***Let's Take A Peek at PEAC-WMD v.5** - by S. Bruce King*

History of AristaTek - Part I

Frequently the AristaTek staff is asked about our background and past experience. There is a description or history of the companys past experience posted on our web site (http://www.aristatek.com/history.aspx), but I felt it might be beneficial and informative to the readers of the newsletter to fill in that history with some additional details. In addition, I wanted to provide some insight into the owners background and past experience so the readers can understand why our perspective of hazardous materials might be different than other developers of software applications or even the readers perspective.

The inventors of PEAC-WMD program, as founders of AristaTek, have hands-on experience with all types of hazardous materials! This is illustrated by the following history of some of that experience developing real-data under real conditions in the field. This is why the PEAC-WMD tools have the most accurate and calibrated databases extant. The PEAC-WMD system is more accurate than other systems because of the inventors experiences of how to differentiate between real data and copied data from non-validated sources. They spent years consulting the Public Safety experts and first responders in the fire services in local communities and industrial hazardous material teams to consolidate the PEAC systems features.

The owners/founders of the company are David Sheesley, John Nordin, Thayne Routh , and Bruce King (the author). Our academic training is as follows:

David Sheesley - BS in Physics and Chemistry
John Nordin - PhD in Chemical Engineering and a Licensed Professional Engineer
Thayne Routh - BS in Electrical Engineering and Computer Science
Bruce King - MS in Chemistry and BS in Computer Science

Owners/Founders Backgrounds

David is mentioned first because he was the original Program Manager of the technical staff while all four of us were employees of the University of Wyoming Research Corporation (UWRC), d/b/a/ Western Research Institute (WRI) which is located in Laramie , WY . His background experience includes working in many areas, much of which relates to atmospheric studies, such as:

1. As a physicist at Dow Chemical Co., working at Rocky Flats Nuclear Weapons Plant, Golden, CO, where processing, purifying, machining and preparing plutonium for the manufacture of pits was performed, the key component of what became known as triggers for nuclear weapons. The plant also manufactured other weapons parts using uranium, beryllium, stainless steel and other materials.
2. National Center for Atmospheric Research (NCAR), Boulder , CO . This involved a number of different projects such as researching the formation of condensation nuclei in the tropics and the jungles of Panama and Brazil on projects for the US Army. The major part of his work was in Atmospheric Chemistry involving the validation of model inputs used to predict long-range transport of natural and man-made material dispersion.
3. Lockheed Martin as Program Manager for an Environmental Protection Agency (EPA) contract, Las Vegas , NV . His tenure included several projects studying atmospheric

dispersion at different locations around the nation for the purpose of calibrating and validating models.

4. Program Manager for U.S. Department of Energy (DOE) Oil Shale Environmental Research Program during the hay days of oil shale research in Colorado , Wyoming and Utah at the Laramie Energy Technology Center in Laramie , WY .
5. Program Manager for the Hazardous Chemicals Research Group at the UWRC, Laramie , WY performing the Public Safety projects for emergency response.

John Nordin is our resident expert on most everything having to do with hazardous materials. His background experience includes working in many areas:

