Process Safety

The big picture and the systems approach

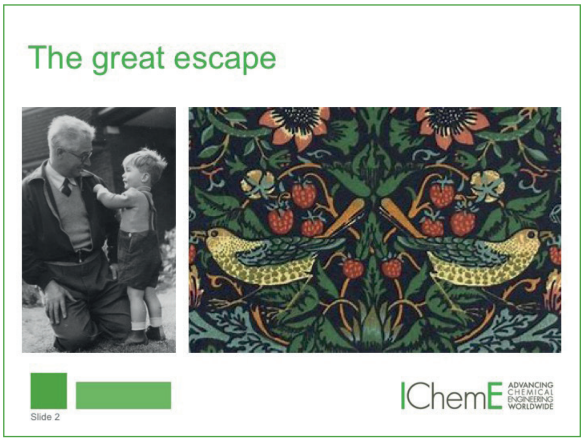
May I start by saying how honoured and delighted I am to have been elected to serve as the 79th President of the Institution of Chemical Engineers.

I would like to record my thanks to Ken Rivers, John McGagh and Jon Prichard: as a newcomer to IChemE's Board of Trustees, I have learnt a lot from all of them.

I would also like to thank Bev Garratt, who makes sure everything works smoothly, and Tara Wilson and Rachael Fraser from Comms, who helped me greatly with preparing this address: the remaining faults are entirely down to me.

The title of my presidential address, 'Process safety: the big picture and the systems approach', reflects my main activities in the last 30-plus years of my professional life, working on depressurisation of high-pressure hydrocarbon systems and investigating many major process accidents.

The great escape



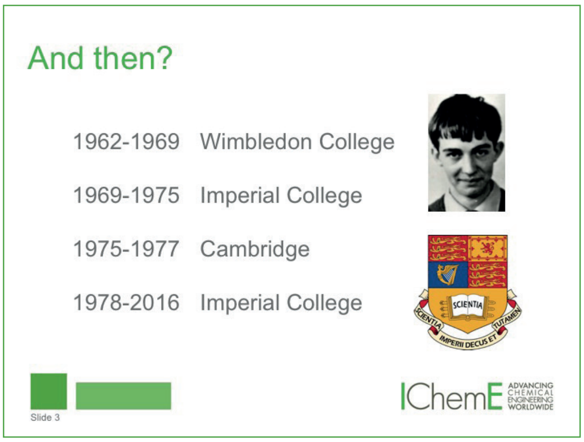
Before I talk about that, a bit about me.

My first contact with engineering came from my maternal grandfather (the photo shows the two of us): he was the Works Engineer at the Liberty's Silk Printing Works in Merton in South London.

When I was extremely young, he made me a wooden screwdriver.

I immediately put it to good use and unscrewed one of the bolts holding my playpen together: it may shock you to learn that I then escaped.

And then?



After that, nothing really happened engineering-wise (other than lots of Meccano) until I was in the 6th-form at school.

I had pretty much decided to study chemistry at university but a remark from a family friend drew my attention to chemical engineering, which, until then, I had never even heard of.

However, after some digging, I decided that it's much more applied outlook meant that chemical engineering, not chemistry, was for me.

My school's careers master asked me what I was going to do after leaving school.

When I told him that I planned to study chemical engineering, he said 'what's that?'

When I then said I planned to study it at Imperial College, he said 'ah - so you're not going to university'.

He was clearly a very perceptive chap.

My entire professional life was then spent in academia, almost all of it at Imperial College, with a brief period in Cambridge.

I went to Imperial in 1969: the photo shows me on my first day there.

I graduated in 1972 but jobs were very hard to find.

I was in fact offered jobs by the National Coal Board, the British Steel Corporation and the National Carbonising Company, all members of the Coking Industry Education Trust which sponsored me at university - and all of course, long gone.

Having all offered me jobs, these companies said that they would decide between themselves and tell me where they would like me to work.

That was in May 1972 - I am still waiting to be told.

