HAZARDS X

Process Safety in Fine and Speciality Chemical Plants

18-20 April 1989 Manchester

DISCUSSION OF PAPERS

AND

REPORT OF FORUM

Notes

1. Q/C means question or comment.
2. R/A means response or answer by presenter.
3. Where 2 authors, presenter given first.
4. All presenters and speakers, with affiliations appear in delegate list (obtainable from D.V. Greenwood or I.Chem.E Rugby, England)

SESSION 1 CHAIRMAN: J H BURGOYNE

Paper No 1 J H Burgoyne

An introductory paper, there was no discussion of the paper as such but Burgoyne prepared delegates for the Discussion Forum (Day 2 see "FORUM").

Paper No 2 Barton and Nolan

Q/C (M L Preston). Heat transfer estimation is clearly an important factor and you quote two early references (1944 and 1965). In I.C.I. we are linked to more recent research at HTFS on agitated heat transfer and work at South Bank Polytechnic is listed. Is there any relevant updated information?

R/A Apologies for rather outdated references. We are currently putting together guidance notes on heat transfer for exothermic reactions where the references will bring it up to date.

Q/C (P F Nolan). We have a major interest in scaling-up reactor data, including heat transfer correlations incorporating Nusselt, Reynolds and Prandtl numbers. Some work was reported at the Boston I.Chem.E/A.I.Ch.E meeting and work continues using a 675l pilot plant reactor used as a heat flow calorimeter. More will be said in presenting Paper No 5.

Q/C (K Palmer). Many industrial incidents are repeats. Are adequate data bases being accumulated for future reference?

R/A Yes, there are a number of data bases available, some computerised and one should always search the literature for reports of similar incidents when starting any investigation. Often however companies have started to operate without a comprehensive search and may-be there is a case for better recording in an easily accessible form.

Q/C (N Maddison). It could be dangerous to use existing data even for some well-known reactions because small changes in chemistry may change reaction parameters. Safety measures may have to be based on a test to produce specific data.

R/A Recorded data could reduce the amount of investigation required but argue that it will often be necessary to do a final test.

Q/C (C D Plummer). Do you feel that the classification used may distort the human factor the errors in reading a thermometer or chart?

Human factors are much more important in manually controlled batch reactions than implied.

R/A A valid point. Under "Prime Causes" there are a number of causal factors some of which are human factors. In fact some causes could be classified as either human factor or some other. Agreed that there was insufficient notes on human factors.

Q/C (Chairman). Referring to the "insufficiency of information", has the position regarding reporting, or recording improved over the last 30 years and is it now satisfactory?

R/A It has improved since the 1985 Reporting of Dangerous Incidents Regulations - probably no more incidents but many more of them reported. However the information given on the form is variable - often very sparse except for those investigated by ASE inspectors. Even then, key information for later analysis may be missing.

Paper No 3 Lavery

Q/C (R T Shone). In assessing a company for risk and determining the premium, how important is their track record (accidents, incidents, claims) in comparison with your assessment of the pro-active safety management issues?

R/A Premium will be determined by the record of the company because the insured has to make a profit based on a 3-5 year cycle. Also taken into the consideration an assessment of the company's safety performance and attitude overall - an incident in one place could cause a fatality in another.

Q/C (W E High). (1) Please explain the term 'Safety Audit'. (2) Distinguish between 'in house' and external (independent) audit?

R/A We are looking for an ongoing regular check on the operation by the operating personnel looking for safety problems that can arise from time to time - housekeeping failure in guarding, etc. We also expect in-depth audits with attempts to identify potential hazards, to take steps to eliminate them and include a study of the design. Audits are also carried out (for our purpose) by outside organisations and we encourage firms who don't have enough expertise to use independent assessors.

Q/C (D J Rasbash). You claim to look for disaster and catastrophic risks. Do you attempt to quantify these risks or do you rely on the firm or their independent advisers for this?

R/A We look at the chemical risks in relation to the premises and the site: Is it covered by CIMA Regulation? What is the risk to surrounding property/people?
Our surveyors are not able to do this and rely upon advice from the site and/or independent consulstants which we in turn give to the underwriters.

Q/C (T McClymont) (1) Please comment on the relative size of the chemical industry as an insurance customer? (2) If a major customer, would it not be of advantage to have some risk surveyors with a chemical engineering background?

R/A Risk assessment is organised on an area basis and a particular area may or may not have a large chemical industry. Some surveyors have had special training to understand chemical and other manufacturing risks. They work closely with a local risk surveyor who should have the necessary expertise. We also have two chemical experts (in London and Manchester) to advise whenever appropriate.

Q/C (K Myers). Representing Factory Mutual Insurance Co. wanted to clarify the role of the risk surveyors: The company insures buildings, plant and loss of production through accident. All chemical risk surveyors are chemical engineers and so are those responsible for the underwriting. We can be called loss prevention consultants/engineers and have a great deal of information and provide service to clients as well as information to underwriters. We are property insurers whereas Mr Lavery represents liability insurance.

Q/C (Chairman). Is the difference between the kind of insurance or a matter of company policy.

R/A (D J Lavery). Difference is that between liability in law because he has done something unreasonable and insurance for the value of damage to property and contents - no conflict between the two.

Q/C (Chairman). Reiterated that the difference was in <u>type of insurance</u> - direct loss or liability.

R/A (K Myers) Agreed that there are two different areas of insurance.

Q/C (R L Rogers). In the USA, insurance companies are much more involved with chemical process hazards, for example in setting standards, giving guidance and training. With greater need in UK, do the insurance companies see themselves getting more involved here?

R/A (K Myers). We do already work closely with the A.I.Ch.E. and provide this service to insured in the US and are starting to work more closely with UK and European bodies - some links with I.Chem.E through Loss Prevention Panel.

Q/C (G Poole). The Loss Prevention Council does this work - it is a combination of the Fire Protection Association, Fire Officers Committee and Fire Research and Testing Organisation with aim of sorting out the technical problems for the insurance companies and working with them.

Q/C (Chairman). An important matter because of lack, hitherto, of cooperation between these bodies.

Q/C (J Crane). Will the employment of chemical engineers in risk assessment result in the reduction of premiums - the difference being that complex hazards are looked at in great detail?

R/A (K Myers). People move from safety assessment to underwriting in my company. Because high risks are anticipated, premiums are high. Employment of chemical engineers will result in better advice being given but unlikely to lead to lower premiums.

R/A (G W Goodenough). 15 years ago insurance was an underwriting business only. We then applied engineering standards and dropped premiums by factor of 10 - this could apply in the long term in the chemical industry by engineering out the risk.

Q/C (Chairman). High premiums may come from "fear of the unknown" - any comments?

