From the Grievousness of War:
The Transition from Ionization Detectors to Ion Mobility Spectrometers in Detection of Vapors In Ambient Atmospheres

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Summary

BACKGROUND AND CONTEXT

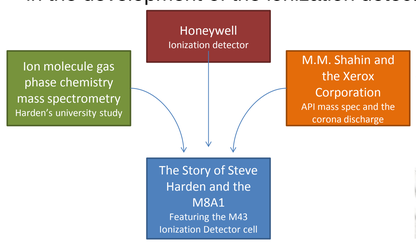
1964: the world of military strategy, weaponry, and defense changed when Egyptian aerial bombers deployed nerve agent-filled artillery against Yemeni royalists in the Yemen Civil War. This use of chemical weapons sparked international furor.

When attention turned to Israel three years later, in 1967, Egypt and its allies again threatened to use nerve agents. The 1965-67 Arab-Israeli conflict launched nerve agent chemical weapons out of the same category as atomic and nuclear weapons, as deterrents, into the category of regular artillery, weapons whose frequent use necessitated functional protection and detection.

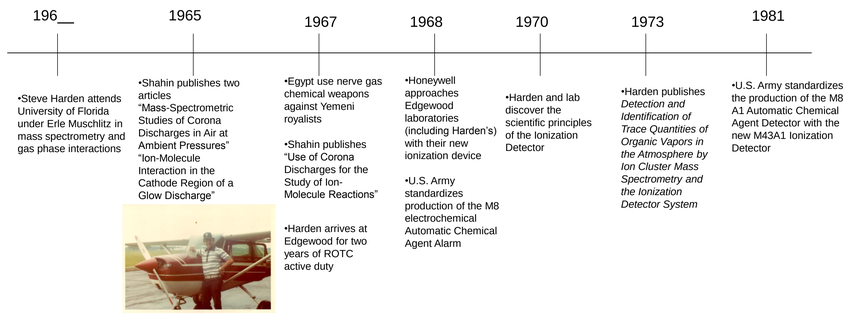
The Israeli Six Day War highlighted the US Army's lack of automated detectors and in response, a "wet" detector with potentiometric response to cyanide was developed rapidly and deployed as the M 8 Automatic Chemical Agent Detector.

Due to the M8's critical inefficiencies, another solution was constantly sought. Dry detectors based on gas phase ionization detectors arose and were explored through the overlap of ideas, personnel, and emerging scientific studies in otherwise unrelated fields. A central figure in this was Charles S. Harden, recently graduated with a PhD following dissertation studies in ion molecule reactions in mass spectrometry.

Others include M.M.Shahin, Glenn Spangler, David Blyth, Martin Cohen, F.W. Karasek, and allied companies including Graseby Dynamics, Ltd and Honeywell, Inc. Their efforts showed that ionization detectors were a bridging technology from wet to dry and that IMS was needed for improved specificity of detection. This poster focuses on the roles of Shahin, Honeywell, and Steve Harden in the development of the ionization detector.



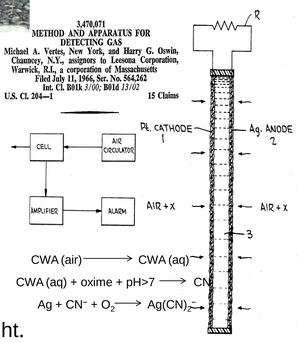
Timeline



The M8

Edgewood Arsenal, now Edgewood Chemical Biological Center, was a direct result of Germany developing chemical weapons in WWI. ECBC became the dominant American chemical weapons center, containing manufacturing plants, training schools, and laboratories probing and pushing the field of chemical weapon agent detection.

In 1964, development of a new method for chemical detection began at Edgewood. Finally abandoning dependence on color-producing chemical reactions, scientists harnessed electrochemistry.



Called the M8 Portable Automatic Chemical Agent Alarm, this new detector used electrochemical reactions to analyze substances. It was basically a large battery, but it was highly specific. However, the M8's weaknesses critically impeded its practicality for battlefield use. Sensitivity was limited due to the high concentrations of nerve agent needed to detect any change in the silver-cyanide solution, resulting in incorrect VX levels . But the M8's most cumbersome flaw was its own composition: the liquid viscera required changing-out every twelve hours. This constant replacement demanded an unbroken, secure supply line; a path that was often one of the earliest casualties in battle. While Edgewood produced the M8 in 1967, Harden and his colleagues searched for something better fitted for soldiers' use.

