Commissioning after major rebuilds and new constructions

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Keywords: Commissioning

ABSTRACT

Commissioning is often the most difficult part of a capital project because although it is almost always possible to construct a plant, until it is complete there will always be some uncertainties about how a one-off system will behave.

Unfortunately, planning for commissioning is rarely as thorough as for other stages of the project and there is always pressure to get the finished plant on-line as soon as possible.

Further, in many organisations there are a limited number of people with experience of commissioning, because large projects are infrequent.

Together these factors often lead to inefficient and even damaging strategies being applied.

This paper discusses strategies and the development of skills that will usually result in more effective commissioning.

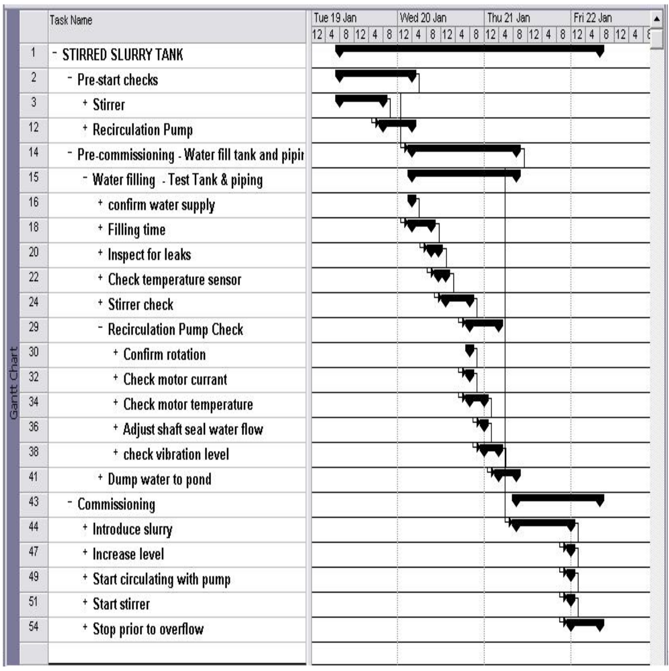
INTRODUCTION

Many capital projects, both for new plants and for substantial rebuilds, proceed quite well until attempts are made to go on-line. At this point there are often prolonged difficulties in achieving design performance or even in getting sections of the plant to work at all.

Our experience from many projects is that this occurs for two related reasons.

Firstly, commissioning a new plant is inherently the most uncertain part of the project. Construction may have its difficulties, but there is little danger that the plant cannot be put together as designed. Projects such as the Sydney Opera House, in which the technology for forming the sail elements had not been resolved when construction commenced, are rare. However, the finished plant will almost always be unique in some ways – often in many ways, and there is no certainty that every possible adverse interaction has been identified, let alone planned for (experience shows that it is very rare for every possibility to be covered).

Secondly, although great care is taken in preparing design, procurement and construction schedules, often little thought is given to planning of commissioning. On even the most elaborate project schedules, commissioning is usually represented by a single bar. Worse, delays in construction are frequently 'overcome' by 'we will reduce the commissioning time'. The project schedule chart below illustrates that even a simple project deserves a well planned and clearly defined commissioning schedule.



A prolonged or difficult commissioning can severely reduce the net present value of a project and result in considerable deterioration of the equipment. Therefore it pays to be well prepared for starting up the plant.

Generally there is a minimum time for any start-up. Efforts to reduce this time will be less cost effective than ensuring that resources are available to address unanticipated upsets.

This paper will attempt to describe some of the measures that can be taken to improve the commissioning/start-up procedure.

GOOD START-UPS BEGIN WITH GOOD DESIGN

It seems an obvious precursor to any capital project is good design. However the seeds of start-up difficulties may lie with decisions taken in the pre-design and design phase. Too often heroic assumptions are made from pilot plant data. Too often materials handling equipment in particular is selected without real knowledge of how it will perform with the media being handled. Too often inadequate spare parts are specified due to unrealistic expectations about equipment performance and ignorance that damage can occur for many reasons.

Proper design will also acknowledge that start-ups require some services and items that are not needed for stable operation. The design will also acknowledge the ways in which plant operation is different during start-up.

