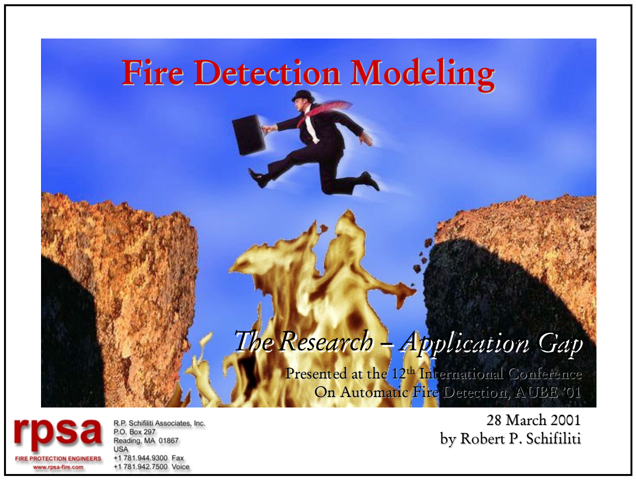

"Fire Detection Modeling
The Research – Application Gap"

Presented at the 12th International Conference
On Automatic Fire Detection, AUBE '01
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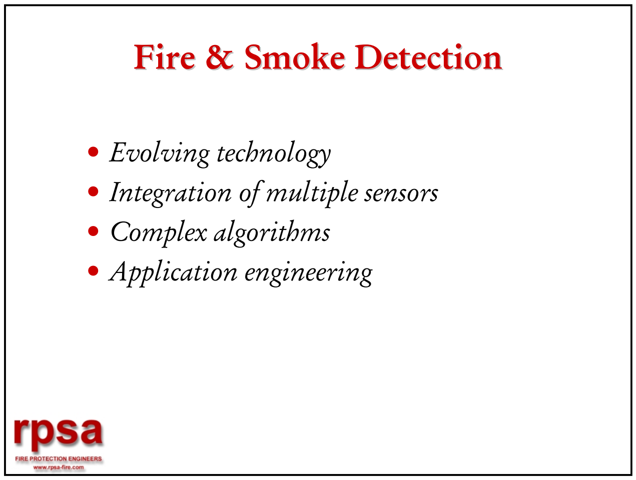
I stand here today and I am amazed. I've attended AUBE conferences since 1989 looking for engineering tools to model fire detection.

I'm amazed at the great steps forward and the new technologies that are being presented at this conference. Many of which have the potential to make my paper irrelevant. I welcome that.

I am also disappointed because we have engineers using computer models with questionable data and incomplete information to say that smoke detectors will respond, for example, in 2.18 minutes to a given fire scenario, giving occupants a 37 second margin of safety to evacuate. In fact, their methodology has a margin of error greater than the magnitude of their results.

I'm also humbled to be here since I come not with new material or new ideas. I come here to make suggestions and ask for your help.



Fire detection technology is evolving - Hardware and software

Multiple sensors are being integrated with complex algorithms to try and identify specific fire signatures or fingerprints

Application of these new technologies is based on the research and testing that went into their development.

Proprietary work. Even here at this conference we are given a peek at your work, but not the full data set. We are not always given sufficient information to understand the limitations of your work or to understand how we might apply it to new applications that even you have not thought of.

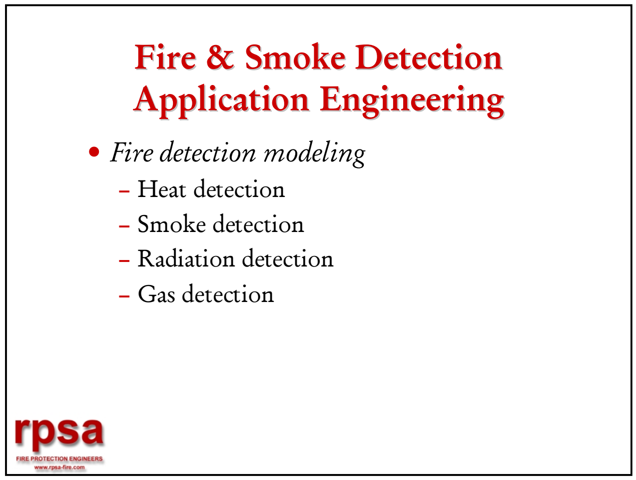
During this AUBE 2001, Oliver Linden said that a blackbox approach was insufficient for product approvals. I agree. However, it may be sufficient for certain performance measurements.

