently made a several locations in Allegheny county: The Pennsylvania Department of Environmental Protection (PADEP) site is located at Carnegie Science Center (CSC), the Allegheny County Health Department (ACHD) sites are located in Lawrenceville (LV) and Harrison Township (considered a rural site for comparison).

Additional sites are the EPA’s State and Local Monitoring Stations (SLAMS) at:

- 39th Street Pittsburgh (1966-present)
- Beaver Falls (1974-present)
- Greensburg (1994-present)
- Newcastle (1974-present)
- Washington County (1965-present)
Air Pollution Grant

National Measurements

EPA reports national average levels of NO\textsubscript{2} as shown in *Fig. 1*. National levels of NO\textsubscript{2} have been in decline since measurements were first taken.

![Fig. 1: National trend in atmospheric NO\textsubscript{2}.](image)

Regional Measurements

The PADEP continuously monitors 13 air basins in the commonwealth including Allegheny County. The PADEP’s monitors show the trend in annual mean NO\textsubscript{2} concentrations statewide between 1997 and 2006 to have fallen from 17 ppb to 12 ppb representing a 29% decrease. All areas of PA were reported below the air quality standard of 53 ppb [7] (*Fig. 2*).

![Fig. 2: Statewide trend in atmospheric NO\textsubscript{2} from 1997 to 2006 [1].](image)
Local Measurements

ACHD has provided data for 2005-2010 at CSC to the authors. Typical data are shown in Fig. 3 and 4 below. Monthly and daily means are consistently below the 53 ppb standard however daily maxima do frequently exceed this level. The reader is reminded that they are looking at one sampling site which may or may not be representative of the entire area. This limitation is a direct result of the fixed location method the regulatory agencies chose to monitor the pollutant. Using the PDT technique a wider variety of measurements would be able to be taken. It is expected that a much larger PDT monitoring network would be able to identify NO$_2$ hot spots not previously accounted for. PDT measurements can be tested for accuracy by validation studies (concurrent checks) against chemiluminescent monitor values. Most studies have shown that variations in values obtained from a PDT and a chemiluminescence analyzer are less than 10 percent [8], this makes PDTs a useful tool for use in large-scale remote air pollution studies.

**Fig. 3:** Monthly maximum (diamonds) and daily means (squares) for that day, NO$_2$ measurements at CSC in 2005.

**Fig. 4:** Daily mean NO$_2$ values for CSC in 2005.
The Palmes Method

An alternative to the instantaneous measurements achieved by chemiluminescence based gas analyzers is a time-weighted average gas concentration achieved using a wet chemical technique. Palmes Diffusion Tubes (PDTs) [9] are routinely used by air pollution monitoring networks world-wide in place of the more expensive chemiluminescent technique. PDTs operate on the principle of gas absorption with the amount of gas absorbed measured using visible spectroscopy. A recent review of PDTs has been published by Varshney et al. [8]. PDTs have a range between 30 – 300 ppb [10], a temporal resolution of between 2-4 weeks [11] and a precision of about 10 % [12].

What is a Palmes Diffusion Tube?

PDTs consist of 4 pieces including (i) a tube, typically 71 mm in length, (ii) a cap, (iii) mesh screens which hold the absorbent chemical, and (iv) a plug (Fig. 5)

Fig. 5: Original drawing of Palmes tube from Atkins (1986) [13], and Shooter (1993) [14].

The PDT shown above is manufactured by several companies. For example Drager (USA) sells the tubes for $50 a piece in batches of 5, Gradko international sells them for $9.50 a piece. We have chosen to manufacture our own tubes (Fig. 6) in order to reduce the price of the piece to less than $1.
Fig. 6: Dimensions of PDT.
Mounting PDTs

PDTs must be mounted outside clear from obstruction. Mounting points are usually located above 7 feet so as to not be easily reachable. A proposed PDT tri-holder is shown in Fig. 7.

Fig. 7: PDT tri-holder. This device mounts 2 sample diffusion tubes and one field blank to a post using cable ties.
NO₂ Determination Kit Contents

The NO₂ determination kit we propose consists of 12 Palmes diffusion tubes (10 measurement tubes and 2 blanks), a tube holder, the chemical regents necessary for measuring the concentration of NO₂, and a spectrophotometer. All prices are subject to change.

