

LAWRENCE LIVERMORE NATIONAL LABORATORY SYMPOSIUM

The Role of Closed-Circuit Breathing Apparatus in Structural Firefighting

The editors of the ISRP Journal are reproducing the proceedings of this symposium held at Lawrence Livermore Laboratories in October, 1984. Due to the length, these proceedings will be published throughout several issues of the Journal. Edited by Mr. Jerry Stengel.

- PROCEEDINGS -**Wednesday, October 23, 1984**

I'd like to officially *open* our Closed-Circuit Breathing Apparatus Symposium. This symposium is being sponsored by Federal **OSHA**, **Cal/OSHA**, **ISRP**, the National Society for Respiratory **Protection** and the Lawrence Livermore National Laboratory.

Our management is involved in safety at the laboratory. Jack knows what a respirator is, understands how important it is as part of our respirator program, and realizes that we need to continue to work to better understand and improve them.

The interest that the laboratory has in safety is just one part of the new world that we're facing here at Livermore, and in the entire country. If you think for a moment about the way life was ten or fifteen years ago and think about the way it is today for organizations, that is, labs like ours, companies as well as government agencies, the external pressure on all of us has changed significantly.

One of the things the laboratory has realized for years is the importance of safety in doing its job. *We've* been concerned about the environment and its protection, and *we've* been concerned about security and safeguards at this laboratory. But recently, the changes that have occurred around us, particularly in the safeguards and security area, the threat of terrorists around the world, coupled with the need for the environmental agencies to feel that they are *imple-*

menting the laws on the books, and the continued concern that all large companies have for the safety of their people, we've had major changes at the Laboratory.

The whole function of safety, *security* and safeguards in the environment have now been centered in the director's office, *and* I've been asked to coordinate those activities for the Laboratory. It's always easy to sit back from a functional area and decide how things ought to be done, but it's a big difference when you have the responsibility to do it yourself. So, I'm learning about things that I really thought I knew but didn't know very well. So, the Laboratory's information on these issues has changed significantly.

The involvement of people like yourselves has gone over the last — just a few things. And one of the things that I've found to be terribly significant in working problems such as the one you're working in today, the closed-circuit breathing apparatus technology, is that it's important that the groups or people who are working on the same problem but at different locations across the country, or even within the *state*, have an opportunity to exchange ideas and thoughts, strategies and tactics on technology well before people get into the production phase or into the application phase.

So, I believe these kinds of extra actions are terribly important to people like myself at the laboratory. I also believe it's time that government agencies, industrial companies and laboratories like this explicitly work together in the community and *don't* separate

themselves because they're supported by different *agencies*. We have *national* policies here which prevent discussions of activities between corporations because of certain trust laws. *But* I think in the long run that's hurting us, because the Japanese policy on the anti-trust is really no policy. Companies work together. They work hand in glove. They work hand in glove with the government for a common cause, that is, the country of Japan. So, I think that extra actions like this are healthy.

I'd like to say one quick word about the laboratory and what we do *here*, for those of you who don't know. This is a nuclear weapons laboratory. Sixty percent of our funding comes to support defense programs of the Department of Energy. The other forty percent of the activities is non-weapons related work, with the exception of \$100,000,000 in defense *work* for the Department of Defense. Our non-weapons programs range from nuclear, that is, magnetic fusion research, to laser fusion research, asymptote separations by means of lasers.

We have a small program called Resource and Recovery, a biomedical program looking at the low levels of radiation of *man*, and some additional work in support of *nondepartment* of energy *agencies* such as the Department of Transportation, Cancer *Institute* and the Department of Defense. We have eight thousand people. We've got about two thousand scientists and engineers, and a thousand with *Ph.D.'s*. Their disciplines range from engineering, biology and statistics to mechanical *engine-*ering. We're also supported by a large professional staff of administrative people

who take care of the *travel*, the procurement and the security of *safeguards* of this laboratory.

The first paper is going to be presented by Bob da *Roza*, and it's the introduction to *closed-circuit* breathing apparatus. Bob has been *involved* in respiratory research here at the Lawrence *Livermore* Laboratory for many years. And I think most of you will be familiar with his work from some of the papers that have just been published for *AHIA*.

The purpose of this *talk* is to make sure that we all know what *we're talking* about, that *is*, really know what closed-circuit breathing apparatuses are. *We're* just really learning a lot about closed-circuit breathing apparatus in detail at the lab. And *it's* one reason we're having the symposium.

Closed-circuit breathing apparatus is the name I decided to use out of a various number of choices. People call them OBAs, oxygen breathing apparatus. We call them *rebreathers*. Some people call them the closed-circuit, *self-contained* breathing apparatus. They're all the same thing. And for consistency, we've tried to use CCBA in the symposium. This is in opposition to the other unit that you're all familiar with, the self-contained breathing apparatus, also called the Scott *Pak* or the *open-circuit*, self-contained breathing apparatus.

Now, what does a closed-circuit breathing apparatus do? To recondition one's breath, you have to remove the CO₂. And that is usually done using granular soda lime. Soda lime is the mixture of calcium oxide and sodium hydroxide. It needs to add some oxygen, and this can be done by using compressed oxygen, liquid oxygen or potassium superoxide. Also, it's nice if it collects some of the water formed either by condensation or traps.

Just to make sure we understand again, the difference between the two units—we're talking about an open-circuit, self-contained breathing apparatus. There is an oxygen supply. That's normally air that goes to some pressure regulator, maybe a couple of stages of regulation, up into a facepiece and then upon exhalation it's vented to the atmosphere. If a positive-

pressure unit, then it goes to a spring-loaded vent valve. This is basically how a closed-circuit breathing apparatus operates:

Person's lungs: the lungs remove oxygen, add CO₂ and water and add heat. Air exhalation from the lungs goes back into the facepiece and then on out through a tube connected to the facepiece where it goes to some kind of absorber, removes the CO₂, and that absorber adds water just because that's the chemical reaction. It also adds heat, which is not particularly desirable. And then somewhere in the system it has to add oxygen. None of the units uses compressed oxygen. When the compressed gas goes to a lower pressure, it always cools down to a *Julie* Thompson cooling and that removes some of the heat. Some of the commercial units will have optional units for heat removal or water removal. Somewhere in the system, *there's* a Ballast volume. There must be a volume somewhat comparable to the volume of the lungs so that when you take that quick breath, you get the air from somewhere. Usually in that air storage Ballast volume, *there're* the regulators and they regulate the addition of oxygen. So, it extracts the steam back up here to let more oxygen come in. Maybe there's a water collector somewhere, either purposely or unintentionally, and somewhere, *there's* a vent valve.

If the pressure of the system builds too much, the gas has to vent. This can be spring-loaded or it could just be a pressure load based upon the resistance of the rubber diaphragm in the exhalation valve - but, there is a little resistance in any kind of valve -- then that gas goes back into the facepiece. In looking at what happens when you use one of those apparatuses, I had to look at a couple of work rates because the way it functions is going to depend upon how hard you're working.

So, I chose two working rates. One is walking. Walking at 2.9 miles an hour. That's just comfortable walking. Or bicycling at 4.8 miles an hour. And in

technical terms, *that's* 208 kilogram-meters per minute. The other working rate is climbing stairs. Now, climbing stairs is also equivalent to running five and a half miles per hour, which a lot of people do for a long time and that's a working rate of 830 kilogram-meters per minute.

Now, note I looked at pulse rate. The pulse rate goes up breaths per minute. Minute volume is the amount of gas that you breathe in and exhale per minute in liters. Oxygen consumption .8 to 2.1 and CO₂ reduced liters per minute. It's a little bit less than the oxygen consumption at these work rates. At higher work rates, it becomes the same, possibly increasing it more.

So, you'll see in the other slides I give some characteristics to the unit while climbing stairs or walking. In one hour of climbing, you get 120 liters of CO₂. Look at the chemistry of it. The amount of soda lime needed to remove that amount of CO₂ is 360 grams. When this chemical reaction takes place between the soda lime and the CO₂, heat is produced - 380 kilocalories.

What does that mean?

What if you put 380 kilocalories into various things? If the only thing that was heated up was the soda lime, it would really get hot, 2,150 degrees C. If you put that amount of heat into 25 pounds of aluminum sort, the weight of the packet would go to 280 degrees C. Or, if all that heat went into the 210-pound firefighter, it would raise his whole body temperature to 70 degrees F. The heat doesn't go to one spot, a lot of it is just radiated out to the environment. But when you get in a hot environment, it doesn't radiate out as well.

Water is produced in two ways: the removal of the CO₂ by soda lime produces 48 grams of water. I've assumed the soda lime is half calcium oxide and half sodium hydroxide, and the sodium hydroxide that it produced is the water. Every time you exhale, you exhale air at 37 degrees Centigrade, 100 percent humidity. So you're going to exhale 163 grams of water. There's no water in inhaled air, that is, if all the water is

being taken out somehow.

What about pressure?

The work rate changes the way the closed-circuit apparatus operates. When **you're** just **walking**, the pressure increases and oxygen vents. This is what we figured from reading the literature. The **Draeger** literature says that you breathe in one half liter per minute of oxygen. The Bio Marine literature says 1.65. This goes into **the** Ballast volume.

When you're just **walking**, the lungs only use eight tenths of a 1 **pm** liter per minute of oxygen, eight tenths minus one half. Something has to happen with seven tenths liters per minute of oxygen. And it appears to me that it must vent. If you're climbing stairs, I figured that the pressure, degrees and additional supplemental oxygen has to be bled in. You have this initial bleed amount that's always being bled in. The lungs demand two half liters per minute, so you have to have supplemental oxygen bled into that. And there is a regulator in the system to do that.

We've just been looking at what I calculated. Let's look at the way a couple of other manufacturers make their devices.

Here's what I calculate of the **BioPak** 60, 240 and the **Draeger** unit. For one-hour unit, I calculate that walking, one would need 48 liters. This is for one hour. For one-hour duration, you'd need 48 liters of oxygen, walking, or 126 climbing. **BioPak** has 190 liters of oxygen in it. And note that 99 liters of that was bled in at this constant bleed rate.

If you look at the four-hour unit, I calculate you need this range of oxygen: the **BioPak** 240, a four-hour unit, has more than you need for climbing. Whereas the **Draeger** unit has not quite enough to be climbing the whole four hours. The **BioPak** 60 has a little more than **that**. **Draeger** has something less than 2.9 kilograms. 2.9 kilograms is the weight of **the** whole canister. So, it includes the metal with the soda lime in it. I didn't find the figure on what the actual weight of the soda lime was. Obviously, the figure is something less than that.

Let's look at the amount of gas you consume. Look at the one-hour unit,

while running or climbing stairs. Your gas consumption in a closed-circuit unit breathing apparatus would use 2.1 liters per minute of oxygen; the open-circuit would use 55 liters per minute of air. This gives you the amount available in the **BioPak** 60, and this gives the amount available in a certified, one-hour unit of SCBA. For that calculation, the closed-circuit would last 91 minutes more than rated, and the open-circuit would last only 46 minutes less than rated. I think experienced people have found that to be true.

