

The Role of Closed-Circuit Breathing Apparatus in Structural Firefighting

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- PROCEEDINGS -

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Thursday, October 24, 1984

How is the Advisory Committee funded?

RICHARD JONES:

It is funded by the Division of Occupational Safety and Health, which has a commitment for travel and equipment. However, the people from industry pay their own way.

What is the liability to a fire department that doesn't follow the breathing apparatus rules?

TOM SEYMORE:

There has been a court case down in the southern part of the country, on the Texas circuit, that had nothing to do with the fire service, but it dealt with a manufacturing company. It was found that they had an OSHA standard, but by the way the standard was scoped out, they had not been required to comply with that at the time the court suit was brought against them.

The court decided that a violation of the OSHA standard was negligence. Now all across the country when OSHA tries to issue a standard on it there is a great reluctance for any more standards because there is concern that there may be more court cases like this.

Obviously, this standard is already in place. And in spite of some of the comments that have been made it is well

documented that there is a real need for positive-pressure breathing apparatus; and a fire officer who has control over the purchasing power of his department, who continues to have his men supplied with filter equipment or negative-pressure equipment will eventually bring some of his people down, either from a HAZMAT situation or some other situation, and he is going to be hard pressed to explain that.

I am certain there probably will be some court suits that will probably come out of that. We will know at that time as to how it's all going to go, but my perception would be that he would be really in a lot of trouble.

RICHARD DUFFY:

There is an imaginary responsibility to provide, maintain and train firefighters to use breathing apparatus.

If a firefighter is seen by an OSHA or Cal/OSHA inspector not wearing breathing apparatus, it won't be that firefighter who is cited, it will be the fire department.

It is a management responsibility to insure that individuals are protected.

We have been working in our locals around the country and pressing for the whole legal liability issue, whether it is for breathing apparatus or any other protective equipment.

The first area that we looked at is whether the department provided equipment that meets the level of the minimum standard prescribed by the states or by the Federal Government.

We are prepared to go after the employer, the fire chief, in civil and criminal liability cases to try to get some protection. That is the bottom line of any protective area.

I travel around North America

teaching firefighters in safety and health areas. My staff and I could talk about safety and health all day.

Everyone agrees at the seminar, but later it becomes a different story.

I addressed the fire chiefs in the state of Washington, specifically about what they had to provide their firefighters.

Because we had the registration list of who attended, they are now fully aware of what the standard is in the state of Washington, and as far as we are concerned, they are liable for members in their department if they do wear substandard equipment.

The liability issue is going to be the issue of the eighties in the fire service.

This question is directed to Tom Seymore and is related to the OSHA requirements.

If NIOSH is the approval agency for breathing apparatus, & if it does not recognize the buddy-breathing interchangeability of the cylinders that Federal regulations permit, wouldn't an employee be using a disapproved device with who knows what kind of liabilities?

In a mishap, could Federal/OSHA be held liable?

TOM SEYMORE:

What we said in our final rule was that we would not issue a citation to the employer if he was going to utilize one of the pieces of equipment that met our criteria.

We are not mandating that anyone use them. If there is a desire by a fire chief for the fire department to use some of the equipment that is fine.

The final analysis as to how well it is used and how long the training is and so

on, I doubt that we would have any liability from the context of how we couched it.

As an example, if a buddy-breathing device is put on that has been made in your own department and standardized, it cannot by form, fit or function modify the normal operation to the hoist wearer.

And the alternative of saying having some way of Kominski method or some kind of fitting that you can screw in there, buddy-breathing ends up being a problem. It has been a problem for us all along.

If a department comes up with some kind of device that is going to meet their needs, hopefully it will be better than taking the facepiece off to switch back and forth.

RICHARD DUFFY:

The big problem is that NIOSH rule is lost for the device when it is operating that way. Our organization was against that during the promulgation of the fire brigade standard, and will still be today.

The issue was that NIOSH has to make some significant changes in 30CFR Part 11 and other regulations that affect firefighters.

In 1977, the fire service held a hearing in Washington, D.C. NIOSH held the hearings in Washington, D.C. for the needs of firefighters in breathing apparatus.

There were no results until the next big issue, which occurred in March of 1979 when three firefighters died in Texas. It was unfortunate that they died, but it was one of the biggest turning points in breathing apparatus for the fire service.

NIOSH began investigations that continue today. However, once again, 30CFR Part 11 was not changed. Revisions began appearing again three or four years ago but there are still many different phases of making changes in it. There are still serious deficiencies in the regulation.

It is archaic and our concerns and demands must be voiced that there changes must be made. The changes in 30CFR part 11 be consistent with the respiratory regulations already promulgated by OSHA.

Hopefully, it will not take three more, or even one more, firefighter to die to make the necessary changes.

For those who are aware of it there is

an insurance program that we lobbied through the Federal Government through the LEAA, the Law Enforcement Assistant Agency. This program awards \$50,000 to a firefighter if dies in the line of duty.

Unfortunately, these claims come across our desks frequently because at least one firefighter every week in the year dies from line-of-duty death.

The ten-year average is eighty firefighters line-of-duty deaths and per year that is significant.

Firefighting is the most hazardous profession in the world, so NIOSH owes us a change. Also, OSHA legislation has to be consistent with NIOSH's regulations.

The next question is directed toward the fire chiefs. And it says:

What are the minimum limits that you feel require fire personnel to done respiratory protection?"

Is this by job duties, radius from the fire scene, or what criteria do you use?

The question is: What is the minimum time frame for donning of the protective breathing apparatus?

Where do you draw the line? When is it clear to the firefighter that they have to be wearing apparatus in your department?

BOB GUYETT:

Our particular policy in our department is upon leaving the station, a firefighter will be in full, protective clothing as a matter of policy. This policy comes from the commander and then an on-duty assistant chief. It corresponds with those particular units, whatever district it is in.

Upon entering a structure, whether smoke is visible or not, firefighters must have protective breathing apparatus on.

In our particular area, the carrier's workers compensation will not cover that particular individual if the appropriate safety devices are provided and he or she does not use these devices.

In Long Beach, our regulation states that when a fire is reported as a

structural fire, before leaving the apparatus you'll have your unit on. You may not have the facepiece on, but you will be wearing the unit and you will not enter the building or an enclosed space.

We also have a major port, so there have been some shipboard incidents in which we were required to wear breathing apparatus. The other part of that is the commanding officer of the unit, or the commanding officer at the scene also dictates any other times breathing apparatus will be worn such as in a hazardous materials incident. Inside or outside, breathing apparatus is required.

CHUCK SOROS:

Seattle echoes what Long Beach is doing. When you roll out the door, the only time the mask is allowed off is if you are in an emergency medical run, and sometimes it might be needed there.

For example, the other day at a fire, masks were left on all through the cleanup which was being done inside a building full of plaster dust.

We are changing a little more in our policies as far as cleanup is concerned but as far as rolling out the door, I think the masks are supposed to be on. And there is a mandatory mask rule.

The next question is directed to Bill Mayo.

Are all of your BioPak 60s modified with the bioshield? And has any unit ever been exposed to a flashback or strap failure?

BILL MAYO:

Yes, they have the shield and we recently had a hospital fire which occurred between the ceiling of the seventh floor and eighth floor of the hospital. The only access to that particular area was through a six-inch slab that was twenty inches square.

The particular company traveling in and out of that area had to go about forty feet in the ceiling space to a four-by-four exhaust-power venter. That is a twenty horsepower venter. So there is a lot of heat buildup in that particular area.

As I went through the shuttle, the influx of additional free air, that is fresh air that supplied that particular area, there was a flashback. It was exposed and came back out through a particular hole in the floor.

We have not had any injuries as a result of that. And another reason that I might add that we feel like it, the particular padding around the breather tubes, if there is heated air, or there appears to be an increase in temperature, then often they'll wet those. It reduces the temperature in the rebreather.

CHUCK SOROS:

May I add something to this? One thing that keeps coming up is air temperature inside of a closed-circuit breathing apparatus. If you are in a heated room when the air temperature inside of a closed-circuit breathing apparatus is going up, what do you think is happening to an open-circuit? I disagree with you because I have shown you the test data that indicates that they both go up to a degree.

BILL MAYO:

That's fine.

The next question is directed to Mr. Tunnel. And it said you claim that inhaled oxygen is a potential killer.

How many firefighters have been injured with closed-circuit breathing apparatus in California or in the U.S.?

Are there any statistics on injuries?

MR. TUNNEL:

Unfortunately I do not have those statistics at my fingertips. My response as to the possibility of oxygen death is that there have been some tests conducted, by one of the federal agencies, which resulted in the discovery that oxygen saturation can simply cause a drying out of the lung itself. And there may, if fact, be respiratory arrest.

This has happened in some cases where the moisturizer in a hospital has not been operating correctly and a person has been receiving oxygen under an oxygen tent.

How accurate that information is, I don't know, because it was generated in 1967 or 1968 at an army hospital. There was a question about that. I believe the Armed Forces Institute of Pathology release the information.

This question is somewhat similar. It says, with the fire services'

same experience with open-circuit, oxygen apparatus since 1946 (and it notes that the MSA open-circuit was an oxygen supplied system. With characteristics such as greater than fifty liters per minute ventilation rates of 96 percent oxygen, a normal use, in firefighting).

How can thirty liters per minute of oxygen, in closed-circuit devices in worst-case situations be so dangerous?

So, the background is that some firefighters do have the experience with oxygen in an open-circuit device which continues to dump nearly pure oxygen to atmosphere with each breath. With that experience, and the lack of accident statistics, the question is "why is there such a high concern when closed-circuit uses oxygen?"

RICHARD DUFFY:

The breathing apparatus still may be used in Grand Rapids, Michigan, and I believe Oakland had some open-circuit, one hundred percent oxygen units.

As far as I am concerned, the user is very fortunate that nothing occurs, especially with the ninety-spit, six percent oxygen-expired air going through an exhalation valve while the equipment is being in a fire.

The answer to the question is not in supporting or going against any manufacturer's equipment, but just looking at fire service experience.

I have looked at statistics back as far as the last twenty-five years and we have never had a firefighter injured because of his breathing apparatus or a closed-circuit that we are aware of. As long as that apparatus has supplied air, there has not been a fatality or a report of injury to us.

Conversely, we have buried many firefighters over the last many years in the fire service because they have run out of air. The instances are not isolated, such as the BART tunnel, but firefighters consistently run out of air while wearing breathing apparatus, and they are no longer with us.

That is one of the issues that we should be looking at.

MR. TUNNEL:

I would like to add that one of the concerns with the use of closed-circuit, positive-pressure breathing apparatus has been that the firefighter, or the wearer of the apparatus, would be protected to a greater degree against contaminants in the air.

And as a result of wearing that kind of apparatus he is more protected because the contaminant simply could not enter into the facepiece.

We cannot find any record of a death or an injury involving contaminants entering the facepiece of open-circuit breathing apparatus and killing a firefighter.

NIOSH decided that positive-pressure was better and yet, you know the old saying, "If it works okay, why fix it?"

CHUCK SOROS:

Back in the early seventies, the State of Washington accepted the first-aid standard that had been written and we took everything from the womb to the tomb. However, only personal protective equipment was accepted in California.

In the state of Washington it was said that all we were going to accept was positive-pressure for the fire service people.

This argument occurred nationwide. A chief on the East Coast, in a fairly large metropolitan area stated, "If my people have to wear positive-pressure, self-contained breathing apparatus, they won't wear anything."

A firefighter is fit tested in a dry room while he is standing still. As soon as the firefighter walks off the rig, he walks into a hot environment, he perspires, and as soon as this occurs, he has broken the seal, and that was the reason for using positive-pressure.

