Burning to save lives

This is a test — but it could be your home if you're not careful.

'We can construct buildings that can't be burned down. But fitted out with modern furnishings, they can, in the worst cases, still be gutted by fire — fatally — in 10 minutes.'

Next to the black skeleton of a lounge chair, in a soot-covered room, Dr Caird Ramsay explains why CSIRO has spent a quarter of a million dollars setting up this special 'burn room' in which furniture, interior fittings, and linings can be systematically set alight under controlled conditions.

'Most fires start in a building's contents, not its structure. We want to assess the fire behaviour of everything that goes into modern buildings, and perhaps devise ways of making them safer. Understanding how fire grows indoors — in enclosed spaces — is the first step in limiting its potential for death and destruction.'

The test facility at the Highett laboratories of the Division of Building, Construction, and Engineering basically comprises a brick and concrete box sited within a large hangar. It can be lined with regular wall and ceiling sheeting and decked out to simulate a typical suburban home or city office. Finishing touches like paintings on walls and reading lights on coffee tables add to the realism.

Surrealistic are the temperature probes poking through the ceiling and from the basement underneath, and the big overhead ducts that suck belching smoke to a 10-m-tall edifice that could be mistaken for a Saturn-V rocket. 'The after-burner is to prevent smoking out suburban Highett', Dr Ramsay informs.

A video camera takes it all in. And safely behind glass panels, in an adjacent control room, stand the researchers. They activate the burn from here, and record temperatures, radiation intensities, smoke densities, air speeds, and gas concentrations on their computer. If need be, they can shower a blaze with water to extinguish it quickly.

The test room is 3 m high and has floor dimensions of 5·4 m by 4 m — large enough to build variously sized inner sanctums that conform with any one of a number of international Standards for burn rooms. Common specifications for size are those set by the International Organization for Standardization and the American Society for Testing and Materials.

A radiator next to a bean-bag...

...and the end result.

The new facility is the first of its kind in Australia; the United States, England, Belgium, Denmark, Finland, France, and Sweden all have similar set-ups. International round robins are important preludes to the setting of world-wide standards for flammability, smoke emission, toxic gas production, and so on, and Australia can now, with this facility, participate with a stronger voice in this process.

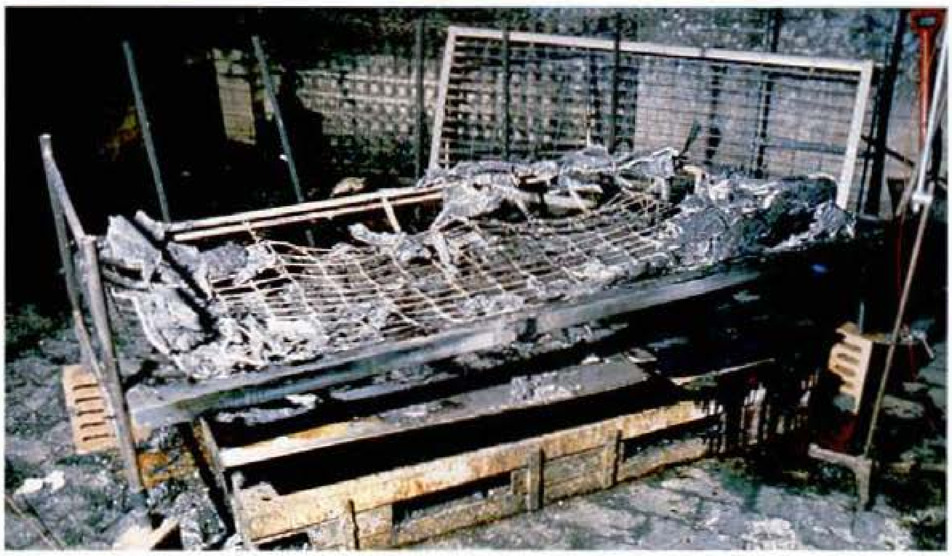
The facility complements the large furnaces at the Division's laboratories at North Ryde, N.S.W., where researchers conduct tests on the fire resistance of building structures.