If you're an advocate of closed-circuit why carry all that oxygen? Why carry all that nitrogen if you really don't need it?

While climbing stairs, a self-contained breathing apparatus needs 9.3 pounds of air per hour. If you want enough air for one hour, and figure the initial apparatus, empty, weighs 20 pounds, maybe more than 20 pounds. One hour's worth of **air**, up here, obviously 29.3 pounds, the weight of air goes up like that per the amount of time you want to be able to use the unit.

However, with a closed-circuit you have some oxygen and some soda lime for only 1.2 hours of weight needed for every hour of use. The weight of the closed-circuit only goes up at that very slow rate of 1.2 pounds per hour. You can see from the long duration, you sure don't want to carry all that extra nitrogen - to be up there with 57 pounds - if you want a four-hour open-circuit unit.

Here're some more comparisons of **closed-circuit** and **open-circuit**.

The 30 minute, **closed-circuit** unit is lighter and it really lasts at least 30 minutes. Whereas the open-circuit, if you're climbing stairs or running, doesn't last that long. The one-hour unit is lighter and it's a closed-circuit, lasts an hour and a half and open-circuit only lasts 46 minutes. A two-hour unit is being developed but I don't think we really want a two-hour unit in open-circuit. It would be more than 35 or 40 pounds. That is higher than the weight

limit specified by **NIOSH**. The four-hour unit will last about two to four hours. It weighs about 35 pounds.

What makes closed-circuit breathing apparatus available?

We have Rexnord Safety Products that make four-hour units. The 45 is not positive-pressure and the other gives time in minutes. Mine Safety puts out the Chemox units. National Draeger puts out a **BG174A** and I understand they're looking into another one. Clifton Precision is developing a two-hour unit and **Survivair** is developing a unit also.

What are some of the limitations of a closed-circuit breathing apparatus?

Maintenance: the absorber must be changed after each use. Once **you've** used that absorber system, there is moisture in **it**. After it cools down and sits, it's going to cake up and clog up. Even though you've only used it five or ten minutes, all the absorber must be replaced. Of course, the **SCBA** **doesn't** have an **absorb-er**. If you use much oxygen, you have to change the bottle. Likewise, if you use much of the air in your open-circuit, you have to change the bottle. If you have a closed-circuit unit that has the heat sink in it, **you'd** want to keep that in the freezer until **you're** ready to use it. Of course, **open-circuit** doesn't have a heat sink.

Some further limitations are that people say closed-circuit gets too hot and too wet. Here are a couple of **conflicting** reasons: if **it's** positive-pressure, the oxygen leaks out and it may start a fire. If **it's** negative-pressure, contaminants may leak in and harm the wearer. And I don't know if that's all true or those are all valid reasons or not. I hope that we find some of that out here today and tomorrow.

There are cost differences. This includes the cost of the unit and the cost to recharge **it**. We charge it with the absorber. In open-circuit SCBA, the cost is around \$1,000. There is a big range on the closed-circuit

In summary, for operations that last longer than 46 minutes where you're doing any work at all, self-contained breathing apparatus can't be used. There are uncertainties about the closed-circuit

breathing apparatus that need to be cleared up so intelligent choices can be made on what to use. This symposium and a study that's starting at Livermore, we **hope**, will provide the needed information to clear up these uncertainties.

Never thought I'd have the pleasure of introducing Alan Hack, but it's a real pleasure. And, I'm sure I'm able to stand up here and say that I first met him down in Los Alamos. He was in an industrial hygiene group and was interested in respirators, but did not know what the respirator research group was working on in the other division or the other section down there, so Alan made a quick change, about six or seven years ago, and went into respirator research. Alan is going to make a presentation on some work he's done: the protection factors of closed-circuit apparatus and their operational characteristics.

There is possible recirculation in the closed-circuit apparatus, which implies that should you get contamination in the facepiece of the system, it could be recirculated and you could be exposed to it repeatedly. Clearly, the positive-pressure, closed-circuit unit, Bio Marine, did provide higher protection than did the negative-pressure, closed-circuit. This is comparable to what we would see if we compared open-circuit units that were both positive and negative-pressure. The duration, if you want to get lightweight with long duration is going to require some sort of recirculation.

I've got a small footnote here, high duration for the closed-circuit, positive-pressure apparatus. There's a potential problem there which should be looked into. Should the positive-pressure, closed-circuit apparatus develop some sort of a leak, the very small contents of the stored oxygen bottle could be lost, leaving the wearer trapped and unable to escape. This problem exists also with an open-circuit unit, but the amount of gas available is so much greater that it may not be as much

of a problem. But, this is something to consider during fitting or training of the positive-pressure equipment.

On temperature, all of the closed-circuit units, with the exception of one, tended to be hot because of the chemical reaction of the scrubber. The airlocks which had liquid oxygen cold source within it were cool, essentially cooler than any of the other closed-circuit apparatus. This was a positive aspect of the liquid-oxygen unit. Clearly, the closed-circuit apparatus are more complex, and the positive-pressure, closed-circuit apparatus may tend to be more complicated than the negative-pressure, closed-circuit.

Assuming that we are selecting a rebreather or closed-circuit apparatus because we require long duration, the facepiece fit must be considered important along with the obvious advantages of positive-pressure. I'd say the advantages of positive-pressure are a greater assurity of fit combined with a proper size mask. And the one concern I had, the loss of gas, would also be minimized by a mask that's properly sized for the wearer's face.

Our next speaker comes to us from the laboratory. His name is Chief John Sharry. If any of you know John, you know that he's a life-safety code expert who came into the laboratory from NFBA, brings a wealth of experience in fire protection and is now expanding his experience significantly in running a fire department and being the chief, and is responsible for a lot of the other aspects of a full fire protection program. John is going to provide us a start-out insight into firefighting tactics and the necessity for long-duration SCBAs.

I may be in the spot this morning of informing part of the audience about the obvious, tactical arrangements where positive-pressure, closed-circuit apparatus and long-duration apparatus are of advantage to fire department operations.

Some of these are rather obvious, but might be worth talking about, as well as some of the concerns that the fire chief has to be aware of concerning long-duration apparatus, dealing with personnel exposure and how much can a firefighter be expected to take in long-duration apparatus.

I also want to discuss some of my concerns with all the new protective equipment that we're providing the fire fighter with and also the fact that we're exposing him to something he's never been exposed to before. Let's discuss some of the tactical things we may run into that require long-duration breathing apparatus.

The first one is the large area building which I think most of us in the fire service are aware of. The Uniform Building Code has a provision as to all the other building codes for unlimited area buildings. An unlimited area building can be built and the building must be sprinklered, but that building may be of any size without restriction as to subdivision by fire walls or fire barriers which may result in a building where travel to get to the fire by the fire department may be 400 feet, 800 feet, 1200 feet or more in order for the fire service to get access to the fire.

This is somewhat limited by the fact that in order to get means of egress out of the building, in order to get the people out from an exit standpoint, there is a requirement that we have to be certain of no more than 400 feet of travel to reach an exit. But when you consider the fact of a fire in the building that may be blocking some of those exits or from a tactical standpoint, you may not want to use those exits as entry points for containment, you may be 800, 1200 feet away.

Obviously, that presents a problem with our standard SCBA apparatus. With that much lead time or that much travel to get into a fire, we're going to consume a great deal of the time available from the SCBA, and then we're going to have to work the fire in whatever way we choose, and then we have to be able to get back out again. As you can see, that would

lead to a very short period of time that you'd be able to work on the fire. Large industrial buildings which are very common to this unlimited area and covered mall buildings are also very common **large** unlimited-area buildings.

In **Livermore** we're going to have a building built up the street in the next few **months** that's going to be over 150,000 square feet. It will be an **undivided**, unlimited-area building. Our saving feature of course, is that it's a sprinkler building as the code would require. High-rise buildings present a problem obviously, in our trying to get access to the building. Hopefully the stairs will remain intact and will provide an access from several floors below up to the **fire** floor and the floors above.

However, as we saw in the MGM Grand **fire**, although the building codes and the life-safety codes require that the stairs be reasonably smoke **resistent** or in some cases be a smoke-proof enclosure, we found that due to construction errors, lack of inspection and lack of enforcement, the stairs were not able to be used by the **fire** department without some type of breathing apparatus. We had a lot of people killed in the stair, who had gone to the stair to use it as an exit and found it not to be an exit.

Consequently, the standard SCBA equipment we wear is time expectancy. Being able to utilize the firefighter on the fire floor becomes quite a bit shortened because of the access problems.

The same thing occurs on floors above for primary search. Once **you're** above the fire you want to make a primary search and get out. You should cover as much territory as you can with as few people as you can. Again, we have the problem of the short duration.

Here are some problems that we have encountered locally and a few other fire departments have encountered also.

Rescue becomes a problem primarily in underground locations, in a tunnel, or possibly in a tank **that's** being repaired or painted. You need to get people in to make a rescue and there can be a collapse, possibly, or someone can be overcome by fumes. There may even be a fire. You

need to get your firefighters in to do any one of those **things**. The problem, of course, is lead time, that is getting in. By the time you get in, your standard SCBA is out of air. That doesn't give you much time to do anything. In fact, it doesn't give you any time. So, we have to work around carrying extra breathing apparatus in, using an air line and any number of other things. All of these present problems which a long-duration apparatus would help.

HAZMATs are a very common problem now. We are called out on many of these every day. We, of course, need to protect our people. It is better to be safe than sorry. So, we probably wear SCBAs more than we need to, but you don't know that when you arrive. A lot of HAZMATs incidents involve large areas establishing a perimeter for control as a hazardous perimeter that may be a quarter mile to a mile in diameter. Also involved is getting people into breathing apparatus at the mile marker and bringing them into the scene of the incident to do whatever work they are going to do. Evaluation containment control results in a great deal of consumption of the capability of our standard SCBA.

A corollary to the HAZMATs is outside our operations because we are finding more and more that we need to put the pump operator in a SCBA. The pumper may be located downwind and even though you don't really want to do that, occasionally it happens. The wind may shift. Now you're involved in an industrial operation and you're not sure **what's** burning. You need to protect your people. Consequently, the pump operator, who may be a quarter of a mile away, needs to get into SCBA. You put him into an SCBA standard short-duration type and you have the problem of rotating bottles and being able to provide him with the protection needed in a reasonable time **frame**. Again, long-duration might be helpful here.

Another concern of the **fire** service is the wild-land firefighting **problem**. There are a great deal of wild-land

fires in this area and we are looking at the exposure to the firefighter from the wild-land smoke. Something that we have historically used, a wet handkerchief over the nose, seemed to work. At least it took the rocks out of the smoke.

Now we're finding that that really isn't enough. And we've instituted here at the laboratory a policy of wearing breathing apparatus at grass fires or wildland fires. We're using the canister type. Some fire departments are not using those canister type apparatus, but are using instead, regular short-duration SCBA. This is another area where it might be helpful, although weight and size of the unit is going to be a problem.