After having worn both negative-pressure and positive pressure in breathing apparatus, I have gone into a lot of fires where I have had smoke in a mask with me. It is very uncomfortable.

But in the same token we're in a place right now - we're in what we call a knowledge generation. We generate knowledge so damn fast we can't even keep up with it. And I don't think we had the technology at that time, nor were we looking for these types of tilings inside of facepieces at that time.

Now, all of a sudden, we've got the technology - know where these things are at, and everybody's saying "Hey, well, why didn't we know about them then?" Because we weren't looking for them. That's why. That's my opinion.

TOM SEYMORE:

To add a few points, that same fire department on the East Coast had an incident involving a chlorine leak.

The department had a number of cylinders and they were following their mandatory mask rule. They were using negative-pressure equipment, which the department liked, and still a number of people were hospitalized. The chlorine concentration was so high that the copper pennies in the pockets of uniform pants turned green.

The firefighters were, of course, totally saturated. Had they been wearing better breathing apparatus, they probably would not have had the inhalation problems that they had suffered.

Tests which had been done by the Navy measured benzopyrene CO and a number of other things indicated that there was a problem with leakage into the facepiece.

They had measured those contaminants inside the facepiece wearing negative-pressure equipment in a few of the tests they were running.

We do not want contaminants inside the facepiece. So that is why we went to positive-pressure. If anyone is still arguing about positive-pressure, it would be a very small minority because of current working conditions.

RICHARD DUFFY:

In 1976 our organization received a grant from the National Bureau of Standards. The purpose of that grant was for every time a firefighter, whether volunteered or paid professional, died we would go out and investigate it. In a fifteen-month period we had approximately a hundred and fifteen firefighter deaths.

One case that still comes to mind was a rendering plant incident in which a rendering plant employee was in a sub-basement, sludge area. He was overcome by what we think were methane and hydrogen sulfide.

The rescuers who first attempted to rescue the individual also were overcome and I believe they died. The rescuers

finally put breathing apparatus on and were able to do the rescue.

When they got outside and took their respirators back off again, most of them had nausea, malaise, vomiting, and they wore breathing apparatus all the time. But they were all demand units.

So, this was a particular case in which we had to fix it because firefighters were being overcome. And that was just gases such as hydrogen sulfide and methane.

Firefighters now work in an environment that has become much, much more toxic than it had been in the fifties and sixties because of the introduction of much more synthetic material.

Carbon monoxide is still the most prevalent gas in fires because of the incomplete combustion of organic materials. However, we are finding greater quantities of the hydrocyanides, the hydrogen chlorinides and phosgene gas. These gases overcome the firefighter more easily than carbon monoxide.

But more importantly we have to look beyond the acute effects of wearing respiratory protection and look at the chronic effects. This country loses more workers every year because of occupational health diseases than it did during the whole Vietnam era while fighting a war.

The occupational health problem in this country is a big public health concern, something has to be done about it.

If firefighters have a way to protect themselves with equipment offering a protection factor ten thousand times greater than the demand unit, they should certainly be wearing a positive-pressure unit.

CHUCK SOROS:

I would like to add just one more comment on this positive-pressure issue. One of the easiest ways to try to discredit something is to determine that it is faulty. And what they did with positive-pressure when they first went out was a case like you talked about here earlier, where they had people-forced air oxygen ventilators in hospitals.

People who later developed embolisms had lung damage to begin

with.

Most firefighters are healthy individuals. They have preventive maintenance type physicals.

So there was an attempt to discredit positive-pressure with the probability of these oxygen inhalators in hospitals.

Is this positive-pressure for closed circuit? It appears that there is a disagreement between two manufacturers.

The next question is to Chief Guyett, it says:

Do you feel that rating units by means of NIOSH testing is practical? When a firefighter uses a one-hour closed-circuit, does it really last one hour?

BOB GUYETT:

If the question is in relation to time, no it is not realistic for the fire service.

My personal opinion is that NIOSH testing, as it is right now in rating, is not accurate for the fire service.

You are speaking of closed circuit, and particularly closed-circuit, positive-pressure, NIOSH is close to having a test standard hour for rating that.

I would prefer NIOSH testing than nothing at all or what had been available before. However, it is still not built for the fire service, nor is the apparatus.

The manufacturers now are listening to the fire service and I'm not sure at all times that the regulatory agencies had listened. There is a much more cooperative attitude now.

It is a long process from the time the decision is made to cooperate to the time good legislation becomes effective.

Bob, you had some very specific numbers earlier today about how long your open-circuits last you in your actual work conditions. Can you contract that to how long your closed-circuits have been lasting compared to their one-hour ratings?

BOB GUYETT:

The one-hour, closed circuits we are using, lasted about fifty-two minutes in a test on one individual. In all other cases, it was in excess of one hour with no problems at all.

The specific figures referred to are for open-circuit tests that have been done all over the place average time, and we did some ourselves using some of the same techniques that we used when we tested the closed circuits.

It is interesting to note that many of our own firefighters complained about lack of oxygen flow.

Interestingly enough, one of the first comments from one of the people in our department who is very negative about the unit and is also a big man said that that was the first unit he had ever put on that he could not turn negative.

The absence of sound has a lot more to do with psychological feeling that the user is not getting enough air rather than the actual fact that there is not enough air.

Dick Jones, would you please define protection factors as stated in your segment of the panel discussion earlier where you listed protection factor under the advantage column.

RICHARD JONES:

Just from the statistics you read on the protection factors that are received on the equipment from various types of tests either are quantitative that the positive-pressure systems is equal as the closed circuit, positive-pressure, as the regular open-circuit.

I have found in most cases, and from talking to the experts, that the protection factor of closed circuit, positive-pressure is at least as equal or probably better.

Is there any new information on contact lenses in positive-pressure facepieces?

TOM SEYMORE:

There is a prohibition on the ANSI standard about wearing contact lenses with respirators, whether it be full facepieces or self-contained. Through use of questionnaires we are looking for feedback and information so that we can come up with a good rationale as to whether that prohibition should be retained or revoked. And we are hoping that maybe we can at least modify if not revoke it.

RICHARD DUFFY:

The International Association of Firefighters just sent a questionnaire out

to over two thousand locals in North America, asking for cooperation with Lawrence Livermore Lab's NESS.

We have asked the union representatives who received this to be sure the administration of the fire department knows about it and fills out the questionnaire.

Cities are probably tired of getting all the questionnaires we send out to them, but this one is going to be very beneficial. It is a problem that I think can be resolved by identifying it and addressing it.

Fire departments need to cooperate with Lawrence Livermore in this important project.

Jim Johnson, what can be done about facepiece slipping around your face from heavy perspiration and body moisture that seems to fill the suits with oxygen enriched atmosphere?

JIM JOHNSON:

A lot of the attention is paid to getting the best fitting mask and that it is put on correctly and that attention is paid to some of the things that Dick Jones noted today about the right length of hoses so that the person wearing the equipment does not find limitations just because of improperly sized equipment.

When I have worn the apparatus, in a test environment using open-circuit equipment, the masks do slip around if you begin perspiring. It is just a reality of wearing a respirator in a work condition.

Now, as regards the oxygen hazard that was addressed earlier, if the closed-circuit system is used, there must be more care used in tightening the seal.

It is more of an individual's choice in the way he tightens his mask and also what he is doing as to why the mask is slipping around.

In really hard work situations, the mask can get bounced around, so we will have to match the job to the equipment. It is not going to be a significant problem if attention is paid, especially in the training of equipment fit and proper use.

The graphs that were shown earlier for closed-circuit breathing apparatus indicate that both

positive and negative-pressure breathing apparatus operates at substantial positive-pressure at some point during their cycle. From a leakage standpoint, are they substantially different?

Does anyone want to address that?

ALAN HACK:

A assume that you are referring to the graphs I had used in the beginning of the session. We had some pressure curves which were the average of the pressure in the facepiece for all the subjects wearing those masks who were not doing heavy work. Only one apparatus clearly maintained a positive-pressure in the facepiece during our tests.

There may be no definition of positive-pressure, closed-circuit apparatus vis-a-vis NIOSH regulations right now. However, they have an operating rule which they can state if they wish.

But on the basis of our test, we were given an apparatus which was designed by the manufacturer to maintain a positive-pressure in the facepiece and did maintain a positive-pressure in the facepiece under the low stress condition of our tests.

I have no qualms about calling that a positive-pressure apparatus. There is no attempt to say that the apparatus would not maintain positive-pressure under all conditions of use. No open-circuit, approved positive-pressure apparatus will maintain a positive-pressure in the facepiece under all conditions if either is used.

Would that device clearly provide the best protection for the largest number of people tested over all other devices?

Some of the other apparatus tended to operate slightly positive or less negative, and also seemed to provide better protection, but there was conjecture on my part that the pressure was responsible for the improved performance.

The next question is somewhat related to protection factor also. It says, 10CFR 20, standards for protection against radiation, limits the protection factor for closed-circuit, positive-pressure SCBA to five thousand, and only then when a quantitative test has been administered.

This compares with the allowable radiological protection factor of ten thousand plus for open-circuit SCBA.

This is contrary to Mr. Jones' study which showed that closed-circuit breathing apparatus provided a protection factor equal to, or greater than, the open-circuit devices.

Why do the experts in radiological protection limit the closed-circuit devices so severely? Shouldn't the fire service explore the reasons for this or for these protection factor limitations?

TOM SEYMORE:

I am knowledgeable about what CRF20 says, but I would assume that the five thousand protection factor is for negative-pressure, closed-circuit breathing apparatus. Is that minimum for positive?

Does the regulation say that five thousand is the minimum protection factor required?

ALAN HACK:

If that is what they would grant you in use.

JERRY STENGEL:

We have seen precedent in the assigned protection factor of the ANSI standards where assigned protection factors have been arbitrarily lowered for some administrative reason. In this case it was a policy decision by Nuclear Regulatory Commission.

Bob Guyett, can you address the so-called fungus growth in breathing tubes from poor sanitation?

BOB GUYETT:

It is vital in any closed-circuit unit of any manufacture, that in your sanitation policy that you set and maintain, that the men dismantle the breathing tubes, dismantle the places where moisture can accumulate and stay, and disinfect and clean them. And if they do that, the unit is fine.

We, in the fire service, clean our open-circuit breathing apparatus very thoroughly when we come back.

At 3:00 in the morning you're hot,

sweaty, you've just lost three hours sleep, you got a heavy date tomorrow on the golf course, and you naturally take about fifteen, twenty minutes to carefully disinfect your facepiece. You probably don't uncouple the exhalation valve and take all the little green things out of that, but, you know, at least you should wipe down the inside of the facepieces with some betadine solution.

The fire service is not a sanitary group. Paramedics have helped us a great deal. They go around saying we have to stay aseptic, and it has helped, because they have forced us to take a look at ourselves, too, and we do a better job now. Fungus growth is a problem, but it is only a problem of maintenance.

If a facepiece is properly cleaned, there is no problem with fungus growth. The problem exists in open-circuit equipment also if it is not thoroughly cleaned.

A few people have alluded to the failure of hardware straps on breathing apparatus. Is there any Federal or NIOSH standard existing to modify the hardware or strap rating?

A firefighter in Syracuse, New York, came down a flight of stairs and the straps fell off his back so he lost his mask on the way down. Does anybody know if there is anything to interface the hardware with the suit?

Firefighters believe that a mask is going to take care of them to 1,962 F when it is rated as such. Is there a standard that says the material must be rated to fail at a specific rate?

RICHARD DUFFY:

There is no standard. In the draft of the NFPA standard we are working on, the minimum standard for firefighters, we are including a strapping test.

