The Engineering and Management of Retrofit Projects in the Process Industries

European Construction Institute

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All European Construction Institute referenced documents are available from ECI at the above address.

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Foreword

Author's note

My career as an engineering project manger has included responsibility for new build and retrofit projects. It became apparent to me that, other than issues related to the scale of work involved, the retrofit project has often provided additional and different challenges and risks; yet they often receive limited attention from senior business management. Equally it appears that there is very little published guidance specifically addressing how retrofit projects need to be engineered and managed and hence my decision to prepare this handbook.

It is clear that retrofit projects, whilst diverse in their scale and complexity, do generally provide a greater challenge than conventional new build projects. The key conclusions from my research in developing this handbook can be summarised as follows:

- The engineering and management of retrofit projects requires an experienced team of staff with the relevant skills and motivation. It is likely in many cases that the engineering and management effort required will be proportionately greater than for a new build project.
- Retrofit projects are inherently exposed to an additional set of risks (safety, extra work, costs, schedule etc) which require active management if the project outcome is to be optimised.
- As for other types of project, the quality of the definition package and associated planning has a significant impact upon the ability to progress implementation with the minimum of surprises, leading to a successful outcome.
- Proactive involvement throughout the development and implementation of the project by operations and engineering staff from the plant (or facility) with which it is associated will have a significant beneficial impact on outcome.

It is my sincere hope that these findings together with the much more detailed information in the body text of the handbook will allow all those associated with retrofit projects to understand them better and thereby improve the likelihood of success.

The contents of this handbook are substantially based upon my own experience and this certainly includes learning from both successes and mistakes; any deficiencies are mine. Nonetheless the content has been greatly enhanced by valuable advice freely given to me by a number of experienced professional engineers based upon their experience. Listed below are those who have provided this support and to whom I express my sincere gratitude.

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1. Introduction

"It is not the strongest that survive, nor the most intelligent, but the ones most responsive to change." Charles Darwin.

"It is not necessary to change, survival is not mandatory!" W Edward Deming.

These comments are entirely valid in the business environment. Carrying out projects is one way to respond to the need for change in business requirements, and therefore those businesses which are most effective in executing such projects will gain an advantage.

A retrofit project is one where the scope includes modification, enhancement, extension or other improvement to an existing entity rather than the creation of an entire new entity (though the work may also include new entities). Such projects are common throughout the building and manufacturing industry and especially so within the process industries.

Within the process industries complete new plants and their supporting infrastructure are capital-intensive investments which typically are intended to operate for 30 years or more. However, within a much shorter time span there arise requirements and/or opportunities to make changes that will enhance the performance, reliability, safety etc of the plant and hence the need for retrofit projects. The infrastructure which supports process plant requires to be updated for similar reasons.

An owner of process plant is likely to sanction many more retrofit projects than complete new plants. The scale of such retrofit projects is generally smaller than for new plant, though this varies immensely from tens of millions of pounds/dollars/euros to a myriad of small projects with values down to a few thousand. The cumulative cost of retrofit projects may well match or exceed that of new build projects over a period of several years.

2. Purpose of the handbook

There is extensive literature addressing the development, leadership and management of engineering projects. However, most is focused on the requirements of major projects and therefore the issues specific to smaller, retrofit projects are either ignored or are at best given limited attention.

Whilst many features of retrofit and new plant projects are similar, there are some notable differences which provide additional challenges. The aim of this handbook is to identify and focus on those aspects which are different and address some of the engineering and management approaches which may be adopted to successfully address them. Issues which are common to all projects will be mentioned where appropriate, but there will be no attempt to address them in detail.

Given that the scale, scope and implementation requirements for retrofit projects vary dramatically it is essential that the project manager and their team select appropriate methodologies for the particular project. Some retrofit projects are relatively straightforward and it is not suggested that all of the issues and processes identified in this handbook should be applied to every project. The aim is to provide advice and support for use as appropriate and in some cases it may well be appropriate to adapt it to meet specific needs.

This is not a Safety, Health and Environment (SHE) handbook, but it will quickly become apparent that much of the content relates to such issues. Whilst the advice given is valid, it may not be sufficient in many circumstances and specialist advice should be sought.

3. Reasons for retrofit projects

There are many reasons for retrofit projects, but almost all are aimed at enhancing or securing the value of the facility to the business. Some more common reasons are listed below. It is sometimes the case that a retrofit project is authorised to address several issues at the same time.