The kinds of things that firefighters do at these various incidents are reasons why long-duration SCBA would be helpful. I've divided these into what I think are activities which are probably most useful to use the long-duration SCBA, and ones that I think we need to be careful about:

One is primary search and rescue, followed by the final search and rescue. It would be very, very nice to have our people in long-duration SCBA for primary search because they could spend more time at this activity. The exertion level is not as high as the actual firefighting. It would be nice to be able to get our people into long-duration SCBA to cover a greater amount of territory for we have to rotate crews. However, there's a limit on that.

Rescues in tunnels, vessels and pipelines where exertion level getting in is low, high exertion level, short period of time, low exertion level as you withdraw, long periods of time, long travel to get to the actual scene of the emergency. In many cases we have observation assignments, not actual firefighting, and the chief officers tend to take these assignments, particularly wild-land fires.

When you get an observation post, you want to look at the travel of the fire. In structure fires you also get assigned sides of the fire: interior, roof, or basement. Now your exertion level is low, but it would be nice to be in there for a longer period of time rather than to

have to **rotate** out to get new air bottles.

In **HAZMAT incidents**, particularly those in the open air, and on observation posts, it would be useful to have long-duration SCBAs. They would also be useful in protecting the pump operator in a location possibly a half mile away.

Some of the things that we have to be concerned with when we use the long-duration SCBA, is the exertion level, or the high-exertion level activity, and our expectance of the firefighter to stay at that high-exertion level activity for a longer period of time just because we have the capability of providing him with a long-duration SCBA.

I see some problems there. Chief officers and management of fire departments are going to have to be concerned and be aware of the fact that because we have a SCBA that permits the man to stay in an area for a long period of time his capability to perform is still going to go way down in those high-exertion activities, and we may be exposing our people to more than we want to or more than we realize we are doing, unless we're very careful.

There are also high-stress activities: rescues, major rescues, people trapped and collapses. Those kinds of things are high stress. You can't expose a firefighter to too long a period of high stress. You have to be careful about his performance, his capability to take care of the emergency and take care of himself. Long-duration SCBA are going to present some problems from a management standpoint at the fire scene, recognizing the fact that our people can't endure what the equipment may be capable of providing. Our tactical concern, as chief officers, is that personnel safety is one thing that has to be paramount in our minds.

What is the limit of the physical endurance of the person who is asked to fight the fire, make the rescue, do the containment, make a search? How long can they stay in there? How long can they be expected to perform that task? One of the nice things about short-duration SCBA is that it makes a nice point to rotate your crew at the end of one tank of air. The crews are replaced. Is that too

short? Is that too long? We're not sure. And, of course, it'll vary depending upon the climate, what kind of fire you have, what kind of heat, what activity the individual's involved in. We're not sure about that, but we need to be a little more careful about how we utilize our people with long duration SCBA.

When should we use it? When can the individual, under what arrangements or what fire involvement, use it? And can he or she be expected to perform?

We also have the psychological endurance as well. High-stress rescue operations creates some problems psychologically for the individual. Although all firefighters are tested for capability to operate for periods of time in the dark in protective equipment, including a mask, the fact is, if you expose that man for too long a period, we're really not sure what the psychological effect is on his performance. A man in protective equipment in the dark, possibly in the smoke, doing whatever activity he's doing in a mask which is somewhat confining, and asking him to do that for longer periods of time may have an impact on the individual psychologically and affect his ability to perform.

What's the limit of the apparatus? We're finding in the last few years that apparatus that we had taken for granted as being capable of enduring the fire environment isn't doing particularly well.

What's its heat exposure? Is it going to fall off your back because the straps burned through? We've had some experience with that recently with SCBAs.

Sometimes we get in places we don't want to be in and we have flame contact. What effect is that going to have on the apparatus?

What's its weight? I know you've talked about weight and its capabilities. You put on something large and bulky and heavy and it really has an effect upon the individual using it. Weight and the size are important. Weight alone is not. It's the size, how it fits and how it's worn by the individual. The key,

when we look at all these concerns, is that long-duration SCBA has a place in the field. It has a place to be used.

It's a choice that the fire officer should have available as long as the officers and management of fire departments and other agencies who use this equipment are aware of the limitations of the equipment. That is, aware of the limitations of the individuals who will be using it. It should be a management choice whether or not to use this equipment. It should be available to us.

Let's discuss protective clothing and some concerns. These are shared by some other fire chiefs in this area as well as across the country. One concern is the level of protection that we give people now, and we're getting closer and closer to total encapsulation because we are putting more and more protective equipment on the fire fighter. We're also cutting down on the biofeedback. We're cutting down on the firefighter's capability to determine where he is and how much heat he is being exposed to. In the old days, it was easy to tell when you were too close because your ears burned, your neck burned or your hair singed, so you backed up. That wasn't good, but it was biofeedback because it told you where you probably shouldn't be. Now we put firefighters in more modern equipment. We put them in wonderful Nomex turn-out coats with triple liners and all kinds of breathing equipment. We put firefighters in turn-out pants, in boots and Nomex hoods because a Nomex hood is going to help them. Firefighters won't get their ears burned in the Nomex hood because it protects the back of the neck and it's a wonderful tool. We also put firefighters in a helmet that is shock resistant. The helmet has a shield in front of it, a positive-pressure SCBA, and the man has no biofeedback. He does not know how far into the fire he is.

What's happening is we're getting them in farther than we've ever had them in before, which results in two things: one, we're exposing them to an environment they're not used to. When we have a failure of the encapsulation

that we built around them that failure tends to be critical. The individual has little or no opportunity to get to an area **that's** safe. The second thing is, **we're** getting firefighters into environments we're not used to dealing with. How do we take care of the individual when he has a breathing apparatus failure while he's closer to **fire** than **he's** ever been or he has a helmet failure? The lack of knowledge in handling these things in the environment is very important. It's important that it be recognized by the chief **officers**, the firefighter and by those in the industry who are dealing with protective equipment.

What are we doing to firefighters? Do we truly understand that by protecting them we are inherently increasing their exposure because they can move closer and can get into an environment that we've never had them in before?

Another observation is that equipment is not always reliable. When we get the equipment into the new fire environment, that is closer to the fire, and in a hotter environment, we're finding the equipment fails. For example, all over the country **we're** having problems with polycarbonate helmets because they're melting. A firefighter's surprised when his helmet melts. Face shields are melting also. We're encapsulating firefighters and they're going into an environment they're not used to. A **Cal/OSHA** required piece of equipment that's supposed to be worn by a firefighter **who's** in a building structurally **firefighting** on the **SCBA**, is a man-down alarm. If you don't move for a certain period of time, it sounds an alarm. That's a good idea but it doesn't work. If two drops of water leak into that speaker it stops working entirely and it has a switch that's not able to be used by a firefighter wearing a glove. If you fall on the alarm you can't hear it. It has the same sound as a smoke detector used in a house, so if you're in a dwelling fire, **you're** not sure whether it's the dwelling smoke detector or the alarm. We get these required things which cost a lot of money, but from a practical standpoint, they're practically useless.

There are other things that are good,

that work in the **laboratory**, but do not necessarily work in the field. I think part of it is that we are getting closer as we get totally encapsulated here. More and more protective equipment permits us to get in closer to an environment that we really **don't** want to expose our fire-fighters to.

We have talked about standards. I have been with the **NFPA** for a number of years. I serve on a number of standards groups and using voluntary standards, I believe, is the way to go. But we also have to protect ourselves from standards, regulations and laws being written by people who may be technically competent but **don't** understand the end use of the product and how it is used by the firefighter, or other agency, in the performance of a job. We also need to discuss regulations that **don't** respond to problems. Sometimes things are regulated that don't need to be regulated.

Management, fire chiefs, management of fire departments and other agencies doing that type of work, need to know the limits of their personnel and their equipment. The technological limit is not necessarily the factual limit that you can use the apparatus for. The psychological effects and the physiological effects on the firefighter must be taken into account. The chief officer needs to make those judgments. He needs to have the information to make the judgment, and he must have the equipment, that is, the tools in his toolbox that he can utilize based upon the job, the exposure and the type of people he has employed.

I am very excited about long-duration **SCBA**. I think it's another tool that we need in the toolbox. But I'm concerned that we overuse it or we utilize it without careful analysis of what its impact is on the individuals whom we count on, the firefighter, to do the job.

Our next speaker comes to us from Washington. His name is Tom Seymore. Tom is in the standards branch of Fed/OSHA involved with a very touchy subject of how much do you regulate, and then taking all the heat when the regulations are passed and the questions are asked, "Well, why did you do it?" So, Tom is going to give us a presentation on the OSHA fire brigade standard.

I'd like to add a few points to clarify what John Sharry said. At the Federal OSHA we do not have the personal arm devices. We didn't regulate that, so you want to make a distinction between Federal OSHA and Cal/OSHA. A number of states have issued standards as called for under the Occupational Safety and Health Act and many of those states have modified the original federal standard. Washington and California had standards and Iowa had standards before the Federal Government had standards for firefighting. There are some differences among the states with regard to the federal standards. That is healthy, if the states need that for their location. They're permitted to do just what, in this case, Cal/OSHA has done.

I'd like to add one other thing to what John Sharry said, and that is he didn't mention the problems salvage and overhaul. One of the things we found out in going through our rule-making procedures, was that salvage and overhaul has a problem with exposures that we didn't anticipate in looking at some of the test data that was collected. We found that the carbon monoxide level was higher in salvage and overhaul than it was at the time of attack. Over the years those in the fire service have taken their breathing apparatus off once the fire is out in order to squeegee the water up, clean and remove salvage covers. That kind of information really prompted this thought: "Maybe there's more of a problem than we anticipated with salvage and overhaul."

The OSHA standards are not voluntary, they are mandatory. We utilized some of the voluntary standards that had been

developed by various organizations before we issued our standards and these became a basis for the federal standard. The OSHA fire brigade standard was promulgated on September 12th, 1980; it became effective 90 days later. The standard was a culmination of over four years of work, and involved extensive public participation during the rule-making process. The federal standard uses the term SCBA, that is, self-contained breathing apparatus. It can be positive-pressure, closed-circuit or open-circuit.

The section of the standard dealing with the self-contained breathing apparatus (SCBA) contains criteria which OSHA considers the minimum amount necessary to provide adequate respiratory protection for those performing interior structural firefighting. Some of the SCBA provisions address new and, in some cases, controversial ideas and approaches. For example, buddy-breathing devices and quick-disconnect valves are permitted if they meet certain specified criteria and the interchangeability of compatible air cylinders is also permitted.

OSHA, at the federal level, did not mandate the use of those kinds of devices. What was said in our standard was that if the fire chief or department wanted to use those kinds of devices and it met our criteria, or a manufacturer wanted to develop such criteria and could sell it to a fire department, it would not be a violation of the federal standards.

We wanted to get ourselves and our compliance people out of a position which would force them to enforce a standard that we didn't feel would be appropriate. We did use some constraint, though some of those things were controversial. The burden is then left up to the fire department as to whether they want to exercise those options or not. Obviously, the interchangeability of bottles has been done before we ever go into the rule-making business ourselves and the final rule permits that practice to continue. Perhaps the most important provision contained in the fire brigade standard is the requirement to wear positive-pressure SCBA when performing interior structural firefighting.