We have NOT developed and evolved Engineering Tools to study and evaluate how new and existing fire and smoke detection technologies might respond to situations outside of the laboratory.

We have discrete bits of science. We have product approval standards

But we lack the ability to combine the science and approval data into engineering tools.

Yet fire protection and building safety are demanding these tools as we try to create flexible, performance based solutions. When the proper tools do not exist, people resort to using improper tools, or using crude tools in ways they were never intended to be used. Similar to using straw or hay to build a house. You get the illusion of structure and performance, but it is destined to fail in a strong wind.



We lack tools to model fire detection

Lord Kelvin said: “In physical science the first essential step in the direction of learning any subject is to find principles of numerical reckoning and practicable methods for measuring some quality connected with it. I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of Science, whatever the matter may be.”

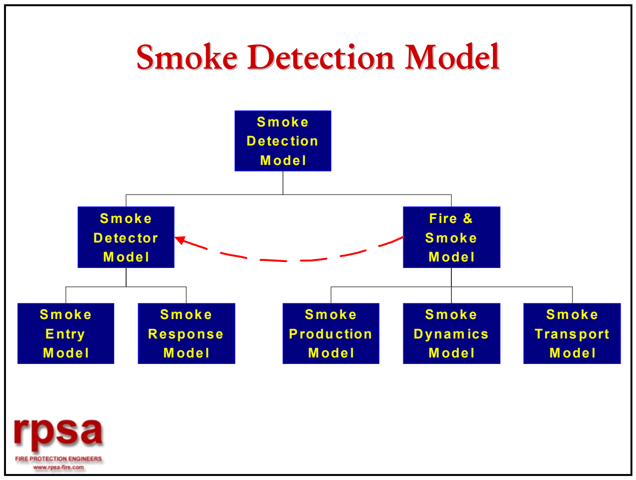
Heat detection modeling is relatively simple, but we lack a test standard to measure a detectors heat transfer coefficient. Perhaps thermistor type detectors can be modeled without regard for thermal lag. However, several presentations at this AUBE 2001 have shown data that indicates there is a measurable thermal lag with these devices. Is it small with respect to the needed accuracy and precision? We need a standard test to know.

Lord Kelvin also said: “With three parameters, I can fit an elephant.” This suppoprts Martin Berensten’s paper presented earlier which shows the power of treating fire detection as a signal processing problem.

The sprinkler industry saw an opportunity and developed appropriate models and methods. This then led to new products and new markets aimed at real fire safety problems, not imagined ones.

Perhaps the best developed and studied models are for radiation detection. Nevertheless, we lack product and fuel data for input to the models.

Thorsten Kempka presented a good summary of the particular needs and model parameters. My paper focuses on smoke detection modeling, but the comments and structure apply equally as well to other methods of fire detection modeling.



Its useful to look at all the components of fire detection modeling and how they are related.

To model smoke detection, we must be able to model the fire and we must be able to model how a detector or sensor responds to the fire.

Its important for application engineers and researchers to understand the difference between ***detection*** modeling and ***detector*** modeling.

The fire and smoke model can be thought of as having several components or sub-models…. These include:

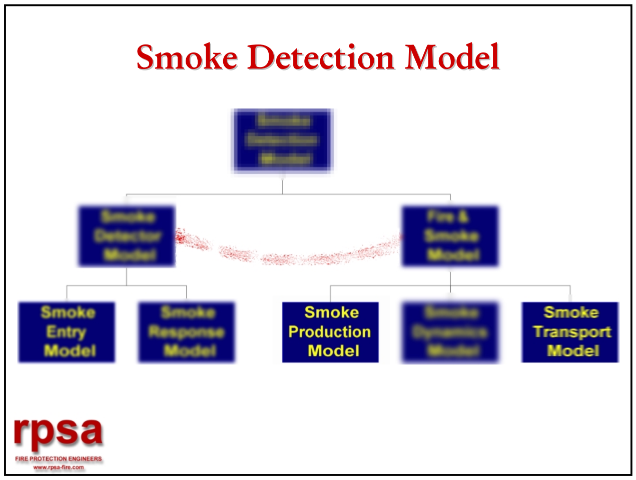
Smoke aerosol production and characteristics including particle size and distribution, particle number or concentration at various sizes, chemical composition, color, and refractive index.