- On completion of the original construction, the plant/facility is found not capable of fulfilling its original performance or SHE objectives and further work is needed to achieve this.
- Debottlenecking to increase production capacity beyond present capability.
- Requirement or opportunity to manufacture different higher value product grades.
- Modification to enhance plant efficiency.
- Replacement of components which significantly compromise plant reliability (on-stream factor) and/or have a high maintenance cost.
- Replacement of worn out or obsolete components with current specification components.
- SHE improvements as a result of identified deficiencies (including findings from incidents on similar plants) or in order to comply with new legislation.
- Repair (including improvements) following fire, explosion or other damage.
- Infrastructure modernisation.

4. Some common differentiating aspects of retrofit projects

The following list is simply a brief overview. The full text of this document identifies the differences in detail.

- Much greater physical interface with existing plant/facilities.
- Requires detailed knowledge of design and operating procedures for existing plant/facilities.
- Requirement for the selection of engineering standards and specifications for compatibility with existing plant is an issue.
- Number of tie-ins (connections between existing and new) is likely to be high relative to total scale of project.
- Some (possibly most) of the construction work will have to be carried out within, or adjacent to, existing plant and facilities.
- Some parts (possibly most) of the construction work will need to be executed in a strictly limited time period in order to minimise disruption to production.
- Precommissioning and commissioning will inevitably include not only the newly-installed elements but also some of the existing plant/facilities.

5. General good project management practice

The key elements of good practice generally applying to the successful management of new build projects are equally applicable to retrofit, and failure to utilise them effectively will almost certainly lead to difficulties in the execution of the project and possibly compromise the final outcome.

These general requirements include, but are not limited to:

- A clear, agreed set of objectives (and success criteria related to them).
- Good project development and definition.
- An agreed implementation strategy.
- A well-motivated project team with all the appropriate skills.
- Effective planning and progress monitoring.
- Effective utilisation of contractors and suppliers.
- Appropriate involvement and support of all stakeholders, especially plant operations.

The general requirements for effective project management are not detailed in this handbook, which confines its focus to the additional and different issues and procedures specific to retrofit projects.

6. Senior management support

All projects will benefit significantly from clear senior management support throughout their development and implementation; ideally this can be achieved by the use of a senior management project sponsor. The project sponsor should have a strong commitment to the objectives of the project, retain an ongoing, non-executive interest throughout its development and implementation and be able to provide support and influence with the senior management of the business when needed.

Even the best-managed projects are vulnerable to both foreseen risks and unforeseen events occurring, and whilst it is directly the responsibility of the project management to deal with them, the needed actions can often only be achieved with the support/consent of senior management. In the case of retrofit projects where there are additional risks and uncertainties, this support is even more important.

For retrofit projects some additional key aspects require active support. These include:

Client (owner/operator) senior management

- Agreeing objectives and priorities and avoiding changes to them. Agreeing the success criteria by which achievement will be measured.
- Recognising practicable limits of estimate accuracy and agreeing appropriate contingencies.
- Agreeing the management strategy for key risks and positive support to assist project managers in addressing unplanned developments.
- Acknowledging the additional risks of a fast track approach. Ensuring that a project does not end up becoming fast track simply due to delays in making key business approval decisions.
- Supporting the project manger in avoidance of non-vital changes to scope once the project is defined.
- Ensuring that there is commitment from plant operations and engineering staff to provide support at the times needed.
- Agreeing a realistic contracting strategy for a retrofit project.
- Recognising benefits of long term relationships with contractors.

Contractor senior management

- Ensuring that bids are based upon a full understanding of the scope and nature of the work and include a realistic projection of required resources.
- Ensuring that the client is informed of perceived deficiencies in scope definition at the time of tender and agreeing the approach to tackle these deficiencies.
- Ensuring that required resources (quantities and skills) are available when needed, including any additional requirements which may arise.
- Providing commitment to meet project objectives.
- Recognising the benefits of a long term relationship with client.

7. Initial development and project definition

For all projects, the provision of a good quality project definition is vital to the successful implementation of the project. Definition forms the foundations for the project and failure to ensure that it is adequate will almost certainly lead to difficulties at a later stage.