Positive-pressure SCBA affords excellent protection against inward facepiece leakage. This superior protection against facepiece leakage is necessary because of the many different kinds of materials in use today which result in toxic smoke, toxic mist and gases. Firefighters are exposed to unknown concentrations of contaminants when fighting fires and do not normally know what contaminants they are encountering - let alone the exact concentrations of the materials which may be present. Because of this uncertainty, firefighters must be provided with the type of protection which affords the best protection against the unknown environments that they may encounter.

This is the reason that OSHA proposed that only positive-pressure SCBA be worn when performing interior structural firefighting. After going through rule making process and public hearings that requirement was retained. During the rule-making process, OSHA received comments which remarked that any SCBA, (negative or positive-pressure) should be acceptable as long as it could achieve a specific protection factor.

There were other commenters who believed that open-circuit, positive-pressure breathing apparatus is the safest type for firefighting. However, they objected to any provision which would also require closed-circuit breathing apparatus to be of the positive-pressure type. These commenters contended that certain closed-circuit, negative-pressure SCBA could provide equivalent protection to that afforded by open-circuit, positive-pressure SCBA.

This issue was the subject of the OSHA hearings which were conducted on the fire brigade standard in 1979. We held three hearings across the country. That, and some other issues, were part of the hearing process. Testimony presented at the hearings overwhelmingly supported the use of positive-pressure, open-circuit SCBA for interior structural firefighting. Which is, of course, permitted by the

standard. There was also testimony and information submitted to the record which identified the following reason why closed-circuit breathing apparatus should not be required to be of the positive-pressure type.

First, there is a need for long-duration SCBA but there is a positive-pressure SCBA (open-circuit, closed-circuit) approved for more than two hours duration. Those that are approved for more than two hours duration are all negative-pressure types. Therefore a requirement which would mandate the use of positive-pressure SCBA would preclude the use of longer approved duration SCBA, like the four-hour negative-pressure unit.

Second, it was contended that certain negative-pressure, closed-circuit SCBA could achieve a protection factor equal to that of positive-pressure, open-circuit SCBA. Though there are some very good protection factors afforded with negative-pressure, closed-circuit units, they are not on the same level as positive-pressure, open-circuit units.

Third, it was contended that a possible hazard may exist with closed-circuit, positive-pressure SCBA. At the Washington, D.C. hearing, a movie presented by Draegerwerk Company demonstrated the possible ignition of materials exposed to oxygen-enriched breathing air leaking from a positive-pressure, closed-circuit breathing apparatus. Draegerwerk didn't make a closed-circuit, positive-pressure unit at the time this was done, so they modified one of their units so it would be a positive-pressure and did some simulation tests.

It is important to note however, that testimony and cross-examination at the hearings did not verify any case where this occurred during an actual fire situation. Based on all the evidence contained in the record, OSHA concluded that the best protection against toxic products of combustion is afforded by positive-pressure SCBA.

OSHA believes that closed-circuit SCBA does have a place in the fire service. First, although OSHA mandates the use of positive-pressure SCBA for interior structural firefighting, it does not

specify that the apparatus must be of the open-circuit type. **Therefore**, the use of closed-circuit, positive-pressure SCBA is permitted by the Federal OSHA fire brigade standard. **Second**, OSHA recognized that there may be special instances regarding the use of long-duration SCBA. The only approved SCBA capable of providing the desired longer-duration is the closed-circuit, negative-pressure type.

Accordingly, OSHA permits the use of closed-circuit, negative-pressure SCBA for special instances requiring long-duration breathing apparatus. At the time the rule was issued, a four-hour, positive-pressure unit was available. If a fire department needed a four-hour breathing apparatus, the standard permits it to use the negative-pressure, closed-circuit unit for that application with some stipulations.

Such SCBA, however, must have a rated service life of more than two hours and be able to achieve a protection factor of 5,000 or greater as determined by an acceptable quantitative fit test. This is one **area** where there **isn't** any given standardized fit test that has been embraced by all professionals across the country.

The OSHA fire brigade standard has had a significant and widespread impact on the fire service and that impact is continuing. Four years ago, when OSHA promulgated the provision requiring the use of positive-pressure SCBA for interior structural firefighting, it was a controversial issue. Today, it is more of an accepted practice, and it is enhancing firefighting safety across the country. There is still much work to be accomplished, and OSHA looks forward to working with you and others in developing better and safer respiratory protection for the fire service.

In summary, we published an advanced notice of proposed rule making, which is the intent of the agency, and it was thinking about doing some rule making in April of 1976. When the initial standards were issued in May of 1971, we included a section entitled, "Fire Brigades". We didn't have any rules at that time, but the aim of the organization was to do something for firefighters. It was recognized as being an occupation having some of the greatest hazards, some of the greatest life loss.

The formal procedure began in April 1976 and a proposal was published in December of 1978. The final rule came

out in September of 1980. There were staggered times for the standard to become effective. In July 1983 the positive-pressure requirement for half-hour duration units used in interior structural firefighting became effective across the nation.

The final rule is divided into only three sections that deal with breathing apparatus, closed-circuit units. The standard for respirators is on page 60708. Paragraph F deals with respirator in the section 191056 for fire brigades. There is explanatory information to help one better understand what we intended by those requirements in paragraph F, and that the appendix information is on page 60716 through 717. We talked about protection factors and also about some of the other aspects of **interchangeability** of bottles in the appendix. The appendix is not mandatory.

A New York newspaper article also dealt extensively with the fire department and the psychological aspects of what happened to the firefighters after being told they had been exposed to **PCB**. We made the decision that we believe the firefighter deserved the best respiratory protection afforded at that time, which, we believe, was positive-pressure, whether it be closed or open-circuit. The fire service needs such duration for its work.

I'm going to be discussing the kinds of interpretations we used to develop a test method in 1980 to test and to expose CCBA's to a fire environment that we felt would be a rational 2nd severe environment. I'm going to first speak about the potential fire exposures to a firefighter in the field as we see them. The kinds that they would likely get into, not by their own activities as far as direct cause, but by inadvertent characteristics of fire conditions. The next thing I'm going to speak about is a few parameters of heat transfer from fire to materials and then the ignition energies that are required to cause polymeric materials to ignite or pyrolyze. The issue that we're concerned about is the **flammability** enhancement in oxygen-enriched environments similar to what one might expect if one had a CCBA that has a leak in it, either in the component or in the junction

between the **facepiece** and the face surface. As a means of setting the limitations for the test, it is necessary to be aware of the endurance of human skin when exposed to fire in order to give us a sense of where the test would have limited severity and yet would be severe enough to test the conditions of the CCBA. And, finally, I'll discuss something about the design of the test rig that we employed for this purpose.

First, I'd like to talk about the conditions of the characteristics of general fires. We're talking about fuels or materials in the three phases that are available in nature: solids, liquids and gases.

We're talking about the increase in combustibility. By combustibility, I mean, either the ease of ignition, the flame-spread rate, the heat-release rate, characteristics of that nature versus the distribution of the fuel. As the surface to volume of the material increases, the combustibility parameters increase. If there is a solid fuel, and there is a fire, there would be a contiguous flame, which is limited to the dimension of the fuel. As the distribution of the fuel is increased, the rate at which the material can burn is also increased and the heat produced from that material is also increased. If a solid material is reduced to dust a dust explosion can be obtained.

Similarly, it is expected that a liquid-pool fire, is confined to the dimensions of the pool as the **surface-to-volume** ratio of that material is increased to the point of the spray, resulting in a much more intense and much more dramatic fire. In gases the limitation is not to **surface-to-volume** ratio, but to the mixture ratio of the gases.

Going from lean to rich limits for gases, we go through regions of increasing flame speed, increasing heat-release rate to a maximum at the **stoichiometric** ratio the optimum ratio of fuel to air, and then we again decrease these parameters as we go to rich limits. In most cases where firefighters are inadvertently exposed to the actual flames of fires that are accidentally started, they are in the range where the **surface-to-volume** ratio was large.

Conditions of possible exposure to firefighters can exist in addition to something collapsing on them, their

falling through a floor or becoming involved in other areas of **fire**. They are the following:

The ignition of a gas-air **mixture**, that **is**, lean or rich mixtures can occur. In ideal mixtures of gases the result is high pressure pulses which can transmit to firefighters for quite some distance.

There can also be the ignition of **transient-heat-release** rate of high pressure fluids. If a fire is occurring in an area where there is a hydraulic system and the hydraulic system is compromised, the result can be a release of high pressure fluid which atomizes followed by an extreme increase in the flame-spread rate and the combustion parameters of these conditions.

A more common system is the back-draft of a fire in an enclosure containing burning fuel which is partially oxidizing the combustion products. If a window is broken **out**, the oxygen concentration is increased and resulting in a flame-spread rate on the partially combusted gases which can actually expose firefighters who are attempting to enter the building or the enclosure to fight the fire.

The other aspects are: a flashback of partially extinguished combustible liquids. If one is using foams to extinguish a pool fire in an attempt to get to an area where people might be located and the foam is not holding the fire, fire flashback can occur where the firefighter is and that gives it limited exposure. There is always the chance where you might have to go through an area that is already involved in fire to escape the combustion conditions. The character of these exposures is that it is transient. The exposure to the firefighter to direct flame would only be of a short duration.

I spoke of lean or lower limit mixtures and rich or upper limit mixtures of gases. I'm sure you're all familiar **with** curves similar to this relative to the combustibility of vapors and mixtures of vapors in air where, essentially, you have allowed regions of combustibility for materials for these mixtures of gases or vapors in air. Back-draft conditions may be an indication of an upper-limit condition of combustibility that, for most gas-phase explosions that firefighters could survive, would be in a region of lower limit of explosibility.

If a fire generated on a flammable liquid

that liquid were to be atomized by a high-pressure system, the fire can proceed in the high-pressure mist and have conditions that almost duplicate a gas-phase reaction. This lower **ordinate** is a function of temperature reaction. High temperatures reach a condition of **autoignition**, and **autoignition** would be **non survivable** for most cases of firefighter exposure.

In terms of how fire creates heat transfer to surfaces to cause ignition of the surfaces, this figure relates the modes of heat transfer available in a fire from flame heat - from flame contact to, in this case, a wood surface. This is a **nondimensional** time versus a dimensional-heat exposure or heat flux. These are actual units.

There are two modes of heat transfer from fires to surfaces: one is the convection of heat transfer, which is the wafting of gases across the surface. The other is radiation heat transfer which is the radiation from an incandescent source. The radiation in this case, **is** orders of magnitude more intense than the convection in terms of potential heat transfer from very large fires. The curve depicts the net heat transfer to a surface indicating that as the surface itself heats up, the rate of heat transfer decreases because heat transfer is a function of the temperature difference between the surface and the hot gases. In any exposure there will be a net increase then decrease in heat transfer.