Smoke is generally dynamic during transport.

For instance, do particles agglomerate or coagulate? How does the size and number concentration vary? How do the optical properties change?

Smoke transport considerations include transport time and velocity as well as soot deposition causing changes in airborne concentrations. Transport time is a function of the characteristics of the travel path from the source to the detector, and includes ceiling height and configuration (sloped, beamed, etc.), intervening barriers such as doors, and buoyancy effects such as layering and thermal inversions.

Once smoke reaches the detector, other factors become important. These include the aerodynamic or entry characteristics of the detector and the type of sensor and how it responds to the smoke sample.



We lack knowledge; We lack data; and we lack connectivity of these model components. Thus, our model can be represented as having some fuzzy and some distorted elements.

Material and combustion research related to smoke production seems to be well developed and now moving on to the effects of composite fuels.

I know of no fire or smoke model that actually models smoke dynamics, meaning agglomeration, coagulation, changes in particle structure and optical properties. The work presented here by Dr. Farouck is promising, but not yet ready for application engineering.

New CFD models promise to help us to understand smoke transport better. But the model still does not account for soot deposition and we are still faced with the overwhelming number of variables in a real situation. For instance, leakage paths, doors open or closed, the effects of ornamental architectural details.

There have been several studies of smoke detector entry characteristics. But as with most good researchers, the reports identified areas for further study. However, the additional work has not yet been pursued.

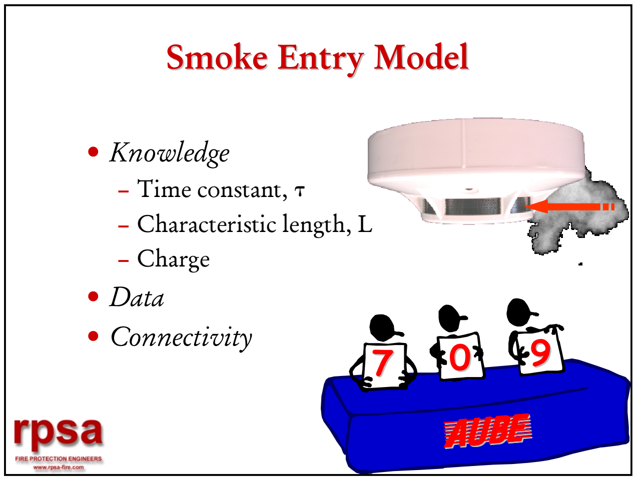
Similarly, there has been much work done on how ionization detectors and projected beam detectors work; and some on how light scattering photoelectric detectors work. But the science is left unfinished and the relevant parameters for a particular model smoke detector are not routinely measured and reported with the products technical specifications.

And why should manufacturers test and report parameters such as entry resistance, chamber constant, or threshold light scattered to cause response when the fire model does not feed the detection model the relevant data?

In this diagram, each of the nodes is an AND gate. Thus, the errors and inaccuracies multiple, creating greater uncertainty as we go up each level.

In the paper, I try to look at each of the models and discuss our knowledge level, the availability of data and the ability to connect that sub-model with the others to create an overall smoke detection model.

In this presentation, let us look briefly at each.



Knowledge: As with heat transfer to heat detectors, smoke entry resistance can be characterized by a detector time constant, τ

Heskestad hypothesized that the product of the time constant and the velocity of the smoke is relatively constant and can be thought of as a characteristic length. It is interpreted as the distance the smoke would travel at the velocity u before the optical density inside the detector reaches the value outside of the detector.

Heskestad and later Bjorkman et al. have plotted test data to determine the L number for a variety of smoke detectors. Additional work has been done by Marrion and by Oldweiler to study the effects of detector position and gas velocity on the L number.

