Expert Witnesses: Avoiding False Economy

by Sean Moran

I am a chemical (aka process) engineer, specializing in water and environmental engineering. In recent years a growing part of my professional practice has been as an expert witness in commercial disputes arising from problems with process plants, most of which originate in the design process.

My first expert witness instruction was in the mid-1990s. I had received no training and found myself being cross-examined in court on my very first case, an experience unpleasant enough to motivate me to obtain training as an expert witness prior to the next time I appeared in court. I have now been cross-examined on two occasions since then (the overwhelming majority of my cases being settled along the way), and it has become a far less unpleasant experience on each successive occasion.

Whilst I cannot discuss the fine details of many of my engagements, I have found that my work as an expert witness has helped me to identify some common issues with problematic process plants. In my own books on process plant design I have turned these into an informal guide on how not to design process plants, some of which may be of interest to legal practitioners.

Engineering Competence

The most crucial issue I have found, both as a troubleshooter and as an expert witness dealing with failing process plants, is that of the competence of those tasked with the original engineering design.

Theoretically, process plants are never built based upon the work of one individual, as QA systems based on standards such as the ISO9000 series require checking of calcs, design reviews and so on. However, the design quality of even the largest plant eventually often comes down to the competence of a single individual. This is because, in practice, process plant design takes place under resource pressure, and even if suitably qualified engineers are available to check calcs, they will not check every box in the spreadsheet used to carry out design calculations.

I consequently always find errors when I repeat a check without time pressure, and with a brief to find mistakes. These can have persisted for various reasons. The original checker might well have had a brief to just get a design signed off, or the design may have been reviewed by a team comprising one engineer from each discipline, meaning that a design will be checked against the requirement of other disciplines, but never actually verified by a second process designer.

It therefore really matters who does process design. Some bad choices I have encountered in expert witness practice involving multi-million-pound jobs are: experienced process designers from another sector; fresh graduates with no previous process design experience; 'year in industry' students; and - most popular of all for plants which don't work: nobody.

The experienced process designer from another sector may have some attractions. They will be able to apply the tools used by all process designers, and will have some awareness of the needs of other disciplines, but they will lack sector specific know-how. On several occasions in my experience, this deficit has made the difference between a working plant and plant beyond economic repair.

Undergraduates and fresh graduates, on the other hand, do not apply the professional's tools at all; instead they naively apply what they were taught at university. Like their research-active lecturers, they often value novelty, rather than avoiding it as a professional would. They lack attention to detail, especially in respect to balancing the cost, safety and robustness implications of their choices. They lack knowledge of other engineering disciplines. Finally, they assume that someone else is going to make sure that the plant really works, especially if they are working for a major company. They are always seemingly unaware that the law requires engineers to be "reasonably competent" on day one of their career, making no allowances for novices. Sadly, the work of these individuals is sometimes worse than those cases where there is no process designer at all.

Those cases I have been involved with in which a process plant was built without any process engineering input are useful to demonstrate what process engineers do and how we add value to a project. Based on what happens when we are not involved, I have concluded the following are the key benefits of involving a process engineer:

Firstly, we analyse design data and set the boundaries of the 'design envelope'; two factors which are crucial to the production of a robust design.

Next, we make all the items of equipment work together to meet the specification. We do this by producing a 'mass balance' calculation, without which plants cannot work as an integrated whole. We also produce a 'process flow diagram' to inform the specification of each of the 'unit operations' which work together to make the plant. Our involvement in unit operation selection and sizing helps to avoid excessive novelty.

We then ensure that the plant is also integrated from a software point of view, by means of a process control system which is based on the engineering drawings and other 'deliverables' which we produce. Process control systems designed without process engineering input do not in my experience produce a cost effective, safe and robust plant. In fact, every plant I have seen of this type does not work at all.

Finally, our involvement in plant layout helps ensure that it produces a plant which is economical and safe to operate. The majority of accidents on process plants can be attributed to poor layout so the involvement of an experienced process engineer from the outset can be a life or death matter.

Expert Witness Competence
So, what is competence in the case of the expert witness? Competence in the opinion of the courts is acquired through relevant professional experience.
Pure academics without practical experience are therefore rarely instructed as expert witnesses in my field, and I have never encountered one. The reason for this is that the academic and professional versions of engineering differ widely. As already mentioned, professional engineers, unlike their counterparts in academia, innovate as little as possible. In addition, academic approaches to plant design tend to ignore the key constraint in the real world: price. Engineers are never asked how they would solve a problem if money were no object; instead, balancing cost, safety and robustness are the essence of engineering. Finally, an assumption frequently made in academia is that any process which works at laboratory scale will work at least as well, if not better, at full production scale. In fact, the reverse is true: it is very common indeed that a full-scale version of a successful lab experiment will not work at all, a problem I have often seen in disputes.