Tests under test

Fire tests have been around for years, and most building codes make reference to them. While existing tests do have value in differentiating a tinderbox from a damp squib, they often don't relate very well to the real world. Some of them are obsolete, in the sense that they can't accommodate a burgeoning number of new materials in new configurations. Grandfather smoked his Senior Service cigarettes in a wooden captain's chair, never in a bean-bag filled with polystyrene beads.

Tests are frequently framed in terms of pass or fail, which means we can't rank items — mattresses filled with polyurethane foam, kapok, cotton wadding, foam rubber, coconut fibre, hairfelt, or synthetic fibre, for example — in order of safety. And many ignore the worst-case situation of a 'corner burn'. When fire begins in the corner of a room, the heat emitted is focused back to its source, amplifying the combustion.

Alternatively, tests may concentrate on the material from which an item is made (a 'material attribute' test), rather than on the complete item (a 'product performance' one). Yet the danger of a chair catching fire depends very much on whether it has a corner between the seat and the back where a cigarette can lodge, or whether it has a gap there through which a cigarette would fall. Polyurethane foam may be more flammable than cotton wadding, but the difference can be nullified if the former is covered by a fire-retardant interliner.



A mattress begins to burn, and before long it's nought but wire.

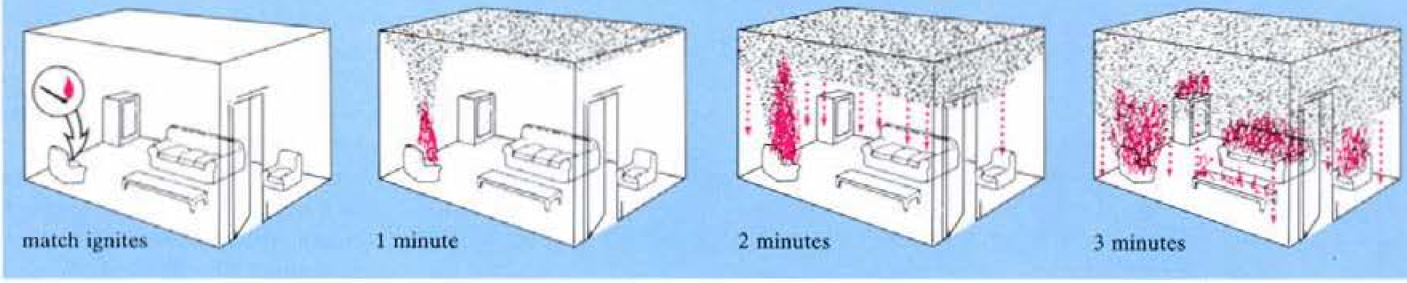
Yet again, flammability isn't the only concern. Most fire deaths result from smoke and fumes, so the proclivity to smouldering combustion — releasing toxic carbon monoxide, hydrogen chloride, and other gases — needs to be just as closely specified as the tendency to support a lively flame.

'Many people have become disillusioned with old-fashioned fire tests', Dr Ramsay admits. 'What we are looking for are graded tests that attach numbers to the degree of flammability. Then we could plug the numbers into suitable computer models. The computer could work out the total flammability of an item, depending on what it's made of, how it's put together, and where it's placed.'

Computer models are becoming increasingly important in fire research. Scientists are hoping that one day, with enough data and sufficiently powerful

In the worst case — a burning match on a polyurethane-foam-padded chair with a polypropylene cover — the whole room can be alight in 3 minutes.

Three minutes to flash-over



Don't invite fire into your home

Upholstered chairs, lounge suites, bean-bags, plastic chairs, pillows, mattresses, curtains, carpets — all have gone up in flames under the watchful eye of fire researchers at the CSIRO Division of Building, Construction, and Engineering. The team has even set fire to an old house and a derelict high-rise office building.