(K Myers). Its a process of development - a long way yet to go.

R/A (P J Lavery). With property insurance, it's possible to estimate the maximum cost of replacement and the time (hence production, loss) to reinstate. On liability one has no idea. Even if you knew the number of people involved there is no way of quantifying the possible claims for compensation.

Q/C (P G Jones). The insurance industry has a lot of data on accident statistics, especially causations. Recognising that there is a confidentiality contract between them and clients, why cannot the

industry make more data available (types of accident, trends, etc) to I.Chem.E and industry so that efforts in prevention can be better targetted?

R/A (Chairman). A challenge to insurance industry!

R/A (D Lavery). Regarding technical information and causation we have a lot of information and do pass it back to I.Chem.E through Loss Prevention Panel and in other ways. Re compensation paid, it depends on may factors and every case is different - no useful information seen to be likely.

Q/C (J Foley). There is no satisfactory correlation between any reduction in premium and the capital cost of implementing extra safety measures following consultation with insurance hazard assessors - particularly with respect to property loss. Please comment.

R/A (N Catford). Comes down to philosophy of your company regarding your will to protect against losses. There are other factors such as loss of market share that cannot be insured - insurance cannot cover for all eventualities. Advice is given to the client to reduce level of exposure to loss based on engineering principles. It is seen as separate from premium issues.

Q/C (J Foley). A plea to the insurance companies to consider the issue of cost of safety measures to reduce loss against level of premiums.

Q/C (Chairman). A fair reflection to the insurance companies.

R/A (N Catford). Companies have to see changes as part of the world wide spectrum of activities. Advice is based on conservation of assets of that particular plant - the operators may already be enjoying a low premium!

Paper No 4 Gibson

Q/C (H Wolfson). Exothermic runaway is spectacular and given more prominence but I suspect a more severe risk to the batch and speciality chemical process is toxic hazard - a man exposed to toxic vapours falls or loses control. Solvent fatalities will be more than 4 in 25 years. Is this assessment the design engineer's job or dealt with in later assessment under COSHH?

R/A Essentially all aspects of safety should be considered together in that technical hazards must be linked with toxic and every type of hazard. Who does it, depends upon the organisation - whether special and traditional safety are assessed by the same people. In I.C.I. it depends on interaction between experts in technical safety, traditional safety and the plant operator.

Q/C (J Cronin). Do you think that the best leadership of a process HAZOP is a "safety specialist" or a plant/process engineer?

R/A HAZOP can become mechanistic - when answering the "what if" questions you must have a full understanding of the process chemistry. Some large scale processes are very well understood and the hazards likely to be associated with lack of control. In fine chemical manufacture many new processes have to be studied and the effect of such things as accidental ingress of water could be disastrous. Hence there must be someone to answer most intricate questions on any abnormality.

Q/C (W High). Is it possible to design a chemical plant free of any source of ignition?

R/A Yes, we do this frequently. It is not necessary to inert gas blanket every tank storing a flammable liquid. If the only source of ignition is static electricity, we can control it. An illustration is the greater number of incidents with hydrocarbon tanks than alcohol tanks - simply due to the greater electrical conductivity of alcohol.

SESSION 2 Chairman: H A Duxbury

Paper No 5 Nolan

Q/C (S Czapko) What are the implications of the reported discrepancies between scale-up data from the Mettler RCI and the Boots 6751 reactor?

R/A We can achieve geometric and kinematic similarity but not dynamic similarity - essentially the fluid mechanics. 33% discrpancy may be acceptable but there is more work to be done.

Q/C (S Czapko). You mean, data can be obtained on small scale but computations have to be done to make use of it?

R/A We need to look more closely at the established correlations used and at the basic fluid mechanics in both sizes of reactors and also at the two control algorithms. The Mettler results allow you to make best use of pilot plant - a valuable contribution to development.

Q/C (J Cronin). Are we any nearer to having a "working man's" guide to application of type of calorimeters or whether the I.Chem.E guidance notes go some way?

R/A There is an I.Chem.E group working on a guide to the safe operation of exothermic reactions. Chapter 2 (Author: P Harris) will concentrate on various type of calorimeter and their applications in this field.

Paper 6 Dixon-Jackson

Q/C (Chairman). Are heat flow calorimeters really for measuring the data needed for good control and for designing relief systems?

R/A WE are using them mainly for scaling (sizing) condensers - they measure the heat production rate therefore steam requirements, etc but not information about factors like two phase flow.

Q/C (Chairman). Perhaps it's the speed of reactions we are measuring?

R/A Response time is less than 30s and it will measure sharp changes like precipitation. You cannot use it for vent sizing but it will give an indication of effects at a given temperature.

Q/C (C Steele). Would it be advantageous if the RCI could be configured to produce control algorithms similar to those encountered on plant - mimicing heating/cooling ramps?

R/A We are making measurements that require a fast response time and very good control. To degrade the equipment to mimic plant times would not be a good idea for obtaining safety data though it could be useful for other purposes.

Q/C (J Wilday). You state that your data can be used for condenser sizing if the material is non-foaming (which would produce two-phase flow). How do you determine whether it will foam?

R/A It is difficult. Sometimes we have observations from a pilot plant or laboratory - or we may heat up the mixture and allow it to boil whilst watching it. Conditions however may be different on the

plant - geometry; scale - and we may rely on general indications plus a check on the plant after the material ceases to be thermally stable.

Q/C Essentially mimicing the vapour velocity that will obtain on the plant?

R/A Our measurements enable us to size condensers for single phase flow but other tests are needed with similar vapour velocity.

Paper No 7 Amery and Lambert

Q/C (N Scilly). Has the use of techniques described (such as D.S.C.) impressed so much that the zoalene incident (Dow Chemicals, Kings Lynn: 1976) would be explicable (or detectable in advance)?

R/A We don't always adhere to the 100°C rule (see paper) - not sure that techniques have improved so much but much depends upon individual interpretation of results.

Q/C (K Dixon-Jackson). Scan rates used (case above) of 120°C/min, much in excess of modern techniques looking for thermal instability.

R/A Better understanding and interpretation of results rather than improved measurement techniques.

Q/C (N Gibson). A comment on scanning rates: we looked, at zoalene with the rate down to 1°C/min and got same result as in 10g tube test.

R/A Confirmed similar observations with certain materials. Differences of up to 100°C have been seen by changing scanning rate from 1 to 20°C/min.

Q/C (R. Shone) Do you have any rule when doing D.S.C. measurements whereby an identified exotherm (say, "x" joule/g) would lead to on A.R.C. test and, if so, what is "x"?