Failure to allow for this can have severe consequences.

An example

A new pulp mill included dimple plate, falling film, multiple effect evaporators.

The plates are very fragile and the operating manual stressed the need to maintain proper level in condensate trough: too low and pump damage, too high and hammer in dimple plates and danger of damage.

There was a very short residence time in each trough and maintaining control in the acceptable range was very difficult. This difficulty was exacerbated because the level indicator/controllers were only ranged over ‘ideal operating range’.

- During start-up, the flows are erratic (6 stages counter-current flow, vapour from one stage is the heat source for the next).
- Condensate levels rapidly went out of range and loud hammer was heard. The steam rate was eased back, with the result that level was lost, pump flow was lost, and the level went high again.
- The controllers were only proportional over a narrow level range - then ‘bang-bang’ – this added to instability.
- The commissioning crew never had any idea where the condensate level was.
- Commissioners were trying to fix it for six stages at once!

The manufacturer’s solution was to advise that:

- Avoiding hammer is only during operation for long period, and it “Does not matter” during start-up from cold.
- Make the system “CRASH THROUGH”
- Hammering was allowed and eventually system stabilised.

The consequences of this action were as follows:

- The system never performed quite to expectations.
- After several years operation, it was discovered that many of the welds on the plates were cracked (inspection of the plates was very difficult because of limited accessibility, so the damage was not discovered until well after all warranties had expired).
- Expensive repairs were required.
- The plant had been damaged before it was in regular use.

The design of the evaporators was adequate for steady state operation, but totally impractical for start-up from cold. These difficulties could have been overcome by some relatively simple design changes:

- Larger, deeper condensate trough (probably the cheapest component of the system).
- Second level indicator/controller with much wider range, would have shown what was happening. The main loop would only be active when level is in range. The manufacturer had built dozens of evaporator systems of this type before.

There was no excuse for this poor design as the manufacturer had built dozens of evaporator systems of this type before. They knew of the problem of plate fragility. And they had seen the problem of hammer due to problems of level control before.

TIME PLANNING FOR COMMISSIONING

When an existing plant is shut for routine maintenance or minor modifications the subsequent start-up should be straightforward, and take ‘about as long as last time’ but in reality unexpected problems often occur and getting back on line can take much longer than expected.

With a new plant the estimation of a realistic commissioning time is considerably more difficult as there is no past experience to act as a guide, and it is to be expected that things will go wrong in unexpected ways.

When trying to make a reasonable estimate of the time that will be required for commissioning, it is suggested that the following approach be used:

- Try to identify everything that might go wrong. Techniques similar to HazOp can be used in this task. Not everything will be anticipated, but the list should be as full as possible.
- At this stage do not eliminate the improbable – these are likely to be the ones that really upset the start-up program.
- For each event, estimate:
    - Probability of its occurrence.
    - What can be done to prevent it (e.g. in design/construction, or start-up program – changed method of start-up)?
    - What would be required to minimise the consequences (spare parts, special equipment, expert assistance available)
- Carefully consider the balance of:
    - Probability of occurrence,
    - Cost of occurrence,
    - Cost of prevention,
    - Cost of being prepared for it.
- Prepare an action plan accordingly.
- Sometimes it will be worth being prepared for low probability, medium-cost consequence events because the cost of preparedness will be very small (e.g. a few days extra on site for manufacturer’s representative) or negligible (e.g. precautions for a more serious threat will also cover this one).

On the basis that everything has been identified (it has not) prepare a realistic program:

- A base time that could be met if nothing goes wrong.
- Additional time for identified possible problems multiplied by probability of occurrence (be careful of problems that are not really independent e.g. fouling of a heat exchanger and poor conversion in a following reactor are probably related).

Now add a sensible time for the unexpected. The time to be added will depend on circumstances, for a complex plant values **might** be:

- +10% for restart of existing plant after maintenance only.
- +50% after substantial modifications or for new plant of established type and familiar feedstock.
- +100-200% for new process or feedstock.

This is the contingency time – any key performance indicator not making these allowances is relying on luck alone.