All observed variations in L that may be attributed to a dependence on velocity

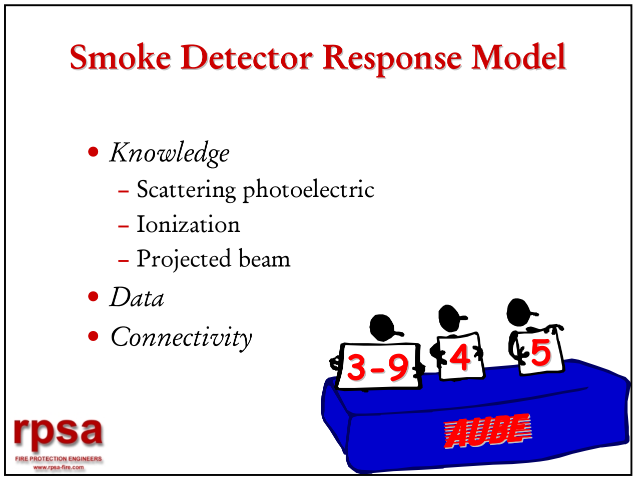
More work needs to be done to study the effects of low velocities and the effects of smoke characteristics on detector entry characteristics. The sharp increase in L at lower velocities appears to indicate that entry resistance may be related to smoke particle size or charge as hypothesized by Dr. Farouck. It is also possible that L is a function of the smoke momentum at low velocities. Thus, the time lag would be inversely proportional to the velocity squared.

Work by Jim Qualey at Simplex has shown that the effects of entry resistance can be more important than detector sensitivity when comparing response to certain conditions.

Data? What data? Until more research is done and a model is completed and made part of product evaluation, we have no way to quantify entry resistance for a particular detector or to compare two detectors.

Connectivity of the resistance model with the fire model is good. Many fire models give the localized velocity vector and as a function of time which is exactly what the current model requires for input.

However, if the entry model changes to require data about smoke particle size, charge or momentum, the fire models must evolve to provide this data.



Our **knowledge** varies greatly.

We know very well how obscuration type detectors work. There has also been a lot of work done to describe how ionization and scattering type detectors work. We've got engineering relations to model obscuration and ionization type detectors, but we don't have a simple, usable model for scattering type detectors.

Data? For obscuration type detectors the manufacturer gives the necessary response data in terms of optical density or obscuration required to alarm the detector.

Ionization detectors – no published chamber constant data

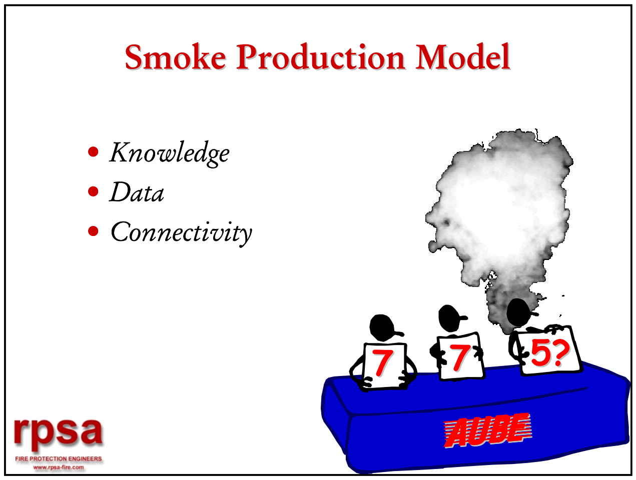
Scattering detectors – no data on threshold response, wavelength of light source and scattering angle

Connectivity is moderate for obscuration detectors – the fire and smoke models give us obscuration or optical density - but rarely tell us at what wavelength the data was measured or correlated. What good is it to use a fire model that describes the obscuration of visible light when the detector uses I.R.?

As for ion and scattering photoelectric smoke detectors, the fire models do not give us data to fit the detector models. The fire models give us obscuration or optical density, but we have no readily available or comprehensive data correlating obscuration to the amount of light scattered.

The fire models don't give us particle number and size, so modeling ion detectors is not possible. The new ion model put forth by Newman at F.M has not been further investigated or refined into a simple engineering tool. When and if it is, we can connect obscuration data from the fire model to Newman's ion model.

rpsa FIRE PROTECTION ENGINEERS



I'm certainly not an expert in this field.

But looking in references like the SFPE Handbook of Fire Protection Engineering we see many tables and graphs of material smoke properties. So, there appears to be knowledge and there is definitely data.