As a fire service person or the next time you as fire service personnel, write a specification for your breathing apparatus, do not solely rely on what NIOSH has put together or what NFPA has put together.

Let me also suggest that you just require that the breathing straps meet two textile tests, one is 5903 which

specify an afterburn and also require fifty degree Fahrenheit, five-minute over test without charring, melting or separation, and what essentially you're going to get is a Nomex strap right now.

One manufacturer will only sell a Nomex strap, and the rest of the manufacturers will probably follow suit.

And you won't see either nylon, polypropylene or other strapping that's been, unfortunately, in the fire service so long. It's too bad that incident occurred. There are many other instances where straps have burnt off.

It has been a problem for a long time, and NFPA is finally going to address it. It appears that now the manufacturers are going to address it and change over to strapping. It's going to add about, I can be corrected, but probably a hundred bucks more than even breathing apparatus on a retrofit.

Many of us are familiar with an incident which happened in Marin County about two months ago where the people lost their units: the tanks dropped to the floor.

One of the questions we had is "If you were to retrofit SCBAs with new straps, might it possibly void the NIOSH certification?"

RICHARD DUFFY:

Yes, possibly, if you did it yourself, but not if you have the retrofit kit.

UNIDENTIFIED SPEAKER:

If the manufacturer received an extension of approval on any device that had already been certified by NIOSH then the NIOSH approval would not be voided.

RICHARD DUFFY:

Now if you go off and do your own strapping, yes, you have voided your NIOSH approval. Unless you go to a manufacturer's retrofit that has received the extension or approval, obviously, you have voided it.

UNIDENTIFIED SPEAKER:

I'm not with any manufacturer, I'm with the government, so I haven't got anything to gain. A user side of the

government, not the regulatory side. I guess just a couple of comments: One with regard to the fire testing that was done on the positive-pressure devices to show that there is flaming going on. I guess I question how useful that type of a test is.

We're dealing with a very deliberate leak in the device. If we went ahead and did a protection factor on that device, I don't think anybody would use it for anything. We're doing it static; we don't have an individual moving; we don't have the vortex and drafts of a fire taking that oxygen and diluting it very quickly.

And we're having this firefighting dummy look at a flame for two to four seconds just two feet away from his face. I don't think too many firefighters would do that. I don't really think — I shouldn't say they don't get that close, they may well get that close, but I don't think they intentionally do try.

My fear is that we often have something good that we set aside to look for something better, and the sailor ends up with nothing. And to some degree, I'm afraid firefighters may get into that situation where they end up with not necessarily nothing, but something that was good being set aside.

Again, I'm not trying to take any one device, I couldn't care less which one is used.

Mr. Duffy, with regard to hydrogen sulfide -- I'm a chemist — don't pass it up. Hydrogen chloride, hydrogen cyanide, phosgene are combustion products. They're very soluble and very easily hydrolyzed when taken out of the air. Hydrogen sulfide is also a metabolic product that you get in waste areas. You can smell it, but your nose gets tired of it, and you're dead. Hydrogen sulfide is very dangerous.

It's a question I ask with regard to this positive-pressure test. I realize that it may be necessary for such demonstrations but it isn't a realistic test.

JERRY STENGEL:

As one of the original sponsors I'll start the discussion on the flame test. Where tests for environmental conditions don't exist then there's a need. When someone fills the need in some way or another, then whatever's done is up for criticism.

When we looked at the previous three tests it was confusing because they

weren't all done by the same outfit or for the same reasons.

And so, to address one of your points, you always have to ask, "what was the purpose of the test, who was doing it and why were they doing it?" Then you have more insight as to what comes out of it.

Speaking of the fire science behind the test design, Norm Alvares went to great length to define what the characteristics of that test would be and why. To paraphrase that, it was the maximum, worst-case environment in which you could expect any firefighters survival to occur at, on the light of having no other tests that were as scientifically designed, I think it was a valid approach. You can look at the results of such a test and say, "if we do the worst case, and we don't see any problem at all, we needn't look any further."

In this case, that wasn't what we found. It wasn't black; it wasn't white; it was gray and required some interpretation. One interpretation that was requested was the interpretation of the people doing the study, recognizing where they're coming from.

So, if one were to criticize those tests as being unrealistic, I don't think anyone else would argue. But, they did fill a need. There was a void in the science there, and the tests advanced our knowledge further than where it had been.

Anybody else want to talk about that?

CHUCK SOROS:

One of the unfortunate things in the fire service is that fire chiefs tend to base decisions based on very few incidents or very few tests. Rather than run a couple hundred tests, ten or twenty are considered sufficient. But oftentimes, ten or twenty is not what we need. We need more data in the long run.

Typically we hear nothing about these types of SCBA tests until they're all done. There may be some pitfalls in the testing, various reports that we're writing or that are written in fire command journals. They're well publicized, and it's not easy to change information after it's reported.

BOB GUYETT:

I've been involved with Cal OSHA, The S.A.F.E.R. Organization (Southern California) and in my own department for over several years now on this fire testing issue. It evolves around the fact that there was a legitimate concern based on old tests that oxygen use by a firefighter in a fire atmosphere in any type of breathing apparatus was a hazard.

Because there was no current testing data, a lot of testing got done quickly by people who were either interested in selling an apparatus or in discrediting one. These tests are subject to a lot of questioning as to their validity.

The legislation that Jim Tunnel and Assemblyman Campbell have gotten through was, hopefully, a method of getting some legitimate test data about hazards with oxygen use in closed-circuit, or open-circuit breathing apparatus for the fire service.

I recommended to my department to buy a closed-circuit oxygen unit because I could not see that the test data showed there was a hazard. And the committee from our department agreed with me.

However, if a hazard were shown, in legitimate tests, which attempt to simulate as closely as possible an actual firefighter's atmosphere that he works in, we would base our decisions on it.

But, if you need long-duration breathing apparatus, we can stack two sixty-minute bottles on the firefighter's back, or we can take the only other thing out there right now which is closed-circuit, oxygen units.

I've told several of the manufacturers that the first one that comes out with a compressed air, closed-circuit unit that lasts over one hour is probably going to grab a sizeable share of the market in a hurry.

Nobody wants to complain about using compressed air. But, oxygen feeds fire. Quote, quote. And we've read that in the fire service for 85 years. So, it is a concern. Yet the departments that are using those units are doing it based on the fact that their best assessment of the test data that has been done is that it is not a hazard.

The history shows that it is not a hazard, but that doesn't mean that it couldn't be a hazard tomorrow. We'd like to have some legitimate current testing done, and that's really what this legislation should allow us to do.

TOM SEYMORE:

The Germans have a test because of some experience that they had with their fire brigades in West Germany where they actually test the facepiece over a flame and try to insure the integrity of the facepiece in a flash fire.

They actually had fatalities of firefighters (fire brigadesmen) in a propane gas explosion, and it was decided by the German government that they ought to be able to sustain a flash fire for a few seconds at the most. The facepiece shouldn't disintegrate on his face: it should still retain its integrity.

So now they have tests in that country for respirators, facepieces. We don't have that in this country. That's what's been said over and over again: that NIOSH needs to revise their regulations in 30CFR Part 11 to address this problem and come up with an appropriate test.

The point of a backdraft explosion is that it's conceivable that a firefighter (especially in light of what Chief Sharry talked about: people going in further and longer) may expect to be involved in a flash fire. The equipment ought to have enough integrity to sustain it at least for a few seconds. Most flash fires won't last any longer than that. In many cases, it'd be milliseconds. So, you need to have a test which is, as Jerry Stengel called it, "worst case."

I've been a training instructor for firefighting for over twenty-five years and I haven't been in any kind of fire like that: I don't want to be.

But I have talked to people on panels and in meetings with people who have been in a flash fire and got badly burned. Their coats burned off them. Their pants were burned off them.

In one case a man was wearing a Scott unit and the facepiece protected his face from burning. The flash fire was so fast it didn't do any damage to that unit, and looking at his face today there are no scars. But all around the back he has scars from skin grafts. He's now involved in lawsuits and going through the agony of having skin grafts.

The testing that was done on the tape that you saw was part of the response by manufacturers to OSHA (not NIOSH but OSHA) proposed regulations for fire brigades and firefighters. In the proposal issued in September of '78, we proposed that positive-pressure breathing apparatus

be mandatory for interior structural firefighting. Because we don't know what levels of contaminants firefighters will be confronted with, we propose using the best protection.

The Draegerwerk Company is one of the premiere manufacturers in closed-circuit equipment around the world and has been in the business a long time. They sent their chief engineer over, that's how concerned they were about the proposal.

Ernst Warneke has been in the business for many, many years (he's since retired) and his personal belief is that there should be no positive-pressure, closed-circuit unit.

And obviously that concept was shared by many other people, because the Bureau of Mines in their 30CFR Part 11 written many, many years ago, didn't provide even a possibility that positive-pressure closed-circuit SCBA could exist. Obviously, the technology has changed, and now it does exist.

Well, the chief engineer's position was there should be no such thing, so he was trying to demonstrate using an obviously jerry-rigged arrangement what he thought might happen. And of course kept asking, "Have you ever seen it? Has anything like this ever happened?"

Then the Bio Marine Company, seeing what happened in public hearings in Washington, D.C. did some tests themselves. They came forth in San Francisco and made their point of view known about how much of a problem it is really.

Obviously, the beta-glass shield, (a protective head) resulted from their own internal management decisions after seeing these test results.

The upshot of all this is that at the federal regulatory level we don't believe we should prohibit the use of this device and we haven't done so. If you needed a long-duration respirator, say a four-hour unit, the only kind that was available at that time was a negative-pressure closed circuit SCBA. We wrote the regulation so that one could use a negative-pressure unit for that kind of duration if you needed it, provided there was some fitting done so that the firefighter wearing it could be assured of having some reasonably good protection. We set as a minimum level,

a protection factor of five thousand.

That happened to be the worst-case protection factor data that we had at that time from Alan Hack at Los Alamos National Laboratory, so we took the worst case.

I think that people like Mr. Warneke were very legitimately concerned about his point of view and were just trying to present what they believed could possibly happen.

Obviously, the final rule came out from OSHA as endorsing positive-pressure SCBA with the caveat for long-duration, and we came to similar conclusions that you've expressed. Since we haven't seen the problems, we really shouldn't go out and prohibit the equipment.

RICHARD DUFFY:

You asked one of the best questions this afternoon, and for one reason: it's typically one of the most asked questions that needs to be answered for the troops.

"What relevance do these standards have to actual field operations?"

And what you have to do in trying to answer that question is divorce yourself from the actual field (using the field experience, and as everybody said, the worst-case experience) to find what you need. Then develop test methods around it - tests which may be quite different from the field environment they are representing.

A typical example is the firefighter from Oklahoma asking "Why do I need an accelerated-corrosion test using salt water, when I don't live anywhere near an ocean?" You have to expect that kind of question.

What you're doing is accelerating corrosion to see how that product would actually act over a long period of time. You must divorce yourself from the laboratory setting and use field experience to define to the people writing the standards what problem you're looking for. Then look at reproducibility of the test.

Another example, one of the biggest, real big problems we have is the 500 degree oven test and the 482 degree Fahrenheit-flame tests that we use in many of the SCBA and the turnout clothing test and how relative that is to the fire service, when no firefighter alive is going to be able to live five minutes

in 500 degree Fahrenheit.

In actuality you're doing a lot of degradation work to a product to assure that, in fact, in worst-case areas that it is going to protect him. So, it has been a great question and I don't know if we've answered it yet.

JERRY STENGEL:

It sounds like the closed-circuit positive-pressure device is a good device and yet the test results are making it look badly. Is that the case?