It is strongly recommended that a checklist is used both to assist in identifying all definition needs and as a tool to assess the quality of the definition for the project. Each item of the checklist can be evaluated for its degree of completeness and its importance to the project to produce an overall rating for definition. The whole project management team should work through the list and challenge one another. An example checklist is provided in Appendix A.

Where definition is significantly deficient, the project manager must make strong representation to the client not to proceed with implementation until the definition is improved. If such advice is ignored the project manager must point out the many additional risks which are involved in proceeding.

7.1 Identification of project objectives

Project objectives are often not fully clear for retrofit projects, yet they are the whole basis for the investment and hence just as important as for major new build projects. The following should be considered:

- Ensure all objectives are identified, understood and agreed by all relevant stakeholders.
- Prioritise objectives and determine which are vital and which are merely desirable.
- Do not confuse project primary objectives with other (highly) desirable aims. Primary objectives are the reasons the project is being considered/implemented and nothing more. Implementing the project safely will be important but it is not a project primary objective. Similarly, meeting budget will be important but is only a primary objective to the extent it compromises overall viability of the investment.
- What are the key factors which will determine success? If possible these should be quantified.
- Avoid objective drift (progressive inclusion of additional elements desired by individual parties).
- The extent (usually minimisation) of impact upon existing production may be an important secondary objective. If this is so, effort should be made to quantify this. This objective may need to be carefully evaluated as it can significantly impact upon project strategy and cost as well as the profitability of the ongoing business.
- Identify which parts of the project have absolute time deadlines. Are they truly absolute? (i.e. are extraordinary measures justified in order to achieve them?)
- A project which is on time and within budget, but which does not fulfil primary objectives, is a failure!

7.2 Feasibility studies, selection of preferred solution

Having identified the primary objectives, it is important to investigate all of the possible solutions for achieving them. Where possible plant modification/extension (retrofit) is involved it is often the case that there are a number of options and sub-options available which merit consideration. There may also be options which avoid any new capital investment and there may be options which do not entirely fulfil the objectives but are otherwise attractive. It is entirely possible that as a result of assessing options the primary objectives will be modified. In assessing options the following should be addressed:

- Identify those primary objectives which are absolutely vital (they absolutely must be completely fulfilled).
- For each option identify all its merits and demerits and where possible quantify them.
- Do sufficient evaluation of each option to check that it is technically or commercially feasible and has no major drawbacks (such as significantly higher capital operating costs or would require a very long implementation period). Also identify any significant implications for other parts of the business (i.e. changes in staff requirements, shutting down another facility).
- Ensure that a clear programme is agreed with business management for the feasibility/selection phase. Avoid this phase of work being unduly prolonged as it simply delays the overall project completion. Avoid doing work on multiple options beyond that which is necessary to make a sound comparative assessment.
- Ensure that everyone is clear as to who will provide what data and that they are committed to the required time frame. Much of the data required may be of a commercial nature, such as the financial impact upon the business of each option, the impact upon suppliers and/or customers etc.
- Recognise that at this stage cost estimates are likely to be no better than "order of magnitude" (±50%). This should not cause a significant problem as the use of the cost estimate is for limited purposes only:
    - To allow broad comparison between options.
    - To allow a (first pass) financial evaluation of overall commerciality.
    - If the option is preferred, to support application for development funding.

  It needs to be emphasised to all concerned that cost figures at this stage may well be significantly different than the final required budget.
- Where a comparison of different capital investment projects is a part of the selection process it may be valuable to involve an engineering contractor in the evaluation, especially if the client already has an alliance relationship with such a contractor. The contractor may have a better feel for (order of magnitude) costs, duration, extent of disruption the project will involve and any significant technical risks.
- Selection of a preferred option (for the achievement of primary objectives) should include all the key relevant parties within the owner's organisation. Assessment should include:
    - Agreement of the relative importance (weighting) of the various merits and demerits for each option.
    - Agreement where necessary to the revision of any of the previously identified primary objectives. For example, if it is discovered that very large capital cost would be incurred to achieve the desired increased throughput, but that 80% of the increase could be achieved for a much smaller spend, then this may by agreement become the new objective.
    - Agreement on the next steps. Where a single option has been clearly selected then usually the next step will be to confirm that it presents an acceptable means of achieving the objectives and then to proceed with detailed definition. Where it is not possible to make a final decision, further work may be needed on two or more options.
- Where the review of options results in a need for further work on multiple options, then it is important that the requirements for further work (in order to make a final selection) are clearly identified with an agreed timescale for completion. Dependent on the similarity of the remaining options, it may also be possible to commence the detailed definition works, to

the extent that this would be common for all remaining options. If detailed definition is not now started then the project is likely to be further delayed.