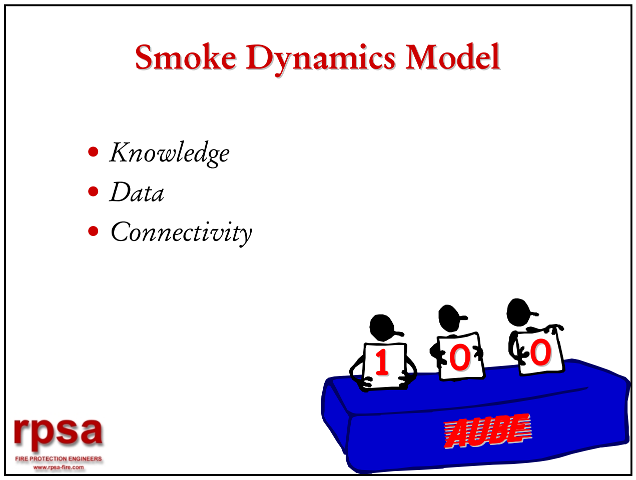
But, as an application engineer, I need to know how good the data is so that I can include its uncertainty in my results. Many of the available data are listed without any indication of their pedigree.

For example: The mass optical density, D_m, for a flaming polyurethane mattress is given in the SFPE Handbook, p. 2-223 as 0.22 m^2/g. Is that based on a single measurement from one sample? Or multiple measurements on a single sample? Or multiple samples and multiple measurements? Also, I am left to assume that two significant digits is the correct precision associated with the data.

I must also point out that the data we have is not always the data needed by the detector model so we may lack connectivity. As pointed out yesterday by Rainer Seibel, no one is reporting the scattering effects of smoke. Why are we reporting the obscuration necessary to operate a scattering type detector?

The paper presented by Darrel Weinert promises to give us a standard method for measuring how smoke scatters light. Will we be able to instrument most test rooms and chambers like the FE/DE?

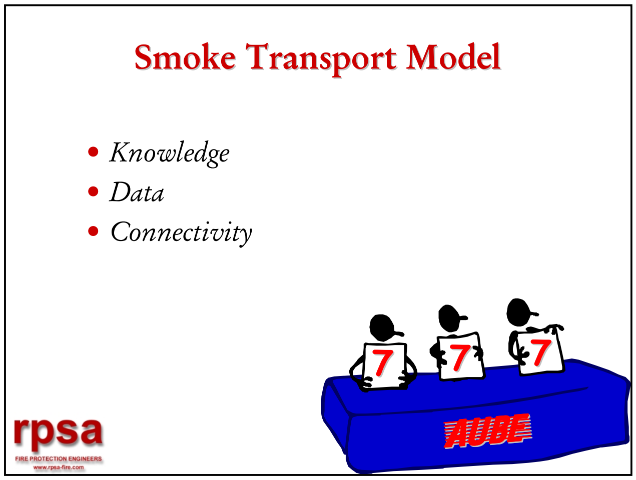
Was the data measured in a large scale test or in a small, bench scale test? If its from a small scale test, then I have to **CHANGE SLIDES** and ask whether I have a smoke dynamics model to understand how to scale or change that data for my real world fire model.



Now, maybe you scientists have a smoke dynamics model to tell me how smoke changes as it moves in a space. Or maybe you can tell me its insignificant.

But as far as I know, no one has developed an engineering model and no one has said when changes in smoke characteristics can be ignored or when they are important.

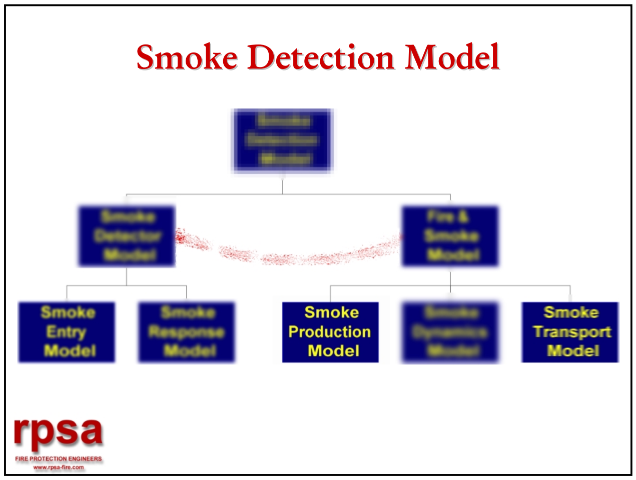
The work of Dr. Farouck presented at this AUBE conference is promising, but far from conclusive and far from be able to be used as an engineering tool.