My expert witness practice is almost exclusively in the field of the design and commissioning of water and effluent treatment plants. I have personally designed dozens of such plants, and carried out troubleshooting exercises on hundreds. As a result, I am thoroughly familiar with normal professional design methodology, an absence of which is noticeable in so many of the cases I have worked on. Knowledge of professional design methodology is absolutely crucial both to producing a working process plant, and in my view to offering expert opinion on how a design ought to have been undertaken by a reasonably competent engineer.

Causes of Bad Design
Separation of Costing and design
In my experience, attempting to design a process plant without appropriate cost data results in poor design choices.

As an example, I once worked for a large UK water company on the design of a major extension to a municipal sewage treatment plant. The company used scientists to choose the "best process", civil engineers "designed" the plant around this selected process, and their estimators carried out a costing exercise based upon the design produced, resulting in the selection of a novel process which was both expensive and unreliable. The scientists took no responsibility for this, as they had no access to costing data, no brief to ensure safety or robustness, and they lacked an engineer's conservatism and dislike of novelty. In any case, they assumed the engineers would make the plant work. Meanwhile, the civil engineers who adopted the scientists' recommendations lacked the training to examine them critically.

The outcome of this exercise was all too predictable to an experienced engineer. The novel process made it to the final decision stage, even though the economics were bogus, and the process was too novel to be used for the first time at such a large scale. The decision to use the wrong process was however sealed when a senior manager expressed an interest in the novel approach. The decision was made to go with the "HiPPO" (Highest Paid Person's Opinion), illustrating how management issues can be crucial.

People Issues
Professional engineers use a combination of explicit and tacit knowledge to make their design decisions. They are also the ones who may find themselves being cross-examined on their decisions decades later on the basis of perfect hindsight.

However, line management, the managers of various disciplines within a company, colleagues and technicians both within and outside the company may well all have their own opinions too. It Is common for a higher-ranking engineer or manager to want to make their own mark on a design, and managers are generally less risk averse than professional engineers. Engineers from other disciplines or from outside the designer's organization have different priorities, and may not be aware of the full picture. So, whilst relevant experience should be respected, it is important not to 'follow the HiPPO' blindly.

On the other hand, I was once involved in a case in which an undergraduate had been allowed to design a full-scale plant worth millions of dollars. None of the several layers of engineering managers who should have been checking the student's work corrected it, nor even asked why a student was leading the job and offering such an unusual design. When I questioned this, I was told "She is like a tiger!"This was clearly quite a formidable student. However, no amount of force of personality can be an effective substitute for a grasp of the facts, together with the training and experience to know what to do with them.

Poor Underlying Data
Poor data is another major cause of bad design, and foremost amongst the sources of poor data are salespeople. Whilst technical sales staff in firms selling well-established products can be an excellent source of reliable information for detailed design, there are risks in relying on the data provided by sales staff, even when they are acting in good faith.

Salespeople may not be aware when the information they provide is inappropriate, outdated or just plain inaccurate. They may also provide data which is selective or statistically insignificant, or omit key facts.

Some salespeople may offer advice on matters they do not fully understand. Whilst their knowledge of the manufacture, operation and testing of their products and how they might be adapted to suit a particular design should be highly detailed, their other knowledge may be secondhand, anecdotal, ill-understood and unsupported by their training or experience.

A minority of salespeople with more questionable ethics tend to be found most commonly in the world of novel products and processes. From my experience I would suggest that warning signs might include a lack of full-scale reference plants or independent reviews of the process on offer; a lack of transparency around the fine detail of the process; the salesperson having no relevant professional or trade qualifications; and the sales literature claiming that the product can, almost magically, resolve a longstanding problem.

Under design

Disputes often arise where a purchaser buys a process plant of one sort or another without specifying a performance test against set criteria before handover. All too often I ask a client if the plant which is not working ever worked and they simply don't know, because they accepted it without a satisfactory performance trial.

Similarly, clients may be unclear whether their plant is actually working or not. Many clients maintain that plants work "work most of the time", when sample analyses show that the plant does not always meet specification. Even when every sample analysis fails, a client may remain convinced that the plant is working the rest of the time.

This sort of frequent plant failure is most commonly an issue of under design. The designer should have designed the plant to plant to work as much of the time as specified in the brief (most commonly 100% of the time, though there are exceptions to this). However, the cost of each incremental improvement in treatment efficiency rises exponentially, so under design is tempting, especially in markets as competitive as water treatment.