TOM SEYMORE:

That was the purpose that the people (in this case Draegerwerk) were trying to show. The chief engineer really had in his opinion some legitimate concerns which he was trying to express as vividly as possible.

And they put a lot of effort and work into that. They made a nice video tape and went to a lot of trouble performing tests.

UNIDENTIFIED SPEAKER:

Can't you design a test that won't make anyone look bad? We did the same type of tests, and we did it for the same reasons.

It just seemed to us that there was a deliberate attempt to make a good device, a positive-pressure device, look bad. This creates a lot of fears: maybe not unfounded, but certainly expert fears. There should be some rational testing.

CHUCK SOROS:

You know, one of the things that modern fire chiefs have a problem with is they have to play with what they call a "political ballgame." They don't often have the expertise such as those present today, Bob Guyett and myself or their staff to advise them. We say this is the best standard.

I've advocated a positive-pressure creating unit in my department, closed-circuit, of course. I say, "It's a good unit and here it is. This is what we want."

One of the biggest problems that you're going to have with acceptance of anything is the training involved. The way you train people is the way it's going to be received in a department, and what the problems are you're going to find. And if you don't get across the benefits that they're going to get out of it, they will

find something negative about it and this will work to your disadvantage.

Unfortunately there are fire chiefs that don't have the luxury of having someone knowledgeable like myself, Bob Guyett or Bill Jones on their staff so that when there is an NFPA standard they can say to their firefighters, "Hey, these guys know what they're talking about. They did the best they could. They put this together for me and this unit's going to do the job."

Nomex coats were a prime example. They thought they could walk right through a tunnel fire with them, and if there was any heat degradation to the coats, they said, "My God, those guys are dummies." Well, the standard wasn't intended to imply that kind of use, but that's what you get and that's some of what you're talking about now. You get the worst case, exaggerated, and then don't have the right people in the right places to dispute the arguments.

JIM JOHNSON:

I'd like to add a comment on the reason why we spent some time editing and showing the tape of fire tests - it was presented as history.

See, one of the reasons why we're here is that there is much information floating around, history so to speak. There were certain things done at certain periods of time with certain purposes. And so, this is a forum to bring everything out. The tape wasn't presented as the answer. It was presented as data that has been around that some of the attendees here may not have seen. They were not valid tests, nor ones that we should be satisfied with.

It was really presented as a perspective, history and a starting point to move on from and learn from, not one to stop with.

CHUCK SOROS:

I have some questions on the compressed air versus the rebreather designs. Basically what we have to be concerned about with the compressed air is the quality of air that we put in the bottle, and which will wind up in a man's lungs. With this rebreather, is there a consideration with the lack of moisture in the air, possibly drying the lungs out? And also these other

chemicals which are used, what is the possibility of them shaking loose and getting into the man's respiratory system? Has that been considered and what should we be doing about this?

JERRY STENGEL:

Is your concern about oxygen or reports of lung disease from the medical literature?

CHUCK SOROS:

No, that's not what I'm referring to. I'm referring to moisture content.

JERRY STENGEL:

Bob da Rosa touched on that this morning when he showed that most of the CO₂ scrubbing chemicals are producing moisture as a part of that removal process. In fact, that's part of the complaint about the heat. The heat is far more intolerable in a closed-circuit unit than it is in an open-circuit SCBA because of the added moisture.

Just to finish off on the oxygen toxicity comment, the medical literature I've been able to review, really applies to an unhealthy population with respect to respiratory disease, and secondly, it's a chronic condition, a long-term condition, produced by exposure to high concentrations of oxygen. But the kind of exposure, if you will, that users of closed-circuit apparatus have is intermittent at best, and does not cause lung tissue damage.

BILL MAYO:

If I might comment about that. One thing that I mentioned earlier is that we have in our department about fifty of the closed-circuit and over sixty of the open-circuit SCBA. Counting the test year and the last four years, we've been using both types for five years. And as time progressed, the men in the department have basically stopped using open-circuit themselves. They have available both of them.

They have a four-stage, water-cooled air compressor. The air is tested periodically at our testing laboratory; we haven't had any problems. The transition has been based on the fact that the advantages of less weight outweighed the disadvantages to a working fireman.

We haven't seen any of these problems

that possibly could happen. But, the men themselves have made the transition from open-circuit to closed-circuit.

CHUCKSOROS:

Before I get off, more important - I'm more interested in the second part of the question I asked about the chemicals that are in this mask breaking down or getting particulate matter into your respiratory tract. I'm not that concerned about the moisture content, I just brought that up.

JERRY STENGEL:

As a start I'll mention that by design there's filtration on the chemical canisters that are designed to limit the amount of particulate that gets out.

Would any of the manufacturers care to comment on the likelihood of the chemicals getting into the breathing air?

UNIDENTIFIED SPEAKER:

I'm not a manufacturer, but based on approximately sixteen years of usage in closed-circuit, the (unintelligible) breaks down before the chemical can break down and come out into the breathing tube or the breathing tract itself. The manufacturers apparently have put the filtration system screens around the chemical in the cartridges you install. So, it does not come out in our experience.

CHUCK SOROS:

One thing that should not be overlooked, Bill, is the fact that the same absorber is used every day in every anesthesia machine in the United States in every hospital. The same type of filtration is used. And if there was migration, it would have to be over a long and extended period of time. The chemical itself is biodegradable. The system has been used for a long time.

On the question of dry O₂ and wet O₂ (oxygen). You can't have it both ways. You can't complain when it's dry or when it's wet. The world doesn't work that way. Jerry already mentioned that part of the process of absorbing generates moisture. If any of you have the misfortune of waking up in an intensive care unit some day, you better look it over. If the wall bubbler isn't there, you are in deep trouble. Moisture added to the oxygen is beneficial and it doesn't take any tremendous experts to answer that

question. A call to a local hospital and talking to the chief anesthesiologist would settle the question in about two minutes.

UNIDENTIFIED SPEAKER:

To give you Navy experience, the Navy uses two rebreathing type of units.

JERRY STENGEL:

Specifically, we had this occur in New York City where we had rebreathers and particulate matter did enter the man's mouth and was burning. It was acknowledged by the manufacturer that this happened. The masks were taken back and supposedly fixed. We got them back and the same thing is happening. It went into their mouths and burned them. We can see the particulate matter, whatever it is. When we put something on our face, we don't expect to get particulate matter into our mouths, yet this did happen with a mask.

So, we're getting into something that we didn't encounter before. When you put a mask on before, all you had to worry about was the ambient air entering the facepiece, not the mask itself.

I'd like to clarify the other part of the question that you're asking about, about contaminants, the SCBA which Bob alluded to also. If you have a negative-pressure unit and experience in-leakage through the facepiece, you also have taken ambient contaminant chemicals inside the SCBA. So when you asked your question, I wasn't sure which of the two you were addressing.

UNIDENTIFIED SPEAKER:

This situation occurred in fresh air, so we knew it came from the mask. It happens.

JERRY STENGEL:

Well, we know nothing is a hundred percent in manufacturing. So, if the quality control slips and the filter doesn't get in right, or it's not the right one that could account for it. The filter could have been damaged in shipping or it could have been vibration damage from storage on a vehicle.

From an industrial hygiene view-

point, most of those chemicals that are used in scrubbing CO₂ are classified as irritants rather than toxins, but are not very pleasant at times: particularly, lithium hydroxide. We would expect that they would be removed from the lung by the ordinary particle removing mechanisms but discomfort would still occur.

UNIDENTIFIED SPEAKER:

I was speaking of an experience with lithium hydroxide.

JERRY STENGEL:

I think there was, in Alan Hack's presentation this morning, some comment about the possibility of some particulate in the airstream confounding the protection factor measurements.

UNIDENTIFIED SPEAKER:

Another point to make is that the rebreathers are the oldest breathing apparatus. Although they might be new to the fire service, they're not new to the people who have been using them for generations. The basic design of them was basically unchanged.

JERRY STENGEL:

That's a true statement and historical perspective.

UNIDENTIFIED SPEAKER:

I'd like to go back just a little bit and address this issue about the approvals and breathing apparatus in general and possibly the need for high performance. I think it's dangerous to - and certainly we don't want to - create the illusion that the present-day breathing apparatus would not pass tests such as flammability tests.

As a matter of fact, most manufacturers sell their products throughout the world and have to deal with certain types of qualifications and certifications, many of which do indeed call for flammability tests as they do in Europe. Just because we don't have a high performance test or flammability test in 30CFR Part 11, don't assume that the present-day breathing apparatus (whether it's open-circuit or closed-circuit) would not pass until at some later time when there is a certification of this type.

Almost all manufacturers, for example,

have passed a flammability test or will pass flammability tests. It's dangerous to assume that because we don't have these tests today that the products that we have today would not pass.

As a matter of fact, most manufacturers are self-policing and do an excellent job of it. You can't believe the number of products that come back to a manufacturer. We hear all the complaints before you do, and we see them. Also the number of requests given to NIOSH on a yearly basis for recertification or a change in form, fit or function are quite high. So, the product that you have today is not the product that you had two or three years ago, and the manufacturer is not going to accept a substandard type of equipment. If he sees a problem in the field, he changes it.

JIM JOHNSON:

There will be, as Tom Seymore mentioned, copies of our contact lens questionnaire for those who have not seen it. For those who are personally interested in it, we're glad to have your input. The more replies we get, the better our data base will be in evaluating the use practices with contact lenses and full-face respirators.

Tom also gave me some information put out by NIOSH on approval of self-contained breathing apparatus with an emergency escape, breathing support system, buddy-breathing. Copies are available.

This concludes the session for Tuesday, October 23.

WEDNESDAY, OCTOBER 24

Now, our first speaker today is Jerry Stengel and he is an industrial hygienist in the Hazard Control Department here at the Lawrence Livermore National Lab.

My topic is: "What is NIOSH-MSHA certification?"

It's a term, an acronym, that needs to be defined and understood among any group who's discussing respirators. I'm not affiliated with NIOSH, although the program might imply that. I just offered to give a brief overview of what is important about the NIOSH certification program particularly with respect to closed-circuit SCBA. It's not a simple topic. To

talk about it briefly is just to overview it, which is all we really need.

To answer the question of what is the certification that NIOSH does, we have to talk about the label, the tests, the agencies, the trust and confidence that's implied; and not only what it is, but what it is not.

The purpose of the label is so that any apparatus or respirator approved under the NIOSH-MSHA certification program will have some evidence of that approval.

When you pick up either the equipment or its container, you'll find some indicator that it has been approved. There will be an approval number, and some other information about use limitations that were stated during the approval process.

So, it's a very important piece of assurance to look for any time anyone's using a respirator. Sometimes the label may not be evident, maybe it was on the package and you don't have the package. But it's worth digging for that extra assurance. As far as the SCBA the approval plate is usually fixed to the apparatus itself.

The approval test is really the regulations that are contained in Title 30 Code of Federal Regulation Part 11. This is law, but it is law about the testing of the apparatus, not law about its use. This introduces the various Federal agencies involved.

OSHA (the Occupational Safety and Health Administration) is the enforcement agency which deals with how equipment is to be used in industry. NIOSH (the National Institute of Occupational Safety and Health) along with MSHA (the Mine Safety and Health Administration), the mining enforcement agency, are participating in a joint certification of the equipment.

NIOSH is not an enforcement agency. They're not putting down rules about restricting use of the equipment. They're providing performance criteria in the test regulations. They apply to engineering tests (bench tests or laboratory tests), and they apply to so-called "man tests" or human subject tests.