1. Before becoming a co-owner of AristaTek, he was employed as research engineer with UWRC during 1986-1999, Mason and Hanger Engineers from 1979-1986, and senior project engineer with Betz Converse Murdock from 1971-1978. He was also the engineer on a water desalination demonstration project for a several year period after obtaining his PhD degree at the University of Minnesota .
2. One major project with UWRC other than chemical spill-related work was developing and testing of a gasifier for garbage, and incinerator for medical waste funded by a private client, which was later constructed as a demonstration project in Alaska . Other projects were related to environmental problems associated with energy extraction, a consultant at the Vertec Incineration Superfund Cleanup site in Arkansas , and consultant on an environmental cleanup project at a government facility in Idaho .
3. While with Mason and Hanger Engineering, he was consulting engineer for U.S. Army Corps of Engineers projects on incineration of explosive-contaminated soils and arsenic- and pesticide-contaminated soils. He performed on-site assessments of hazardous chemical contamination at seven army depots and weapons manufacturing facilities and an expansion of nitric acid production facilities at Radford Army Ammunition Plant.
4. He has sampled PCB-contaminated soils and sediments in Waukegan Harbor superfund site under contract with the EPA.
5. He has written computer software for mass/energy balances for TNT thick liquor recovery plant and for incineration processes. He has consulted on red water and chemical weapons disposal. He also developed methodology for feedstock preparation for a U.S. EPA mobile incinerator.
6. He consulted on oil spill release studies at the EPA test facility, Leonardo , NJ .
7. As Senior Project Engineer with Betz Converse Murdock, he worked directly with over 100 industrial clients solving a wide variety of environmental problems.
8. He was the lead scientist and POC for UWRC with EPA and industrial participants during the Kit Fox field experiments conducted at the HAZMAT Spill Center on the Nevada Test Site.
9. He was the co-developer of the basis for the proprietary vapor dispersion model used in the PEAC software application.
10. He oversees the day-to-day maintenance and update activities of the PEAC database used in the PEAC-WMD software application.

Thayne Routh is our in-house software expert and oversees all the software development activities AristaTek undertakes:

1. Thayne provided computer support to administrative and technical groups at the UWRC. Projects included

    a. A project management information system, accessible from both a PC and a VAX.
    b. An interface code for a thermo hydraulics simulation program.
    c. A kernel database system to facilitate the rapid development of new database systems.
    d. A Windows mail program that permits the easy transfer of files and memos across a network.
2. He designed software, data acquisition design and fabrication, selection of hardware and equipment, and operations of the integrated systems used in the UWRC field research program conducted at the HAZMAT Spill Center on the Nevada Test Site.
3. He has developed and supported custom designed software for the acquisition and subsequent analysis of commercial cable TV network systems to allow optimum upgrading and repair of cable systems.
4. He was the co-developer of the basis for the proprietary vapor dispersion model used in the PEAC software application. He developed the original PEAC software application and database implementation on the Apple Newton MessagePad platform using the Newton script programming language.
5. He developed the original and subsequent PEAC software application and database implementations for the Windows and Windows Pocket PC operating systems, using the C++ programming language. And he monitors and co-ordinates all the upgrades as improved data bases are developed through rigorous quality control procedures.

Bruce King (the author) uses his chemistry and programming background to coordinate the activities of the AristaTek staff. His background includes:

1. He was a research scientist for US Bureau of Mines and US DOE providing chemistry, software programming and management support for a series of underground coal gasification (UCG) field experiments conducted at Hanna , WY during the 1970s and he analyzed all the components of this hydrocarbon extraction process.
2. He was the UCG consultant during the 1980s for an engineering consulting company located in Laramie , WY .
3. Starting in the late 1980s and till 1999, he was a research scientist for the UWRC. Activities included supporting bench scale demonstration projects in oil shale, coal and heavy oil projects together with the characterization and analysis of all production and by-products.
4. He was the Test Director for the Kit Fox Series field experiments conducted at the HAZMAT Spill Center on the Nevada Test Site working with the industry and government experts to develop the data acquisition and daily operational protocols.
5. He assisted in the development of the original PEAC database and the subsequent updates to the PEAC database. As the Chief Operating Officer of AristaTek, he directs all the technical and operational activities.

All of the owners have been trained in OSHA Hazwoper classes, and were outfitted up to Level A in order to conduct hands-on hazardous materials projects outlined above. These technical backgrounds and combined experience illustrate the fundament knowledge and experience the owners/founders of AristaTek have used to invent, produce and maintain the patented PEAC-WMD systems. This brings a unique perspective to the solutions of decision support for the problems and issues associated with hazardous chemicals and their behavior when released from storage and transport containers. The following description of the UWRC field experiments conducted by this team provides additional perspective to show how the PEAC systems development is unique for Public Safety research and first response.