A plant which has been under designed may "work" some of the time, but "working" – to an engineer - means meeting specification at all times, and the specification usually includes acceptable ranges of availability and product variability. Working some of the time is more properly called "not working" from an engineer's point of view, though non-engineers may have another opinion.

Inappropriate crossover from other sectors

Sometimes, in my engineering sector, plants do not work because someone – often from the oil and gas industries - thought that water treatment plant design was an easier variant of the sort of process design they are expert in.

In my professional life I have seen many effluent treatment plants designed by experts in the design of paper mills, refineries, and various other kinds of manufacturing facility (rather than in effluent treatment). These plants are often needlessly expensive, lack robustness, and miss the basic tricks of the specialist.

For example, the designs of non-specialists tend not to fare well when any non-liquid enters their pipe work. Pipe blockages, (such as the fatbergs which appear in the national press from time to time) are the key reason water specialists make far more use of open channels than other process designers. I have seen non-specialists learn the hard way why open channels are used on more than one occasion.

In addition, specialists know how to design to handle feed variability – or what goes into a plant. We tend to add far more buffering capacity to our plants than non-specialists, to deal with potential variability in flow and composition of feed, and the increased possibility of unscheduled maintenance. Non-specialists may try to surmount this issue by simply making everything much bigger than it needs to be, but many items of plant can be too big as well as too small.

The fallacy that water treatment plant design is easy leads to another trope: the notion that it is an ideal starting point for a new designer. This may seem cost-effective, but graduate chemical engineers usually have very limited knowledge of water chemistry, as well as the equipment used for water treatment, biology and statistics. By the time companies have paid for the correction of the mistakes based in this lack of knowledge, they may have spent many times what it would have cost to employ an expert.

My Working Methods

Site Investigations

I always insist on a site visit when carrying out an expert witness engagement, even if a plant no longer physically exists. There are several factors which cannot be determined remotely, and should always be personally and directly verified. I list the most important of these below. In my visit to site, I always ask to see Operating and Maintenance (O+M) manuals, and to interview as many operators, managers, and technical support staff involved in the process as possible.

If possible, operators should be interviewed individually, and informally, using open ended questioning to encourage them to speak fluently about day to day operations, as well as the occasional incidents, accidents, and emergencies.

Engineers love a war story, so it usually doesn't take too much encouragement to get workers to talk about what is really happening once they are out of the earshot of management. You may however have to exercise discretion when reporting on how you found out certain things!

It is telling if nobody on site knows where the O+M manual is, if it is found dusty and neglected on top of some filing cabinet, or if it has been hand-amended by operators. I see all three of these situations frequently in troubleshooting and expert witness work. They suggest strongly that the plant is not being operated in accordance with its designers' intentions.

Whilst O+M manuals are frequently neglected, or even lost, all but the very worst sites have a maintenance log kept by operators. This is usually kept in a logbook, most commonly by hand on templates in a loose-leaf folder. The handwriting is frequently illegible, and I will often need to ask for a transcript in order to decipher it.

However, once deciphered, these logs are often very informative, and I prefer to have read them before interviewing the operators, as the logs tend to contain an unselfconscious account of what operators have actually been doing, rather than what the O+M manual says they should have been doing.

If an O+M manual can be found, I ask how many of the present operating and management team were trained in plant operation by the company which constructed the plant. I also ask how many of them worked alongside the commissioning crew. This is often a place where operators learn tricks or shortcuts used in commissioning which are inappropriate to everyday operation, or where they gain access codes for instrumentation which management did not intend them to have access to.

The use of such tricks and unauthorized access to control levels which operators are not supposed to alter have been the cause of several fatal accidents in process plants. In effluent treatment, it is more likely in my experience that such interventions are at the root of mysterious problems which only occur when management are absent.

That said operators are often quite capable of inventing their own shortcuts to save themselves work. On one plant I saw, a high water content in thickened sludge was found to be due to the operators having changed the grade of polymer used, in order to produce a sloppier, wetter product which did not require periodical leveling (by operators) in the dumpster. That this doubled the costs of waste disposal bills at the plant was of no concern to the operators!

It is commonly the case that the staff I interview believe that they already know what the problem is, and will tend to offer only the data which supports their pet theory. Detailed questions are required to get past the usual pre-digested explanations to the basic signs and symptoms which allow me to make my own judgement on what might be happening.