Their survey of houses destroyed in the 1983 'Ash Wednesday' fires brought out those design factors important in preserving buildings against bushfires (see *Ecos* 43).

Recent work has involved studying the burning behaviour of a stack of plastic letter trays (for Australia Post), jerry cans filled with petrol (for the Standards Association of Australia), a pile of wool bales (for a wool store), and an enclosed steel-framed car park and its petrol-detonated cars (for BHP).

From his extensive experience with indoor fires, Dr Ramsay can offer this advice to people on choosing the safest fittings for their homes.

UPHOLSTERED CHAIRS AND LOUNGES. These items are often ignited first in house fires. Nowadays most use polyurethane foam.

The main danger lies with the smoke and gases they emit on burning — which frequently kill long before flaming combustion occurs. Unlike more traditional materials — like cotton wadding, which smoulders and smoulders — polyurethane foam is more likely to burst into flame after some time spent smouldering.

Design factors, outlined in the main text, are important, but the major consideration is the type of covering the foam has. Squares of foam covered with cotton, rayon, or linen can be ignited by a smouldering cigarette inserted into an abutting join, whereas foam covered with wool, vinyl, or leather cannot.

Foam can, however, be set alight with a small flame, like a match; and when it has been, it will produce smoke and fumes at a great rate.

BEAN-BAGS. If it has a heavy vinyl cover, a bean-bag is unlikely to catch fire from a cigarette or a match. However, larger heat sources such as portable electric radiators can set it off, and once it is alight the polystyrene beads will give off large amounts of heat and choking black smoke.

CURTAINS. Curtains also figure prominently in starting house fires. Common ignition sources are cooking stoves and portable radiators. A burning curtain allows fire to spread to the ceiling.

The many possible combinations of decorative material and lining will each behave somewhat differently. However, in general, a light-weight open-weave fabric will burn more readily than a heavy closely woven one. Once alight, most will continue burning, except for heavy-weight wool and some specialty synthetic fibres like mod-acrylic.

MATTRESSES. Natural padding materials like cotton wadding or coconut fibre are prone to ignition by cigarettes, whereas polyurethane foam, normally covered with cotton ticking, will usually go out when the cigarette does. The better fire performance of foam in mattresses compared with foam in chairs underlines the design factor: mattresses lack crevices in which cigarettes can lodge.

PILLOWS. Down and feather pillows can't be set alight by small heat sources. Polyester fibre and polyurethane foam pillows, lacking crevices, can't be ignited by cigarettes, but small flames can be their downfall. Rubber pillows can be ignited by either source.

BLANKETS. Wool blankets are safest because they are difficult to burn and will actually slow down the burning of other bedding components.

CONTINENTAL QUILTS. In their traditional form — filled with down or feathers — they present no additional hazard. But synthetic types, filled with polyester, can add fuel to the fire.

ELECTRIC BLANKETS. Despite the fact that they must conform to an Australian Standard for fire and electrical safety, electric blankets start numerous fires each year. Misuse is invariably to blame. Maintain and use yours strictly to the manufacturer's instructions.

CARPETS. In the event of a fire, carpets and other floor coverings are rarely the first things to ignite. Carpets that won't ignite or continue to burn when exposed to cigarettes, matches, embers, and other small ignition sources conform to Australian Standard AS 2404 and bear the 'Australian carpet mark'.

Your furnishings and fire. G.C. Ramsay. *CSIRO Division of Building Research Information Sheet* No. 10–92, 1986.

Studies on the fire behaviour of some mattresses, pillows, and bean-bag chairs. G.C. Ramsay and N.A. McArthur. *CSIRO Division of Building Research Reports* Nos. R86/1, R86/2, and R86/3, 1986.

computers, they will be able to calculate, without actually setting fire to anything, the way a fire will spread in any given building.

But much more match-lighting and observing of fire behaviour will need to go on before comprehensive information fills the data banks. 'Here is where our burn room will play an important role', Dr Ramsay emphasises, 'but it's a slow painstaking job.'