So, in 30CFR11 we have both types of tests that the equipment has to undergo. And the tests vary widely depending on what type of respirator you're talking about. When we talk

about closed-circuit breathing apparatus, the tests are skewed very heavily towards how the apparatus performs during human subject testing. This should give those approvals some added relevance to their human users. Laboratory tests don't have much popularity these days, so it's easy to criticize the performance of a respirator because nearly everything that's known good about it is based on what happened in the laboratory. "But, tell me about what really happens in the field," the critics say.

Well, it's not the field, but very heavy emphasis in the certification process on closed-circuit apparatus is placed on what happens during the human subject testing. Part of that reason is because there are no proven breathing machines that can simulate metabolic activity of humans. It's simply much easier to use humans right now. Although a future research direction for NIOSH is to develop an acceptable breathing simulator.

NIOSH is primarily a research agency: not an enforcement agency. It is a health research agency which does respiratory protection research both in-house using their own staffs and by contracts let throughout the industry. NIOSH does much more than respirator research. Occupational Health and Safety Research is their charter. But, we focus on the respiratory protection part of that and particularly on the respirator certification and approval activities that occur in Morgantown, West Virginia.

There's an awful lot of trust and confidence which users put into being able to locate a NIOSH approval label as opposed to picking up an apparatus that doesn't have any evidence of this testing having been done. I think that's well-founded. Some of the trust and confidence comes from knowing that and independent agency who's neutral with respect to industry has applied the performance tests that are in 30CFR11 and come to a conclusion about how well the respirator is built and how well it's likely to perform.

That approval is almost totally based on the specific tests that are in the so-called test schedules of 30CFR 11, but there are also some judgment factors and general design criteria involved. Theoretically a respirator could be built that would pass all the laboratory tests, but judging from the materials that are

used or the way that the apparatus was constructed, it would not survive in the field. NIOSH certification process has the capability of applying some limited amount of judgment to deal with this situation.

So, testing and approval certification is difficult to describe briefly. But in an overview, you get the idea that there is an independent agency that has evaluated any respirator that carries a stamp of this approval.

A little bit about the history. The history of these standards is interesting. About the turn of the century in the mining business, the mines had a nasty habit of exploding and catching fire. That cost quite a few lives.

And from a health and safety standpoint, the mining industry was extremely hazardous. There was so much concern a new agency called the Bureau of Minest was established around 1911.

Part of their response to mining disasters was to better protect those doing rescue work. It became apparent that they were not only losing people during the disasters, but also after the disasters when people went in to try to rescue victims. A major factor in that loss of lives turned out to be the problems with the breathing apparatus that was being used.

So, the first focus in respiratory protection of the Bureau of Mines was in the mine rescue breathing apparatus. They developed the first approval schedule and were also instrumental in developing new breathing apparatus by 1920. That was the start of the approval business. The Bureau of Mines had control over approving equipment that was introduced in the underground mine environment. For example, sparking materials could light off a methane gas explosion which could trigger a disaster. So, they wanted to prevent those kinds of things from happening.

It was very consistent with the kind of strict controls they were using on other pieces of equipment to have a very stringent testing and approval schedule for the type of breathing apparatus that would be allowed to be used in these post-disaster rescues.

Growing out of that effort, more equipment became available for more use in all industry, and more approval schedules were developed for other mining applications including above ground work. After 1970, the Occupational Safety and

Health Act, where the enforcement business was separated out from the Bureau of Mines, the enforcement agency was formed and the Bureau of Mines was doing solely research to support Mine Safety and Health Administration. NIOSH was created to do research to support OSHA and general industry. NIOSH and MSHA retained under law a joint interest in respirator certification.

That's sort of how we got here. In terms of what it is not, NIOSH is not a regulatory agency and they're not conducting environmental tests. They are all laboratory tests, not intended to provide assurance relative to use in any specific industry, such as in firefighting.

In other words, NIOSH doesn't approve a closed-circuit or an open-circuit SCBA as a firefighting device. It is not a guarantee of safety or health to the wearer in any industry as some people have implied NIOSH certification should be. It's also not a field test for ruggedness or reliability, although NIOSH has capability in a research mode to study performance of respirators in the field.

So, in summary, I think that in some ways we need to express a gratitude for a thankless service. NIOSH does what no one else has found another way to do. Despite proposed improvements or changes to the current system, we still have it. And it's not unlike the government approval systems of many other countries. It's not particularly unique to the United States. Such an approval standard could certainly be revised more frequently - maybe the system should be changed that would allow it to be revised more easily and be more responsive.

But here we are today. NIOSH has many initiatives under way about revision of the current test standards. So with that background, let's continue.

Our next speaker is Rick Duffy representing the firefighter's union and is directly involved in all aspects of SCBA use in the fire service. Just one of those is his activity as the Chairman of the NFPA, SCBA Committee. He's going to give us an opening review on that with reference to closed-circuit

breathing apparatus.

As I start out this morning, I'll be wearing a different hat than I wore yesterday, and I'll be speaking as Chairman of the Technical Committee for Protective Equipment on Fire-fighters which develops performing standards for firefighters' protective clothing and equipment.

One of the standards that we've been working on for many years is a standard on respiratory protection for firefighters. Back in May of 1971, a landmark voluntary consensus standard was passed and NFPA called it 19B, Respiratory Protective Equipment of Firefighters. Essentially what that standard did was eliminate the canister mask from use in the fire service and it happened rather dramatically and overnight.

Again, reasons were firefighter deaths. There were firefighter deaths in Boston and in New York. A firefighter in Sacramento, California today is in a nursing home essentially brain dead because of a fire he fought in the late 1960s using a canister mask. So, the fire service recognized that because of the oxygen deficiency potential in any fire, canister masks weren't the way to go and they developed this standard for SCBA.

It took another ten years for a revision of that standard to come about. Essentially, 19B then became NFPA standard 1981, self-contained breathing apparatus for firefighters.

This was another landmark for NFPA standard on protective clothing and equipment, because not only does it now require SCBA, but it requires that (1) breathing apparatus of the open-circuit mode be of positive-pressure and (2) the closed-circuit mode because of the testing criteria of NIOSH be at least NIOSH approved. It was a short document. It's only one page long and doesn't have any performance criteria in it at all.

In 1981 we set up a subcommittee, or continued a subcommittee that was in existence, to do specific performance requirements for breathing apparatus. We started off on a very ambitious task to do both the open-circuit and closed-circuit in one document. Realizing the problems, which I'll get into in a bit, we had to separate. And about a year ago in subcommittee work, we separated open-circuit from closed-circuit -- we're working on the open-circuit first. As we

complete that, we will use much of the information we've used in the open-circuit standard and adapt it to a closed-circuit standard. So, I'll be talking about the two standards here today, but limiting it to the open-circuit mode. The standard, as it's drafted right now, of course, can change. There's going to be a meeting this week on it.

I'd like to at least give you an overview and some of the reasons why we picked these criteria for performance standards. The standard will, of course, have definitions and administrative areas in the beginning such as we had before. It'll have specific labeling requirements as well as required maintenance and training instruction provisions which would require the manufacturer of such devices to provide specific information on training and specific information on required maintenance to the users.

And then we get into the design and performance requirements. The standard we first started working on came out of a lot of work that Jerry Stengel and Bruce Held did here at Lawrence Livermore through the ANSI Z88 Committee. Subsequently, ANSI agreed to allow NFPA to develop the standard since it was specifically for firefighters. NFPA took all the work that Jerry Stengel's subcommittee did on the draft ANSI standard and put it in effect with NFPA, or worked with NFPA on it.

We are not trying to replace all the work that NIOSH does. We are requiring that the breathing apparatus, to meet the NFPA standard, still meet the NIOSH-MSHA certification. At first we called it the high-performance standard for firefighters. We have since changed that to Minimum Standards for Respiratory Protection for Firefighters. This is a minimum standard, it is not a high-performance standard or an optimal standard, so we are still requiring the NIOSH-MSHA certification. We are going to have a weight requirement on the apparatus itself, excluding the air vessel which currently is twelve, thirteen pounds. Then we get into the most important aspect of the standard itself and that's a base-line performance test. We were going to require that the breathing apparatus be able to maintain positive-pressure when tested at ambient conditions on a breathing machine at a rate of one hundred liters per minute. This has to be done throughout the various tests and after all the environmental tests are done. The

exhalation pressure cannot exceed five inches of water.

Using that base-line test as we go through the environmental tests, the first test that we perform is the hot and cold temperature shocks. We do this for obvious reasons: One, is the shortcoming of the NIOSH-MSHA criteria that right now only looks at performance in cold environments at temperatures specified by the manufacturer (typically, minus 25 degrees F).

We are still going to do those same tests. We will cold soak the apparatus at minus twenty-five and then test it on a breathing machine; we will then cold soak the apparatus at minus 25°F and spray it with water while we're testing on the breathing machine.

We will then do a high temperature test that NIOSH doesn't do. Right now, we're considering soaking the breathing apparatus at a 160 degrees Fahrenheit for a specified time and then running it on a breathing machine without water spray, followed by a run on the breathing machine at a higher temperature with water spray.

Again, 160 degrees F was not picked for the flame or the heat environment of a fire. It was more representative of the storage environment whether it's kept in the trunk of a car, whether it's kept in a cabinet on a fire department rig in hot areas, or whether it's next to the engine area of the rig.

The next test was the temperature shock. We may have a breathing apparatus stored at minus twenty-five degrees F on a rig and have to go into a fire station where immediately temperature is much higher than ambient. However, we may have the inverse, when it may be hot and one enters extreme cold for bottle changes. We've developed a standard where we're going to cold soak it down to minus twenty-five and test it in one hundred sixty and do the inverse: soak it at one hundred sixty and test it at minus twenty-five degrees F. We want to make sure that the apparatus maintains positive pressure during this shock.

The next area that we looked at is an area that's still giving us a lot of problems. It's the impact test. We looked at different drop scenarios that happen in the field. Typically, firefighters coming out of a fire,

exhausted from the work they've just performed, may unstrap the breathing apparatus, and let it fall on the ground. Obviously not a good practice, but typically, it happens every day.

The other scenario we looked at was firefighters either pulling the apparatus down from a truck and dropping it or donning it over their head and dropping it from that height.

We looked at test drops of breathing apparatus a number of times at both one meter and at two meters, but obviously there were a lot of problems in doing it. The main problem was concern for the person who would stand there and drop a pressurized cylinder two meters and risk the consequences.

But, the real problem, regardless of the training technician, was reproducibility. How could we drop that thing, be fair to all breathing apparatus tested and be accurate and be able to reproduce that test. We were also unable to think of a way to do a reproducible test. We think there's a need for it. You can go into any fire department's mask service unit in this country and ask that repair technician what's his number one problem, and he's going to tell you "the valve assembly on cylinders."

They're typically bent. The threads are typically dinged and banged up. I think it's a lucrative part supplied by the manufacturers. They would probably sell that particular replacement part more than anything else on a breathing apparatus. We feel something should be done as most valve assemblies now are aluminum. We may go back to a performance requirement that would force another material. We're not condoning the dropping of a breathing apparatus in the impact test, but we're looking at the reality of it.

Vibration is another test that we are going to address. We adapted a test that the military put together in their military standard to environmentalists to simulate breathing apparatus sitting in vibrating rigs running down city streets with potholes, especially in our part of the country. There will be a vibration test included to address the durability of the apparatus.

The next test which we saw examples of yesterday is the flame test. Dracgrwerk developed a testing procedure in Germany which was adopted by some of the European standards. We looked at that

and made some changes to require that the breathing apparatus be hooked up to the breathing mannequin and breathe air while being exposed to a flame for a specified period of time while breathing. Once the flame is taken away, there can be no greater than a two-second afterflame.