1. Palmes diffusion tubes (PDTs)

The kit contains a total of 12 tubes, 12 caps, 12 plugs, and 36 screens. Both the tubing and the screens were purchased from smallparts.com. The tubing is made of white translucent nylon and the screens are comprised of a stainless steel mesh. The caps were purchased from McMaster-Carr and are made of a hard, rigid plastic called polyethylene. The plugs are also made of polyethylene and were purchased from Lake Charles Manufacturing. Prior to the ordering of materials, we extensively researched the various types of plastic materials that could be used for the tubing. In addition, we experimented with different types of caps and plugs to ensure that the end pieces fit tightly so that the diffusion tubes will not be affected by ambient NO₂ during storage. Prototypes diffusion tubes were constructed and field tested during November of 2011. Each kit will contain 12 caps, 12 plugs, 36 screens, and 12 tubes. The total cost for these parts included in the kit is $4.80.

<table>
<thead>
<tr>
<th>PDT (set of 12)</th>
<th>Cat. No.</th>
<th>Price $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cap (x12)</td>
<td>9567K19</td>
<td>0.60</td>
</tr>
<tr>
<td>Plug (X12)</td>
<td>90A3</td>
<td>0.36</td>
</tr>
<tr>
<td>Screen (x36)</td>
<td>B000FN0PX4</td>
<td>2.28</td>
</tr>
<tr>
<td>Tube (includes price to cut each tube) (x12)</td>
<td>B001GMJFK2</td>
<td>1.56</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>4.80</td>
</tr>
</tbody>
</table>
2. Palmes diffusion tube holder

The PDT tri-holder was modeled in Solid Works, a 3-D computer aided design program. The tri-holder was then printed by a 3-D stereolithography machine in order to use as a sample prototype (Fig. 8, 9). This piece of equipment will be produced by Shapeways at a cost of $52.86 per holder.

<table>
<thead>
<tr>
<th>PDT Holder</th>
<th>Price $</th>
</tr>
</thead>
<tbody>
<tr>
<td>To mount 3 tubes (as shown in Fig. 8, 9)</td>
<td>52.86</td>
</tr>
</tbody>
</table>

*Fig. 8: 3-D model of tri-holder parts.*
Fig. 9: Finalized 3-D model of tri-holder (one arm installed).
The following chemicals are required for analysis of the PDTs: N-(1-Naphthyl)ethylenediamine (2HCl) (NEDD), ortho-phosphoric acid, sulfanilamide, sodium nitrite, and triethanolamine (TEA). Full Material Safety Data Sheets (MSDS) will be included.

All prices from Fisher Scientific except TEA from Cole Palmer.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Amount</th>
<th>Cat. No.</th>
<th>Price $</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEDD</td>
<td>0.14 g/0.005 oz</td>
<td>AC20690-0250</td>
<td>0.46</td>
</tr>
<tr>
<td>o-phosphoric acid (Certified ACS)</td>
<td>50 mL/2 oz</td>
<td>A242-4</td>
<td>3.01</td>
</tr>
<tr>
<td>Sulfanilamide (Acros)</td>
<td>20 g/0.7 oz</td>
<td>AC13285-0025</td>
<td>3.10</td>
</tr>
<tr>
<td>Sodium Nitrite (Certified ACS)</td>
<td>1.2 g/0.042 oz</td>
<td>S347-3</td>
<td>0.23</td>
</tr>
<tr>
<td>Triethanolamine (TEA)</td>
<td>10 mL/3 oz</td>
<td>EW-88141-80</td>
<td>0.75</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td></td>
<td>7.55</td>
</tr>
</tbody>
</table>
4. Container list and price
All containers were chosen from midwestbottles.com and will be color coded using red and white bottle caps (Fig. 10).