This is the time that the task of commissioning can be reasonably expected to take and any pressure from outside must be strenuously resisted.

A Gantt chart (or similar) should be used for commissioning if the minimum time and critical factors are to be identified:

- ☐ Identify the sequence(s) in which items must be commissioned/started.
- ☐ Identify the resources (people, equipment etc) needed at all times (avoid the conflicts when three groups all need the e.g. sonic flow meter on the same day).
- ☐ Modify the plan to something realistic.

PRE-START UP SAFETY REVIEW

In many jurisdictions a formal PSSR is a legal requirement, and even if not required by law it is a wide searching and useful exercise which will indicate not only whether a plant is safe, but also whether the plant is ready and able to be commissioned.

It is wise to perform a PSSR under the same circumstances as a HazOp would be indicated:

- ☐ For any new facility.
- ☐ For any substantially modified facility.
- ☐ For any facility modified in a way that may affect safety.
- ☐ Desirable after any major shut.

The nature of the review and the amount of detail required will depend on the work that was undertaken during the shut, but will normally include some or all of:

- ☐ Standard operating procedures.
- ☐ Safe work practices.
- ☐ Maintenance procedures.
- ☐ Emergency measures and procedures.
- ☐ Training standards of crews.
- ☐ Drawings, operating and safety procedures up to date?
- ☐ MSDS provided?
- ☐ Equipment and installation in accordance with design and applicable codes.

From the list above**,** the value of good operating instructions prepared well in advance cannot be stressed too strongly in ensuring a good start-up. They should be prepared well in advance and be constantly updated. Many potential start-up problems are in fact identified at this stage.

HAZOP

A Hazard and Operability study should be undertaken at least twice during the design of a new or substantially modified plant. For more minor changes it will probably be sufficient to perform a HazOp before the work program is finalised. It is also wise to perform a partial HazOp whenever major changes are made during the design process and a final Hazop when the plant is almost complete – on an 'as built' basis.

Although there are some similarities between a PSSR and a HazOp, they are really addressing different issues and having performed one does not remove the need to perform the other.

PRE-START INSPECTION

Even after minor shuts it is essential to walk the plant looking for safety issues, incomplete work and other things that might affect start-up.

This inspection is not undertaken according to any particular check list and can include anything that is noticed, but specifically it is to include:

- ☐ No slip/trip fall hazards.
- ☐ All fire equipment accessible and in place.
- ☐ Adequate access space.
- ☐ Adequate lighting (night inspection required).
- ☐ Electric panels' accessibility.
- ☐ Warning signs in place.
- ☐ Safety rails, kick rails safety cages, gates etc.
- ☐ Safety showers and eye-wash stations.
- ☐ Drains clear and covered.
- ☐ Housekeeping.
- ☐ Guards secured.
- ☐ Nips guarded.
- ☐ Field controls, switches, valves accessible and working.
- ☐ Insulation sufficient, adequately installed. Cladding suitable for location.
- ☐ Interlocks working.
- ☐ Access panels secured.
- ☐ Labelling complete.
- ☐ Equipment properly held down and grouted.
- ☐ Electric grounding in place.
- ☐ Construction waste and tools removed.
- ☐ Noise standards met.
- ☐ No sharp edges or pinch points.
- ☐ Spades, isolations etc removed.

SPEEDING COMMISSIONING AND CRASHING THROUGH

There is usually pressure to accelerate commissioning by any means as this can accelerate hand-over from the project to operations. There are times when this acceleration can be very damaging in various ways. It is common experience that there is more wear and tear on a new plant during commissioning than in 5-10 years normal operation. Any measures that will worsen this effect must be resisted.

When things are going badly there can be a great temptation to force the pace – pushing on although the plant is not behaving as it should, or shortening warm-up times etc to catch up. This is often called "Crashing Through'. This is always a risk and sometimes a serious risk. However, sometimes certain types of crashing through may be justified.

Crashing through usually involves either mechanical crashing (over-stressing of equipment) or process crashing (working outside of stable conditions) and sometimes both occur simultaneously.