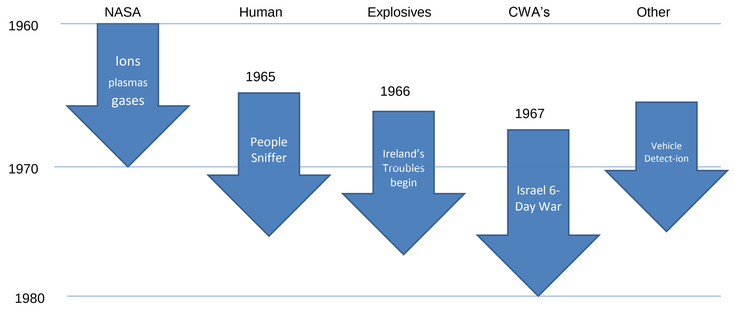
The Ionization Detector

Founded in 1885 by an individual inventor of an automatic heating apparatus for houses, Honeywell was a massive conglomeration of acquired companies with one focus: automation technologies. In 1957, Honeywell absorbed a company with an automatic fire detector. It sensed atmospheric particulates larger than clean air, such as smoke. This sensor was the base for Honeywell's ionization detector.

The ionization detector manipulated the movement of ions and electrical fields to change air's standard electrical properties.
It was simply a large circuit, comprised of two wires/plates, a radioactive source, a battery and an amplifier. Ion identification was based on Time of Flight and an amplifier produced a spectrum graph of current amount and time.

Honeywell came to Edgewood - very early 70's as I remember - looking for funding to develop an "ionization detector." They didn't seem to know exactly what they…but they did know that if their device sniffed organic chemicals similar to chemical warfare agents that they could detect a change in electrical current in the thing…Because of our work on atmospheric pressure ion chemistry we were tasked to come up with mechanisms and to try to understand the ion chemistry."
~Harden, email 2013

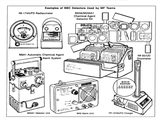
In laboratory tests, when nerve agent was introduced to the ionization detector, the huge organophosphate molecule was pushed through an electrical field and into a chamber allowing the smaller ions to undergo recombination reactions while the larger, slower organophosphate ions ambled down to the detector plate. It was, essentially, an ion filter, not an ion sensor.
In the late 1960s Honeywell approached several research groups in Edgewood offering the ionization detector as a solution to many detection needs.

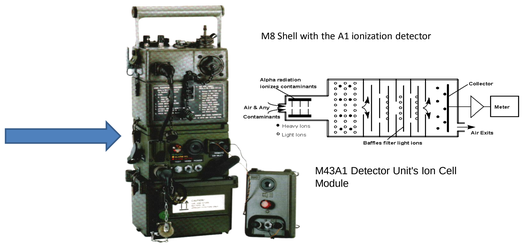


In 1965, M.M. Shahin, a scientist working with Xerox Company, began to examine a specific process in the Xerox 914 Copier called the corona discharge. He modified the two vacuum chambers of a mass spectrometer by creating a pin hole in the divider between the ion source chamber and the analyzer chamber. Placing a corona wire in the ion source to create electrons, Shahin flooded the ion source chamber with regular air and flowed the discharged ions into the analyzer through the pin hole. With these alterations, Shahin initiated laboratory use of atmospheric pressure ionization mass spectrometry. This momentous discovery was virtually lost amid the mass of ion chemistry done during that era. However, his reports on APIMS were among the literature Harden and the Lab combed through in their search for an alternate system to the M8.

"The M8 was a logistics nightmare, however, it was the state of the art…[We] had the idea to see if we could replace the "wet" detector cell in the M8 with a "dry" one.
I do remember making several marketing trips during the mid-70's to funding organizations to pitch a "Product Improvement Program (PIP)" that ultimately resulted in replacement of the wet chemistry M8 with the (dry) ion chemistry M8-A1."
~Harden, email 2013

The chemistry inside the API source of Shahin's mass spectrometer was the same chemistry inside the ionization detector and the same chemistry in ion mobility spectrometry. The continuity of scientific principles makes Shahin' work essential to the development of gas phase ion chemistry at atmospheric pressures.





Conclusions

Wet electrochemical detectors, initially developed in 1967, lacked response to mustard gas and some nerve agents. Consumables burdened military logistics. The M8's selectivity, poor sensitivity and need for constant supply lines made it ineffective on the battle field. Dry detectors based on gas ions, underwent extensive development in the 1960s. A Honeywell ionization detector used a "filter" effect based on mobility dependent recombination. C.S. Harden recognized a need to understand detector foundations employing M.M Shahin's recent description of API-MS.
Additional testing of the ionization detector revealed its low selectivity of response, offset by superb convenience of use, simplicity, and low detection limits. Unlike the M8, there were no regular consumables. The M8A1 featuring the M43A1 Ionization Detector was deployed 1981.

Continuing the search for a reliable, sensitive, selective, and sturdy chemical agent detector, Harden met with D.A, Blyth, a Porton Down physicist who had independently developed a British MOD device based off similar principles of ion chemistry. Called DICE, it failed to fulfill the quality of detection Blyth thought necessary, just as the M8A1. After 1974, a joint team of Harden and Blyth settled at Porton Down to pursue the chemical principles of APIMS and mobility separation resulting in an improved chemical agent detector.

Existing knowledge of IMS and a growing experience in trace detection compelled a next stage of development beginning in 1978……..(to be continued)

References

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