Instead, I decided to do a PhD at Imperial and after that went to Cambridge as a research assistant in the Engineering and the Chemical Engineering Departments.

In 1978, I was lucky enough to be offered a lectureship at Imperial and stayed there until I retired.

From 2001 onwards, my time was spent mainly in management, initially as Head of Department in Chemical Engineering.

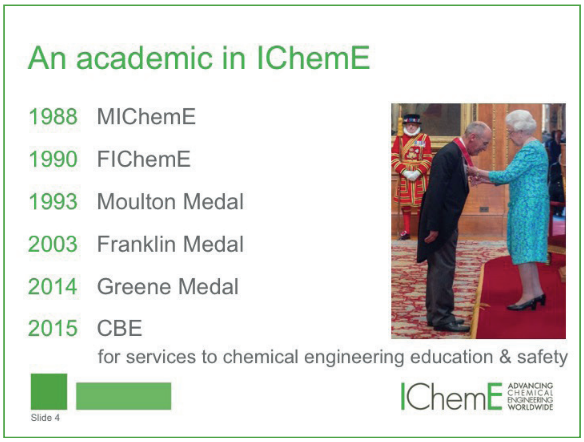
I then ran the Engineering Faculty and finally did the jobs at the top of the College that no-one else wanted to do, including:

- academic promotions (which I thoroughly enjoyed…);
- space (the most important thing in the world to most academics…);

and:

- disciplinaries (so I appeared at some Employment Tribunals…).

An academic in IChemE



While I was at Imperial, I also got involved with IChemE.

I have to confess that I delayed applying for membership of IChemE partly through laziness and partly because of a perception that IChemE did not welcome academics in those days.

This perception proved to be false: I applied to become a Member in 1988 and was interviewed by Simon Waldram: my membership has stood me in really good stead ever since.

It has given me real credibility when teaching students, especially when teaching Safety and Loss Prevention, and when acting as a consultant.

I have also met lots of other chemical engineers through IChemE, many of whom are good friends.

The Institution has also been very good to me: I have been lucky enough to be awarded several medals for services to IChemE, contributions to its publications and my work in safety.

The Institution also put my name forward for a CBE, which I received from Her Majesty The Queen at Windsor Castle in 2015.

I am immensely grateful for all this.

Teaching

Although most academics describe their research first and then mention their teaching as an afterthought, I will do the opposite since I am convinced that education is as important as research for the reputation of any university.

I have always thoroughly enjoyed doing lots of teaching and have taught most parts of the undergraduate course: this is a list of just some of them.

One innovation I made in 1995 was to introduce the concept of Mastery.

Mastery is those bits of chemical engineering that each and every graduate simply must be able to do.

So, it comprises things like sizing a pipe or a heat exchanger or a compressor and being able to conduct basic mass and energy balances.

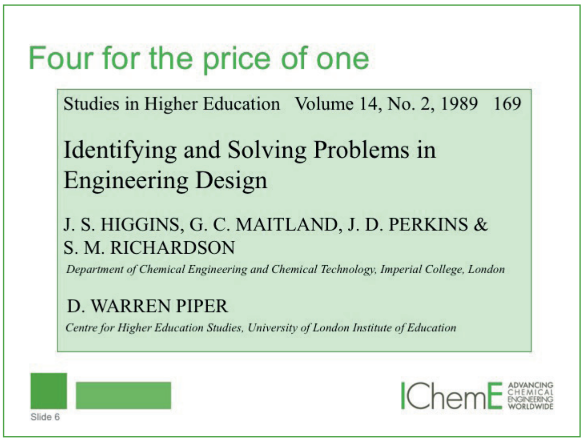
The exam has a pass mark of 80% and must be passed before students can progress to the next year of the course or graduate.

I stole the idea of Mastery from a university in Canada which was having problems with some its medical students confusing different parts of the human body, with predictably unfortunate results.

I also taught a problem-solving course for 1st-year students: the photo shows me in action.

You will be relieved to hear that it is the last photo of me tonight.

Four for the price of one



I would now like to claim a record.