Mechanical crashing is an attempt to accelerate the path to steady operation by mechanically over-stressing equipment. E.g.

- ☐ Rapid heat-up with the risk of differential expansion damage or refractory failure.
- ☐ Accepting hydraulic hammer, cavitation.
- ☐ Running beyond design pressure, temperature, torque etc

This approach is very rarely justified. It presents significant risk of expensive damage to equipment, or at best of shortened equipment life. The only potential gain is a small amount of time and there will usually be large penalties at a later date (or even on the current date!).

The need for this approach is a consequence of poor design, or **more often** inappropriate objectives (such as getting the plant running by a particular date rather than considering the life-time performance of the plant).

Process crashing through is attempted when the process goes unstable or through an undesirable stage as it is brought up to capacity and the problem is solved by pressing on in the expectation/hope that it will stabilise as it reaches design capacity. Some common examples are

- ☐ Foaming in evaporators at low concentrations.
- ☐ Unstable condensate levels and intermediate steam flows in multiple-effect evaporators.
- ☐ Unstable product size in pelletiser circuit

In such cases the system can usually be brought to steady operation by slowly allowing equilibrium to be approached and/or by operating at a very low rate for some time. Sometimes there is the alternative to press on and rapidly bring the equipment to design inputs and then wait for the equipment to settle – although some over-riding of normal control actions may be required.

This approach can save a lot of time, but is not without its risk because the system can become choked with off-spec material and need to be shut down and cleaned out before a fresh attempt is made (e.g. evaporator foam-over contaminating condensate system, excessive fines throughout a pelletising loop etc). Another problem that can arise is fouling of heat transfer and slurry systems (e.g. over-heating of exchangers with inadequate process flows, slime build-up in rising sections of slurry equipment).

Sometimes the consequences can be more serious because carry over of material from a stage which is not working properly can damage or interfere with the operation of downstream equipment. Typical examples include:

- ☐ Evaporator carry-over causing corrosion, or plugging of mesh entrainment separators.
- ☐ Un-reacted chemical components poisoning catalysts.
- ☐ Solids carry-over eroding pumps or vacuum pumps.
- ☐ Hydraulic hammer.

It will be apparent that many of these problems are equivalent to those resulting from mechanical crashing through.

In almost every case that we have observed the problems only arose because the design of the plant did not make proper allowances for the special requirements of commissioning and start-up. Although we consider crashing through to be rarely justified, there are other ways of speeding the overall commissioning process that can be very effective.

ACCUMULATING PROBLEMS

During most commissionings there will be problems that require a full or partial shut to resolve. This can be managed in two ways:

- ☐ After each fault is found, necessary parts of plant should be shut and the fault rectified. This will ensure that subsequent commissioning are on plant that is nearly right and will not be complicated by effects of 'temporary fixes' that create constraints that will not be seen later. Obviously this approach requires multiple shut downs and start ups and is very time consuming.
- ☐ Note faults and work around them in the short term. Then continue operation until the faults have accumulated to the point that you can no longer move forward. At this stage stop and fix everything at once. This approach is usually faster (sometimes **much** faster) but it can make some commissioning tasks difficult and even create apparent problems that don't really need to be solved. This approach may also exacerbate resource availability issues (labour resources in particular)

Despite the reservations, the 'accumulate until you can go no further' approach is usually the most effective.

PARALLEL COMMISSIONING

Start-up time can be significantly reduced by commissioning some units in parallel, instead of pure consecutive commissioning. However before this is attempted it must be recognised that this requires:

- ☐ More resources.
- ☐ Careful planning to take full advantage of time savings.
  - ☐ **Very** good communications between the various commissioning crews and with the commissioning captain[i].

Failure to meet these requirements ca**n** result in wasted time and break down of morale. When this happens, commissioning will take much longer than if the sequential approach had been used.

RETROSPECTIVE DESIGN CHANGES

Once the plant has been started a few times it may become apparent that plant was not adequately designed for start up. This can be due to neglect at the design stage or because of problems that were not previously apparent. In either case, this is the time to correct these design deficiencies.