<table>
<thead>
<tr>
<th>Container</th>
<th>Cat. No.</th>
<th>Price $</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2 Oz plastic bottle for NEDD</td>
<td>Pbwhset.2 (inc. cap)</td>
<td>0.15</td>
</tr>
<tr>
<td>2 Oz black plastic bottle for Phosphoric acid</td>
<td>pbnatrdset.67 red cap</td>
<td>0.18</td>
</tr>
<tr>
<td>1 Oz plastic bottle for Sulfanilamide</td>
<td>pbrdbnmset1-c (inc. cap)</td>
<td>0.20</td>
</tr>
<tr>
<td>0.2 Oz plastic bottle for Sodium Nitrite</td>
<td>pbnatrdset.67 green cap</td>
<td>0.18</td>
</tr>
<tr>
<td>3 Oz plastic amber or black bottle for Triethanolamine (TEA)</td>
<td>pbnatrdset.67 green cap</td>
<td>0.18</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>0.89</td>
</tr>
</tbody>
</table>

*Fig. 10: Containers.*
5. Glassware

All prices from Fisher Scientific, P = plastic, G = glass.

<table>
<thead>
<tr>
<th>Glassware</th>
<th>Price $ (Glass)</th>
<th>Price $ (Plastic)</th>
<th>Cat. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volumetric flask, 1 L x</td>
<td>73</td>
<td>132</td>
<td>10-210-636-P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10-198-52G-G</td>
</tr>
<tr>
<td>Volumetric flask, 100 mL x 6</td>
<td>182</td>
<td>136</td>
<td>10-199D-G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0-210-633-P</td>
</tr>
<tr>
<td>Beaker, 100 mL</td>
<td>3</td>
<td>3</td>
<td>S306942</td>
</tr>
<tr>
<td>Graduated cylinder, 25 mL x 5</td>
<td>50</td>
<td>80</td>
<td>S00038-G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0300739-P</td>
</tr>
<tr>
<td>Totals</td>
<td>308</td>
<td>351</td>
<td></td>
</tr>
</tbody>
</table>

6. Spectrophotometer information

The spectrophotometer chosen for this kit is the Vernier SpectroVis Plus current price $449 (Fig. 11). This device was chosen through extensive research for a device that can measure at the required 540 nm wavelength required to analyze the PDTs. It was selected because it is currently the cheapest and only spectrometer available.

The device will be a useful tool for high school educators, either supplementing their existing equipment or becoming their first exposure to environmental analysis.

Fig. 11: Vernier SpectroVis Plus spectrophotometer.
7. Packaging
We have selected the following hard plastic injection molded carrying case (*Fig. 12*) for the complete kit which includes items 1 – 5 above. The case will have custom cut foam interior to house each component for shipping and a custom made adhesive sticker bearing the kit's name. A second case would be required for glassware.

*Fig. 12*: PDT kit carrying case.
A mock-up of the interior is shown below *Fig. 13*:

*Fig. 13*: PDT kit carrying case. Red = phosphoric acid, yellow = sodium nitrite, green = NEDD (small), TEA, sulfanilamide (organics). Lower right is a space for cuvets, far right is a space for the SpectroVis cable.

A mock-up of the cases insert containing the tri-holders is shown below in *Fig. 14*.

*Fig. 14*: PDT kit case insert.
A mock-up of the cases label is shown below in Fig. 15.

Fig. 15: PDT kit case label (sample only).
## Total Cost

Table of itemized costs:

<table>
<thead>
<tr>
<th>Component</th>
<th>Price $</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDTs x 12</td>
<td>4.80</td>
</tr>
<tr>
<td>Tri-holder for each kit</td>
<td>50.24</td>
</tr>
<tr>
<td>Chemicals for one analysis</td>
<td>7.55</td>
</tr>
<tr>
<td>Containers for one analysis</td>
<td>0.89</td>
</tr>
<tr>
<td>Glassware/plasticware</td>
<td>350</td>
</tr>
<tr>
<td>Spectrometer</td>
<td>449</td>
</tr>
<tr>
<td>Carrying case, foam insert and labels x 2</td>
<td>50</td>
</tr>
</tbody>
</table>

The total price of the kit is $ 912.58 +/- 137 (+/- 15 % to account for price increases). With replaceable chemicals priced at $ 8.44 for each analysis.

PDT kits will be assembled by students at RMU under the supervision of qualified faculty members. Diffusion tubes will be cut by the Engineering lab assistant and students on work study assignment.
NO$_2$ Determination Calculations

Detailed explanation of how to calculate the NO$_2$ concentration using the PDT technique is expected to be beyond the comfort zone of a high school student. We will employ a NO$_2$ calculator which will take the analytical result from the spectroscopic analysis and convert it into a concentration of NO$_2$ in air.