The bottom curve indicates this by the amount of energy **reradiated** from the surface of the material. Now, in any case where a firefighter might be concerned, the levels of heat transfer will probably be in this regime, such that there will never be a chance for the surface temperature to increase to the extent where reradiation would become a significant effect.

The means for defining the critical **irradiance** for ignition of a material is a curve that indicates the critical irradiance, and this is just strictly thermal radiation to the surface from an incandescent source. The irradiance versus one over the temperature is

plotted, arriving at a specific point which is almost an asymptote for critical irradiance for ignition. At this **point**, critical **irradiance**s are approximately eight calories per square centimeter per second, which is approximately three watts per square centimeter. It takes about ten seconds for this particular material to ignite. This is the only column we're interested in. This is the irradiance level for piloted ignition for a series of polymeric materials similar to those that might be used in CCBAs. None of these levels is less than two watts per square centimeter, so an ignition condition for the kinds of materials that could be used in the systems are of the level or of the order of two watts per square centimeter or greater. This is a level that is quite available in direct fire contact for short durations.

There is real concern, however, if the oxygen concentration in a mixture is added or varied. The curve describes the ratio of ignition time to the time to ignition at one atmosphere and standard conditions to the oxygen partial pressure in this mixture.

How much oxygen do we have added to the mixture that **we're** using? The dotted curve is where you simply change the total pressure of the gas to enhance or increase the concentration of the oxygen. The solid curve indicates where you, actually, just changed the oxygen concentration. As the oxygen **concentration** is increased by either means, there is a decrease in the time to ignition. However, by increasing the pressure, the ignition parameters are decreased more than by just increasing the oxygen concentration.

As corollary to this, the flame-spread rate is also enhanced by increase in oxygen concentration. And here this is a comparison between the addition of **retardants** to a cotton material to indicate that no matter whether the **retardant** is in there or not, increase in oxygen concentration is going to cause an increase in flame-spread rate. If there is a condition in a SCBA or a CCBA where there is a leak and a person is exposed to fire, not only will the ignition time be decreased, but the flame-spread rate on the material that can possibly ignite will be increased.

Other evidence has shown that the inclusion of **retardant** materials can decrease the time to ignition more substantially. Another parameter that is of concern in setting the conditions for our test is the response of human skin to heat transfer. These areas set the limit to the kinds of heat transfer that can be available in different fires. This indicates the temperature at which damage is done to the tissue.

Most firemen who have experienced back-draft have indicated that they felt pain but never received anything worse than a **first-degree** burn. That would limit their exposure to this region. **Therefore**, the exposure in our tests should be limited to conditions that would fall within this **region**, below the time when the temperature of the skin would achieve sixty degrees centigrade.

Tests on the **irradiance** revealed that the thermal radiation alone required to create these kinds of temperatures in the skin indicate that even very, very low levels of irradiance, .4 watts per square centimeter, will effect and cause this kind of temperature rise up to severe pain region. If the irradiance that is available in transparent fires is achieved one and a half to two watts per square centimeter, this temperature rise can be achieved much more quickly. Up to sixty degrees centigrade in skin temperature can be reached within **five** seconds. The resulting burn is an accumulated effect, not just the effect of the temperature rise. The temperature must be increased and decreased before skin damage will not occur.

Our conditions are to provide an exposure level which is severe, but not too severe, and a test that is reasonable to couple with potential leaks in the **CCBAs** and yet not cause ignition of the CCBA material. And, we also **don't want** to accrue anything worse, or the potential for worse, than a second-degree burn in a potential mannequin or analogue of a mannequin.

These tests were done in 1980 in a fire test cell because it is ideal and a simple area in which to do the test. The cell has the necessary instrumentation and all of the diagnostic characteristics to do that. The test procedure is schematic. In this drawing, we provide a hundred liters per minute of natural gas to a burner; the burner is naturally **droughted** so it has a

partially premixed flame. It produces a flame of .6 meters. The flame **temperature** is measured at 120 degrees centigrade. For a flame of this character and optical density, the energy level is less than three watts **per** square centimeter and our exposure durations were of two minutes - two seconds and four seconds each, giving a fluency of approximately one-and-a-half watts per square centimeter to the surface of the dummy and the mask. This set gives an indication of the type of exposure achieved. This is a mask of which I **don't** know the designation. This is the flame exposure to the mask. And, if **you'll** notice, by incandescence on the inside of the mask, that there was indeed a transfer of **fire** to the interior, because we had actually contrived a leak and, ultimately, this coupled into a combustion that sustained itself until we put it **out**.

*Chuck Harder is our next speaker. He's going to talk to us about **fire** test results. Chuck makes it all work; he collects the data; he puts up with our changing things and generally has a good outlook on life; and we collect a lot of good data.*

I would like to cover briefly the **fire** tests on closed-circuit breathing apparatus. Fire tests on closed-circuit breathing apparatus were conducted by **Draeger**, Bio Marine, and the Lawrence Livermore National Laboratory. As there is little written documentation on the tests by Draeger and Bio Marine as to the work rates of breathing machines or the size of the introduced leaks, this information cannot be covered at this time. The tests were set up at Lawrence Livermore. To create an oxygen lead, a stainless-steel tube was inserted between the **facepiece** to face seal. The tube was .12 inches outside diameter, with an inside diameter of .065 inches, which gave a leak rate of approximately .75 liters per minute. A humidifier was placed in the exhaust line to give a better representation of exhaled breath. The CO₂ source was used only for the oxygen-generating unit. The labora-

tory's breathing machine was used to operate all units at a moderate to heavy work rate of 52.53 liters of air per minute. The test head was mounted on a pedestal and placed .3 meters from the flame source at an angle to give a three-fourths exposure view. A **Navywool watchcap** was used to simulate hair because the Navywool watchcap is not fire retardant treated. The **closed-circuit**, oxygen breathing apparatus was placed on the pedestal over a firefighter's turn-out coat. After the facepiece was mounted on the test head, a firefighter's helmet was placed over the head harness and watchcap. The flame source was between 1000 and 1500 degrees C and extended approximately .6 meters from the burner face. Each unit was subjected to a **two-second** and four-second exposure to the flame.

I'd like to describe very briefly for you California Assembly Bill 3520 which **covers** positive-pressure, closed-circuit breathing apparatus. I'd like to give you a little idea of how it came about and to make some observation on the process which brought it to our attention and what we found once we got into the subject area. Assembly Bill 3520 which covers positive-pressure, closed-circuit breathing apparatus was passed by the legislature in August of this year and it was signed into law by the governor in September. The bill requires the division of Occupational Safety and Health to contract for the testing of positive-pressure, closed-circuit apparatus, and specifically, as it relates to situations likely to occur during interior structural fires.

The law specifies that the testing address the issues of inhalation temperatures, moisture condensation in the user's mask and lungs, and the possible risks resulting from dislodgement of the mask within a fire situation. The law states that the standards board will develop a numerical definition of what constitutes positive-pressure. These standards will apply to everything that is used in California. It is basically an exploratory testing bill which requires standards to be evolved from those tests. The simplicity of that bill belies a very long history. It is the only bill of this type in the nation.

Because of the controversy that brought it about, the issue that **it**

addresses. Second, because the bill is a good example of how legislation is determined and prepared. And third, because it's also an example of what one, single, very determined individual can accomplish.

In the early winter of 1982, Mr. James Tunnel approached Senator Watson with a problem. He informed him that NIOSH had mandated exclusive use of a piece of firefighting equipment for which no safety standard existed, and he felt that the piece of equipment might very well be dangerous in certain situations. As is common practice, the Senator assigned a staff member, myself, to inquire into the issue and determine if legislative action was necessary and appropriate. This decision on her part initiated what proved to be a three-year effort on the subject.

The study determined that there was, and still is, no question that the firefighting industry needs a new breathing apparatus that can provide extended time within a dangerous environment. It is obvious even to nonprofessionals, such as legislators, that the new building materials, toxic spills, tall office buildings, tunnels, shafts and chemical facilities all present specialized problems to the firefighter, and that we all realize that they may well be beyond the capacity of the traditional Scott airpak. The potential value of positive-pressure is also apparent to anyone who just looks at the issue for the first time. It follows, very logically, that a constant flow of clean air past the face of the firefighter would be a better method of providing him air in a safe environment than depending on a rubber face seal.

Beyond the theoretical, a number of deeply disturbing facts were found, such as the case that NIOSH had required the use of positive-pressure apparatus, not only in hazardous atmospheres, but in structural fires. Their reasoning in supporting testing was unknown and unavailable. We were also aware of a number of incidents which challenged the logic of their decision.

NIOSH had no definition of the term positive-pressure, as well as no standard for it. Among individual fire departments there was also found some dissatisfaction and some serious problems with the equipment. The Boston Fire Department had tested such equipment and decided that

it was unsafe and ceased its use. The San Francisco Fire Department came to the same conclusion and took the same action. The Washington, D.C. Fire Department expressed some serious reservations about it.

In tests of the products that were undertaken, there was disagreement among the officials and witnesses who had viewed it as to how successful they were. We discovered that after some substantive changes to the devices, orders had been issued by the Federal Government to stop sales. Tests conducted prior to the use of the equipment in the Three-Mile Island reactor number two indicated serious problems with it.

There was enough evidence accumulated that the state should look further into the mandate that it be used as stated by NIOSH, as well; and we were concerned about the potential risks of introducing pure oxygen into a fire environment. While the flow of oxygen past the facepiece may have a negligible effect in the surrounding airspace, it's known that oxygen collects on the hair and clothing of the wearer, exactly where you would not want it.

The possibility that an accident might dislodge the facepiece and allow pure oxygen to flood into what might be a contained space with fire present was of greater concern. The potential of fire in an oxygen-rich atmosphere is apparent to anyone and was dramatically demonstrated in the NASA fire which killed Gus Grissom and a number of other astronauts. As nonprofessionals in the field, but familiar with the violence and confusion that can occur in a rescue and fire-suppression operation, the state felt that there was some likelihood that a situation like this could happen.

In order to resolve these questions, Senator Watson introduced Senate Bill 1999 in March of 1982. That measure required the State Standards Board to adopt regulations concerning the safety of the positive-pressure equipment. The regulations were strengthened by concluding that failure to abide by any regulations developed by the Standards Board would constitute failure to maintain a safe environment. Cal/OSHA, and, to a lesser degree, the Standards Board both resisted the bill.

They, and much of industry, maintained that such action was unnecessary and that current regulation and testing was adequate.

In our legislative system, each proposed law is heard a minimum of six times. It is heard once in assembly or senate policy committee, it then goes to a finance committee, then it goes to the full floor of either house. That operation is repeated in a second house, so there are six hearings on every bill. When 1999 came before its very first policy committee in April of that year, the administration's representative approached the Senator, offered to institute the testing and develop the standards, if we were willing to drop the bill. This is a common practice within the legislature, something akin to plea bargaining done in trials. It saves everybody the time and effort of going through the lawmaking. The state agreed, and the bill died.