Lurking danger

A fire indoors is a very different animal from one outdoors. When you put a match to your incinerator, the flames build up steadily. Most of the heat is lost to the atmosphere, so you have no trouble staying close by.

Inside a room, it obeys different and more complex physics, and the danger quietly multiplies. First, instead of a match, imagine a cigarette dropped into the back of a lounge chair. Cigarettes, you should know, are among the major causes of fires in houses. A carelessly discarded fag can stay alight in a concealed crevice for as long as 45 minutes.

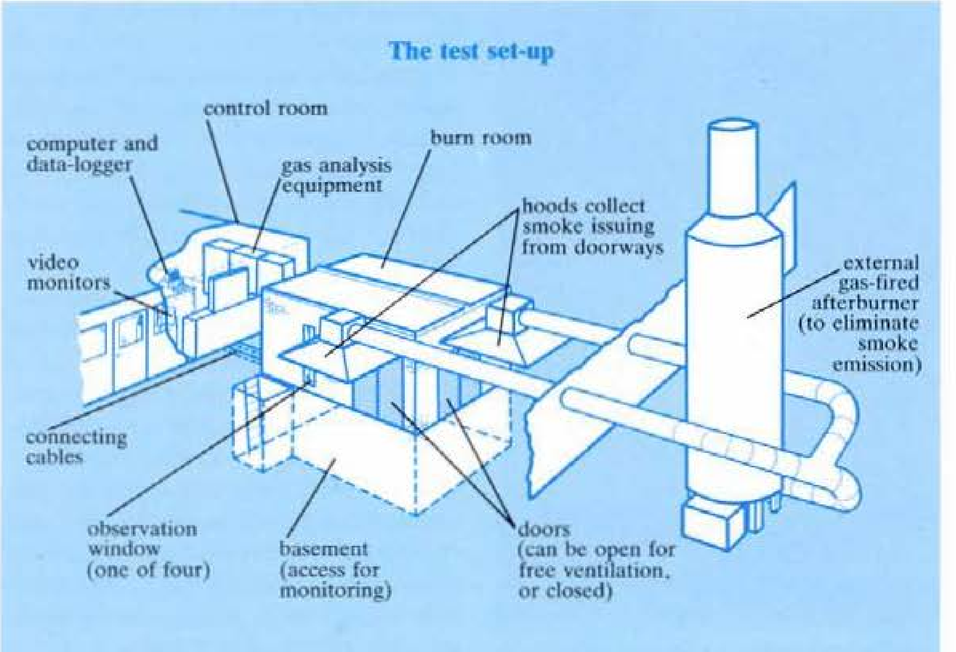
Then, after smouldering away, the chair's upholstery suddenly ignites. Within perhaps 30 seconds, smoke, combustion gases, and heat begin curling upwards, and before 1 minute has passed they have started building up in a trapped layer under the ceiling.

As the chair continues to burn the layer gets hotter and thicker, and after 2 minutes it starts radiating heat back down to the chair and other furniture in the room. After 3 minutes or so the trapped heat can become so intense that we see 'flash-over' — everything in the room, including combustible gases, has reached ignition point and bursts into flame.

Experiments have shown that some polyurethane armchairs can, 5 minutes after ignition, give out 1–2 megawatts of heat. That's no more than a lively incinerator produces; but when it's confined in a room it can easily induce flash-over.

After flash-over anybody still in the room would be dead. People rarely appreciate how quickly a small fire indoors can turn into a deadly inferno. They waste time going to the laundry to get a bucket of water instead of making sure everybody else is out of the house. By the time they get back, the fire will almost certainly be out of control.

Billowing clouds of smoke and toxic gases quickly spill through doorways and along halls, enveloping and incapacitating sleeping occupants in the rest of the house.



The burn room, essentially a brick and concrete box, sits next to a control room within a large hangar. An after-burner gets rid of smoke.