Team Research Experience

As owners/founders of AristaTek and former employees of the UWRC, the history of the facility and its staff is traced back to when it was established in 1940 to investigate heavy oil petroleum resources. In the 1960s it became a U.S. Bureau of Mines research facility for continued research in heavy petroleum resources and also the lead USA federal laboratory for shale oil research. In the early 1970s the facility started research programs in tar sands resource recovery and underground coal gasification development. With the 1973 oil embargo and rising energy prices during the 1970s, it was a key research facility in developing oil from unconventional sources. In 1978 it became a U.S. Department of Energy Fossil Energy (DOE-FE) research facility called the Laramie Energy Technology Center .

In 1983, it was de-federalized and became part of the University of Wyoming also located in Laramie , as the University of Wyoming Research Corporation. When the so-called oil glut arrived in the mid 1980s, the federal funding of energy research decreased and Wyomings Congressional delegation suggested WRI address other research programs that would have more opportunity for funding from the federal government.

To completely relate how that happened I would like to relate the following story. One position that David Sheesley held in the newly formed UWRC in 1983 was the Director of Marketing for research project development. UWRC had most of its expertise in energy extraction from unconventional oil resources, also known as synthetic fuels, and the associated health and safety development that must be developed for new products. At that time, the lone Congressman for Wyoming , Richard Cheney, was visiting UWRC and came into Davids office. The crux of the conversation was that energy research was going to be reduced because energy prices were much lower than in the late 70's. David was asked, if UWRC cant continue to receive funding for National energy extraction research, what other types of expertise does UWRC have that could be useful to the Nation. The answer was public safety, since UWRC had extensive experience in assessing and developing the necessary safety and health considerations to deal with new by-products in oil production. David explained that UWRC staffs past experience dealing with the environmental and safety problems associated with energy extraction was valuable experience in understanding hazardous chemicals from any source.

The United States Congress decided the Nation would use this Wyoming resource and research projects were included in the 1986 Superfund and Reauthorization Act (SARA)[1]; specifically Section 118(n), that outlined a DOE funded research program to investigate and develop new hazardous chemical technology and develop a technology transfer program for the private and public sectors. Beginning in 1987, the field projects included in this program were conducted in Laramie , Wyoming and at the Liquefied Gaseous Fuels Spill Test Facility (LGFSTF) located on Frenchman Flat at the Nevada Test Site, the LGFSTF is now known as the DOE HAZMAT Spill Center or HSC within the DOE NNSA.

For those not familiar with the Nevada Test Site or the HSC, the diagram in Figure 1 provides the reader with a perspective of where the projects I will be describing were performed. The Frenchman Flat location was the site of some of the early 1950s nuclear surface detonations. The HSC site is now used for different projects, e.g., work performed by DTRA (Defense Threat Reduction Agency), the national laboratories and used for the Department of Homeland Securitys radiation training course at the Nevada Test Site.

One of the first projects under the SARA program that the founders as UWRC employees conducted was an investigation of 123 hazardous material accidents and report on their cause and the resulting response actions taken by those in charge. This report (Nordin, 1989)[2] found some similarities between these accidents. One specific observation was that the responders had used essentially no prediction tools to develop emergency evacuation zones or consider what portion of the public was at risk. At a number of these incidents, responders didnt have appropriate tools available and those that did, didnt have properly trained individuals on duty that could operate the software technology.

To address national chemical spill concerns not being met by the SARA implementation, Congress also decided to implement more research in the 1990 Clean Air Act Amendments (CAAA) that dealt with upcoming regulations that were to be imposed on industry in the late 1990s and the predictions of toxic vapor clouds during worst case conditions. The upcoming regulations were the Risk Management Plan (RMP) regulations to be imposed on industry. It required industrial facilities, which had threshold quantities of certain toxic chemicals, to develop a response plan in coordination with local Public Safety officials for the emergency response to catastrophic release of those chemicals.