Over the next six months very little activity occurred on this issue despite numerous communications on the part of the state. In November of that year, a new governor was elected, and by January a new administration was in place, and apparently the new administration did not seem to feel bound by the promises of its predecessor. For more than a year, Senator Watson and Mr. Tunnel sought Cal/OSHA's attention on the issue by means of countless letters, telegrams and meetings seeking some action on this issue.

It proved a surprisingly divisive issue because it generated extremely strong reactions among both proponents and opponents. The position people took on this particular issue tended to be very hard, and this went beyond what is commonly encountered in the legislature.

In the beginning of 1984, we concluded that further legislation was necessary. Therefore Assemblyman Bob Campbell agreed to require the testing and consequently drafted and submitted Assembly Bill 3520. The same concerns over fire safety, which initiated action by Watson, were those that motivated Assemblyman Campbell.

During the following months, Cal/OSHA began to review the issue. An advisory committee on the apparatus was formed and some limited testing was undertaken. The testing chiefly concerned

oxygen leakage around the mask, and it was less than the amount the legislature had sought, so they continued forward with the bill. The bill, despite the divisiveness of the issue, did very little in front of the legislatures. It never received a negative vote, went through all six hearings and was signed by the governor without any serious objection by any of the members.

I'm convinced that the passage of the measure was due to the propensity of the legislature to come down squarely on the conservative side of safety. I'm sure that each elective official who voted on it thought that if we are to err, let us err by being overcautious rather than rash.

It was never truly a question of whether or not the benefits of positive-pressure outweigh the costs, but rather, that costs are known before requiring the use of any life-supporting technology.

During the three years required to change the policy on SCBA, Senator Watson, Assemblyman Campbell and the other legislators were faced with conflicting evidence from a variety of sources. This is the norm on most of the issues that come before the legislature. In the face of such conflict to require further study and more firm standards seems reasonable.

The motives of everyone involved in this effort have been seriously questioned. It is unfortunate that one manufacturer in the United States produces this equipment. It must have appeared that our efforts may have been targeted against that company though this was not the case. With the introduction of any new technology, one can expect a shake-down period for users, producers and regulators to work out the problems in the design and practice. The legislature felt that this should occur in a laboratory and not in a field as essential to a fireman as his breath.

The most disturbing discovery that the legislature came across during this process was that this issue did not seem isolated. It was not just breathing apparatus which had these sorts of conflict. There were similar problems described by firemen in any number of life-supporting devices, and there were widespread complaints against it.

I concluded by offering a sense that I certainly hope that the very deliberate attitude expressed by the legislature in

Assembly Bill 3520 would extend to other devices which are currently coming onto the market and which firemen are being required to use in their work.

The next speaker is Richard Jones who is head of a committee looking at respiratory protection, essentially, self-contained respiratory protection used by the fire service in the State of California.

There was an advisory committee which came up with a bill which was submitted to the Standards Board and it came up for a final hearing on June 30th of 1983. The result of the hearing was that Section 3409 would prohibit use of closed-circuit, positive-pressure, self-contained breathing apparatuses in fire activities until NIOSH certifies and approves positive-pressure type units.

This was rejected by the Standards Board because of the controversy that there are six on one side and a half dozen on the other side; and it came back to the division and they asked us to do some further testing. This action occurred in June of 1983. The testing at that time was primarily aimed at the hazard associated with dislodgement of the oxygen mask, the positive-pressure, closed-circuit type.

What was the hazard involved there? There were other things that people were concerned about. They were concerned about the moisture in the mask, the face of the mask and the temperature in the mask.

The Advisory Committee met and wrote a protocol which was aimed at the oxygen concentration problem and there was also an attempt made to introduce some of the other items into the testing. The protocol stated that the committee wanted firefighters to wear the protective equipment which is outlined in Article 10.1, which is probably the finest safety standard for firefighters in our country. Article 10.1 outlines, not only respiratory equipment but also gloves, boots and turnout coats. The committee wants firefighters to wear and use the equipment as

indicated in Article 10.1.

The Advisory Committee at that time wanted to have approximately thirty people involved in this test. As it was, we only ended up with twenty-four because one unit we thought could do some tests actually didn't have the proper equipment and cancelled out. This was a field test; this was not a laboratory test. The Committee wanted firefighters to simulate going through a fire, doing the things they would do in a fire while wearing equipment to see what kind of oxygen concentrations would be found around the mask and helmet, around the ears, around the necks and under shields. Equipment was used to measure the oxygen concentration in the mask in the first test which was held in San Francisco with the San Francisco Fire Department. The group moved on down to the San Diego Fire Department, where the actual temperature in the mask was measured. The fire department supplied the people and the equipment and whatever was necessary, and we got ourselves down there and did what we had to do to get it done.

This is San Francisco and if you look over to the right-hand side, the gentlemen over there, they have a machine, or actually what you use for simulating chopping holes in the roof. That was one of the operations we wanted them to do. The other people are just kind of standing around waiting their turn; we cycled them through about every five minutes so we wouldn't bog down and get everybody at one place at one time. Here's a close-up of the individual working on that machine.

Now, this is another apparatus which the San Francisco Fire Department has which they simulate pulling down a roof. They have a weight there and it's spring-loaded and they grab that with a hook and they pull it down and it goes back up. We had these people do that for three minutes, just like they did the ax operation for three minutes. Then they actually went on up to the top of the sixth floor of their training building and then back down. And we had a smoke room where they went in the smoke room for approximately three minutes.

I will want to comment on the smoke rooms which we used both in Long Beach and San Francisco. There were not

high temperatures in there, so we weren't trying to simulate high temperatures in the fire like you would find in an actual structural fire.

Now, here are the results of the test that we did. And you can see that we checked the oxygen concentrations in the helmet, under the shield, around the mask, the hose part and the whistle area and inside the mask.

Bio Marine equipment primarily was used because that was the kind of equipment that was available. San Francisco brought disused equipment back out, brought it back up to standards, trained firefighters in equipment use and then testing was done. In Long Beach the equipment was currently being used.

There was some concern about the oxygen concentration around the whistle, but this concentration is found at the actual time that the whistle blows to indicate that the pressure is getting low and the fireman should get out. We checked on everybody underneath the helmet and we had no problems in that area. If they had a shield, we checked that also. There were no problems around the mask. There is equipment that probably would not require a shield and actually there might be some departments which were not using the shield.

As the eleventh subject at San Francisco, we got forty percent oxygen in the hose area and also around the whistler. The high concentrations were the result of an individual's attempt to bring the pressure down so that he could activate the whistle. He pressed the bypass valve, which released oxygen into the area activating the whistle. This was the primary reason for such high readings. Only one test was run on mask temperature and that was a ninety-five.

There was one case that indicated leakage around the seal. Temperature in the mask was NR in this particular case. There were people who indicated moisture in the mask. That can result in a fogging of the mask and then in some cases dewdrops would actually form inside the mask. One individual said that his visibility had been, actually, restricted by about fifty percent from moisture in the mask. I do believe that moisture in the mask is a considerable problem.

Test duration ran from approximately twelve to sixteen minutes. Some people

are very energetic and run through the test very rapidly, and others take their time. That is the main reason for the difference in time.

We did find that the flow of oxygen seemed low. Five people in the San Francisco test commented that they felt that the flow in the mask was low. However, these people had not used the equipment very much and I don't know whether or not their observations were the result of not being used to the equipment. I know any time you use new equipment, it takes a little while to get acclimated to the characteristics of that equipment. But, I have heard from other people that occasionally people say they feel like the flow is down low.

One hose was too short. The man was rather tall and I don't know whether we didn't get the pack high enough on the individual or possibly he was so big that he actually did need increased hose lengths.

We moved on down to Long Beach and they did not have the equipment San Francisco did -- so to simulate chopping holes in the ceiling, we just chopped up pallets.

Here's the gentleman coming up at the top of the training facility heading back down again with the pack on. The hose parts that we tested and the whistles are over in this area.

Here is one of the firemen coming out of the smoke room. A chief helped us send the people through the room on a five-minute interval.

This is some of the test equipment used. We used the Edman to check the oxygen concentrations around the shields, helmet and mask.

The compliance officer from the Long Beach office helped me with the testing. Here he's actually doing the oxygen testing. Here we are doing both oxygen testing. This device over here is for temperature reading.

These are the results of the Long Beach test. One of the comments we got from the San Francisco test was that we should probably test twice. Not only do we test at the end of the fifteen or sixteen-minute session, but we should also test at a midpoint. We thought that was a good suggestion, so that's why you see two numbers in each block. The upper right-hand block is the

midpoint, the lower, or the upper left and the lower right is the finish one.

We had no problem with high reading. There was one high reading under the shield. In talking to the gentleman, he commented that his mask was leaking under exhalation. When we looked at it we noticed that his mask had been cocked for some reason. To check it out we had him straighten it back up, stand around and then use the equipment for about five minutes. When we tested again it came out all right. If a mask is cocked, and it will be worn for quite a while, there will be a leak and there's going to be a build up in concentration. These concentrations rise underneath the shield more than they do around the oxygen mask. In an oxygen mask, concentrations are going to dissipate, but under the shield they tend to hold the oxygen in. There were no problems around the mask. There was no problem with hose parts.

The criteria that we used was that if the reading was below 26 percent, we were not concerned. We felt that that was very safe. If the reading was from 26 through 28 percent, it was marginal and anything above that was unacceptable. Those were the parameters that we set in the protocol. There was no problem with the whistles. Inside the mask concentrations went from 68 to 96 percent. I think that you can be assured that you are going to get oxygen concentrations of 85 to 96 percent in the masks.

When you first begin to use the mask, there are gases such as carbon dioxide in the air supply. As the mask is used, eventually there is going to be a high concentration of oxygen in the mask.

We had three cases of leakage at the seal. Temperatures in the mask varied from 82 to 93 percent and these were not under severe tests. There is definitely a temperature problem because in an actual fire the ambient heat is high, so those temperatures are going to go up. About twelve people reported moisture in the mask. We performed some artificial leaks. There was a two-second leak and under the hood there was a twenty-two second leak. In simulating the dislodgement, there was an artificial leak of four seconds. Simulating the dislodgement, there was a twenty-eight second leak. There was also an artificial leak of four seconds and

twenty-three seconds. This leak was around the mask where the oxygen dissipates.

After the tests were over we looked at the advantages and disadvantages. The duration is still longer if it is needed and the weight of this type of unit is lighter. The protection factor is at least as good and probably better than you would find in an open-circuit apparatus. It has a two profile as far as the bottle goes. The whole package is much smaller and it allows the fireman more maneuverability while getting in and out.

Those were the advantages. The disadvantage is the enriched atmosphere and we are concerned about this. We need to do some additional work in this area. Temperatures were higher and moisture was a problem. The equipment is more complex and the man in the field has a problem working on it. He must change the soda in it and charge the oxygen. This is going to be an additional requirement for any person using the equipment. Shop people who have worked on the equipment indicated that it was easier to work on but at the fire site it was more complicated. Closed-circuit equipment will be contaminated so the entire system must be dismantled and cleaned. But with air bottles, the only thing contaminated is the mask, and that can be washed out. One other item that might be a factor to some people is the cost of the closed-circuit, positive-pressure system which is considerably higher than the bottle system.