7.3 Existing design and engineering data

The design of retrofit projects will need to refer to existing data. The following guidelines should be followed:

- Identify data likely to be required. Check its availability and in particular how reliable the data is. Is it complete and up-to-date?
- If data is not complete and/or up-to-date, decide what measures will need to be taken to provide requirements. Who will do this work and when? If work is to be done by a contractor it is essential that the contractor is explicitly advised of this requirement. It is also essential to recognise the time consumed by this activity. If this work can be largely completed within the project definition phase, it will provide a firm basis for detailed design and reduce project risk.
- Determine whether existing drawings are to be used (revised) for the project or a new set is to be produced, or a combination of both.
- Identify standards and specifications to be used for the project and review compatibility with those used for the existing plant. See also section 16.

7.4 Process design

For any process-based project the process design forms the core for the definition of the physical scope and the basis upon which the detailed design is carried out. It is therefore important that process design is sufficiently progressed in the project definition phase to provide a sound basis for implementation. For retrofit projects this requirement is perhaps even more important than for new build. Some specifics which should be addressed in the definition phase are listed below:

- Ensure that not only the new and revised process elements have been detailed, but also the associated process design requirements for utilities, feedstocks and additives. This should include checks that existing infrastructure has the capacity to accommodate additional requirements.
- Ensure that flowschemes clearly identify what is new, already exists and what existing elements are to be removed (this may need a separate set to show removals if they are extensive).
- Have pipes and valves been sized? If not this is a significant outstanding uncertainty.
- Check flare/vent systems; a process change can impose a disproportionate increase in required maximum capacity. If flare /vent headers have to be replaced, this could be a major cost item.
- Identification of tie-ins. Ensure all tie-ins needed are noted and check that piping and equipment being tied into have capacity for new duty. Carry out first pass evaluation to identify timing/conditions under which the tie-in must be carried out. See also section 16.14.
- Are modifications to control and/or safeguarding systems required? If so has:
  - A user requirement specification for control and monitoring been provided?
  - A narrative outlining safeguarding requirements been provided?
  - A process data listing of new loops been provided?
  - Integration with existing systems been defined?

- Availability of spare capacity within existing systems been identified?

- Has an initial process safety review be carried out?
- Is new process technology involved? If so, are specific requirements identified? Have risks been evaluated? Is there a contingency plan if technology does not work?

7.5 Scope of the project

A narrative scope of project should be provided in all cases. This should aim to provide sufficient detail to allow those who will be involved in implementation to make a valid assessment of the overall work requirements. It should also identify specific timing requirements for elements of the project. For retrofit projects the following should be included:

- Identification of items to be removed. Where these are not shown on flowschemes, provide mark-ups of relevant drawings where possible. Ensure that items to be removed and then re-used are specifically noted.
- Identify timing requirements for removals. Identify any special precautions required.
- Ensure that all new items not shown on flowschemes are listed. Where possible, provide sketches or mark-up showing locations and sizing (e.g. building extension, control panel extension, new underground drain). Use of photographs may be helpful.
- Identify new or changed requirements for process/product quality analysis. This applies to both on-line and laboratory-based requirements.
- Ensure that an overall programme is provided and specific timing requirements for installations are identified (i.e. what must be installed at plant shutdown?).
- Identify standards and specifications to be applied. Where these differ from current industry standards, ensure all parties have relevant information.
- Identify any special or specific materials required (e.g. requirement for commonality with existing on plant, requirement for a custom design, use of nominated vendor).
- Where study work has not been completed during the definition phase, list outstanding work and identify the party who will do it (and approve it) and the required timing. Note that outstanding study work constitutes scope uncertainty and should be avoided if practicable. Examples include:
  - Checking existing utility and feedstock lines to confirm suitability for revised duty.
  - Checking existing structures to carry new loadings.
  - Checking capacity/capability of existing control systems to accommodate new requirements.