You can appreciate that modelling the entire course of an indoor fire on a computer is a daunting task. The program needs to consider the flaming combustion zone, the rising thermal plume above it, the hot gas layer beneath the ceiling, and ventilation. Turbulence of air is very difficult to model because large eddies can grow from features as small as 0·1 mm across. Supercomputers are a necessity, and Dr Ramsay doesn't plan to enter that field just yet.

Nevertheless, fire researchers overseas have used simplified models to study aspects of fire behaviour in homes, hospitals, aircraft, tunnels, stadiums, shopping malls, and airports. For example, the Fire Research Station in Britain has spent 7 years developing 'Jasmine', which can show how air circulates into a burning building and how the smoke layer deepens with time.

In the United States, the National Bureau of Standards has developed ASET, which calculates 'available safe egress time'. This fire-growth model requires figures for rates of mass loss, smoke release, production of toxic gases, and heat build-up. Most existing tests, as we have noted, fail to provide the necessary data. They will need to be modified, or a whole new generation of tests devised.

Dummy cigarette

For more than a decade, Dr Ramsay and his colleagues have been trying to devise better fire tests — tests that are more reproducible, have more discrimination, and can return a numerical value.

For example, they have documented the inadequacy of the ball of crumpled newspaper — which some tests call for — as a standard ignition source (which paper you buy does make a difference, but whether you use the sports pages or the comics is immaterial).

One British Standard test calls for a certain 'crib of rectangular sticks of Scots pine' as ignition source: this has the disadvantage that the result depends on which way the blazing crib falls. The CSIRO researchers have devised a set of replacement cribs — piles of criss-crossed wooden sticks — that have a wider base and don't fall over. The set is graded in six sizes — 50, 100, 150, 200, 300, and 400 g — so that a degree of fire performance can be specified.

While cigarettes bear a major part of the blame for setting off house fires, extensive research by the CSIRO group has demonstrated that cigarettes themselves make poor standard ignition sources, even though a number of international Standards call for them.

In the first place, cigarettes differ in the way they burn. Even when the Standard specifies the cigarette's size, packing density of tobacco, smouldering rate, type of filter, and so on, results show up inconsistently. Not even specifying the brand (Senior Service has become an entrenched standard) overcomes the problem.

Moreover, a cigarette may burn at very different rates, depending on how firmly it is pressed into upholstery and on what the covering consists of. But the biggest drawback, so to speak, is that a cigarette produces only a single value of the initiating source's intensity and time of application. Therefore only a pass or fail result can be entertained.

If we had a variable ignition source, then a graded result — what degree of heat the item could withstand without smouldering and bursting into flame, for example — would be possible. In this way, different performance levels could be specified, depending on the intended end-use, and

Building in a bushfire-prone area?

If you are, a new video, 'Buildings and Bushfires — Improving the Chances of Survival', is worth studying. With actual bushfire footage and explanatory graphics, it answers questions such as:

- What are bushfires like?
- How do they spread?
- How do they destroy your house?
- What can you do to build a better house or renovate your existing one in preparation for the next bushfire?

The tranquility of the bush belies its potential to burn fiercely when conditions are suitable. Bushfires can destroy human life, buildings, grazing land, and fencing and generate alarm and fear. Most people believe that buildings in the path of large bushfires have little chance of surviving. But the facts show that buildings do survive severe bushfires, not by mere chance, but because of good siting and design.

This video shows how bushfires start building fires, and describes the roles played by embers, radiation, flame, and wind. It makes clear that well-designed buildings have a very good chance of survival, and that they can provide a refuge for people when disaster looms.

The video has been produced by CSIRO and the University of Melbourne. Its message reflects the knowledge gained by CSIRO researchers when they surveyed 1150 houses ravaged by the 'Ash Wednesday' fires (see *Ecos* 43 and 55). The Distributor is:

Video Education Australasia,
21 Reckleben St, Castlemaine, Vic. 3450
Telephone (054) 72 4799.

numbers would be available for use in computer models.