R/A Depends on temperature of exotherm in relation to proposed plant operating temperature. If applied, would put "x" at 300-400 joules/g)

Q/C (J Cronin) Does the variation in peak area (indicating heat of reaction) in D.S.C. results on 2-notrophenol reflect a sensitivity effect or a variation in sample size?

R/A Sample size nominally all the same, so it is a senstivity effect depending on factors like shape/appearance of D.S.C. trace,

uniformity of packing, sample size. Calibration is done for each scan rate - leading to difference in area.

Note See also under Paper No 8.

Paper No 8 Rogers

Q/C (G Amery). Referring to your obtaining cooling curves for your process vessels. These can change - for example as a result of jacket fouling or heavy precipitation in the vessel. What value would you then use?

R/A Dealing with hazards we must be conservative. We do comparitive tests with materials as similar as possible to those going into the plant. On the plant we always have cooling systems but the tests are designed to show what will happen if we lose the cooling effect - in fact, with precipitation particularly the agitator puts heat in. Finally, we would attempt to get information with similar materials on the plant. There is no single test to provide this information - we're supposed to be magicians!

Q/C (Chairman). Comparitive tests carried out elsewhere confirm the reliability of the Dewar calorimeter.

R/A Yes, we have used Dewars for many years but after comparison with and experience of working with a proprietary calorimeter 15 years ago we came to understand them both. Very similar results are obtained. In fact our results correlate and with vent sizing work done for the DIERS programme. Often there's a lack of understanding of the chemistry - so often changed during development. Because Dewar gives us quickly a direct simulation of what will happen on the plant it is our principle means of testing.

Q/C (M L Preston). Relevant to Paper No 7 and 8. Analysis for interpretation of calorimeter results seems to be a case for modelling and the use of Expert Systems. has anything like this been done?

R/A (G Amery). Short answer is no but we are considering possibilities for looking at the data.

(R L Rogers). Problem of using an Expert System is that you do not know what to look for. We use simulation methods but back them up with experimentation to check - no knowledge of work in Expert

Systems field relevant to chemical reaction hazards. The 100 degree rule is a problem because so much depends on judgement. Beware of finally specifying conditions that are quite uneconomic in practice.

(G Amery). I believe that Expert Systems cannot give information not already known but can remind us of factors easily forgotten.

(P F Nolan). At the Boston conference it was reported that Dow (Michigan) are developing Expert Systems for ARC and DSC data. AT South Bank we are beginning to study the possibility.

(R L Rogers). Have seen some Expert Systems and they produce useful logic trees, etc that do prevent things being overlooked but I can see no likelihood that they will obviate the need for tests in the near future.

Paper No 9 Scilly

Q/C (D I Matthews). Regarding the Case Study, why add "B" at all if the aim is to produce "A"? What is the desired product?

R/A Looks as if we are going round in circles but the equations show this is not so. We are making a large amount of "A" (chlorine). "B" is made during the process and is consumed.

Q/C (J Wilday). You claim that common mode failure is taken care of by applying Boolean algebra to the fault tree. This is right for "OR" gates but if two common mode events enter an "AND" gate, the wrong answer may result.

R/A One factor is that in a fault tree you have few "AND" gates - and to improve rehability, put in more "AND" gates. Follow a tree with nearly all "OR" gates and you can go right through to the top, so if base event can occur the full event can occur. Good fault tree packages are made available: ORCHARD; IRAS; FP3. These often do the Boolean reduction and provide a good graphic package.

Q/C (R Currie). Undersizing of bursting discs appears to be a significant problem. What are the major reasons?

R/A People may not understand the chemistry and don't know enough about the process. They do not consider the possible need for a BD (pressure relief) at the time of process development.

(Chairman). Are not BD more reliable than relief valves? You quote Lees' data of 0.012 failures/demand but later (see paper) the

failure rate for relief valves seems to show relief valves to be much more reliable than BD.

R/A Those figures are from nuclear industry which is "clean" and refer to inability to meet set pressure requirement - not a failure mode. I would use 0.016. BD have "the edge" on relief valves but we need more information.

Q/C (Chairman). We think BD much more reliable. When we say that alternatives must be more reliable than relief systems: which, RV or BD?

R/A Taking lowest common denomination would say, BD.

Q/C (Chairman). Not generally but OK for reactors. Regarding the matter of the relief device operating before the bursting pressure of vessel is reached, that is not good enough for reactors because the pressure is rising and the materials causing it must be released before the bursting pressure is reached. Regarding the use of a dedicated valve, would not the more frequent use of a RV help keep it operating better than one never used?

R/A If one uses a flow control valve to shut off a reactor feed - system is unreliable - against the principles of safety.

Q/C (K W Readman). The figures given for the 24000 valves tested do not state whether tested "as removed" or not - blockage not mentioned.

R/C Tested "as removed" but I don't have enough detailed information. The H.S.E. would be glad to have more information from users of relief devices.

Papers Nos 5-8 General Discussion

Q/C (P G Jones). Testing methods presented here include ARC, DTA, DSC, Dewar techniques. What technique(s) would you recommend for the smaller companies (who presumably cannot use all of these)?

R/A (K Dixon-Jackson). Based on own experience would recommend Dewar flask as basis for screening test.

R/A (R L Rogers). Would recommend a very small scale screening test followed by trials in the Dewar flask. He stressed the need for caution by referring to the slide showing the results of a Dewar test (500g) that exploded - though damage was entirely restricted to the protective cubicle in which experiments were contained.

Q/C (G Amery). Stressed again the need for small scale screening and pointed out that preference for smaller quantities of test material encouraged use of the DSC.

Q/C (P F Nolan). The more you spend, the more sophisticated you get and in economic terms you cannot beat the Dewar flask.

SESSION 3 Chairman: N Gibson

Paper No 10 N Maddison

Q/C (M McBride). You you try different pipe diameters, calculate the overpressures and then decide whether acceptable? I refer to the P_2S_5 case.

R/A We would follow the normal DIERS methodology - usually assuming homogenous two-phase venting using the long equation for a tempering reaction or the DIERS system for a non-condensible gas. In the example we were concerned with after-effects - could have calculated vaporisation rate but for the possibility of ignition inside the reactors. We would not use direct scaling - that is only applied with a foaming system.

Q/C (Chairman). Sometimes useful to have two vents: one to relieve gas at low pressure and a second for runaway reaction at a higher pressure.

R/A We say we don't provide for runaway in "FCMO" but we do provide for other causes like excessive sparging, overheating, etc - a relatively small vent. But such a relief may result in major discharge of materials and consequent effects must be considered.

Paper No 11 Duxbury and Wilday

Q/C (R Currie). What do you do to ensure whether the transient preceeding steady-state discharge would result in over pressurisation of reactor?

R/A We use DIERs methods based on experimental work and the transient would probably be non-equilibrium - consider it unimportant.