Calculations are shown below in spreadsheet form (Fig. 16), an internet web page based calculator or cell phone application will be written. Development of this tool is expected to cost around $1000. Spreadsheet Converter is a tool that can be licensed for $217 (Fig. 17), the remainder of the funds will be applied to smart phone app development.

![Fig. 16: PDT tube calculations using Microsoft excel.](image-url)
Palmes Diffusion Tubes (PDT)
Source: modified from Shooter (1993)

DATA:
- Molar mass NO₂ = 46.01 g/mol
- NO₂ concentration absorbed on TEA = 0.500 ppm
- Exposure time (hrs) = 642 hrs
- Diffusion coefficient for NO₂ = 8.154 cm² s⁻¹
- Outer Radius of tube = 0.55 cm
- Length of tube = 7.1 cm
- Outer Volume (SATP) = 24.0 L

CALCULATION:
- \( Q = \frac{0.5 \times (C_C - C_p) \times \text{m}^3 \times t}{1} \) (if TEA absorb all NO₂ then \( C_p = 0 \))
- \( Q = \frac{0.5 \times (0.154 \times C \times 0.95)}{1 \times 7.1} \) (note)
- \( Q = \frac{74.206186 \times \text{cm}^3 \times t}{1} \) (after changing time to hours)

In 1 hr a Palmes diffusion tube of these dimensions samples 74.2 cm³ of air. The TEA absorbs NO₂ to the following volume \( V_{NO₂} \) over an exposure period. Note: the number changes if the radius and length changes.

\[ V = \frac{74.206186 \times \text{cm}^3 \times t}{47640.37} = 47640.37 \times \text{cm}^3 \]

equal to the volume of air diffused through PDT over the sampling period.

No. moles (N) in Palmes Diffusion tube is calculated from the concentration absorbed on TEA:

\[ N = \frac{0.5 \times 0.5 \times 1}{} \text{mg L}^{-1} \times 1 \text{g} \times 0.0001 \text{mol g}^{-1} \]

\[ = \frac{0.00001 \text{mol L}^{-1} \times 0.0042 \text{L}}{} = 4.564225 \times \text{mol} \]

This number of moles of absorbed nitrate was distributed in the volume \( V \) of gas sampled as NO₂, so the concentration in the atmosphere is \( \frac{4.564225}{47640.37} \times \frac{46.01}{1000} \times 0.0001 \text{mg cm}^{-3} \)

This can be converted to ppm by multiplying by molar mass (g/mol), multiplying by 1600 mg/g and multiplying by \( 10^6 \) cm³/m³.

\[ \left( \frac{4.564225}{47640.37} \times \frac{46.01}{1000} \times 0.0001 \right) \times 1600 \times 10^6 = 0.0441 \text{ mg cm}^{-3} \]

Now convert mg/cm³ into ppm NO₂ in air using conversion equation (SATP):

\[ \frac{0.0441 \text{ mg cm}^{-3} \times 24.0}{48 \text{ g cm}^{-3}} = 0.0226 \text{ ppm} \]

Since 1 ppm = 1000 ppm

Fig. 17: PDT tube calculations converted to html format (web based) via Spreadsheet Converter.
Chemiluminescent Analyzer as a Validation Check Against PDTs

A chemiluminescent continuous NO\textsubscript{2} analyzer from Teledyne (Fig. 18) would be used to check the reliability of the PDT time-weighted technique. This device would form the basis for ensuring high quality PDT measurements since PDT derived data could be compared against this device. The monitor would be also be used as a teaching tool to show students the type of technology commonly used by state and federal agencies.

The monitor represents the major portion of this grant and is an essential component for ensuring the quality of the data collected by the stake holders.

Fig. 18: Chemiluminescent continuous NO\textsubscript{2} analyzer from Teledyne.
Workshops and Educational Outreach

RMU has been conducting Summer Camps, for middle and high school students since 2007. During that time, over 280 students have been educated on subjects including Animatronics, Engineering, Forensics, Legos NXT & Robotics, CSI, Art & Science, Effects of Pollution in Ecology and Wildlife. Camps generally run for 3-5 days, from 9am-4pm, students are given daily meals from Parkhurst dining.