Again, we are not thinking firefighters are going to be sticking their head in flames, but during the video of flame tests an occurrence more dramatic to me than the flaming of the mask was the Rexnord apparatus, where the facepiece strap broke away during the test. Since then, Rexnord has changed the material in their facepiece for that problem and perhaps others; but we certainly don't want that to happen. I think that's why the flame test is very important to test for the durability of it in a flame environment.

Another area of flame testing that we're looking at was mentioned yesterday, and that was looking at the strapping, the belts, the webbing, and any fabric materials used on a breathing apparatus. We hope to require that it meet Federal Test Method 5903 where the materials are put into a Bunsen burner flame for a specified period of time. When the flame is removed you can't have a char length greater than four inches, and afterflame greater than two seconds, and there can be no dripping or melting. Essentially this will eliminate materials such as nylon and polypropylene. In the past they have been used as fabrics in breathing apparatus, but really have no business being in the fire service.

We also looked at the radiant heat component. But because the flame test was so severe, the draft right now doesn't include a radiant heat test. We figured the radiant heat measurements would be picked up during the flame tests.

Another problem the fire service identified is corrosion problems of breathing apparatus. So, we put in the accelerated corrosion test where the apparatus is put in a salt fog for 48 hours and then washed off and examined per the military standard. It's a very difficult test that will require changes in many of the manufacturers' equipment that passes tests. I think hard anodizing will have to be used on many of the regulator parts to pass. But it's something that's needed when you're in an atmosphere or an environment such as the SCBAs that are used in the fire service.

Another area similar to the corrosion

test came from problems that were identified by the Fire Service (in Miami and then in other cities later on) the use of foam.

Essentially, the problem that was identified in the field was that when foam was utilized and firefighters were walking or wading through it, regulators started honking or free flowing. That is in the draft of the standard right now, but again this week it's going to be looked at again in more detail. Right now, the standard does have a foam test but we are having trouble with reproducibility.

A particulate test is included for the obvious reason. One of the biggest problems in fires is particulate -- not only the particulate from the combustion, but typically in the overhaul area where ceilings are pulled or walls are pulled for fire extinction. Because of the high particulate it certainly should be tested for in any performance standard.

Facepiece lenses are another piece of equipment that is typically replaced frequently by service units all over the country. The biggest problem is they smoke up, they scratch up and you obviously can't see out of them, so they need replacement.

We are looking at a breakage test using the ANSI Z87.1 criteria for breakage. I know it's not that stringent a test but we are going to include it in the NFPA standard.

And we also have decided that the committee should develop their own specific test on lens abrasion. This performance test will require at least a hard-coating of all lenses, which will extend the life for replacement of that particular lens.

Another area that we're looking at on the test is addressing a typical thing that is done by firefighters wanting to talk: they would typically remove their facepieces. Obviously, on a positive-pressure, you'd go onto free flow with loss of air if you lift the facepiece. Well, again, we're not condoning that practice but it is done. Many departments refused to switch over to positive-pressure for that sole reason. Not looking at the health protection, but looking at that particular problem, some manufacturers have now gone into means, whether mechanical or automatic, to suppress the flow. It's

typically called an automatic free flow or a free-flow controller.

We are not requiring these on the breathing apparatus in the standard right now, but if so equipped, that particular component cannot change the operational mode of the SCBA positive-pressure.

And finally we looked at one operational concern of firefighters, a communication test. You can talk to any fire department in the country and ask them how well you can hear an individual or talk to an individual with a breathing apparatus on, and you will hear "It just can't be done." We looked to see what kind of test we could either develop or adopt. We decided on the ASES 3.2 test for measuring word intelligibility and the draft of the standard has that right now. However, it just gives you the test methods, and you have to specify how it is to be performed.

Currently, we specify that at 80 feet with a 90 decibel A-scale background noise at 100 hertz, you would have to pass the test with ninety-percent intelligibility. Quite essentially the tests have fifty or so words to be spoken while the individual at the specified background and distance will have to pass the test by understanding ninety percent of the words. It is a very, very difficult test especially with a breathing apparatus on and at high-level background noise.

You don't have a communication device on your SCBA, but, indeed, that manufacturer has to have one available and approved for his breathing apparatus if, indeed, he wants to have an NFPA label. This is similar to a nose cup is on SCBA. You don't have to buy a nose cup, but the manufacturer has to provide it.

Now, what happens when we finish this open-pressure SCBA? We're going to then look at closed-circuit breathing apparatus. There are many problems that have been identified. The number one problem is that the breathing machine we use for open-circuit, obviously, cannot be used for closed-circuit breathing apparatus. We have to get metabolic simulators and they're not easy to come by. I'm sure most of you will be buying plenty of them.

But again, that was the main problem that caused the separation of SCBA closed-circuit from SCBA open-circuit. Also dead-air-space tests will have to be done with carbon dioxide and inspired air

temperature performance criteria have to be developed.

It took the fire service until 1971 to finally put together an NFPA standard on wearing SCBA instead of canister masks. It took ten more years to require that only positive-pressure SCBA be used by the fire service. In the past three years, we finally put together a performance standard for the firefighting environment.

If, indeed, the committee finishes its work this week, they're going to do some test verification in the next month. If that work is kept on schedule, this particular document will leave subcommittee by this January to go to the full technical and then it goes through an NFPA cycle that takes at least two more years. Then there's public Comment and on to the NFPA body itself for voting. There would be a new standard by the spring of 1986 if we keep that schedule. It takes a long time putting together performance standards. Those of you who have worked on those types of committees understand it. But we're uncommitted to putting intrinsic safety into the tests and the breathing apparatus used by firefighters.

The next speaker really doesn't need much of an introduction. Bruce Held has been in respirators ever since I can remember. If you trace his history, he worked at Los Alamos respirator research, was a moving force in ANSI as Chair-man of Z88, and all at once we have the ISRP Society and Journal which he helped start, to focus attention on respirators and their problems. Some of the basic SCBA work that has motivated equipment changes was planned and conducted by Bruce. The secretariat of ANSI Z88 Committee is held by the Lawrence Livermore National Laboratory. The chairmanship of the committee is being transferred from Bruce to Bob da Roza of the Lab's Safety Science Group which I operate. Bruce, will tell us where we're going in the ANSI business.

Where we're going in the ANSI business is one of the more difficult things to predict, so we should start by taking a look at the past. The one ANSI standard that deals with closed-circuit breathing apparatus is Z88.5 which is

titled Practices for Respiratory Protection for the Fire Service. This particular standard was published in 1981. We in ANSI have the same difficulties as Rich described getting an NFPA standard approved. The Z88.5 subcommittee was first formed in 1976. I chaired it and it took us until 1981 until it was published. The major problem that we had getting it approved was exactly how to apply positive-pressure to the fire service. At the time we first started meeting, our estimates were that ninety-five percent of the fire service was using the demand (negative pressure) apparatus.

We finally got that resolved with a five-year limit on the use of demand apparatus within the fire service. At that time we also recognized the need for the closed-circuit apparatus.

The philosophy that was adopted then in Z88.5 was that positive-pressure SCBA had to be implemented by 1987. Then we went on to say that the only exception is that an approved, properly fitting negative-pressure, closed-circuit device could be used if no approved positive-pressure SCBA can provide the length of service time necessary for firefighting in high-rise buildings, below decks on ships, in tunnels or in other situations where devices with shorter service time may not be adequate.

That is where we stand today. As far as the future is concerned, I hope that NFPA will also take over this particular standard addressing closed-circuit SCBA performance. This work belongs within the NFPA organization, just the way they are now working the NFPA standard for the test criteria on open circuit SCBA.

The precedent that we had as far as ANSI is concerned is the old Z88.4 which was the respiratory practices, or respirator protection against coal dust in the mining industry. That was a case in which we felt that the Bureau of Mines, now MSHA, by their enforcement standards did a lot better job than could addressing the needs of their particular industry. Hence, Z88.4 was dropped and we do not have that standard any longer. Hopefully, NFPA standards will be so effective that Z88.5 can eventually be replaced. Possibly to keep the ANSI activities complete in respiratory protection, the new NFPA standard,

when completed, can be simply adopted by ANSI Z88. Likewise Z88.5 could be an NFPA standard which is adopted, giving it double strength too.

So, this is the direction I would foresee the American National Standards Institute going as far as respiratory protection standards. I think the results of this conference and the studies that are being done on the closed-circuit apparatus will probably have a lot of influence on how ANSI handles the closed-circuit apparatus in the future.

JIM JOHNSON

I'm going to present the next talk on some future research and testing that the laboratory here will be doing, at least in part, for Federal OSHA and for some of our internal interest. By way of introduction I thought I'd take a chance here to tell you where I work and how the safety department is organized. I work in the Hazards Control Department which has five divisions which cover the whole gamut of occupational safety. Now, Bruce and Jerry Stengel are in the industrial hygiene group in the safety division, which is the user part of the laboratory. They maintain the respiratory program that supports our fire department, but John Sharry, who spoke earlier is in charge of that division. Roberta Rodriguez, whom I'm sure most of you have met, works for Bruce maintaining the respirators and distributing them to the various users. Now, there is a special projects division which is like the R&D division of our department. Dick Griffith, is my division leader and he'll give us some closing comments later this afternoon. Norm Alvarics, who also spoke earlier, heads up the Fire Science Group; I head up the Safety Science Group; and we also have a Radiation Science Group within our division. So, those three groups then perform R&D activities to support the rest of the health and safety at the laboratory. Bob da Roza then is a senior scientist in my group and he heads up the specific projects that we're involved in.

Now what I'd like to tell you a little bit about respirator studies that we're doing at LLNL in conjunction with and sometimes for OSHA. One of the things that makes us a little different than some organizations is that we have an ongoing research program within the laboratory

also, so that there is both outside funding and inside overhead funding in our respirator studies. Now, we currently have a beard study that's being sponsored by OSHA and LLNL to measure the effect of beard growth on protection factors of self-contained breathing apparatus. I didn't put positive-pressure in there because that's really assumed. And in our looking at the open-circuit, self-contained breathing apparatus, we're going to try to simulate a work environment and hopefully provide some data that puts this issue to rest.

Although, I sometimes wonder. The beard problem has been around for the twelve years that I've been in industrial hygiene. I hope we get some more clear data so that we can make a final decision on it. Bob da Roza is the senior scientist on this project and we are experiencing administrative difficulties with the Human Subjects Committee right now. They are very fussy on what you do with humans, even when you're just trying to do something a fireman does every day. I don't think we could get human subjects' approval for what a fireman does.

Another project that Tom Seymore mentioned is certainly one that he (OSHA) is very much interested in funding for us, is the contact lens controversy. It has been around for many years as part of the ANSI standards. You talk to people, and you say, "How did they get in there?" Talk to Bruce Held and say, "Bruce, where did the data come from?" "Well, you know, somebody said or somebody brought in this piece of paper when we were back putting the standard together..." And you say, "Well, where is it, can we pin it down?" We can't find anything to establish a data base. So, what we're doing right now is establishing a data base so we can see what the effects of contact lens wearing is on respiratory performance.

When we gave a respirator training class out in Salt Lake City, a question from the back was, "Well, how can you do that? How can you even bother sending a questionnaire out? Our corporate policy says that you won't wear contact lenses. End of discussion." Bob and I smiled at each other and said, "Well, that's one way to run an industrial hygiene program." But, the reality of the situation is that there are a lot of people out there wearing contact lenses, especially in the fire service. What we want to do, specifically, is ask "Do full-face respiratory users

routinely wear contact lenses?" Our initial survey forms coming in now indicated yes. Significant numbers of people are wearing contact lenses in full-face respirators. Have we had any reported problems from this practice? Which is very crucial to the controlling of it. Look at how we're gathering our data base. We have a questionnaire which we sent out to about 1200 California fire departments. The Society of Fire Service Instructors received about 5600. Rich Duffy mentioned that he just put out about 2300 in his IAFF Newsletter. We're hoping to get out another 200 in various industrial and government organizations. So, we're sending out around 10,000 questionnaires.