R/A (J Wilday). Runaway reactions are relatively slow (ie non-explosive) so there is not much transient before steady-state discharge.

(A Duxbury). Question asked at DIERS: Was a time of 1s important before steady-state reached - the answer being NO and experiments bore this out.

Q/C (P G Jones). You say the methods may give a size that is "too big", then you go round again. What criteria lead to this conclusion?

R/A (1) It's often applied to existing processes and size may be bigger than that installed. We may also wish to put a new process into existing equipment - can cause trouble. (2) Other methods tend to give a size only marginally smaller - not worth making changes.
(J Wilday). Do not agree. Occasionally with a non-natural foamer you get a significant reduction but may wish to demonstrate that an existing vent is adequate.

Q/C (N Maddison). Calculation based on peak gas rate can oversize a vent because with foaming systems it may be shown that reactor will empty before reaching peak rate - direct scaling then applicable with significant size reduction.

R/A (J Wilday). For "gassy" systems the preferred method can oversize but difficult to find an alternative without experimentation.

R/A (A Duxbury). The methods are simple because they are analytical integrations of the differential equations that model the systems but approximations have been made to enable integration. They have then been tested against computer models based on experimental work - errors shown to be very small.

R/A (N Maddison). You can resort to other methods such as reducing the inventory, if economic, or special control measures.

R/A Two phase relief is based on releasing the contents whilst the pressure is still rising. It is therefore very advantageous to reduce the set pressure as much as possible - on existing equipment it is often set at design pressure.

Q/C (G Goodenough). With a change in duty of a small reactor, the estimated vent size may be greater than the size of the vessel branch. (1) Can the "orifice effect" of the branch be ignored provided a larger relief device is fitted. (2) Can you offer economic/practical solutions for the modification of existing vessels to increase the venting capacity.

R/A Normally you would have to change the branch size. Firstly, the branch (nozzle) area is going to control the flow by choking;

secondly the branch will be long enough to establish equilibrium flashing flow - therefore no way except by changing the nozzle (or vessel!).

In gas venting, limitation is by "sonic" flow; in two-phase, flow limitation is by the equivalent, called "choke" flow. The calculated area is that of the smallest in the vent system. Only in liquid flow through orifices do you get pressure recovery.

Q/C (C Steele). What about (1) the effect of solid suspensions on flow?; (2) risk of blocking?

R/A Solid suspension was not part of DIERS studies - solids may stay in vessel (heavy) or be so light they don't affect flow. I know of no cases of blocking (from this cause). We don't think suspensions have a large effect compared with other uncertainties.

R/A (N Maddison). Something of a "hunch" at the moment. If solids are about same density as liquid - unlikely to be a problem but work in hand because of so many processes involving suspensions.

Q/C (C Steele). On small scale, ratio vent size/particle size much less than large scale - what effect on small scale results?

R/A (N Maddison). Will certainly effect some measurements eg DIERS test procedure, VSP (vent pipe 1mm) - particles could be up to this diameter.

R/A Low velocity two-phase flow (ie conveying) - the effect of solids not great but in case of two-phase choke flow little information is yet available.

Paper No 12 High

Q/C (H A Duxbury). Do we need to take account of directional effects in the design?

R/A With vented cubicles there will be strong shock wave directional effects near the vent but at distances of several cubical dimensions away the wave is almost hemi-spherical. Fragment effects may also be directional but are much less predictable because of irregular trajectories.

Q/C (J Cronin). The damage potention of fragments is of importance and is critically dependent on velocity and impact area/geometry so an estimate of fragment mass is required. Calculation of kinetic energy is discussed in one paper but is there a standardised method

available for mass distribution?

R/A Very difficult to predict the number of fragments, produced by vessel rupture, also the size distribution of the shape - many discussions held. We are searching for a method. N Scilly claims to be developing a methods however and we look forward to seeing results.

Q/C (I L Edwards) (1) Does the pressure/time characteristics of the shock wave from a vessel failure differ from that of a TNT explosion and thereby affect the application of the usual TNT equivalent?
(2) Can the pressure wave following rupture of a vessel containing two fluid phases be predicted?

R/A (1) There are significant differences but they may not necessarily change the analysis.
Iso-damage curves in the form of rectangular hyperbola represent pressure and impulse combination which at mid-span give a particular deflection or damage. Rise time is also a factor but it is possible to get useful answers concerning the theory of dynamic response. This enables use to be made of the TNT model. A key parameter is T/T_N, T being load duration and T_N natural period of vibration - if greater than 10, pressure can be regarded as quasi-static. The nuclear blast data can be used as they are for long duration (several secs) and much information is available. (2) Don't know of any direct information.

Paper No 13 Crooks

Q/C (W High). Many accidents seem to occur because permit to work procedures, through properly set out and adopted are frequently ignored. What can be cone to improve?

R/A HSE supports every attempt to improve the use of permits but is unable to enforce them. It has recently published a document on Human Factors - drawing on Permit to Work systems and has participated in Advisory Committee for Oil Industry in producing guidelines for Permit systems. Piper Alpha was an example where certain systems were not used because everyone thought he knew what everyone else was doing. Industry must enforce its own procedures.

Q/C (K Palmer). Do the new regulations on pressure systems and transportable gas containers cover for transport on the public highway?

R/A Yes it does. New regulations are in two parts and replace gas cylinder legislation - Conveyancing Regulations 1931 (cylinders in transit).

Q/C (K J Myers) (1) Factory dilatual International, as an insurer does inspect work permit systems in operation and makes recommendations - paper systems are not enough. (2) A slide shown suggests that relief of vessel contents be provided safely as far as is practicable. Who decides: HSE, local management, insurer?

R/A "So far as is practicable" has a specific legal implication and depends on balancing cost of provision against the consequences of no provision. Responsibility lies with the plant operator/user but the other bodies may give advice.

Q/C (H A Duxbury). The slide was not quite clear in meaning - it did not say "vent as far as reasonably practicable". Alternatives to pressure relief can be acceptable.

R/A The requirement under Regulation 4 is that the operator shall provide devices to prevent danger and any such devices to relieve pressure shall do so safely (Refer to the Regulation for full text!) Alternative could be subjected to legal judgement. He agreed that alternatives could be acceptable.

Paper No 14 Cassidy

Q/C (J L Cronin). You mentioned that CIMAH requirements include the consideration of external hazards (aircraft, earthquake, etc). Such assessments are available to some industries but are they presently available for the chemical industry?

R/A All the methodology produced by SRD for HSE (contract) - or others is published. (Charge only reflects editorial and publishing costs - not production). If an enquirer does not wish to buy and run a particular computer model, SRD will do this for the client at a moderate charge.