As of a few minutes ago, I think that this paper, based on the problem-solving course, is the only one co-authored by four Presidents of IChemE: Julia Higgins, Geoff Maitland, John Perkins and now me.

There she blows

My main topic of research for the last 30-plus years has been modelling depressurisation or blowdown of high-pressure hydrocarbon systems.

My colleague, Graham Saville, and I developed the computer program BLOWDOWN, which we have used on over 300 installations world-wide.

I am pleased - and greatly relieved - to report that none of these installations has ever had an accident related in any way at all to our work.

Not yet, anyway.

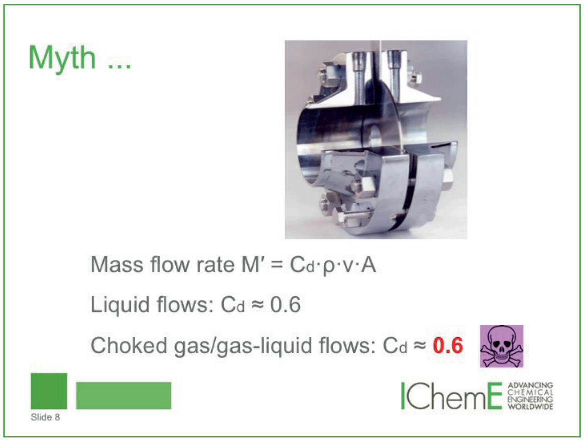
Depressurisation matters mainly because it inevitably leads to cooling, which can in turn lead to low-temperature embrittlement: plant has failed catastrophically like this in practice.

Our work was initially sponsored in a major act of faith - and with significant funding - by Shell, to whom we will always be very grateful.

We quickly appreciated the vital importance of experimental validation, preferably at full-scale: the photos show a scrubber from a Shell platform at Spadeadam (near Hadrian's Wall) and North Rankin Alpha (on the North-West Shelf offshore Australia), where we did work with Woodside.

In work like this, experimental validation is vital: intuition (mine, at least) is simply too fallible.

Myth...



Regrettably, there are lots of myths about depressurisation.

One myth concerns the value of the discharge coefficient to be used for the choked (sonic) flow in the restriction orifice fitted downstream of a blowdown valve.

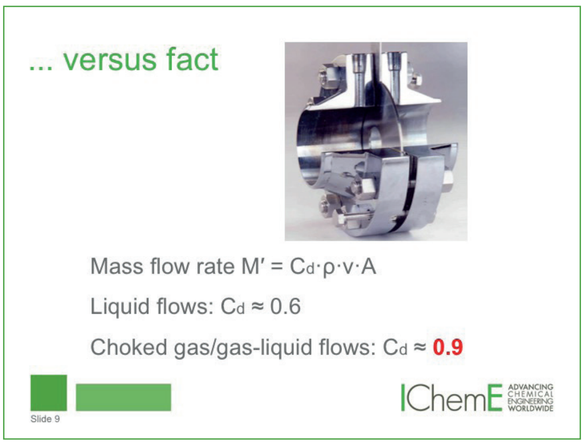
The mass flow rate M' is related to the density ρ speed v and area A by a correction factor, the discharge coefficient Cd.

To calm your nerves, this is the only equation in my presentation: I had to include one to remind you that I am a genuine nerd.

For a liquid, the value of Cd is around 0.6, as (almost) everyone knows.

Some people also use 0.6 for choked gas and two-phase gas-liquid flows.

...versus Fact



But, at least for hydrocarbons, our experiments have shown conclusively that the value is in fact about 0.9.

We published this work 13 years ago in Process Safety & Environmental Protection, one of my contributions to IChemE as a learned society.

And yet the value of 0.6 still persists in some quarters.

This is sometimes based on the argument that, if the actual value is 0.9 rather than 0.6, the flow through the orifice is 50% higher, so the upstream plant blows down more quickly (which is good if there is, say, a fire): this is right.

It is then argued that sizing the orifice using a value of 0.6 is, therefore, conservative: this is wrong.