We would like to conduct 4 day workshops with both students and teachers designed to give them an introduction to air pollution measurements, the NO\textsubscript{2} diffusion tube measurement method and spectroscopic analysis. The associated costs of the workshop are as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Price $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructor Salary</td>
<td>400</td>
</tr>
<tr>
<td>Food, 4 days x 15 people</td>
<td>500</td>
</tr>
<tr>
<td>Printing</td>
<td>100</td>
</tr>
<tr>
<td>Safety Goggles</td>
<td>225</td>
</tr>
<tr>
<td>Total Educational Expenses</td>
<td>1225</td>
</tr>
</tbody>
</table>
Total Grant Monies Asked for

The total cost of ten PDT kits, the software development, chemiluminescent analyzer and educational workshops is outlined in the table below.

<table>
<thead>
<tr>
<th>Component</th>
<th>Price $</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDT kit x 10</td>
<td>9,150</td>
</tr>
<tr>
<td>Cost for web calculator/Android/iOS development</td>
<td>1,000</td>
</tr>
<tr>
<td>Chemiluminescent analyzer for PDT Validation</td>
<td>15,263</td>
</tr>
<tr>
<td>Grant money to fund workshops for teachers and students</td>
<td>1,225</td>
</tr>
<tr>
<td>Totals</td>
<td>26,638</td>
</tr>
</tbody>
</table>

Goals and Sponsorship

The goals of this project are thus as follows:

- To introduce high school students to the study of atmospheric pollutant gases.
- To promote the Palmes method to a wider scientific audience.
- To showcase methods of precise quantitative spectroscopic analysis.
- To measure NO$_2$ in a wide variety of locations in order to assess the occurrence of hotspots in the area.
- To promote awareness of Pittsburgh’s air quality issues in the local community.

We are seeking sponsorship of the monitoring kit from Fisher Scientific, Vernier, and the Pittsburgh Spectroscopic Society.

The total grant monies asked for is therefore $26,708. We hope to have included all of the relevant information in this document. Should you require more information than has been provided please contact the authors at the included address. We thank you in advance for your consideration of this project.
References


*Thanks to Dr. Paul Badger, Dr. Tony Kerzman, Richard Spaulding, Jonathon Krepps, Megan Geiseler (Environmental Science) and Robert Saltsgiver (Engineering) for their help in preparing this grant.*
# Appendix

1. Teledyne Quote

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<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>DESCRIPTION</th>
<th>LIST PRICE</th>
<th>EXTENDED PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Air Pollution, Multimodular, Monochromatic Analyzer</td>
<td>$15,956.00</td>
<td>$15,926.00</td>
</tr>
</tbody>
</table>

**CUSTOMER NEEDS TO SPECIFY:**
- Speed Range: 3   
- Optional: Speed Range 2  
- 200 ppm, 10 ppm, NO2, NO, CO  
- Panel  

**MOUNTING:**
- 30A: Rack Mount for TDIQ with Chassis 120"  
- 31B: Rack Mount for TDIQ with Chassis 120"  
- 31A: Rack Mount for TDIQ with Chassis 80"  
- 29: Carrying Handle  

**GENERAL:**
- 47: 150 mA output (Either available: NO, NO2, CO, or CO2)  
- 48: Carrying Case Kit for one-year operation: Analyzer  
- 49: Operation/Supplemental Test Kit, One Year Operation  
- 50: Air Pollution, Multimodular, Monochromatic Analyzer (Emission DH Certificate)  

**OPTIONAL CALIBRATION:**
- 50A: Ambient Zero and Ambient Span  

**NOx TUBES:**
- 50B: NOx Tube, NOx, Universal, 10 mm ID, 100 cm  
- 50C: NOx Tube, NO, Universal, 10 mm ID, 100 cm  

**COMBINATION:**
- 50D: 50B + 50C  
- 50E: 50B + 50C  

**MISCELLANEOUS:**
- 50F: Additional Manual  
- 50G: Carrying Case Extension, Warranty  

**TOTAL PRICE:**
- $15,956.00