Q/C (H A Duxbury). **Are environmental aspects for safety reports handled by the HSE (Bootle) in the same way as safety risks?**

R/A There is an interface with the Dept of the Environment. Also CIMAH regulations apply to indirect as well as direct risks and risks to the environment. Thus regulations not only conform to H&S W, etc Act but also the European Community Act.

Q/C (F C Lloyd). (1) Please comment on the likelihood that what is "reasonably practicable" before an incident is no longer so after an incident?

(2) What is HSE prepared to do in defining what is "reasonably practicable" in specific situations?

R/A (1) There are two ways of finding probabilities where frequent incidents occur; probabilities can be derived from available data. Major accidents are rare and probabilities have to be synthesised. The balance may change - may be affected by further incidents. "Political" effects (public perception) may change the level of acceptance.

(2) HSE do discuss problems with operators and may have to enforce changes - possibly using Risk Assessment procedures. Sometimes, companies can persuade HSE to accept proposals based on Risk Assessment because of low probability.

SESSION 4 Chairman: J A Barton

Paper No 15 Lloyd

Q/C (I L Edwards). Questioned the use of MOC values (say, 5%) at temperatures and pressures above atmospheric when lower values should be used. U.S. Bureau of Mines Bulletin includes a method for effect of T and P but may give too high values for effect of T. Experimental work is needed.

R/A Agreed with this but in practical terms it may not be possible to obtain precise figures and advised several additional purges, each reducing the oxygen conc. by 2/3 to obtain a very low value.

Q/C (C R Dykes). Re the problem of static electrical discharge with insulating plastics what are your views about use of PTFE-lined piping?

R/A Flow of liquid through plastic-lined pipe will create static which can ignite any flammable mixture then entering the pipe. With "conducting" fluids (eg methanol) an earthing section will dissipate

the charge. With non-conductory fluids (eg benzene) static is a problem - which can be 1000 times worse if water droplets present. A conducting grade of PTFE can be used.

Q/C (J A Loudon). (1) How does one maintain N_2 purging on a vessel whilst charging solids? (2) Do you ever apply continuous O_2 monitoring to processes (other than centrifuges)?

R/A (1) Maintain the vessel effectively sealed whilst changing by the use of eg rotary valve or double flat valve. N_2 blankets quickly disappear with the chargehole open, eg with a 6 inch chargehole, agitator running, the blanket disappeared within 3 1/2 minutes. No problem with liquids; powders usually occlude about 50% (vol) of air and rotary seals also act as pumps thereby diluting the blanket. Hence a continious inert gas purge is needed.

(2) In some situations eg some milling operations we prefer to rely upon attention to the purging system rather than oxygen measurement.

Paper No 16 Beever

Q/C (R L Rogers) (1) How many and what size baskets would one use in tests to determine safe temperatures for $1m^3$ I.B.C. (2) What safety factor should be applied?

R/A (1) 150 or 200mm (2) Examine errors in measurments and do an error analysis to determine minimum and maximum lines. Apply a safety factor above this in case test material is not representative. Exercise caution in dealing with thin layers.

Q/C (J Singh). If a risk situation is identified what is the best way to calculate the time taken to ignition?

R/A Below the critical temperature the time to ignition is very long (maybe infinite): Above the critical it is very short. A characteristic time to ignition can be calculated. From the self-heating tests, obtain constants M and N from which the adiabatic time to ignition can be calculated. This is probably the worst case but would be safe - actual times somewhat longer.

Q/C (E Spina). An incident (fire) occurred due to the build-up of textile dust in a duct (temperature 60-70^{o}C). Would this be dangerous?

R/A If the build-up was less than 2-3 mm it would be perfectly safe.

Q/C (K Dixon-Jackson). With non-fan-assisted ovens erratic results were obtained - but so were the oven temperatures.

Q/C (J Cronin). Regarding the critical parameters for non-regular geometrics, how was this obtained from the original Frank-Kaminecki approach and how reliable were the figures for odd shapes?

R/A The figures are extremely reliable because they have been computed to a large number of significant figures. If you can identify the geometry, can be found to any degree of accuracy. With more obscure geometry, approximate methods may be needed - the method would have to be examined for its precision. Yes, it is done numerically.

Paper No 17 Lunn

Q/C (N Catford). The nomograms lead to large areas for silos - maybe difficult in practice and can only vent from top. What advice for adequate venting?

R/A Technique of Hughes was to inject, as with the 201 sphere, producing a very turbulent explosion. This would probably not occur in silos - would suggest first examining the nomogram and consider what is necessary to fit in a vent. If know of no nomograms for low-turbulence dusts but unpublished work is being done.

Q/C (K J Myers). Are hard copies of slides showing effect of venting ductwork available - effect on P reduced?

R/A Not available as such because they are in Part 3 of the I.Chem.E "Dust Explosition and Prevention Guide" (copyright - available on I.Chem.E exhibition stand).

Q/C (H A Duxbury). (1) Regarding explosion doors, there seems to be an error on p242, presumably 10 or 25 kg/m^2. (2) The Germans make explosion doors which are tested to obtain an effective equivalent panel area. Do we have any equivalent in UK. (3) Is the Swift-Epstein method useful for unusual shapes since it relies on internal area?

R/A (1) Correct. (2) A project starting at Buxton is concerned with this approach to venting. (3) It does - Swift's examples published in Nolan's journal apply to the curious shaped building and he specifies that the vent area be evenly distributed.

Q/C (W. High) How should one estimate the appropriate safe area in the vicinity of a vent? Would 8 x vessel volume be reasonable, assuming the blast then becomes a spherical fireball and base the "safe"

distance on flame radiation levels? External explosion may also be considered.

R/A There is no predictive method for those effects and it depends on the enclosure volume. Experience has shown that in $20m^3$ the flame can stretch 18m beyond the vent opening.

Q/C (K. Patterson) Factory operators need simple methods of calculation. HSE has used vent ratio – Hartmann Bomb methods. Are there any cases where such vents have failed to provide sufficient protection?

R/A The problem with its vent ratio method was the very high vent areas predicted for reasonably sized volumes - even bigger than size of the enclosure. There's no real difficulty with nomograms. Fire Research Station also test out the proposals.

Q/C (D.L. Matthews) Despite the shortcomings you mention of the Hartmann Bomb method does it give erroneous results – is the flame quenching a semaus matter?

R/A It gives too low a rate of pressure rise and of maximum pressure so you cannot use it with the nomogram.

Q/C But does Hartmann tell you whether dust is explosible?

R/A You should use the vertical tube apparatus.

Q/C (K. Palmer) Many existing individual vents have been based on traditional Hartmann - Vent-Ratio approach and in fact the method gives results compatible with the nonogram for plant volumes up to about $30m^3$. (not trying to put Hartmann results into nomogram philosophy). There seems to be no need to reassess them and eventually such equipment will be phased out.