The difference between a sign and a symptom is important. I would define signs as those things which I can observe directly, whereas symptoms are those things which operators (or in some cases management) feel might be happening. I rely on signs. Symptoms should be treated more cautiously.

Operators are not always wrong in their diagnoses, and their reports of symptoms do have evidential value. However, it is usually the case that if the problem really was understood well enough to fix it, I wouldn't have been instructed. I start by assuming nothing and taking no-one else's word for anything, to enable me to find the underlying cause of the problem.

When walking around the site, I am not just looking at and listening to the plant and how it is operated. I am also smelling. A repulsive smell of fatty acids will lead me to suspect inefficient handling of fats, oils and greases. Other specific smells, such as egg-like sulphides and thiols, cabbage-like mercaptans, fishy amines, and the 'pissoir' stench of ammonia all tell their own tales, usually of failures in biological treatment plant design or operation.

I will look out for examples of design elements which I know from experience are hard to control well, or actively create operational or maintenance problems. I will also be on the lookout for giveaway signs of poor maintenance, such as hammers on a string for 'percussive maintenance' purposes, or 'hammer rash' on equipment which has not yet acquired a hammer on a string.

I always ask for, (but rarely obtain) design data, design drawings and calculations, plant specifications, and purchase order documentation, which should make clear what the plant was originally designed to do. The best chance of finding these (or at least part of them) is usually within the O+M manuals.

I measure all the equipment, and use the same design heuristics as I use in early stages of plant design to estimate the capacity of each unit operation on the plant. These highlight possible design bottlenecks and often also design errors.

In the rare cases where design information is available, I compare that with what I have seen and measured on site.

Once I have gathered all this information, I am usually able to start to generate some candidate theories about what might be going wrong. These might involve problems with design, construction, operation or maintenance, or combinations of these.

I then need to work out how to rationally decide what the problems are. If I am acting as a troubleshooter, I will need to devise ways to fix the problems, whereas an expert witness instruction will tend to focus more on why the problems occurred in the first place.

Expert Witness Conduct

Whether I am troubleshooting or carrying out an expert witness engagement, I am frequently surprised in reviewing the reports of other experts by how little information other engineers have gathered before being willing to commit a professional opinion to paper. Many experts in my field seem willing to offer an opinion supported by a statement of truth without doing any of the things I have listed above, in areas far from their professional experience.

In my field there is also a plethora of retired engineers who have effectively become experts in being experts. I am frequently surprised that such individuals are never challenged on their currency in a profession they retired from decades previously, and instead appear to be spending their retirement producing substantial numbers of cheap, short reports mostly consisting of the same boiler plate for every case.

I find that when other experts of this type are faced with an opinion based on a more rigorous analysis than their own, the more professional among them tend to vary their opinion. They will generally be able to do this without worrying too much about their client suing them because their reports will have been drafted in such a way as to allow this, being heavily caveated and written in quite careful language.

Their less careful brethren, however, may be forced to stand their ground, even in the face of a more robust analysis, otherwise they may find themselves open to the possibility of legal action themselves, if their report gave a client an unreasonably optimistic view of its chances of success in court. I have been in court watching the cross- examination of such an expert and it was painful to observe. How much more painful it must have been to experience.

As for those 'experts' without qualifications, experience and training, I have on occasion been required to have a "meeting of experts" with amateur advocates who sought to undertake horse-trading on both the facts and my opinion on the matter. As the recent case of Andrew Ager showed, it is possible for an entirely unqualified person to operate as an expert witness for a considerable time. With 98% of cases settling short of court, it might be a long time before one's expert evidence is truly tested.

Lastly there are the "experts" selected solely on price. I have never faced one of these in court, though I have had to exchange reports and attempt to conduct a meeting of experts with them on more than one occasion. All cases involving them in my experience were settled before the evidence was tested. The plainly partial and unsupported opinions expressed in their reports and their sometimes overtly abusive behavior in meetings of experts would not have done their clients any favors in a courtroom and certainly would not have aided the court's understanding.

Sean Moran
Sean is a chemical engineer of twenty-eight years standing with a water and environmental engineering specialisation. His background is mostly in the design, commissioning and troubleshooting of industrial and municipal water treatment plants.

He has produced three books on process design for Elsevier. His first book was " An Applied Guide to Process and Plant Design". His second book was an update of the classic Mecklenburgh's "Process Plant Layout". His third book, "An Applied Guide to Water and Effluent Treatment Plant Design" came out in 2018. The second edition of his first book has just gone on sale, and he is presently making a start on his new book, A Dictionary of Chemical Engineering Practice.

He is a trained and experienced expert witness.

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