Part of the response plan was to deal with toxic vapor cloud dispersion during the worst case conditions. These worst case conditions are defined as stable conditions and are characterized by nighttime conditions when wind speeds are very low, less than 2 mph. Wyoming s UWRC was named in Sections 103(f) and 901(h) to conduct these additional research investigations. These investigations were conducted at the HSC and were to also assist in development of the data sets and modification of the existing toxic vapor cloud dispersion models to improve the technology and provide reliable prediction tools for those having to respond to or plan for accidental hazardous chemical releases. These activities were to be jointly funded and directed by the DOE and EPA.

A hazardous chemical problem might be what is different between worst case conditions and conditions that might occur during the daytime and when winds are considerably higher than 2 mph. Chemical vapor dispersion is a complex and involved subject but is essentially related to the amount of turbulence (mixing) exhibited by the atmospheric conditions. Primarily, the turbulence arises from two factors: (1) surface heating during the daytime causes rising air from the warm surface to create turbulence, and (2) horizontal air movement (wind) across a surface, particularly a surface with buildings, cars, vegetation, causes the air to tumble and create turbulence which affects dispersion of airborne chemicals. The lack of turbulence, from ground heating at nighttime and low winds speeds, reduces how fast a toxic vapor cloud disperses or mixes into the surrounding atmosphere, and the vapor cloud has a tendency to persist and be carried a longer distance downwind. The name worst case condition is used since the chemical vapor cloud doesnt disperse rapidly and individuals downwind are at risk of exposure to higher concentrations for longer distances.

The interesting fact is that in previous field research studies conducted before these experiments, there was only very limited information or datasets available for the mathematical modelers to compare their results against, i.e., validate their models. Most of the previous research and the resulting data sets had been created measuring vapor cloud dispersion in neutral conditions, i.e., daytime with wind speeds in excess of 10 mph. In addition, these field experiments had been conducted at sites that represented essentially very flat surfaces, so turbulence from wind tumbling over obstacles was limited and not as representative of the real world as would be desired.

The first field experiments were conducted in the summer of 1993 and were designed to demonstrate and investigate certain issues:

1. That dense gas behavior could be observed by releasing smaller volumes of a heavier-than-air simulate without having to resort to the large volumes used in earlier field experiments.
2. To characterize the HSC site with regards to the transition from neutral to stable atmospheric conditions that occurred at sun set. This was basically to measure the wind direction change, if any, as the conditions changed from >10 mph to < 2mph.
3. Test a suite of new real time gas sensors to ensure that the gas concentrations could be measured at 1-second intervals as the vapor cloud passed through the instrumentation arrays downwind.

The objectives in the 1993 experiments were achieved and design was started on the next series of experiments.

The dispersion investigations culminated in the Kit Fox Series and UWRC was funded by industry, [3] Department of Energy, and Environmental Protection Agency to include investigations of dense gas releases in both neutral and stable atmospheric conditions. Chemical releases across three different surface configurations (roughness), e.g., the surface configurations were to represent (1) very flat conditions with no obstacles to promote turbulence, which is the normal appearance of the HSC dry lake-bed, (2) moderate or medium sized obstacles that would represent crops or low vegetation, and (3) higher obstacles that would represent the buildings and superstructure you might find around a refinery or chemical facility.

A question the reader may ask is how do you simulate vegetation or even better yet, how do you simulate a refinery or industrial facility on a dry lakebed? The answer is we had the help and input of some very capable engineers and scientists that do a lot of work in wind tunnels. The technical advisory group was composed of some internationally recognized experts:

1. Dr. Gary Briggs, NOAA/EPA, Research Triangle Park , NC - Developer of the Briggs sigma coefficients for Gaussian dispersion.
2. Dr. Jerry Havens, University of Arkansas - Co-developer of DEGADIS (dense gas model used in EPAs ALOHA application).
3. Dr. Steve Hanna, James Madison University - Custodian of the American Petroleum Institute (API) HGSYSTEM and HEGADAS Model.
4. Dr. Rex Britter, Cambridge University - Co-developer of the Britter McQuaid Equations, one of the first sets of empirical formulations for predicting dense gas vapor dispersion.