R/A Accepted this reasoning.

Q/C (H.A. Duxbury) If explosion doors are made to shut again, is there not a risk of causing a partial vacuum - sucking in the equipment?

R/A Yes, it is necessary to provide vacuum relief.

Paper No. 18 Moore (presented by S. Cooper)

Q/C (N. Gibson) (1) In the hybrid vent - suppression example on a spray dryer, personnel were protected from flame, not from pressure. If explosion is killed very early there should be no need for a vent. (2) How effective is suppression against aluminium dust explosions?

R/A (1) We assumed that the reduced explosion pressure would escape from the dryer - i.e. volume over the roof would be overpressured (possibly 0.3 bar). Injury could result and we suggested extending the vent (duct) by 2m but such protection was not proven. (2) Major problem is the burning temperature and we have not identified a suitable suppressant to take away enough heat from the interior of the fireball - only as a barrier on periphery. This achieves reduced explosion pressures of 3-5 bar and 2.5 bar has been achieved. Thus we should combine with a vent.

Q/C (R.L. Rogers) Please give a value for reliability of suppression systems.

R/A No figure is available but in 35 years, these systems have never failed to suppress a specified hazard. There are many complexities in any attempt to measure reliability so we rely on self monitoring the suppressant content plus stringent maintenance.

Paper No. 19 Shields and Webster

Q/C (E.L. Edwards) The equation quoted for atmospheric dispersion was based on work done for loading fuel into aircraft and warnings are given about low wind speeds and temperature inversion. Are you applying this equation inside buildings?

R/A We apply the equation for small leaks and find agreement with other equations used in industry - would not apply it for toxic materials or large leaks. Inside buildings, take account of the ventilation pattern and use other equations.

Q/C Could you have Zone 1 in only a part of a building - the rest Zone 2?

R/A No experience of this but it could depend on ventilation pattern.

Q/C (H.A. Duxbury) (1) You dismissed flashing flow because the leakage holes are "small". Do you mean that the flow-path is short?

R/A (1) Yes, the flow-path is small and for hazard area analysis large leaks are not considered.

Q/C The distance for flashing flow is about 10cm irrespective of hole diameter (validated from 1mm to 500mm).
Your gas flow equation is for subsonic flow and since for vessel pressures over 1 bar g flow will be sonic your calculation is safe.

R/A The paper gives a sample of methods used but others can be used when appropriate.

Q/C (C.D. Plummer) Refering to the I.P. Code (Draft Revision), Ref. 7, was it worthwhile producing this method and is it acceptable to HSE?

R/A Method in use for 10 yrs, may pre-date the I.P. Code and no complaints from HSE.

Q/C What factors are used for the unpredictables like human error or unexpeceted ignition source?

R/A Hazard area analysis is for the purpose of electrical equipment classification - human activities within the area may be dictated by the classification and must be determined by extensive study of plant operation.

Q/C You had no zoning of gain 350m pipe (slide shown) and no Zone 2 surrounding Zone 1 areas.

R/A A large length of pipe containing few joints and no valves - leaks not overlapping - may be unclassified. We have considered defining "Zone 3" areas for such situations where special electrical equipment is not needed but other precautions would be specified.

Q/C (T. McClymont) You have reclassified a totally Zone 1 area to mainly Zone 2 with small areas of Zone 1. Please comment on any incidents of Zone 2 electrical equipment being unadvertently installed in Zone 1 areas.

R/C After reclassification, no major changeover was made but when replacements became due, the electrical engineers have the opportunity to use Zone 2 equipment if preferred.

SESSION 5 Chairman : K. Dixon-Jackson

Paper No. 20 Jones

Q/C (S.A. Jaggers) 50 incidents in "a few months" should give considerable concern over the safety of computer control. What type of incidents have been surveyed?

R/A These incidents occurred over about the last 18 months following a 6 month period in which preliminary studies showed insufficient information about computer systems in reports. Not all are chemical industry but do show trends associated with computer systems. HSE will publish a booklet on "dangerous control" when sufficient data is to hand (hopefully next year).

Q/C (J.C. Beresford) Referring to the quoted figure of 10^{-8} per year for probability of failure on demand - generally an undemonstrable figure - will HSE offer guidelines on the degree of hazard appropriate to use of safety - related software.

R/C This figure is being sought by CEGB and the nuclear inspectorate for their new reactors. My point was to question whether a system - particularly the software can be validated to that level of integrity. HSE recognises that the levels of integrity required by (say) nuclear power stations at the top end and (say) simple machinery would cover a wide range. HSE is investigating this range and hope to come forward with recommendations - the subject of Paper No. 21, Brazendale.

Paper No. 21 Black

Q/C (E. Crooks) I interpret what is stated about Category 0 and 1 systems to mean that most process plants will have a combination of "0" plus "2" or "3". What additional precautions will have to be incorporated to ensure that the mechanical integrity is adequate to prevent the plant being taken beyond design limits in the event of failure of a Category 1 control system?

R/A There are situations where a Category 0 system (say) relief valve may not protect the plant under all circumstances (e.g. runaway reaction; vessel designed for a specific temperature overheated). Thus a Category 0 system may protect against pressure rise and Category 1 system by controlling the conditions that could otherwise lead to operation of "0" system. Regarding design, first segregate then obey all requirements for quality, reliability, etc. We support HSE in all requirements and go even further than the EEMUA document in defining how such systems are realised for the process industry.

Q/C (J. Brazendale) Whilst agreeing with segregation, it is important to ensure that possible interactions between two systems is carefully examined (e.g. relief valve and an instrument protective system).

R/A "O" devices must be designed taking into account possible failures of "1" and "2" systems and of the process plant itself. Emphasised the importance of segregation and when different control systems are integrated, great care is taken to ensure that overall safety is maintained. Where there is opportunity for over-riding a control a strict permit system must be operated.

Q/C HSE has been seen to suggest avoidance of PES in safety systems and this applies to the EEMUA document in preferring "O" systems. On occasions a combination of "O" and PES - based "1" system can enhance safety - provided a full understanding of function.

R/A Beware of taking credit where not justified - e.g. undersizing a RV because it is backed by a control system!

NOTE The EEMUA document will be on sale in June.

Q/C Regarding the classification, is a human operator considered to meet requirements of a Class 1 system or should he be eliminated?

R/A In the diagram we did include the operator. We would recognise his contribution as we would recognise his contribution the other way. Views differ on how far we should go to design out the human factor but even expert computer systems cannot reason from an understanding of process.

Q/C In EEMUA document no credit given or taken away from human element - so much depends on information given at the time, training, etc but would not rely on operator for anything to be done in short term.