The researchers at the Division have devised a dummy cigarette that they consider constitutes a good ignition source. Their 'cigarette' is in fact a tube of metal containing electrically heated resistance wire. The suggested test protocol is to press the tube (with specified force) into the junction between two vertical and horizontal upholstery pieces and measure the minimum electrical power needed to induce smouldering.

The protocol is presently under consideration for incorporation into those Australian Standards that rate furniture as not prone to smouldering. For Standards specifying furniture not susceptible to flames, the CSIRO researchers would like to see implementation of their test with the variously sized cribs.

Safe polyurethane foam?

Beds used to be the starting point for most home fires; now, according to overseas statistics (the only ones available), the most frequently cited item is upholstered furniture.

At the burn room's control panel.

Whoosh! (It was once a pillow.)

Although no conclusive set of figures has been published, circumstantial evidence blames increasing use of polyurethane foam in three-piece lounge suites. The material is soft, hard-wearing, and cheap to make, but it is more easily ignited by a flame than traditional padding materials. Once alight, it tends to burn faster and release more smoke and fumes.

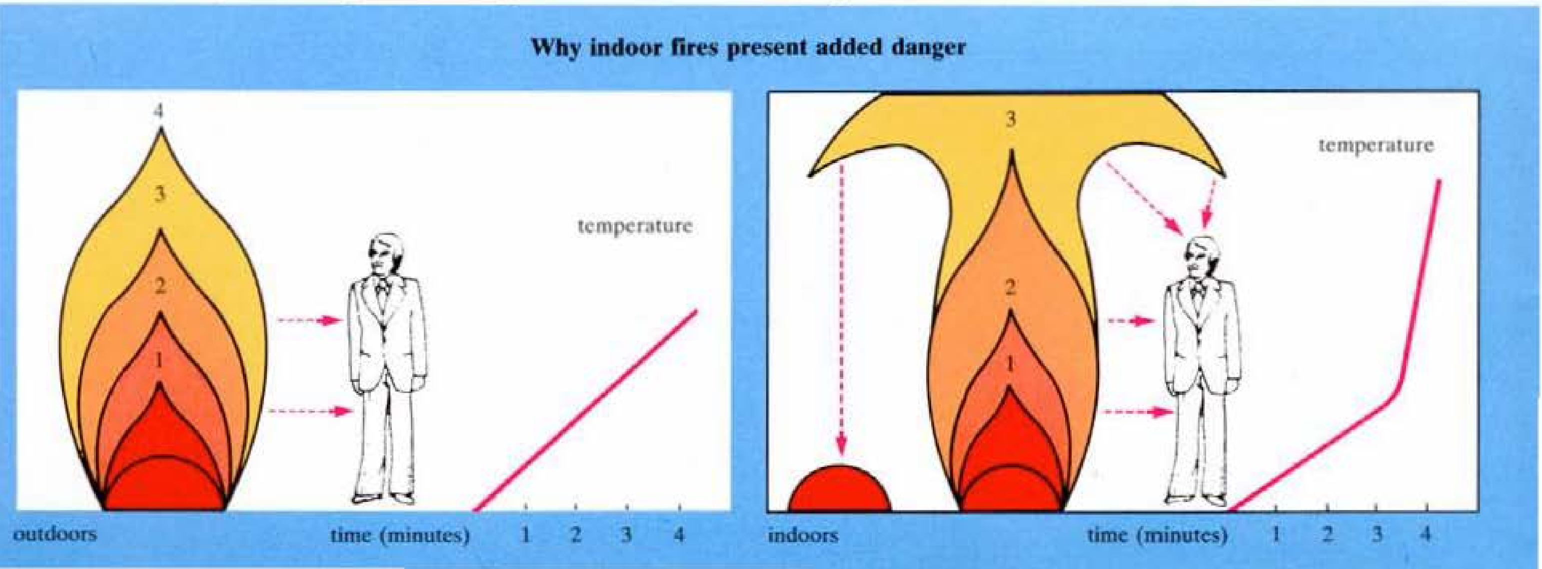
It is expected that in Britain the use of common polyurethane foam will, following public pressure, be banned from February 1989. This action arose from some tragic fires in which polyurethane foam was incriminated. Should Australia follow suit? Our Federal Bureau of Consumer Affairs is currently considering that option, along with others such as placing warning labels on furniture with poor fire behaviour.