The first task was to develop a grid of small rectangular flaps that would represent low vegetation that might be found around a refinery or chemical plant. Dr. William Snyder used the EPAs Atmospheric Research and Exposure Assessment Laboratory (wind tunnel) at Research Triangle Park , NC to do the initial iteration of the grid development. It this process, different sizes and spacing configurations of rectangular flaps were setup and air flow measurements were made to characterize the air flow and turbulence over the grid. The objective was to develop the size and spacing that would replicate the normal flow that has been measured in previous field experiments. Portions of the size and spacing measurement work was repeated and compared to the RTP results using a wind tunnel located at the University of Arkansas and operated by Dr. Jerry Havens[3].

The tasks to replicate the flow characteristics of a large-scale facility were done by UWRC through contracts with Cermak, Peterka and Petersen, Inc. (CPP) at the wind tunnel facility in Fort Collins , CO . The work involved taking a scale model (1:300) of an actual Exxon refinery and measuring the flow and turbulence across the scale model in the wind tunnel. Once the flow characteristics had been measured, Dr. Petersen and his staff used the technique of spacing larger rectangular flaps till they could replicate the same flow characteristics measured for the scale model (Figure 2).

The dispersion investigations culminated in the Kit Fox Series that was funded by industry, [4] Department of Energy, and Environmental Protection Agency. This was the first large scale field experiments (see Figure 3 below) conducted to understand dense gas behavior in worst case conditions (stable atmospheric conditions).

The fabrication of the test grid as shown above (Figure 3) and below in Figure 4, took a considerable amount of time and effort to install. The small rectangular flaps cover an area over 9 acres in size and amount to ~6,700 flaps. Each had to be properly spaced on the row and each row had to be separated properly and the flaps set in a straight line. The large flaps that represented the super structure of a facility was fabricated out of 2 sheets of 4 x 8 plywood attached to 2 square steel posts set in the dry lake-bed surface.

The tall pointed objects at the front of the test grid (Figure 4) are modified Irwin spires and are based on a technique used in wind tunnels to promote the initiation of turbulence. Without the spires at the front of the test grid, the test grid would have had to extend several hundred meters upwind. These spires helped to jump-start the turbulence that would have entered the test grid with several hundred meters of small flaps.

Figures 5 and 6 recorded some of then UWRC staff, now co-owners of AristaTek, as they installed different portions of the instrumentation and control systems used in the Kit Fox field experiments.

The project was a true collaboration of academic, industrial and governmental researchers coming together to achieve a common goal. The individuals identified in Figure 7 are just a fraction of the different participants involved in the project that attended the pre-test review.

As described earlier, the objective was to conduct dense gas releases across three different surface configurations during both daytime and nighttime conditions. One problem was that there was limited access to the test site and considerable time was involved in the installation of the rectangular flaps that represented different parts of the surface configurations. Doing the most complex surface configuration first, which included both large flaps and the 6,700 smaller flaps, solved this problem. Once these first series of releases were completed, the large flaps, as seen in Figure 4, were removed during a single morning and another series of releases were conducted over several days with just the small flaps in place. These small flaps represented a release where only vegetation was the surrounding type of obstacles and the amount of turbulence from wind motion was reduced.

The final surface configuration involved removing the 6,700 small flaps, which took about 3 days, compared to the 4+ weeks to install those flaps. Then the last series of releases were conducted where the surface was basically the dry lakebed, which is about as flat as a table top and twice as hard.

The testing involved using carbon dioxide as a surrogate dense gas, which was stored as a vapor in a set of large tanks constructed back in the 1980s for other experiments (Figure 8). These tanks were connected to the test grid via a 500 foot long 12 in line that dropped into an 8 in line that ran another 580 feet to the release point.