R/A Must neither, expect too much of operators, nor take them out entirely.

Paper 22. Brazendale and Lloyd.

Q/C (D.M. Hunns) You appeared to say that software design standards should be independent of risk - is this not at variance with the benefit versus safety gain balance (ALARP philosophy)?

R/A It is, deliberately, because for any specific level of safety, certain measures are needed - high or low level. Problem is then split : first define the appropriate level - don't pre-judge the situation. We must move away from the situation where a software failure can be said to be cause of death/injury.

Q/C (R.L. Rogers) The reliability of PES should not be less than that of other systems. There is a debate about reliability of relief devices, etc. but mitigating factors seem to make reliability better than calculated. Does this apply to PES?

R/A Reliability calculations can be abused - information is often scarce and only time can tell whether PES reliability can be estimated effectively.

Q/C (N. Gibson) can safety devices be controlled by computer alone or are hard wired systems in parallel still required?

R/A The purpose of computer is to form an expert concensus view that by taking certain measures a specific level of integrity will be achieved.

Q/C Then are HSE satisfied than safety systems can be controlled by computer alone?

R/A Yes, we do accept that.

Q/C (W.S. Black) What part does demand rate play in the requirement for safety integrity?

R/A Integrity does depend on demand rate hence the term "integrity level" intended to define a level within the software but extremely difficult to quantify.

Q/C (J.C. Beresford) Would you then explain in more detail the meaning of "integrity level" and how it relates to both risk and probability of failure on demand?

R/A *As proposed it is the qualitative chance that the safety functions* allocated to software will be achieved - a measure of achieving safety functions. In a demand system, ideally specify as probability of failure on demand as for hardware. In a continuous system, some sort of relability metric over the year is needed. The problem is finding a measure to cope with both since both are present in software systems.

Q/C Are these "integrity levels" to be assessed as part of the overall protective measures including self-acting devices?

R/A We are developing a software element from previous PES guidelines which deal with whole system - i.e. all aspects affecting control and safety should be considered.

Q/C (W.S. Black) When counting "systems", does HSE count the operator (as a system) as something to be replaced?

R/A HSE view the human system as most important going right back to design and implementation. Inclusion of the human element is gaining ground and should be more formal - research being considered.

Q/C (P.G. Jones) Operator role is seen as specific part of any control loop - can enhance or degrade it sometimes depending on the environment in which he works. (Reference to H.S.E. documents).

Paper No. 23. Higham.

Q/C (W.S. Black) There would be great benefit in detecting covert failures - will govern eventual safety of any system we can achieve. What percentage of covert failures in (say) a transmitter would be picked up by your techniques?

R/A If a resonant element, would say 100% but a passive element (e.g. stain gauge) less certain. The key factor in detection is the interface between the sensor and the enclosure for the sensor. For instance a strain gauge could fail to respond without being apparent whereas a DP cell failure because one lead blocked would be immediately apparent.

Q/C If that can be believed, requirement for period testing can be dropped - has any consideration been given?

R/A Yes, you have a constant monitor - shows up any instrument "gone to sleep" without affecting the process measurements.

Q/C (P. Jones) This is a monitoring system par excellence - even in measurement of normal process parameters information is obtained about the process system to show how well it is working - instruments, pumps, valves, etc.

R/A Signal analysis picks out small changes in large quantities but a lot of time is needed to develop it.

Q/C (D.M. Hunns) (1) What practical problems do you envisage in using the technique in the complex noise environment of (say) a noisy power plant? (2) How can you set criteria which would determine that expensive plant be taken out of commission for major maintenance?

R/A We are about toe embark upon this sort of investigation. So far measurement techniques have been developed which will be applied to process systems.

Q/C (W.S. Black) Have you considered covert failures in the final element of a protection system?

R/A No - we are starting with the measurements then move into many applications - e.g. study the movement of a control valve.

SESSION 6 Chairman: P.G. Jones

Paper No. 24 Love

Q/C (W.S. Black) If the answer to a HAZOP question is related to properties of control system does not that make the system safety-related - needs to conform to all HSE requirements?

R/A Have been talking about conventional, proprietary batch type control systems. Ultimate safety does not depend on it. The control system is not necessarily a safety system - must distinguish between safety features and final protective system. Control system may pick up faults and control them before the protective system - a proper function therefore.

Q/C Taking credit for that function makes it part of the safety system.

R/A The final protective system is a separate (independent) system - HSE policy.

Paper No. 25 Jaggers

Q/C (C.R. Batchelor) Interested in your software modification procedure, how do you handle and document changes made during commissioning?

R/A Maintain a software log in which details recorded and file listings of changes.

Q/C Do you number the versions?

R/A Trace a module by its date and reference number within the log.

Q/C (K. Patterson) Given previous discussion about failures to enforce permit to work systems, how do you ensure a complex set of change control instructions are carried out?

R/A System is not complex. The forms are simple though reasoning behind the change may be complex and carrying out the instructions depends on management environment in the company.

Q/C (J. Foley) On a production basis software changes are likely to be mainly towards "user friendly" - displays, etc. not requiring input from a Q.C. or G.M.P. Dept. How do you handle authorisation?

R/A All changes by same group - authorisation level depending on nature of change.

Q/C (W.S. Black) Please give more detail about your computer documentation method.

R/A It is an electronic mail system whereby the documentation is circulated more quickly and can be signed off electronically.

Paper No. 26 Hunns

Q/C (R.L. Rogers) It is possible to develop a testing procedure when the hazard has not been identified?

R/A Cannot test if the hazard is not known to exist - that's why safety wisdom is a series of epitaphs! The methane example was given because though the hazards of methane were known the effect of high pressure water was not appreciated - too many assumptions made. In this case, the basic knowledge was available but not used.

Paper No. 27 Wilson

NO COMMENTS/QUESTIONS.

FORUM Chairman : P.G. Jones

Introduction. (Chairman)

An opportunity for professional engineers either as individuals or as representing an organisation or institution to identify problems to HSE, academia or I.Chem. E. (A) State any need for more research in the process safety area and loss prevention. (B) Draw attention to unpublished papers. (C) Many issues discussed at this symposium are referred to in Hazards Symposium Papers but has anything been missed? (D) What gaps should be studied? (E) What more guidance should be issued? (F) What is needed with regard to theoretical modelling? (G) Any other area?

(G. Evans) Re (F), papers given at Bradford soon after Flixborough (particularly Vic Marshall) should be of interest.
(Chairman) comment of interest to record.