Zone type fire models don't have the resolution needed for most fire detection modeling problems. But, new CFD models and certain other models such as Heskestad and Delichatsious's t^2 correlations are good engineering tools for modeling smoke transport.

But we have a real engineering problem with data. How much do we know about the actual scenario we are trying to model and how much information do we have to have to answer our question?

For example, if I am asking what effect the use of plastic upholstery has versus leather on the expected detector response I can be a bit more relaxed about my input data regarding small ceiling obstructions. I am seeking a relative answer and changing only one parameter. But if I am trying to determine the actual expected response time of a detector, I need a lot of detailed information for my model and I must perform reasonable sensitivity analyses on all input data.



Right now, our smoke detection modeling capability is fuzzy – not in focus.

We have some estimation methods that can be used to understand relative effects or to do gross sensitivity studies. These are discussed in detail in my paper.

But, with the possible exception of projected beam smoke detection, these estimation methods can not be used to give absolute answers.

On one side of the gap we have scientists and researchers studying fire and smoke and developing fire models.

On the other side we have researchers and manufacturers developing new fire and smoke detection technology.

Application engineers just want to go for a ride on the train!

Today, it is not possible to accurately compare smoke detector response to other fire related models such as egress time or structural response to heat. If smoke detection is to be a part of tomorrow's performance based solutions fire models and detector models must evolve and work together. The evolution of the fire and detector models must include a feedback loop to ensure that they meet to form a detection model.

Fire researchers and detector researchers need to communicate if we are to meet in the middle and have reliable and accurate engineering tools.

Last year, the SFPE held a Research Agenda Conference. Experts from around the world gathered to identify and prioritize engineering research needs. That report is available at: http://www.sfpe.org/technical_activities.html

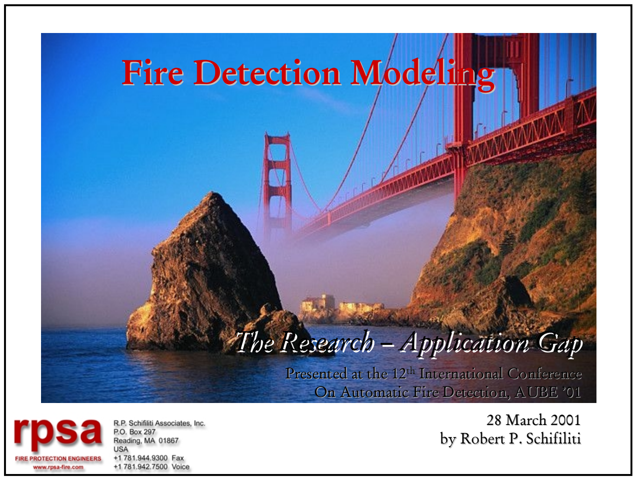
Recently, the Fire Detection Institute held a smaller, more focused meeting to identify needed fire detection research. That report should soon be available, possibly on their web site: http://www.firedetinst.org

If we are to bridge the Research-Application gap, we must continue the dialog we have begun between fire researchers, detector researchers and application engineers. And, more importantly, we have to implement and put into practice the strategies that have been identified in the SFPE Research Agenda report and the Fire Detection Research Workshop.

Detector and fire models need to better report and present limitations and potential errors. And, application engineers must be more conscious of the limits on a model's accuracy and precision and must provide useful feedback to researchers involved in product development and fire research.

We must plan ahead.

We need to establish a clearinghouse or central location where researchers, manufacturers and students can go to see who is working on what aspects of the fire detection modeling problem. A place where hypotheses can be posted and students and researchers can select topics and find others interested in the same subject.



I also propose that the next AUBE conference include a session dedicated to Application Engineering. So that researchers and those in product development can see what we do and how we do it.

Finally, I ask that when you return home and continue your work that you think about the Fire Detection Modeling Research-Application Gap and ask how you can help close the gap.