Dr Ramsay favours that last option. As we have mentioned, it's not just the padding material that determines the flammability of a piece of furniture — the type of covering also plays a crucial role. For example, polyurethane foam covered with cotton, rayon, or linen can be ignited by a smouldering cigarette, whereas foam covered with wool, vinyl, or leather generally cannot.

The design of the lounge — its cigarette-catching ability, for instance — is also important. Placed in the middle of a seat cushion, a cigarette will usually fail to ignite the underlying foam; but wedged in the junction between two cushions, ignition is much more likely. Buyers should also look for a substantial heat barrier underneath the item. A plywood base will fend off heat from newspaper burning on the floor, but open webbing or thin fabric will not.

Any labelling should take the performance of the whole item into account. Then the consumer could choose the level of performance appropriate to the environment in which it will be used — in exactly the same way as labelling of children's

Outdoors, a fire grows steadily; indoors, trapped heat causes a fire to suddenly 'take off'.



nightwear provides a basis for choice. Homes without open fires and where the occupants don't smoke are intrinsically safer, whether for wearing nightclothes or lounging in thickly padded armchairs.

Of course, some environments demand the highest possible level of fire safety — enclosed public spaces, in particular. Auditoriums, theatres, trains, and trams are filled with large numbers of people and, in addition to the normal fire risks, they are exposed to the danger of arsonists as well.

Transport authorities anticipate the worst, and many conduct their own tests — or get CSIRO to do them. A new seat must not only withstand a smouldering heat source, but flaming ones as well. It matters little to public authorities if more expensive 'combustion-modified' foam is called for, or that such foam is firmer and less comfortable (it invariably is) than ordinary foam.

However, most people would not choose a train seat for their lounge, even if it's safer — and would certainly not if it's more expensive than something more comfortable.

Polyurethane foams catch fire easily because they are good thermal insulators. When they are exposed to a flame, the surface becomes hot very quickly. The urea linkages in the polymer break down, releasing isocyanates and other gases in a thick yellow smoke. A molten mass of material forms, which can develop into a fiercely burning pool.

High-resilience foam, spiked with fire retardants, is more densely cross-linked than the usual polyurethane foam. Bonds are therefore harder to break, and combustion is harder to initiate. But the foam is also denser and more rigid. Densities of 60–70 kg per cu. m represent three times the weight of conventional material, and add to the cost too.

Manufacturers here and in Britain improve matters by adding substances that, on burning, form a layer of hard char. This prevents oxygen reaching the interior of the foam. Tests have shown that this lengthens the time taken for a piece of foam to burn by a factor of five or six.

'Flash-over' — when everything in the room reaches ignition point.

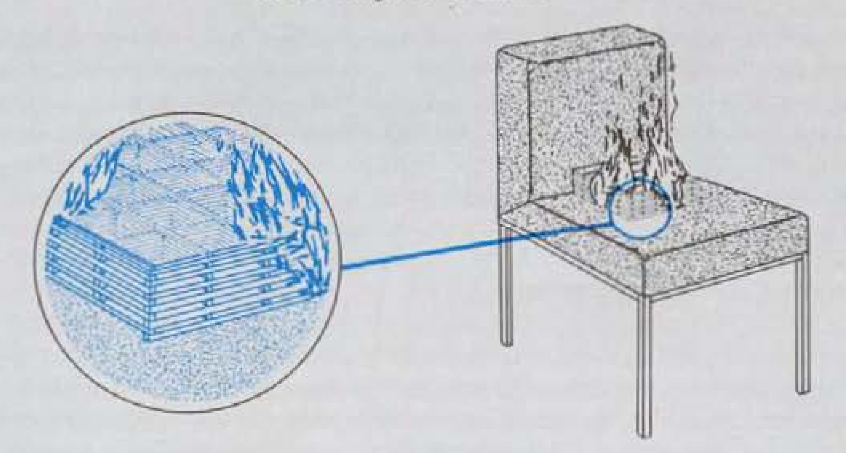
However, potential problems have arisen with the British requirement for such modified-combustion foam: some people have questioned the durability of the new material; and how will more expensive locally made furniture fare against that imported from the rest of the European Economic Community?