[i] The selection of the commissioning team members, and particularly the necessary skills of the Commissioning Captain can have an enormous effect on the efficiency of commissioning, but this is outside the scope of the present paper.

Remedial work may not be expensive, but may be more difficult from a management point of view than technically. The designers may resist rework because they are reluctant to admit errors. The project manager may be reluctant to spend more money just as he/she was hoping to close off the project accounts. Optimism can keep people persisting with an unsatisfactory plant.

Experience suggests that if the problems persist, it is much less costly overall to make the changes than to accept persistently prolonged and damaging start-ups.

An example

- ☐ An expansion to a pulp mill included extra Multiple Effect Evaporators. It also involved an increase in proportion of pine to hardwood processed.
- ☐ The evaporators foamed badly and difficult to start up the (extra pine increased foaming, but the problem goes away once evaporators are working and concentration of liquor rises).
- ☐ This foaming resulted in large quantities of contaminated condensate that severely overloaded the effluent recovery system.
- ☐ Solution – retrofit a 'sweetening' line – recirculates some product to feed so that feed concentration is above foaming region. This soon solved the problem.

SAMPLING AND ANALYSIS

"*What you cannot measure you cannot control"*

Well before commissioning begins it is useful to spend some time thinking about possible problems, and how samples can be taken to test the extent of the problem. If there is no provision to take meaningful samples then action must be taken to cure this well before the plants is commissioned, and beware that sample points are often requisitioned for use as pressure tappings or flushing points.

An example

- ☐ A new pulp screening was installed but there were no sample points between stages – too expensive.
- ☐ The system would run, but its performance was poor.
- ☐ Technical Department was asked to fix it but said they could not because they had no way of knowing what was going on.
- ☐ Sample points were then installed; the system was soon optimised and subsequently performed well.
- ☐ Penny pinching in design cost money by delaying start up.

Arrange to do as much analysis as possible on site - and around the clock because rapid analysis greatly improves progress in problem solving. (Many lab instruments that will not be required once the plant is settled down can be hired for a few months).

Make sure that people know how to perform the tests properly and that there is access to people who can interpret the results – numbers alone are of limited value.

For analyses that cannot be done in-house, arrange for outside analysis.

Make provisions for quick turn-around and week-end work where necessary. Government laboratories and universities are not usually geared to week-end work and universities are rarely geared to rapid turn-around by industrial standards. Privately owned labs are usually better geared to rapid work and out of normal hours service – but may not have the interpretation skills.

Remember, some tests inherently require quite a long time to complete (e.g. BOD5)

Some consultants provide both engineering support and chemical and physical analysis. Using these can expedite trouble-shooting as the engineers, scientists and analysts are used to working as a problem solving team. If this capability is available in-house it is even better.

EXECUTION OF COMMISSIONING PLAN

Earlier in the paper reference was made to preparing a Gantt chart for commissioning.

Once commissioning starts it is important to work to the plan, to track actual progress against the plan and to modify the plan as necessary (modifying is the opposite of abandonment of the plan, which far too often happens in real commissionings).

- ☐ Work towards the plan but with NO allowance for problems as you go.
- ☐ If the first stage has gone without problems, the project is now ahead of schedule, but it is essential to maintain pressure on the commissioning rate because larger than anticipated problems may still be ahead (as already noted, the plan is very much an 'averages' exercise – what is gained in one place will probably be lost elsewhere).

Overall, commissioning will probably take about as long as predicted by the methods presented above:

- ☐ If ahead of time – this is a bonus
- ☐ If falling behind time – CONTINUE WITH PROPER PROCEDURES – Except in special circumstances DO NOT attempt to "crash through".

DEVELOPING TROUBLESHOOTING SKILLS IN COMMISSIONING

When things go well, commissioning does not require any special skills. However, most commissioning exercises present multiple problems and a successful commissioning is not one in which there were no problems as much as one in which problems were solved rapidly. This requires the development of some special problem solving skills

Troubleshooting during commissioning is not unlike that in an existing plant – with one important difference: with an existing plant you know that it can be made to work (it used to work until the problem arose). Therefore troubleshooting often comes down to identifying what has changed and how to accommodate the change. The troubleshooter can be fairly confident of eventual success.