If we get forty or fifty-percent return we'll have a good data base to establish experience and any problems that exist in this area. To date, we're not seeing anything that would indicate there is a significant problem with the practice of wearing contact lenses and full-face respirators and it is being practiced. The only comment that I think is really important on this is there needs to be a risk benefit analysis. Contact lenses let people see better when they wear the respirators when you chat with people, they tell you. So, you have to decide, well, the one in a million that might cause a little problem, is it significant? Should we ban the use of them to protect against that one occurrence and deprive people of being able to see better? To me that's the real problem that we need to deal with there.

So, what we're going to do then with the results is summarized actual experience. And should our experience from these questionnaires support a change, we will certainly make that recommendation from the studies that we're gathering to OSHA for their review and action.

Another project that we're just starting to think about in this symposium was one of our initial starts into getting into oxygen breathing apparatus. And these are some of the things we feel need to be looked at when we talk about OBA's. Again, we need to gather a data base to better understand these operations and how we should use the equipment safely.

We need to evaluate the facepiece seal. Things are a little different if you

look at the oxygen breathing apparatus in that most apparatus come with one facepiece size. There is one type that's not generally used in which you can get different sizes. You might think, "Wait a minute. I buy three sizes if I have air purifying respirators, wonder why with an apparatus like this there aren't three sizes available." So what we're going to do is look at how these masks perform under air-purifying negative tests, just to see how good they fit people. We need to look at each unit through the whole operational time. In other words, if we have a two-hour unit or a four-hour unit, we need to evaluate that and collect data.

We need to measure the inhaled gas as a function of temperature, humidity, CO₂, oxygen and facepiece pressure. There's always a question of various temperature effects on this type of equipment, because it could be used in Alaska down to Alabama. We're going to see Rich and his NFPA committee come out with some NFPA recommended tests for closed-circuit equipment and we're going to be interested in that.

Last, but not least, we need to evaluate each unit's flammability potential. We're looking at the data we have to date as a start to see where we should go. You saw the fire test films yesterday, we're interested in picking up from there and going forward.

Just to give you the total overview, another subject that we want to look at is the powered air purifiers. We want to test commercially available units as far as design performance and see what we can draw from some work there. We're also interested in perceived and actual temperature effects on these respirators.

A lot of you may not realize, but about seven or eight years ago, the laboratory built an unapproved device here called the Daisy Pak, which was a powered air purifier that we used for a special application. It worked very well and we thought it was the only answer to the job we had, so we're very much interested in making sure this equipment is available and I think the concept is very good. Now, what other topics have we been talking about with the federal folks and we're personally interested in here as far as respirator research?

Hank Howard will be glad to tell you about chemical resistance of respirators. The Benicia (California) incident with anhydrous dimethylamine showed that

some of the components in respirators can be catastrophically affected by chemicals that they may encounter. So, this whole area needs to be looked at carefully. We're interested in the actual test methods of, or required for, NFPA approval. Rich's NFPA Committee will say, this is what they want but how do you do it? How do you do it reproducibly?

Yesterday, Tom Seymour mentioned buddy-breathing. And it's an important concept but, again, it needs to be evaluated. There needs to be some real careful looking at equipment performance when it comes to using buddy-breathing on the SCBA. Respirator cartridge performance with mixtures is a problem that we see going on right now. We have a small study starting at LLNL. It was Jerry Stengel who requested that we look at epoxy mixtures on air-purifying respirators.

Probably the hottest potential potato is respirator fit-test methods right now. Do we really know what the protection factor is of respirators out in service?

Well so, that's a quick overview of the kinds of topics that we currently see need to be investigated from our perspective and from our interactions with Federal OSHA. Wanted to let you know that we at LLNL are going to be involved in respirator research at varying levels, and we are enjoying it.

Our next speaker is Loren Myhre who comes from Brooks Air Force Base, Texas. He has done much work investigating thermal affects of breathing apparatus and how they influence the man-machine interface.

I will describe the problem of heat build-up, not only in the breathing apparatus, but also the heat build-up which is associated with any task requiring a protective garment or protective ensemble. I will concentrate on the firefighter's protective garment, because that's our main concern right now, although, there are others that we know of as well.

The first thing that I'd like to mention is that in using a laboratory test to evaluate any system, whether it be a garment or a breathing apparatus, I feel it's absolutely necessary to set the evaluation criteria according to the user that is going to be using the system. This is where I've had a difference of opinion

for some time with NIOSH certification requirements. To be fair to NIOSH, of course, the original requirements were set up early in this century without the knowledge or the equipment that we now have to set reasonable standards. But yet, the certification requirements that are applied by NIOSH do give manufacturers something to both shoot for and hide behind. For example, if NIOSH says, "If you do this, it's a thirty-minute system," then the manufacturer says, "According to NIOSH it's a thirty-minute system. Yet we know that thirty-minute systems can really be nine-minute systems in hard work. I will tell you more about that later, but the point is that it is more reasonable to look at the user, find out what he is going to be doing with the system and then rate it accordingly.

We're talking about heat stress and firefighters so here is a photograph of firefighters in the U.S. Air Force wearing the reflectorized bunker (protective coat). They're just standing still, but they don't do that all the time. We have a big airplane called the B52 which firefighters must be prepared to cool down if there is any kind of a fire at all. There have been several fires, very serious ones, and the job of cooling down the aircraft and rescuing personnel is a difficult one. The rescue is difficult because the firefighter must wear the protective garment here as well as the breathing apparatus, and get on top of this airplane, by climbing up the ladder and entering the cockpit from above. In there, there's only room for one person, yet it's his job to rescue the pilots and the crew who may be unconscious and sitting in a burning airplane.

I show these photographs and describe this to show that it is a very difficult task for the firefighter to go in wearing the breathing apparatus and cut loose the pilot and the crew, pulling them out by hand and getting them to the point where other people can help. We have measured the task and we know the energy cost, we know the ventilatory requirements placed on the breathing apparatus. They are considerably more, of course, than what was originally established by NIOSH for the approval of a thirty-minute system.

This slide could be any fire

department. The man is entering a building wearing the protective equipment. He is also carrying two different lengths of hose line and he's carrying a "water thief." The burden here is excessive. In fact, the burden that he is carrying, including all the protective equipment is in the excess of probably one hundred fifty pounds. By definition of the task in a structural fire, it's his job to enter the building, climb up the stairs (extending his line as he goes), and then begin to search and rescue. We have studied this task as well and the energy requirements are equivalent to an oxygen consumption in excess of two and a half liters per minute. That translates to a ventilation requirement on the breathing apparatus of as much as eighty or ninety liters per minute. If he's going to do this job, he must do it with as little resistance to inspiration as possible. The tasks that we chose to measure are important ones where the breathing apparatus is absolutely necessary. We are trying to use those tasks in setting our evaluation criteria for U.S. Air Force application. I recognize that this might be considered severe based on what others are doing in evaluating the breathing apparatus, but we're not going to apologize for that because we are trying to protect the man that's doing the job. It is absolutely necessary that we know what he's capable of doing and that's why we use these criteria.

To accomplish this, we performed a study about six years ago in cooperation with Los Alamos National Laboratory where we were studying the thirty-minute system. After determining the energy cost of firefighting, we then used this information to set the work load on the treadmill to simulate it in a laboratory as closely as possible.

And in this case, we have a man walking using a breathing apparatus. In these studies, we studied the characteristics of performance of the breathing apparatus for the thirty-minute system. Here we're showing the Scott, but we also studied the MSA, the Globe and Survivair. We were looking at such things as the negative and positive pressure inside the faccpiece, the temperature of the air breathed, and the duration of the air cylinder. We did this at three different work loads which represent various firefighting activities.

We found that a fit man can work for a

long period of time at eighty percent of his work capacity. This is the kind of a person that you'd like to have doing rescue operations because he's fit. He can find and remove a victim without getting exhausted himself and having to leave the victim there. A fit firefighter could work with a ventilatory requirement in excess of seventy liters per minute. He would drain this SCBA in as little as nine minutes. Now, the average time for twenty-two subjects which were used in this study was somewhat more than nine minutes (something like fourteen minutes) when working at eighty percent capacity. And that's only common sense really. The harder you work, the more air you're going to use. And in this case it was hard work.

We also found something more distressing when we studied both the demand and pressure-demand system. Although they had been highly advertised by the manufacturers as being positive-pressure under even hard work conditions, there was negative-pressure on every inspiration in moderately hard work. Again, the criteria for hard work was set up by NIOSH and it was inadequate for firefighters. In fact, I think some of these criteria were more applicable to mail carriers than to firefighters.

An even more startling fact was that the firefighter, as I understand it, is told that when the warning bell goes off, he has about five minutes left in his system. That's when he's down to 500 psi of air pressure in the cylinder. At that time, even the positive-pressure (pressure-demand) systems, had a great increase in resistance to inspiration. For example, they might have gone down to minus one inch of water column pressure during a normal inspiration during the first part of the work load. But after the cylinder pressure got down to 500 psi and below, the resistance to inspiration would be down as low as five or six inches of negative water column pressure. That is distressing! It would be to me. If I'm a firefighter, and I'm in a situation where it's really tough and I know now I just have a little bit of time left to get out, I want to hurry out. Yet at that time the resistance is exceedingly great. It can cause a starvation for air or oxygen, which can be quite dramatic in its emotional effect.

These are things that we found with the self-contained breathing apparatus. Then

the next thing we did was look at the heat stress which was imposed by the bunker. Of course, this is familiar to most of you who are familiar with firefighting. In addition to this heavy garment which is reflectorized to reflect the radiant heat, the self-contained breathing apparatus adds another fifteen to sixteen kilograms. The total burden placed on the firefighter, is in the neighborhood of forty-five or fifty pounds that he's carrying over and above his normal body weight.

The conditions that were selected for this study, were based on what we found to be true for firefighters. But we cut it back a bit, we used sixty percent of his work capacity rather than eighty percent in the previous study. The reason we use sixty percent is that at eighty percent we couldn't find very many people who could work long enough to do this study. With this burden, it is just difficult to work at eighty percent capacity.

The conditions in the environment (the treadmill in the lab) determine the work load. You'll see that we have infrared lights both back and forward of the firefighters to simulate some radiant heat. The air temperature in the room in this test case was a warm environment of 104 degrees Fahrenheit. The radiant heat which was added by infrared lamps was 118 degrees. That means that the person actually felt 118 degrees Fahrenheit even though the air temperature was only 104. Now, this isn't excessive. I'm sure firefighters get into much hotter situations than that. But, this was considered to be a normal hot day in the Southwest of the United States in the summer. So, even without a fire, a firefighter could be wearing this garment and walking in the Southwest in the summer and be under these conditions.

The other test condition was a cool condition of 75 degrees Fahrenheit such as probably in this room. We wanted to see how long a person could work under these conditions before he had to quit based on heat build-up.

I should give you a little physiology background here. In terms of body temperature, the normal resting temperature of a man and everyone in this room is around 37 degrees centigrade. That's 98.6 degrees Fahrenheit. So, 37 degrees is your

normal. As you work in a warm environment, you get warmer. As you get warmer you sweat and that usually evaporates to keep you from getting exceedingly warm. But, in a protective equipment system such as this, although you're sweating, the sweat does not evaporate. Because you'll have no means of cooling, you're just going to get warmer. You can continue to work and you can continue to increase your body temperature until it reaches 39 degrees centigrade where we have found that you have significant performance and judgment decrements.