The main reason why it is wrong is that, if the flow rate through the downstream vent or flare system is 50% higher, speeds can be much higher, which can in turn lead to excessive vibration and even line failure: this has happened in practice.

I am labouring this point because the argument that 0.6 is conservative shows no understanding of the behaviour of the whole system: the system is not just whatever is being blown down upstream of the restriction orifice.

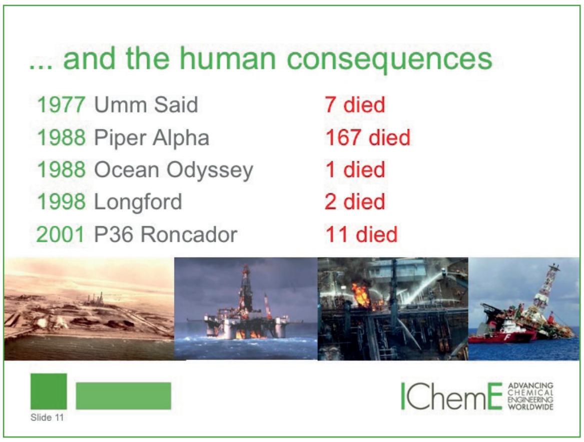
This is why systems thinking - about the right system - is vital.

Major process accidents…

Once we had developed BLOWDOWN, we got involved in investigating a number of major process accidents, including many not listed here.

Tonight, I will only talk about Piper Alpha.

…and the human consequences



An obvious common factor of all of these accidents is the tragic loss of human life.

More than that, I worry (like Trevor Kletz before me) that the lessons learned so painfully from accidents like these are gradually lost by succeeding generations.

Corporate memory is short and, regrettably, it is getting shorter.

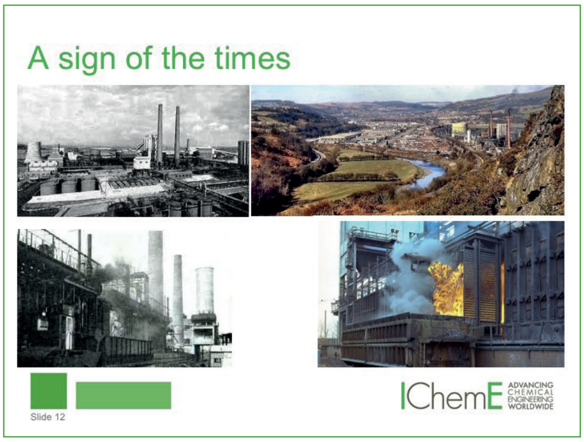
A less obvious common factor of these accidents is that connections to infrastructure beyond the plant in which the accident occurred proved to be a vital contributor to the cause of the accident or to its consequences.

Again, dealing with the right overall system is vital when considering safety: if we do not, we simply never consider some issues, let alone deal with them.

I am sure that this all terribly obvious and well known to most if not all of you: please forgive me if I am teaching you how to suck eggs.

But I am regularly surprised how often I am asked as a consultant to work on the wrong overall system and hence answer the wrong question.

A sign of the times



Before discussing Piper Alpha, I want to tell you about my first experiences of an accident and a near-miss.

As an under-graduate, I spent two summers working on coking plants, the first at Nantgarw (up the Taff valley from Cardiff) in 1970 and the second at Worsbrough (south of Barnsley) in 1971: both have long since disappeared.

I had my first experience of a process accident at Nantgarw.

Coal is charged into a battery of ovens from above.

When the coke has been formed, it is pushed out from one side of each oven into a receiver on the other side.

The drivers of the pusher and the receiver cannot see each other because the battery of ovens is in the way.

One day, the driver of the pusher started using yesterday's timetable while the driver of the receiver was using today's.

As a result, the hot coke was pushed out of the wrong oven.

Those of us walking past the ovens at the time moved away (code for: ran) as fast as we could: luckily, no-one was hurt.