The release point was located underground in the center of the large flaps to simulate a ground level release inside the super structure of a refinery or chemical processing facility, Figure 9.

The instrument array consisted of 90+ gas concentration sensors positioned in four downwind arrays to measure the real-time concentration as the vapor cloud moved downwind from the release point. These sensors were subjected to a daily calibration procedure prior to each days releases, which in turn were used to develop the QA/QC data associated with the data reported at the end of the experiments.

An array of meteorological sensors was installed in and around the array to allow the characterization of the atmospheric conditions prior to and during each release that was performed. These meteorological sensors included the typical mechanical anemometers as shown in Figure 10 that provide wind direction and speed at multiple levels at specific locations, which were co-located with temperature sensors to measure the temperature profile at these locations. This information was used to characterize the atmospheric stability during each release.

In addition to the mechanical anemometers, a series of 3-axis (an example is shown in Figure 11) and 2-axis sonic anemometers were installed at multiple locations and levels. These sonic anemometers provided high-resolution measurements (100 reading/sec averaged to output 10 reading/sec) in the horizontal plane (2-axis units) but also in the vertical axis (3-axis units) to allow direct measurement of the turbulence within the test grid.

In addition to the meteorological instrumentation within the array, there was a 24-m tower adjacent to the array that allowed installation of instrumentation at 8 levels to fully characterize the atmospheric conditions during the experiments (Figure 12). This tower had additional instruments that recorded humidity, soil temperature, solar radiation, net solar radiation and barometric pressure.

The last element of the data acquisition system was the recording of measurements related to the release of the carbon dioxide vapor from the tank farm through the delivery system and eventual release in the test grid. This involved monitoring of pressures and temperatures at multiple points and also the remote control and positioning of different valves in the proper sequence to delivery the proper amount of vapor during a release. The flow rate measurements were done with two separate and independent systems to allow cross checking of results.

Testing consisted of multiple releases during a single day. This was a combination of short duration releases, approximately 20 seconds in duration, and what were called continuous releases, that lasted from 2-8 minutes in duration. Because the prevailing winds entering the test grid had a tendency to shift, a critical aspect of the testing was to monitor these ambient winds and start a release when the wind was lined up with the centerline of the test grid. This would provide the greatest cloud capture by the downwind instrumentation arrays as the cloud dispersed after being released. A large number of releases were performed with over 70 being captured almost entirely within the downwind instrument arrays.

After the field-testing was completed and the test grid dismantled, the data calibration and initial analysis was performed. This was a long and complicated process, which was delayed when the EPA temporarily terminated funding for the project at the end of September 1995. With considerable prodding and pleading, the funding was eventually restored and the two-volume data report was prepared and delivered to the industrial participants, DOE and EPA.

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[1] The 1986 SARA legislation that put Wyoming into the business of investigating hazardous chemical technology also created the State Emergency Response Commissions (SERCs) and the Local Emergency Planning Committees (LEPCs).

[2] Nordin, John, *Survey of 123 Toxic Chemical Release Accidents in the United States and Applicability to Future Development of Department of Energy Nevada Spill Test Facility Programs,* Contract DE-AC-0l-88FE61472, Western Research Institute, Laramie, WY, January 1989.

[3] Dr. Jerry Havens along with Dr. Tom Spicer are the researchers that maintain the DEGADIS vapor dispersion model. The DEGADIS model is the dense gas model used in the EPA/NOAA CAMEO Suite ALOHA vapor dispersion model.

[4] Petroleum Environmental Research Forum (PERF Project 93-16), which comprised the following ten companies: Allied Signal Corporation; Amoco Corporation; Chevron Research and Technology Co.; CITGO Petroleum Corporation; Clark Oil and Refining Co. ; Exxon Research and Engineering Co.; Marathon Corporation; Mobil Research and Development Co.; Phillips Petroleum Co.; and Shell Research and Development Co.