(W. High) (1) Difficulty in getting certain information, e.g. how to establish safety distances for rupture of a B.D. on gas filled vessel - either theoretical model or practical measurements. Some problem exists with vessel rupture - shock wave, fragment trajectories, venting or escape of flammable gas into enclosed area, buildings (2) Permit to work procedures - I.Chem.E. publication expresses "pious hopes". In difficult industrial situations, it is very difficult to supervise properly so guidance is needed (F)
(J.A. Barton) Re (1) above, work has been done (e.g. Christian Mequeson organisation with FLAX Code and current work at TNO, sponsored by HSE and a group of companies. It is looking at explosions in arrays - gas released into arrays and ignited : flame speed, pressures generated in the rig and blast pressures outside measured together with a a study of spread to other arrays. Work started small scale but is being extended and results will be applied to TNO multi-energy method for blast pressures.
(W. High) Firstly, information from some sources is very difficult to get, despite importance of the subject. Secondly, many models have shortcomings, e.g. DNV or Vertex Code have severe limitations and British Gas are not publishing results - more generally available information needed. More development is needed in the analysis of turbulent flow with respect to its effect on flame speed.
(Chairman) We hope that proceedings of this symposium will be taken to heart by those in possession of this sort of information.
(H.A. Duxbury) Endorsing above remarks, stated an interest in explosion of flammable gas clouds with small flammability range - related to whole study of gas dispersion modelling. The American CCPS are researching the formation and stability of aerosols and results will eventually be published - but where do we stop?
(J.H. Burgoyne) the reluctance of organisations (mainly industrial firms) to publish results of hazards research has always been a problem for the organisers of these symposia. Considerable persuasion is needed, though the position has improved over the 30 years of these meetings. For 1991, N.W. Branch is planning a

meeting to which papers and reviews on process safety research will be especially invited. I hope that people producing such work will bear this occasion in mind in planning their publications.
(Chairman) That gives you 2 years to produce the papers and a forum for their presentation.

(N. Gibson) Gas dispersion modelling must be related to real situations such as in a works environment (buildings/plant in the way). The results of experiments in open spaces (Salisbury Plain) are not relevant, neither should we be concerned about dispersion outside the factory because nowadays that must not be allowed at any time. Models used for area classification also come into this category because minimum wind speeds are assumed - but they do not occur between the walls of buildings, etc. (e.g. old I.P. Guide).
(C.D. Plummer) Calculation methods for real obstructed path gas dispension have been published recently (Deaves : Loss Prevention Bulletin, Jan 1989). We are now researching topographical effects over real "hilly" sites and have carried out analysis of leak probability added to weather characteristics, topographical effects and population density to give F_n and iso-risk curves and also risk criteria. This work will be published.

(Chairman) Re. Permit to work rules (W.G. High) would say "... required to have a safe system of work ...." Section 2 H & S.W. Act. Is the problem that a different system is needed to make it feasible to implement - whether in the chemical industry or elsewhere?
(W.G. High) Experience in giving the I.Chem.E. module on Permit to work to a wide range of audiences has produced reply : "impossible!" Short cuts often taken, nobody bothers, yet few accidents. The procedures are sensible - what is the solution?
(K. Patterson) As an example, I recently saw welders working near a large ammonium nitrate storage. When staff were questioned about permits, the assumption was made that rules do not apply to contractors!
(T.J. Rose) Permits are often issued on a routine basis for repetitive jobs and then tend to be ignored. Perhaps operators should : (1) Question whether they are needed for routine jobs; (2)

Design specifically for different jobs to suit the problem, reflecting organisational response and tailored to match the particular risk involved. Too often a standard form is used for quite different situations.

(Chairman) Human behaviour is much involved and HSE has issued guidelines which are really to open up the debate. Permit problems are just one aspect.

(E. Spina) Agree that permit systems need to be carefully analysed with respect to the particular situation - not generalised.

(J.L. Butterworth) (1) Management style is crucial - level of concern expressed by senior management is reflected at supervisory level, hence essential for management to set up and maintain good procedures. (2) Endorse that the type of permit should be matched indivudally to the level of risk (3) Standard operating procedures can in some situations eliminate the need for permits. (4) What training (and qualifications) are required for supervisors who implement permit systems?

(Chairman) HSE is concerned about levels of competence, especially in relation to forthcoming European requirements - will consider your question.

(K. Dixon-Jackson) Does Mr Lunn (Paper No. 17) know of any research re. the hazards of hybrid mixtures (flammable gas and dust mixtures) that tend to ignite at levels for the gas?

(G.A. Lunn) There is some information in Bartkecht's book (Ref. 3) and in ISSA (Ref 4). We have done very limited small-scale research into mixtures (or layers) of coal dust and methane (below the LEL at 0 - 4.8%) main observation being a large increase in violence of the explosions. Other topics have priority over this work.

(A. Black) Following the methods given in Paper No. 11, what advice can be given for design of catchment systems to contain the discharge (in our case non-toxic)? How sized? What length of connection line is tolerable? How can we design for multi-discharge to one pot with safety?

(J. Wilday) Some information will be given in one chapter of the report to be produced by the I. Chem. E. Fellowship (Relief Systems). Many problems re. disposal systems have to be answered and CCPS have a group looking at some of those.

(H.A. Duxbury) A paper to the Boston symposium (CCPS, March 1989) by Keite gave moderate detail for design of vessels for discharge from relief systems. Re. common discharge into one system, this practice is generally not advised but if there's a choke point between the reactors and manifold, it may be acceptable with care.
(N. Gibson). As either a fine chemical or contract manufacturer I would be very concerned about the risk of incompatible materials reaching the same catchpot. Inert blanketing (expensive) may be needed. Considerations of the problems in the fine chemicals industry lead towards other methods of protection (process control) - they are more flexible.

(R.W. Lower) Speaking for a small company (in U.K.) with limited resources, we need some simple, quick reference system for recommended guidelines for designing for safety (e.g. a bulletin).
(Chairman) (1) I. Chem. E. have a comprehensive library and data system. (2) HSE library system. (3) The British Library system is good, provided that specific questions are put to it.
(H.A. Duxbury) Also the I. Chem. E. Symposium Series, safety video, the Loss Prevention Bulletin and Institution publications. Refer to Bernard Hancock, I. Chem. E., Rugby.

(K. Palmer) Symposium is mainly about runaways, etc. inside reactors. What about external causes - external fire or shock? This area needs attention and should extend to packaging, warehousing, general handling and include concern about the "domino" effect.
(H.A. Duxbury/J. Wilday) External fire will add to the heat generated by a runaway inside a reactor so increasing the rate of temperature rise. Fire effect alone is usually less than the effect of a runaway but the two together must be taken into account.

(Chairman) Some questions raised cannot be answered and suggestions made may or may not be followed-up. We want the maximum publicity to be given to them however and full consideration by subsequent Hazards Symposia organisers.