In summary, we recognize that that equipment is a specialized piece of equipment. I don't think that this equipment is going to replace the air bottles. However, there are cases in which there is an advantage to using this equipment, as many people have indicated.

I would like to introduce the first speaker, Mr. Rich Duffy. He's an industrial hygienist for the International Association of Firefighters, the National and International Firefighters Union. The International Association of Firefighters is a member of organized labor. It is affiliated with the AFL-CIO and the

Canadian Labor Congress. I'm the director of Occupational Health and Safety with that organization in Washington, D.C.

Tom Scymore addressed the standards used in the country right now, the Fire Brigade Standard, as they're called. This was a classic piece of legislation to help protect firefighters.

Interior structural firefighting is occurring even though firefighters are not inside the building. They are fighting a structural fire in a basket of a narrow device. In this country and throughout North America, firefighters are not supplied with breathable air in these circumstances, and many times they are exposed to smoke and toxic conditions.

Then we get to the parking lot fire. This one we never worry about. We call it the parking lot fire because that's usually what the lot becomes when overhaul finishes.

And then we get into the areas that we talked about, specialized use of breathing apparatus. Such a fire occurred in Elizabeth, New Jersey in April of 1979. It was a chemical-control fire and there were 55-gallon drums on the site. By the time the fire started, there were forty thousand. The first company from the Elizabeth Fire Department did not wear breathing apparatus at all and neither did anyone else throughout the course of the fire. The fire was put out the next day, mainly due to the assistance of the New York City Fire Department which sent over a boat and just deluged it with water. There were over four hundred firefighters involved in this particular fire. Over the night of the fire, the next day of the fire, and through the clean-up period respiratory protection was not worn.

The IAFF investigated this fire. Complete physical exams were done for over four hundred of the fire service people in scene. Physical exams were repeated twice since the original exam and the firefighters involved experience chronic health problems due to lack of using respiratory equipment. Clean-up personnel at the same fire, stayed many months on the scene, cleaning up 55-gallon drums. They did wear respiratory protection although while they were on

the scene, there were significant problems. Even though it was April, it was quite warm. Heat exposure was obviously a problem and duration was a significant problem. Clean-up personnel were wearing half-hour bottles and open-circuit breathing apparatus, but by the time they got suited and taped into the suits, had very little time to do their required work.

Another fire in Jacksonville, Florida, in January of this year, was a PCB fire. PCBs are polychlorinated biphenyls. People were mixing used PCBs and transformers and capacitors with white gasoline and selling it as fuel oil. But one day it burned. We hear about PCB problems all the time. People in Northern California have heard about it with the Del Monte building. In this case, there were high PCB exposures. Tetrachloro-dibenzofurans and tetrachloro-dibenzo-dioxins also formed after the fire and very little was done.

This is where regulation comes in. People said there was no need for that much regulation. However, the U.S. Government would have evoked superfund at this particular site. They decided not to do so because this administration feels that businesses are capable of cleaning up. We were in great disagreement, especially when they went downtown and they got manpower people to do the cleanup. Firefighters were allowed to be on scene even after the fire.

On the right -- below the firefighter's feet -- the levels that were found were over thirty thousand parts per million of PCBs and that is before we got any of the furan or dioxin measurements back.

Here are the clean-up personnel that were sent in. Instead of having experienced clean-up people, they went downtown for manpower, handed them a few chemical suits and said, "Go on fellows, start cleaning up." It didn't work and respiratory protection was not worn. When we arrived on the scene, the NIOSH industrial hygienist and I wore a self-contained breathing apparatus.

Not only are firefighters exposed by not wearing breathing apparatus in structural firefighting, but in a training area at the Opa-Locka Airport in Dade County, Florida, where kerosene was normally burned for FAA required drills, a young entrepreneur went to the fire

chief and gave him free spent solvents that burned better than kerosene. The 55-gallon drums of spent solvents, xylene toluene for example, that had gone through a manufacturing process and so had picked other contaminants such as heavy metals would be rolled out. The drums were spiked underneath an old jet and set on fire. Then the FAA drills would begin. No breathing apparatus was worn. Breathing apparatus is not typical when in a crash-fire rescue. Firefighters were needlessly exposed during that particular incident.

This is a New York City firefighter down after smoke inhalation at a fire for not wearing proper respiratory protection.

The classic photo of firefighters in this company is this one. I could just have shown this picture and probably not have said anything else this afternoon.

This is a chemical control fire in Elizabeth, New Jersey. Firefighters are in a "red" area and so all must wear self-contained breathing apparatus. Also his boots are rolled down and the only protection on his hands are the calluses on his palms. The turn-out coat is made out of a coated cotton and the helmet is one of his dress hats.

In conclusion, I just want to say what firefighters should wear. Breathing apparatus should be worn and it should be of a positive-pressure nature. It also needs to be lightweight and low in profile. For specialized use, firefighters need long duration equipment. If it is a heavy unit, for example, a one-hour, open-circuit unit, firefighters are not going to wear them.

In Washington, D.C. there was a fire last week in a government building that did \$120,000,000 worth of damage. It was an unsprinklered building so it was a significant fire. Firefighters tried an interior attack to put it out but were unsuccessful. Instead they had to set up master streams outside to put out the fire.

The government's position, in this case, was that it didn't need to be a sprinklered building because there was really no life hazard involved. However, there was a significant life hazard because twenty-five firefighters went to the hospital for smoke inhalation.

They do have one-hour units in Washington, D.C. but because they weigh thirty-five pounds in the open-circuit nature, they did not wear them, especially

after walking up nine stories inside the building.

Is closed-circuit the answer for firefighters particularly in a specialized situation? The International Association of Firefighters believes it is.

The next speaker is Chuck Soros from Seattle Fire Department. Chuck is also on the NFPA Self-Contained Breathing Apparatus Committee and brings some special insights.

My position on the use and needs of self-contained breathing apparatus for the fire service is one that should not rule out anything that is going to benefit the service. The stipulation that needs to be added to this statement, however, is that it must be performance oriented, realistic, and cost comparable. There is also a need for an industry to work and listen to the fire service, to welcome equipment that is technically designed but is not pragmatic. The marriage between this practitioner and the technician must exist.

It has been my privilege over the last couple of years to serve on a host of committees that have worked to develop criteria that will fill the needs of the fire service. All too often, however, many of these groups are interested in grant proposals to further someone's educational career or design a unit for the fire service that they could not afford or use. We, the fire service, end up frustrated and stymied.

One of the earlier points I stressed was performance criteria. The NFPA Committee on personal protective equipment is presently winding down a high performance document on open-circuit breathing apparatus. I have been associated with this work for the last ten years, and it has only been in the last two or three years that we have really pooled our efforts.

This document reflects the needs of the fire service and frequently the committee had to develop test criteria to meet our needs. The need for flammability criteria is also addressed, as well as hot and cold soaks and vibration tests. We have fire helmets

that must meet 485 degrees Fahrenheit temperatures and turnout coats that meet the same criteria. However, there are straps on breathing apparatus on the wearer that catch fire and melt at 135 degrees.

Breathing apparatus fails but clothing doesn't. This is one reason for mandatory performance criteria between open-circuit or closed circuit equipment. The time frame, that is, hours versus minutes, of our closed-circuit breathing apparatus is constantly debated. My position is that sixty minutes will fill the needs for the fire service.

I do not know how many of you have actually fought fires, but based on my experience, if you use a mask for sixty minutes, you are done. I have gone through four or five bottles on open-circuit units and the fatigue factor is tremendous. Consider the environments, weight of the turn-out equipment worn, anxiety, and fear, - loss of body fluids, weight of breathing apparatus and hose, and also the actual energy used to combat the fire. After six minutes, you are ready for a break and I do not care what good physical condition you are in, these factors take their toll, individually and collectively.

My comment on cost comparability is a very realistic need from both the manufacturer's point of view as well as the user's. Everyone is aware that cities work on a bid process and financial prosperity is not each city's long suit today. No one gains anything by making a unit that is cost prohibitive. The fire service needs breathing apparatus to function but must be realistic. It is necessary to have a unit that provides positive-pressure but be easy to don and is durable. Running field checks on a unit before you enter a fire is ludicrous and some units vibrate apart enroute to a fire. Durability and dependability are important.

In September of 1980, I attended the First International Respiratory Research in Morgantown, West Virginia. I was the only firefighter in attendance at this meeting. There were two other labor representatives, both of whom were from International Unions, in addition to two women steelworkers. The conference was so steep and academic that the three of us could not understand any of the papers.

We waited for the practitioner's point of view, but it never came. Finally, I was able to speak. I asked people what they were going to do for the fire service. And the answer was that a man in the fire service is a "macho man," and he doesn't want to listen to what we have to say. I said that I wanted to reiterate the fact that the fire service needs good R&D programs and it wants to know that the service has equipment that can be used and will meet the demands of the job.

Most of the West Coast cities have mandatory mask rules, so if a man in our fire department does not have a mask on, he is going to get some time off. Firefighters know that with the influx of hazardous materials presently on the market, they may not walk away. As a result, the fire department wants better units, open or closed-circuit. Build something that is going to function. Also, listen to what firefighters have to say.

I'd like to see cost and complexity and sanitation tests run now. Some of the tests are four years old. I would like to see what they are now. Things have changed since the testimony hearings in San Francisco. Some of the complexity issues that were addressed earlier need to be amended by certain individuals. This is a unique piece of equipment, and that particular piece of equipment should be worn by individuals that are going to use it all the time, not just on a random basis.

The next speaker is Tom Seymore, who spoke earlier. He represents Federal OSHA and was involved in the development of the Fire Brigades OSHA Standards.

I would like to help John Miller better understand what Federal OSHA did when it promulgated its rule for the positive-pressure breathing apparatus because there were some misunderstandings. First, there are two organizations at the federal level that were involved with this subject under the Occupational Safety and Health Act. The National Institute for the Occupational Safety and Health is the approval agency for respirators. In the OSHA standard, OSHA as a regulatory agency, mandated that NIOSH-MSHA

respirators be utilized. NIOSH is the regulatory agency. They have criteria that is used in evaluating various manufacturer's devices and respirators. NIOSH approves, or does not approve, respirators based on test results.

OSHA had heard a lot of criticism about breathing apparatus. Many of those criticisms were lodged at the ineffectiveness of the present certification criteria, of which NIOSH is fully aware. The agency, as part of the final determination when issuing its final rule, wrote a letter to the Surgeon General asking him to seriously consider revising the certification criteria so that it would be more in line with the way respirators were being used in 1979 and 1980 and even more so today.

Although OSHA has a definition in our standards for what positive-pressure is, NIOSH doesn't have a definition or any criteria for closed-circuit, positive-pressure respirators. OSHA defines positive-pressure breathing apparatus as being self-contained breathing apparatus in which the pressure in the breathing zone is positive in relation to the immediate environment during inhalation-exhalation. OSHA would like to see NIOSH revise its certification criteria, recognize closed-circuit, positive-pressure apparatus, add the appropriate criteria and evaluative criteria.