Now, 39 degrees centigrade is not critical for life. A person can increase his body temperature to more than 41 degrees centigrade before he has heat stroke. But at 39 degrees centigrade, you find people getting irritable, making judgment errors, and stumbling which can be critical in a situation like this. So, 39 degrees is a good stopping point for a person who is working under heat stress.

The objective of this study was to see how long can a person work before he gets to 39, that being the end point. That has bearing on what we're heard so far about how much air you can supply a firefighter before you have to get him out for some other reason, such as heat stress.

The statements made yesterday were absolutely appropriate, concerning the fifteen or twenty-minute system which we now have in the thirty-minute bottle being a nice stopping point for taking a break. When you have a greater air supply, you are denied this stopping point and then you must consider such things as eventual heat stress.

In this study we found that the firefighter working with a cotton suit, just like street clothes could work for fifteen minutes and his heart rate would reach about one hundred twenty during the five-minute rest, it would recover very nicely and he could go on all day at that rate.

The protocol was for a fifteen-minute workout, followed by five minutes of recovery in the suit, removing the suit and resting in just street clothes. Fifteen minutes was selected as the work time because we knew that that's about how long the thirty-minute cylinder would last under these conditions.

In this case you can see that the person wearing the bunker had an elevated heart

rate of about one hundred sixty-five compared to one hundred twenty with street clothes. That's a pretty high heart rate and that's real honest work. The heart rate increased very rapidly during this fifteen minutes. The difference in rates was the difference which was imposed just by the burden of the garment and the breathing apparatus.

What does this mean in terms of heat stress at two work loads at forty percent and at sixty percent of their work capacity? At forty percent work capacity, a person could do work all day long. He could just stop for a coffee break and lunch and he would not get fatigued working at forty percent. At sixty percent a person can work for hours with just normal breaks for a glass of water and lunch and not be extremely fatigued.

These are not excessively high work loads. But the critical thing here is the rectal temperature or the core temperature. At the start of work, the body temperature increased almost one degree during the first fifteen minutes. That means, if it's going up at that rate, for thirty minutes, he would have gone up two degrees and been at the stopping point. At an easy work load in a warm environment, the body temperature increases at a rate that would deny you more than thirty minutes of continuous work. You couldn't do it. You'd be in a dangerous situation if you did.

Another important point is that when there is no chance to cool off by evaporating sweat with that avenue of cooling denied, the body temperature does not cool down during rest. That's something that a fire chief should remember, in that if a firefighter gets hot wearing a bunker, you can't just sit him down for fifteen minutes and cool down. You must remove that bunker. Now, that is for easy work. Probably a lot easier than most firefighters would engage in.

Take a harder work load of sixty percent which is not exceedingly high, and is something that a person could do for hours without fatiguing. The rate of rise a body temperature increases at least as rapidly or even more so than before: in this case, one degree in fifteen minutes. Now, ten minutes of rest after work did not allow this person to cool down. He reached 38.3 degrees at that point. One of the subjects in this study even reached 38.9 degrees during that fifteen minutes of work. That there are individual differences

and some people may get hot quicker than others, depending upon their personal characteristics and how they are prepared to go to work that particular day. But, in general, about fifteen minutes of exercise will give you a one-degree rise in body temperature in a warm environment and it would mean that thirty minutes would be the maximum before you would have to be cooled.

The heart rate represents the relative stress and in this case 160 to 170 beats per minute. That's pretty hard work. The rectal temperature rise in thirty minutes is to 38.5 degrees centigrade. He has a half a degree to go. During the recovery period, he reached almost 39. This is with intermittent work and rest. Again, we're showing that the heat stress can be the limiting factor when we provide firefighters with longer-duration breathing supply. It's the heat stress that's going to stop him.

Now, why does the body temperature rise rapidly? I gave you a good clue in that the sweat is not evaporated and this case shows exactly that. Wearing cotton clothing, the sweat rate is six hundred grams per hour, and almost all of it is evaporated: eighty-seven percent.

When you wear the bunker, the sweat rate increases tremendously, to about 1500 grams per hour, because of the heat load of the clothing. The evaporation is limited to nineteen percent. So, all this causes wringing wet clothes, but there is very little cooling provided by that minimal sweat.

The conclusions than in this study would be that thirty minutes of work may be considered maximum for a firefighter doing normal firefighter activity while wearing the bunker. And sixty minutes would be possible in a cool environment. But I don't know firefighters who always work in cool environments. In the winter in New York, they would, unless they are actually in the vicinity of the environment and that would be a trade off. You'd have to make a judgment. If the person were outside away from the radiant heat of the fire and not working too hard, you could certainly wear this for an hour. But, if you are in an environment that's at least as hot as 100 degrees Fahrenheit, thirty minutes should be considered a maximum.

We studied most of the closed-circuit breathing apparatus that were available at the time. You've seen some of them on display. We looked at Draeger, Scott, Bio Marine and an early version of the Bendix which has become now Clifton Precision. We studied them for the same characteristics we did with the (open-circuit) self-contained breathing apparatus for the pressure in the facepiece during both inspiration and expiration. We studied them for the air composition, both oxygen and CO₂ during breathing, the temperature of the breathing air, and the duration of the air supply. The subjective comments of the subjects were also noted.

The results then can be summarized briefly. The work load is quite demanding - it was sixty percent of capacity. For example that translates for this subject to a ten percent grade on a treadmill at 3.3 miles an hour. That's a very comfortable walking rate up a mild hill. It is a work load that could be done for hours without undue fatigue.

We did a rough estimate of the total air supply provided by the instrument study. By starting at a certain pressure in the cylinder, looking at the pressure drop during work and then extrapolating to the zero point of the pressure, we get at this work load. For example, the Draeger would have lasted approximately one hundred sixty minutes. The Scott lasted almost the same, one hundred fifty minutes, certainly well beyond two hours. The BioPak 60, just a little bit short of sixty minutes. I might mention that the MSA tested was a sixty-minute open-circuit system, and under these stressful conditions, it didn't quite last sixty minutes: didn't expect it too. The protocol used was to walk for twenty minutes, rest for five, walk for twenty, rest for five and walk for twenty, resulting in sixty minutes of total work at this load while wearing the breathing apparatus.

You will see that every SCBA studied had a negative-pressure during inspiration. The negative-pressure varied, of course. Initially the BioPak 60 was just below one inch of negative-pressure, but it continued to go down as the work load continued. The Scott was not very good in this respect. You can see it went negative as much as minus four inches during the first and second period. The pressure in the facepiece was certainly

negative during every inspiration at this work load.

So, I will take issue at the statement, yesterday, that the positive-pressure, closed-circuit breathing apparatus provides a least as much protection as does the positive-pressure or pressure demand, open circuit self-contained breathing apparatus. We haven't found one yet that is positive-pressure. That's not to say that we are being critical because I know it's a difficult task to make a closed-circuit system a positive-pressure system. It's not easy. The technology is coming, but right now it has not arrived.

Let's look at the temperature using the different SCBA's. We'll use the self-contained breathing apparatus represented by the MSA sixty-minute open circuit system as a standard. Testing was all done in a normal room temperature of about 75 degrees Fahrenheit.

During this work the MSA inspired temperature was around 26 degrees centigrade; that's not bad. It's quite comfortable but I know firefighters even complain about that. They don't like breathing warm air. Temperatures of course, would be higher than 26 degrees Centigrade if they were in a warm environment and if they were in a radiant heat environment of a fire.

What happens to the closed-circuit systems? The Draeger very slowly builds up in heat during the first twenty-minutes but then rapidly climbs up to more than 42 degrees during the second work bout; that's very warm. The Scott has a little more rapid build-up to 42 degrees during the first two minutes. They all recover slightly during the rest period, as expected. Then the Scott maintained around a 38 to 40 degree temperature for the duration of the work loads. The BioPak 60 initially experienced rapid increase up to about 36 degrees, followed by a very rapid one up to about 46 degrees in the second work load. So, they're all relatively hot by subjective feelings.

Listening to the subjects' responses, other comments were that during the first ten minutes, every system fogged up. Now I know that there are some anti-fog devices which can be placed on the visor, but all of the systems fogged up. Every one of them caused the subject's face to sweat, dripping sweat in his eyes. The Draeger has a "windshield wiper" that looks rather comical, but it is effective because you can move the fog away.

Some of the SCBA's systems developed a bad taste or a bad odor, which was probably a chemical reaction with the CO₂ absorber chemical being used and the metal.

But they were all hot, they were all wet and by subjective feelings they were all inadequate for reasonable work in a stressful environment.

The last thing I wanted to show you, since we did a complete study on the breathing apparatus, was the composition of air in the facepiece during inspiration in percent oxygen. Most of these systems have a one hundred percent oxygen source. The oxygen concentration starts at around sixty percent for both the Scott and the Draeger. The Draeger then drops during work and it maintains right around forty to forty-five percent during the first forty minutes. The BioPak 60 starts at around forty-five but climbs up to more than eighty percent during the second bout of work. The Scott was pretty steady throughout at around sixty percent. These are oxygen-enriched atmospheres: Forty percent is certainly higher than the normal breathing air represented by the MSA, our standard type of self-contained breathing apparatus, which is near twenty-one percent.

What does this mean? Physiologically it means that a person who is breathing air that is enriched in oxygen can work with greater ease at any given work level. We know that. We know that oxygen increases a person's work capacity. You can work harder without fatigue when you are breathing oxygen-enriched atmospheres.

That sounds good, and it is under some circumstances. But it can also be a significant problem, one that we are working on right now.

When a person is breathing in oxygen-enriched air, he is denied some of the clues of fatigue. People learn to pace themselves for work, and they will not work harder than a level they're able to maintain for a reasonable period of time. In other words, people tend to work between fifty and eighty percent of their work capacity. If they're breathing pure oxygen or high oxygen (more than thirty or forty percent) then they can work harder without that same clue of fatigue.

I say, this is a double-edged sword

because it gives you a greater work capacity, but it also denies you the normal fatigue signals. If you are dealing with a person who may have cardiovascular disease, he may be working at a higher work load than his heart is accustomed to or capable of sustaining. You could have a problem.

An example of a problem would be if a person is breathing a sixty or eighty percent oxygen mixture and working hard. Then all of a sudden he stops working and he's laboring to recover. Now, if this system is pulled off his face all of a sudden, that oxygen tension drops back to twenty-one percent. That's quite a shock. It would be like working hard in an airplane that is pressurized to sea level and then all of a sudden the pressure goes to fifteen thousand feet or so.

What that means, then, is during those critical moments of recovery he could be placed in extreme distress. It could trigger a cardiovascular incident. I'm not saying that it would, but it is something that deserves study before we really accept an oxygen-enriched breathing system for people who may be at physiological risk. That risk should not be significant for a normally fit, healthy individual, but it may be critical for a person who might have heart disease.

I might mention (I'm sure you're aware) that in America the firefighters as an occupational group have a higher incidence of heart disease than most other occupations. There is a greater incidence of people succumbing to heart disease. So, this is a consideration I will leave with you as a challenge in the closed-circuit breathing apparatus.

And this is my final conclusion: the closed-circuit breathing apparatus does have a heat stress supplied to it, which when added to the bunker, magnifies the heat stress. It can be a limiting factor. One to consider. And I also challenge you to really come to grips with the physiological significance of breathing an oxygen-enriched environment for hard work, especially in a population where we know there is a high incidence of heart disease.

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