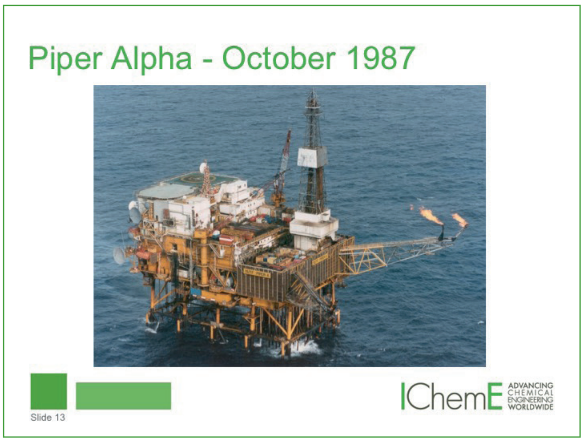
My first experience of a near-miss was at Worsbrough, where a man was painting the gas holder, paint brush in one hand - and lit cigarette in the other.

The plant manager, to whom I was speaking, went to 'have words' with the man: I moved quite fast in the opposite direction.

This was before Flixborough and the Health and Safety at Work Act.

Life was more relaxed then - unfortunately.

Piper Alpha



Apart from getting married to Hilary, who is here tonight, and the birth of our children and grandchildren, the Piper Alpha disaster on 6th July 1988 was probably the most significant event in my life - even more perhaps than becoming President of IChemE, if that is possible.

It resulted in me spending a lot of time giving evidence at the ensuing Public Inquiry.

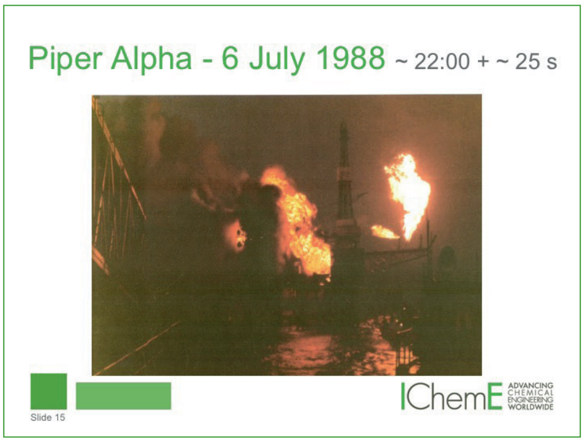
But do please note in what I say here, I am in no way criticising, let alone blaming, anyone for what happened.

This is not about blame; it is about learning lessons so as to minimise the chances of it ever happening again.

The photo shows Piper in October 1987, 9 months before the disaster.

The first explosion on Piper was at about 22:00: it produced a fireball, shown here in the first photo of the disaster, about 15 seconds after that first explosion.

The fireball reached all the way round the far side of the main accommodation module, where most of the 226 men on board were off duty.



About 10 seconds later (i.e. about 25 seconds after the first explosion) the fireball engulfed the helidecks, the main means of escape for those on-board Piper.

Before Piper, it was thought that, in the event of an accident on a platform, there would always be time for evacuation by helicopter: as in so many ways, Piper changed all that.

Spilling crude oil led to a pool fire on the 68-foot level which heated up the unprotected oil and gas export and import lines running along its ceiling, just under the floor of the 83-foot level above.

At about 22.20, the gas line to Piper from the Tartan platform ruptured, leading to an initial release at about 3 tonnes per second, which was about 1½ times the then UK gas consumption rate.

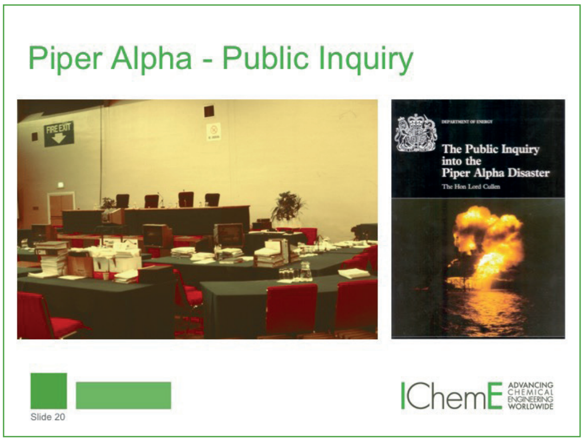
Immediately afterwards, the whole platform was engulfed in fire: amazingly (to my mind), it survived for about another hour.