With a new or significantly modified plant there is not the luxury of knowing that you are attempting the possible. Regrettably, occasionally a plant is built that cannot be made to operate in its original form within an acceptable time frame. Fortunately this is quite rare, but prolonged commissioning because of unfamiliar problems is much more common.

As with many practical skills, the main way of developing commissioning expertise is through practice. The learning process can be accelerated by watching how more experienced commissioners work.

Some organisations do not have enough experienced commissioners, but there are many experienced commissioners who can be hired as consultants, and their skills are fairly portable across industries. (The hirers can learn by watching them at work).

Significant equipment changes should have an expectation to involve the equipment supplier at all stages. Often the equipment purchase price includes some level of technical and commissioning support. Alternatively support can be negotiated with the supplier. In either case the technical representatives of the equipment suppliers should be one of the most valuable resources utilised for smooth start-up and trouble-shooting. They know the equipment much better than you do and will have seen most of your problems (or similar ones) previously.

Good suppliers will be interested in how their equipment integrates with the rest of the plant, in getting a smooth commissioning and in controlling your costs. There is an element of self interest in getting repeat business but usually a genuine interest in their job and customer service.

Supplier technical representatives can help you with problems outside of the contract. There may be a fee for this service, but it is almost always good value for money.

It is generally not wise to deal with a supplier company that operates on the basis of a buyer beware principle. However if that is the case, suitable retention money should have been negotiated to ensure that there are options for a quick fix so that commissioning is not further delayed..
There are some useful guidelines that can accelerate the learning process:

- ☐ Remember your theory – often problems relate to obscure fluid flow phenomena or peculiar chemical effects. Also remember heat transfer – it is remarkable how many heaters don't perform properly because inlet steam is not saturated (especially at low load).
- ☐ There are common, simple causes of problems that can be checked (despite these having already been checked in pre-commissioning:
  - Motors run backwards – not always apparent at very low loads.
  - Impellers are not always attached to shafts.
  - Cavitation is often due to rubbish in the inlet line (not just because the liquid is too hot, or the head too low).
- ☐ Heat exchangers can foul-up very rapidly from debris left in tanks or deposits formed from upsets in other equipment.
- ☐ Valves do not always stroke properly, act in the right direction, or seal when closed (look for welding rods trapped in trim).
- ☐ Saturated steam passed through an almost closed valve becomes superheated. Superheated steam is a very poor heat-transfer medium. Heat exchangers seem to be too small even at low duty.
- ☐ Lines that were cleared during pre-commissioning may now be blocked.
- ☐ When instruments seem to be reading incorrectly, this may be true. Small pieces of PTFE tape for plug holes in flow meters. Little bits of string (reinforcement from rubber belts) can jam flow switches open.
- ☐ Non-return valves can be very unreliable.
- ☐ When several contractors are involved troubles will often arise at the interfaces – each will blame the other and progress will be slow.
- ☐ Having one primary contractor and making others sub to that contractor increases initial cost but does not necessarily solve this problem – it just moves the arguments from one site office to another.
- ☐ Where new plant is added to old plant, take the time to determine how the old plant works, and whether it really works the way the supervisors think it works.
  There are few challenges worse than old plants connected to new ones where the old plant does not perform at anywhere near the level that people have claimed for years (nor is this uncommon).
- ☐ Modern instruments can be bad news because they are so flexible!
  People will put in data that may be wrong as their logic is that it can easily be changed later. "Later" can sometimes turn out to be "some months later" with a whole lot of hassles in between.
- ☐ Data logging can be a great help, BUT:
  - The quantity of information can hide the problem (it is very useful to have available someone who is good at statistics).
  - At first, many of the logs will have the wrong tag numbers. It is surprising how difficult it is to spot this (flows, temperatures, pressures, concentrations all tend to move together during start-up).
  - Instrument engineers are usually busy fixing instrument and control problems – fixing historic records is low on their list of priorities.