Chuck Soros mentioned vibration, among a number of other practical test criteria, that need to be developed and should also include mechanical impact protection and the flame spread for harnesses and waistbelts. OSHA issued its standard, but recognizes that there are still things that need to be done in this area.

OSHA is interested in what results from this conference. We hope that some good things come out of this. In its final rule OSHA did not mandate the use of positive-pressure, closed-circuit equipment. We did not prohibit it. Governmental agencies, at any level, should be very concerned about prohibiting things unless there is concrete evidence for prohibiting it in all aspects. There may be some applications the fire service might want to use for long-duration equipment.

OSHA believes that the fire chief and other officers, including financial people, will be better able to make those kind of determinations as opposed to having the Federal Government prohibit a piece of equipment like this.

Our next speaker is Bill Mayo. He is a Chief from Gadsden, Alabama and represents user experience.

Some felt that it would be a good idea to give user experiences with both open-circuit and closed-circuit respiratory equipment. My particular department has about thirty people in the fire suppression. In 1979 and 1980 we did an extensive study in order to make some changes with open-circuit breathing apparatus. We have used, and still do use, MSA and Scott equipment. There are about sixty-five units in our department and we have about fifty-four units of the closed-circuit.

It has been expressed here that firefighters were carrying a piece of equipment on their backs that weighed about thirty-five or forty pounds and things were not being done to improve the equipment that they were using.

We conducted our tests, in a safe manner, for over a year, through the academy we have in our department using fire experience, with selected individuals and the BioPak 60.

The different advantages that Mr. Jones mentioned — it is ironic that we labeled and had those particular things itemized there because the weight has a tremendous factor.

The idea we also felt at that time, the reason we weren't getting new equipment in as far as the airpaks were concerned, was because in our particular area, the open-circuit airpak there wasn't any need to develop and implement something new into the fire service because they were selling all they could in the area anyway.

So, we felt like this particular change by doing this experiment and by using

closed-circuit breathing apparatus certainly enhanced the job that could be done by the firefighter, and in our opinion may even do it in a safer way and with better and lighter equipment.

It is compulsory in our particular area to don an airpak. We have not had one injury since 1980 as a result of the poor performance of an airpak.

We have the largest Goodyear manufacturing plant in the world in our city. We are quite frequently in areas where an hour's duration equipment is required.

Whether it's open-circuit or closed-circuit, something definitely needs to be done in the fire service to enhance and improve the equipment that is being used.

Our next speaker, Jim Tunnel, has been involved with both the legislative history that John Miller had outlined before, the history of the bills in California, and also with the Cal/OSHA advisory committee,

As recently as April of this year, one of the manufacturers said to Assemblyman Campbell, with reference to this bill, "We have written you concerning Assembly Bill 3520 which you introduced. We do not feel that the bill is necessary or desirable at this time." It is a shame that some manufacturers have felt that way.

I support Assembly Bill 3520 by the California State Assembly and its assembly members and the adoption of it, by law, as it was signed into law by Governor Deukmejian.

AB 3520 is a landmark in the history of fire safety. There has always been a recognized worldwide need for more adequate life-support systems for firefighters. This need came to light before California was a state.

As technology has advanced, many times serious hazards have been created that have had a great impact on firefighters suppressing interior structural fires.

With the introduction of plastics in our society, as an example, unique and deadly gases are routinely introduced into the smoke created by interior fires.

For years, the best protection available to firefighters was a wet cloth covering the nose and mouth. That idea was

followed by a variety of inventions that finally evolved into the gas mask of World War I.

About the same time, chemical rebreathers and compressed air bottles were introduced as components of life-support systems for a firefighter. There have been other designs in breathing apparatus, some less practical than others.

Included in this history have been products sold to fire departments represented by the manufacturers as offering a level of protection that was either impossible, or marginal, and usually proved to be misleading on an intentional basis.

Since the early seventies much more consideration has been given to methods of protecting firefighters against toxic gases than ever before. Fire departments, at the same time, have tried to be more scientific and technical in their evaluation of breathing apparatus.

This has resulted in fire departments and organizations such as the California division of Occupational Safety and Health working more closely together in the common good rather than only one mandating a policy.

They are being forced to accept it without the benefits of their specialized expertise in firefighting problems.

Nationwide, the decision makers and state agencies with no hands-on experience have created policies involving firefighters. That concept should be changed, but probably will not be until more legislation, such as Assembly Bill 3520 by Assemblyman Robert J. Campbell, is enacted into law.

In the early seventies, discussions turned internationally to positive-pressure in the facepiece as a way of flushing away any poisonous gases that might surround the firefighter.

As technology progressed, concerns grew about high-rise building fires and the ability of firefighters to advance or retreat on major fires hundreds of feet in the air, what was described then as vertical tunnels of death where firefighters using compressed air would have to go out several times with their apparatus to enter the high-rise.

Two manufacturers who produced

closed-circuit oxygen rebreathers were Bio Marine Industries of Melville, Pennsylvania and Draegerwerk AG of Germany. Both offered their products to the fire service as a solution to limiting time factors of other apparatus used by firefighters.

The Draeger apparatus had been used for a number of years in mines throughout Europe while the Bio Marine was a new product. Both manufacturers were aggressive in their marketing.

In an effort to put their products into the hands of firefighters, many statements were made that were misleading and prospective users tended to ignore the hazard because they did not know what the hazards were.

Some members of the firefighting and safety communities were astute enough to recognize such maneuvers, while others accepted as face value much of what they were being told by the manufacturers. They assumed that the supplied information was valid and passed it along to their superiors.

Hearings were conducted by the United States Department of Labor and National Institute for Occupational Safety and Health to determine the absolute need for such apparatus by fire services.

Until then, long-duration, oxygen breathing apparatus had a reputation, for being, for the most part, a mine-rescue tool.

In the early seventies, some of the fire departments had purchased pure-oxygen apparatus from Mine Safety Appliance Company. And for a variety of reasons, the units did not last long in service. Mine Safety Appliance Company withdrew the product from the market.

Since those hearings, there has been a mandate by NIOSH that only self-contained, positive-pressure breathing apparatus should be worn by firefighters for interior structural firefighting.

While adoption of this policy appears, on the surface, to offer a safer apparatus for the firefighter to use, NIOSH neglected to consider in their mandate the hazard to firefighters using oxygen as a part of their life-support system.

One is left to wonder if this omission is intentional because a NIOSH mandate clearly addresses only that apparatus defined as positive-pressure. This solely encompasses compressed-air units, not

oxygen **rebreathers** for which no positive-pressure **standard exists**.

There presently exists no standard in the United States, either on the state nor the federal level, as to what numerically constitutes a safe level of oxygen in positive-pressure breathing apparatus.

There has been no limiting factor developed to protect the wearer of such apparatus against inhaled, high-temperature air caused by chemical reaction in the apparatus or methods of relieving the high humidity throughout the life-support system.

Humidity, oxygen, fire and high-temperature inhaled gases in any oxygen breathing apparatus are all potential killers in the profession of **firefighting**.

Assembly Bill 3520 is the first step towards addressing these problems. California has always been a leader in fire science technology, and funding by the state government is truly unique in this respect, as evidenced by the unanimous passage of AB 3520 by the California Assembly and Senate, and emphasized by the signature of Governor Deukmejian to underline his support.

The second step and beyond, of course, is why we are gathered here today. If what we do saves the life of a single firefighter, it will be a victory for all of us.

The next speaker is Dick Jones, whom you have heard of earlier this morning from work with Cal/OSHA, particularly riding herd over the Advisory Committee who is the investigations and the field studies that you saw reported earlier.

I would like to tell you where we were going as far as AB 3520 is concerned. One thing that hasn't been mentioned" is that actually \$40,000 was allotted from the General Fund to be used as the appropriation to conduct those tests which are going to be necessary.

Now we realize that that is not going to be a sufficient amount. The Division of Industrial Safety, estimated another \$100,000.

Fortunately, the lab in Livermore has received a grant from the Federal Government to conduct tests in the same area, also to cover contact lenses and facial

hair. So, we're hoping.

I would like to get together with the Federal people on their particular grant to see if we can complete all of the goals which 3520 lays out for us.

I would like to talk about advisory committees, as handled in California.

When an advisory committee is formed, representatives are chosen from labor and management. Also included is the technical expertise from manufacturers, doctors or others who have needed information.

They are put together on a committee and their job is to come up with a proposed standard which the division will take. In most cases, this is usually sent right on in a rule-making package and forwarded on to the Standards Board.

The Standards Board, in Sacramento, is the only group who can adopt, amend or repeal the standard.

That cannot be done within the division, which is an enforcement agency. However, it does get into the role of making standards and putting the packages together in some cases.

Once the package goes to the Standard Board, it will go to a public hearing, which is announced forty-five days in advance. The public is invited to attend.

Based on our recommendations, the Standards Board either might send it back to us to make some amendments to it or they might pass it, as is, depending on the amount of comments.

That is basically how the standards are evolved in California.

I also think that it is important for NIOSH to come up with a numerical definition of a closed-circuit, positive-pressure system.

While they are looking at the criteria they set, possibly they can take into consideration the use by firemen.

Conducting tests on a self-contained breathing apparatus without considering the firefighter is wrong. The firefighter works in an environment far removed from those of us who might be out cleaning up a chemical spill.

If NIOSH can take a look at the proposed standard, possibly coming up with some special requirements to provide the firefighter with a suitable device for use under the current conditions.

Our last speaker, Bob Guyette, is a Chief from Long Beach and represents some more user experience with closed-circuit.

I would like to talk about safe use of equipment.

We have had closed-circuit units in use in Long Beach since 1980. There is one factor needed to make that unit safe, and that is proper training.

Our firefighters are not aware of the differences between open-circuit and closed-circuit units. They are not aware of the silence of the operation of an open-circuit unit and they are not aware of the return air heat. It frightens them. Any firefighter who breaths in warm air thinks he's in deep trouble.

Until we train firefighters to understand the mechanics of the equipment, and tests show that the amount of heat that is generated is not harmful to them, we will not overcome that fear. The other part of training is an issue that was touched on, and that is **canitation**.

There is a great problem with it in Long Beach. If the individual who oversees the cleaning of that apparatus in the station **isn't** concerned, it won't get cleaned. A closed-circuit unit obviously has more problems in that area. That is a number one need for safe use of a closed-circuit unit.

Now I have a philosophical question. When we buy ropes, ladders or the majority of our equipment in the fire service, we absolutely insist that it have a one hundred percent overload factor in its construction.

However, when we buy breathing apparatus, according to the regulations that are now written, we absolutely insist that it have a fifty percent underload safety factor.

That does not make good sense to me. A sixty-minute rated bottle would last a working firefighter, about thirty minutes, and a thirty-minute bottle will last, on the average, about seventeen minutes.

When dealing with long-duration, I'd just like one with an accurately rated duration.

Those are the two factors that I think need to be considered.

More excerpts from this symposium in the next issue of JISRP.