Eventually, however, the other gas lines (to the Claymore and MCP-01 platforms) and the oil line (to the Flotta refinery) ruptured.

At about midnight, very little of Piper remained - just the wellheads, in fact.

The flames from the ruptured oil and gas lines were about 200 metres high, producing at least 100 gigawatts and probably much more.

Public Inquiry



The Public Inquiry was held at the Bridge of Don (north of Aberdeen):

- Lord Cullen and his assessors sat in the four high chairs;
- witnesses like me sat at the extreme right, beside a stenographer;

and:

- barristers representing the numerous parties involved sat at the tables.

The Inquiry led to the Cullen report, which I feel is a real masterpiece and merits careful reading and re-reading.

The report made 106 recommendations, all of which were adopted by Government and then implemented by the offshore industry.

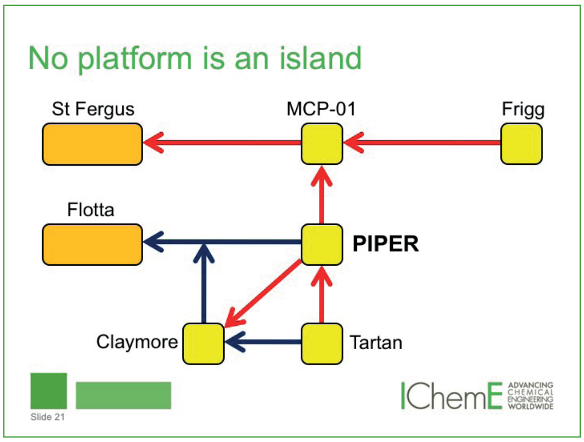
However, some of them do now seem to have been partially forgotten, at least in some quarters.

But IChemE has certainly not forgotten.

Last year, it published several papers in a special issue of the Loss Prevention Bulletin as well as numerous articles in The Chemical Engineer, blogs and a press release, marking the 30th anniversary of the disaster.

And I am delighted that action by the Safety Centre and the Safety and Loss Prevention Special-Interest Group has also led to the availability of the Cullen report as a free download from the web: it is well worth a look.

No platform is an island



In my view, one of the opportunities that Piper offered is that no-one knows exactly what happened, so its lessons inevitably cover a wide range of issues, whether they actually contributed to the disaster or not.

As a result, there are a great many lessons that can be drawn: I will draw just two, to illustrate my hobby-horse about systems thinking.

The first lesson arises from the source of the oil for the pool fire on the 68-foot level that led to the failure of the Tartan gas line and then inexorably to the failure of the other (red) gas lines and the (blue) oil line and hence to the loss of Piper.

The question is: where did this oil come from?

There was insufficient crude oil on Piper to account for the fires - so some of it must have come from the main oil export line.

Either the emergency shut-down valve on the line did not shut completely or the line itself failed in the vicinity of that valve.

Tartan and Claymore were still exporting oil for some time after 22:00, some of which pushed oil in the line back to Piper, contributing to the overflow from the 83-foot level to the 68-foot level underneath and so to the pool fire heating the import and export lines.

This is not to say that, if Tartan and Claymore had stopped exporting oil earlier, the Tartan gas line would necessarily have remained intact, but it did not help matters.

From a safety perspective, Piper was not an island: the system was not just Piper.

It was also the installations and lines to which Piper was connected.

Getting the system right is key when considering safety.

The second lesson stems from the communications failure between the platforms near Piper.

Piper was installed first, so communications between the later Claymore and Tartan platforms were routed via Piper.

When Piper's communications went down, Claymore and Tartan were left very much in the dark.

In those days, there was very little if any redundancy.

This is why Claymore and Tartan kept producing oil, long after the first explosion on Piper at 22:00.