EXAMPLES

The paper will conclude by presenting some real examples:

Poor pump performance

In a long-established plant, one section was shut for routine maintenance. On re-start one pump had poor performance and delayed the entire plant. The motor had been removed and re-fitted. Reverse running was suspected:

- ☐ A very competent rotating machinery expert checked the unit and pronounced correct rotation.

- The wiring of the motor was checked and found to be correct. The problem persisted for over a week
- Eventually it was found that the wires were incorrectly connected at the MCC (a mistake apparently made several years before).

The problem had previously been 'fixed' by reversing the wiring at the motor.

One problem – several causes

A fluid bed incinerator used a circulating load of ferric oxide as a reagent. Some of this broke down to dust and was fed to a pelletiser to reform the required particle size.

The system did not work well – initially the dust formed pellets that broke-up when returned to the bed – when this was fixed the pellets were too large.

The problem was solved – rather a lot of times!

- Iron oxide previously was pelletised with a binder incompatible with new process
- Salt in system
- Dust too hot
- Dust too coarse (maybe)
- At this point a new sub-process of screens and grinders installed
- Pelletiser too steep
- Even with expert advice and lab proof of problem this last issue was never addressed

Several problems - one cause

Sometimes a fairly minor problem in one item of equipment can create problems well downstream – some of which can be quite obscure

A long established plant underwent a major rebuild – including an upgrade to a lime kiln. The new oil-burner did not work well initially resulting in poor kiln product quality.

The sequence was then as follows:

(1) The kiln product contained some quicklime plus a lot of unburnt limestone.

(2) This went forward to the slaker-causticiser and built up in the bowl (i.e. the grits removal system overloaded)

(3) The agitator in the bowl then overloaded and stopped.

(4) The only way to remove all the unburnt limestone was to dump it to a small floor drain.

(5) This resulted in the drain filling up with unburnt limestone and lime mud.

(6) The level in the drain backed up and lime mud slurry was sucked back up the condensate line from the atomising steam supply to the burner. *How did this happen? - presumably the steam line had been turned off to have a look at the burner?*

(7) This then made the burner run even more poorly.

CONCLUSIONS

This paper has attempted to demonstrate:

- The need for proper design and planning for commissioning.
- The problems that can arise from improper commissioning strategies.
- That better strategies are available
- Special skills must be acquired for effective commissioning.

The results of effective vs. ineffective management of commissioning (and the events leading up to it) can be illustrated by the following table of the outcomes of eight projects.

<u>Risk assessment (risk to your reputation, and/or health and temper</u>	Rating out of 100% 0% = bad, 100% = good						
Rating out of 100% 0% = bad, 100% = good Capital cost (2009 $ approx)	A $20M	B $250M	C $0.75M	D $2M	E $3M	F $100M	G $90M
Standard technology or process?	90%	95%	50%	100%	100%	75%	5%
Modifications/fixing process problems involve long delays? *(eg heating up/cooling down, emptying flammable solvent)*	No 100%	Yes 0%	Yes 0%	No 60%	No 100%	Yes 0%	Very long -25%
Do I have faith in the competence of the designers?	100%	100%	90%	100%	50%	100%	20%
Do I have faith in the competence of the commissioning team?	95%	100%	100%	100%	90%	90%	60%
Do I have faith in the competence of the project manager?	90%	90%	100%	40%	50%	100%	25%
Do I have faith in the competence of the operators?	90%	90%	80%	20%	60%	0%	0%
Has the project been fast tracked?	No	No	No	No	Yes	No	No
HAZOP conducted? Were the right people at it?	Yes 95%	Yes 80%	Yes 100%	Yes 40%	No	No	???
Any unexpected major problems?	No	Yes	No	No	No	No	Lots
<u>End result</u> How long was it before project settled down? % of target output and quality achieved Addition Damage done to equipment/raw materials loss, fuel wasted **RANKING**	4 weeks 100% 660% None **1**	2 months 90% 555% Small **2**	2 weeks 100% 520% None **3**	2 weeks 100% 460% None **4**	2 weeks 90% 450% V small **5**	Months 90% 365% Small - med **6**	Years 70% 85% V large **7**
LEVEL OF FRUSTRATION	V small	Small - medium	Nil	Small	Small	Medium	Very large