While Australia presently has no Standards for the fire performance of any furnishings other than carpets (which are rarely the first thing to ignite anyway), the Standards Association of Australia is currently evaluating different test methods (including CSIRO's dummy cigarette one) for upholstered furniture. A satisfactory test could form the basis of new labelling legislation.

Tragically, about 100 lives are lost annually in Australian home fires. Dr Ramsay believes that an effective labelling system would reduce that toll.

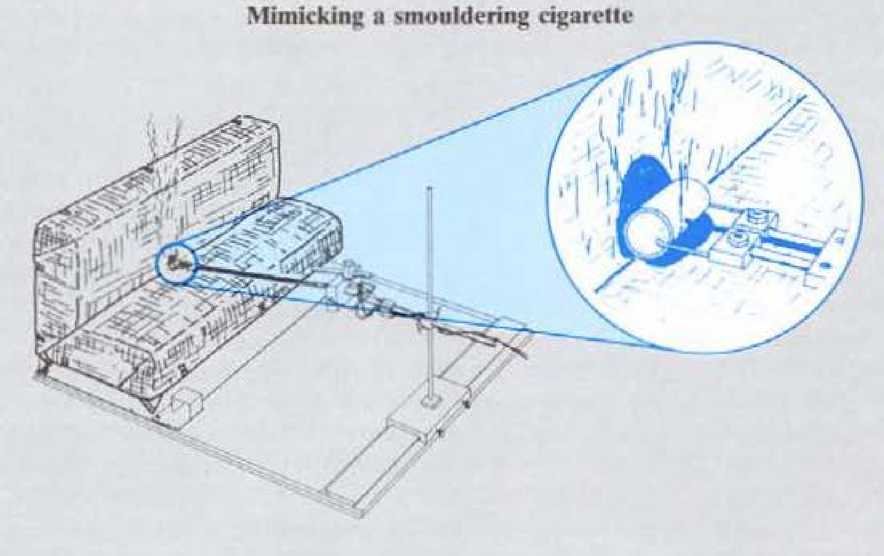
Andrew Bell

How susceptible to flame?



To gauge the degree of flammability of an item of furniture when exposed to naked flame, CSIRO researchers have devised a test wherein a 'crib' of criss-crossed pieces of wood is ignited on top of the furniture. Cribs vary from 50 g to 400 g in weight; the bigger the crib (without fire starting and spreading), the better is the fire performance of the item.

Mimicking a smouldering cigarette



The tube of metal resting on the piece of furniture is heated electrically in this CSIRO-devised test. Ignitability is gauged by the power level required to induce smouldering combustion.

More about the topic

Fire tests — old technology for new problems. G.C. Ramsay. *Fire Journal*, 1986, **11**(2), 19–23.

'A Protocol for Assessment of Fire Behaviour of Furniture using Large Ignition Sources. Part 1: Upholstery Combinations. Part 2: Actual Furniture Items.' G.C. Ramsay and V.P. Dowling. (CSIRO Division of Building Research: Highett 1983.)

'A Protocol of Assessment of Smouldering Behaviour of Upholstery Combinations.' G.C. Ramsay and A.P. Cerra. (CSIRO Division of Building Research: Highett 1985.)