Again, the system was not just Piper: it also included the neighbouring platforms.

A systems approach or nothing

From all this, I draw one big, if totally unoriginal, lesson: we must consider the big picture - over the whole life-cycle of a plant.

If we do not, we will miss something important and possibly crucial.

The corollary is: safety is nothing without a systems approach.

Indeed, systems thinking is key not just to safety but to all of chemical engineering.

I then wonder: how is a systems approach taught in under-graduate courses?

Bill Wakeham spoke about this to the Computer-Aided Process Engineering Special-Interest Group in 2014.

Like him, I am convinced that a systems approach must be:

- integrated into the core or it will be perceived as separate and less important;

and:

- taught explicitly: if it is taught implicitly, the students may simply not 'get' it.

Strategy 2024

I have stressed the importance of the big picture in relation to safety.

I now want to look at the importance of the big picture to IChemE, as demonstrated by its recently published 'Strategy 2024'.

Quite simply, this strategy is IChemE's big picture.

Now we have it, I am certain we will be much more successful in what we do.

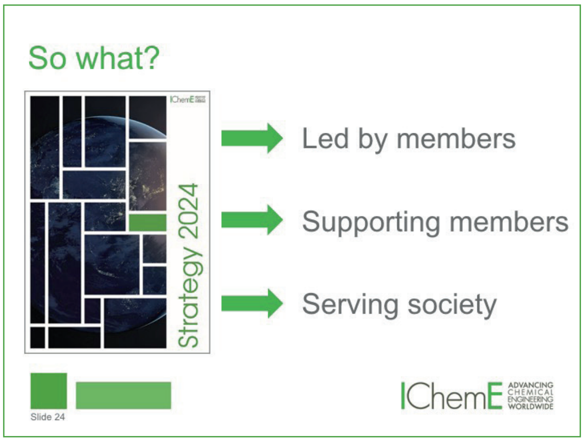
And we will know that the IChemE has been more successful if it:

- is even more respected for its professionalism and technical competence;
- is even more recognised as a vibrant learned society;
- has an even more engaged membership that receives and adds value;

and:

- is even better known as a high-performing organisation (how it works internally).

So what?



All of these points are discussed in detail in the 'Strategy 2024' document and I urge you to read it, if you have not already done so.

It is now up to all of us - led by the Board of Trustees but working with the whole of the membership - to deliver the strategy.

The obvious question is then: 'so what?'

Well, if we achieve these things, IChemE will truly be:

- led by its members;
- support its members;

and:

- serve society.

This is precisely why IChemE exists.

In a recent article in The Chemical Engineer, Ken Rivers wrote that developing the strategy was hard but the harder bit, delivering it, follows now.

I would just add that it is a 5-year strategy:

- so not everything can be done at once;
- certainly not all by me or while I am President;

but:

- I will do my utmost to implement as much of it as I can.

Indeed, while I am President, I want to pay particular attention to four themes that emerge from the strategy.

A leading voice in process safety

The first is to make IChemE even more of a leading voice in process safety.

Of course, I am not the first to say this: Ken Rivers said the same thing in his Presidential Address in 2018.

IChemE already has many truly world-leading activities in the process safety area.

But they do seem to me to be somewhat less than joined-up.

If they were more joined-up, I am sure they would have much more impact.

Like Judith Hackitt, after the Grenfell Tower tragedy, I also feel that safety should be a mandatory element of every engineering degree.

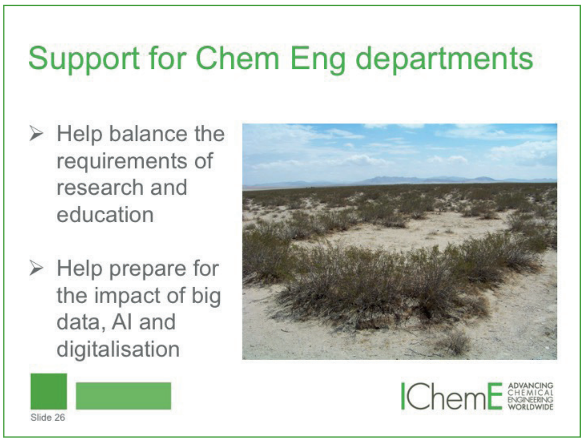
I am often surprised at how little some - not all - (non-chemical engineering) engineering courses include: IChemE has a real opportunity to assist in this.

I also think we could do more to improve learning from past mistakes: lessons need to be learned and then acted upon or they have to be relearned - at great expense.

Ken Rivers, in his Presidential Address, talked about learning lessons leading to good practice leading to common practice: I cannot put it better than this.

But it is up to all of us to make sure it actually happens.

Support for ChemEng departments



The second theme is to support our excellent chemical engineering departments, of which there are several new ones and many small ones.

Academics are very well aware that there is tremendous pressure to do research.

This is often led by perceived - if not always real - promotion criteria.

I really welcome the breadth and excellence of that research: colleagues are working on aspects of chemical engineering that I never even dreamed of.

But, at the risk of alienating some or all of my academic colleagues, I worry that there is a bit of a hole in the centre.

I wonder: who will teach the basic aspects of chemical engineering enshrined, for example, in Mastery?

Or who will teach process safety?

The photo shows a creosote bush: it starts as a little plant and then grows by working its way outwards, forming a ring and leaving little or nothing in the centre.

Chemical engineering departments must not be creosote bushes.

I would like us all to do what we can to ensure that this does not happen.

To conclude this point, John McGagh spoke in his Presidential Address in 2017 about the impact of big data, artificial intelligence and digitalisation on chemical engineering.

As a result, we will have to rethink aspects of under-graduate course design, delivery and accreditation - and also CPD - or we will simply get left behind.

But I am delighted that IChemE is already on the case.

A successful centenary in 2022

The third theme is to ensure that the IChemE centenary in 2022 is successful.

I want us to be able to celebrate the hugely valuable contribution that chemical engineering has made to society in the last 100 years.

I also want us to prepare IChemE for the next 100 years.

Amongst other things, Geoff Maitland talked in his Presidential Address in 2014 about climate change.

Following on from what he said, I think that, if IChemE is to be ready for the next 100 years, it must speak out and do more on climate change.

I know that the Energy Centre has done and is doing really great work in this area: IChemE should rightly be very proud of this.

But I think we have to do more – otherwise, we may get stuck with policies that have little or no evidential basis.

Just look at the Oval Office.

Work together for the better

The final theme is to ensure that all parts of IChemE work better together.

I want to encourage more members to become more involved in IChemE.

To my mind, this is perhaps my most immediate and important theme since, if we achieve it, it will be so much easier for IChemE to achieve all its other aims.

One way in which I think we should do this is to recognise and reward the large numbers of unsung and dedicated volunteers at grass-roots level in IChemE.

There are, rightly, lots of awards for research and technological innovations, but I also want us to make awards to those volunteers who help us deliver our aims.

Finally - after recent events - I want to help re-build trust in all parts of IChemE.

I know that this is an ongoing process: trust must continually be earned.

I am always very happy to talk to members about anything related to IChemE.

I much prefer to hear about niggles before they grow into issues.

And, if you want to do so, you can always contact me via the IChemE President's e-mail address, which I will give you at the end of the presentation.

Let us not forget

I make no apologies for ending with a picture of the buoy marking the site of Piper Alpha, with Piper Bravo in the background.

Piper's many lessons are as relevant now as they were 30 years ago: we must not forget them.

If this sounds rather downbeat, let me assure you that I am very positive about what chemical engineers can and will contribute to society.

Our tasks are changing and will always be challenging.

But I would much rather be challenged than bored with the same old routine stuff.

The challenges are why I have enjoyed (almost) every day of my working life.

Jonathan Seville, in his Presidential Address in 2016, asked if IChemE can remain relevant.

My emphatic answer is yes: we must - and we will.

Keep in touch

And, with that, may I thank you all very much for your attention.

Please do keep in touch.