7.6 Project strategy

All projects should have, as part of the definition, an identified and agreed strategy for implementation. Development of the strategy must involve the plant operations function, and where alliance relationships exist, involve key contractors and suppliers who are likely to contribute to project implementation. Some issues specific to retrofit projects include:

- Provision of existing plant data.
- Provision of plant-specific knowledge, especially covering process and process control. Recognise the need for involvement of plant based staff (or others who have detailed knowledge) throughout the design and construction phase. Ensure that they will be available when needed.
- Determining the extent of requirement for review of existing plant as part of safety reviews.

- Agreement of safe working practices for work within, or adjacent to, existing live process plant. Identify permit processes. Agree with the plant operations function in principle what work they will allow within live plant and what must be done at plant outages.
- Agree overall timeframes for the project and for any specific time sensitive-elements. This agreement will need to include plant operations function and, if significant production interruption is foreseen, also the business. Where applicable, analyse the balance of benefit to the business of higher project cost against lower loss of production.
- Identify intended split of work. What will be done by client/owner and what will be contracted out? This should be done in some detail to ensure that there is clarity in respect of boundary lines of responsibilities and interfaces. This is often a more difficult issue than for new build projects. To the extent that the client intends to retain work in house they should carefully assess resource (people with relevant skills/knowledge) needs and ensure that they will be available when needed.
- Identify contracting strategy, covering types of contracts to be used, tendering approach, potential contractors to be used etc. Include initial schedules for development of tender packages, tendering periods and target contract award.
  - Recognise that significant benefits arise from the use of design and construction contractors and their staff who are already familiar with the plant. This shortens the learning curve.
  - Recognise that, in many cases, the level of scope definition and/or conditions under which work will be executed provided in tender documents will not be sufficient to support lump-sum type contracts.
  - Are incentives to be applied? If so, they should be linked to key deliverables (for the contract), and should be linked to profitability for the contractor (i.e. they should not threaten contract cost recovery).
  - Identify who will be responsible for managing construction contractors in terms of commercial, technical, SHE compliance and schedule compliance issues.
- Identify the point at which risk assessments will be carried out. Ensure that when this is done all relevant parties are involved in the assessment and identification of who will manage the risks. A first pass to identify significant project risks should normally be carried out within the project definition phase; where possible this should involve key contractors.
- Identify and agree the basis upon which project authorisation will be sought. In particular, agree the quality of estimate to be provided. It is often impracticable to provide a 10% estimate for a retrofit project without carrying out significant detailed design work, which in turn would result in project approval (or rejection) at a time far too late in the overall project cycle. See also Section 9.
- Agree the design approach. Will existing drawings/documents be re-used? Will a multi-discipline 3D CAD model be provided? What is the requirement for updating of existing design documents and the requirement for as built documents? This should be agreed with the design contractor before their contract is finalised. See also section 16.7.
- Determine the location of the design team. For a retrofit project, there is a significant need for the designers to account for requirements related to the existing plant. This includes:
  - Access to existing design documents and other information.
  - Need for field checks and measurements.
  - Need for design reviews including plant-based staff.
  - Need for development of plans including input from plant-based staff.
  - Support to construction work.

  It is therefore essential (even with the availability of electronic data transmission) that the ability of designers to visit site is not significantly constrained. If the design contractor has his office close to the plant site, then it may be acceptable to carry out the design in this office with visits as needed. However, if the design contractor's office is remote from the site then the setting up of a site design office must be seriously considered. Two options can then be looked at:

- Basing the whole design team at the site.
- Basing only a small team at the site who will focus on required site work and liaise with the main design team.

The best option for the project will depend upon a number of factors, but this is an issue which must be resolved before finalising the design contract.

- Identify schedule and timing of design reviews. Identify parties to be involved.
- Identify who will manage handover, precommissioning and commissioning. Identify who will carry out tasks related to this.
- Identify requirement for preparation of revised operating and maintenance manuals and for training of operators. Identify resource to carry this out.
- Identify requirement for update of the maintenance management system.
- Identify project specific SHE issues and outline management approach. This is effectively the initial development of the health and safety plan. In particular:
  - How is design executed to minimise construction HSE impact (in-plant work)?
  - The practical maximisation of off-site work.
  - The extent of need to review existing plant process as part of overall process safety review.
  - How tie-ins will be executed (note the need to address not only piping tie-ins but also instrumentation, electrical and civil).
  - Identify any issues regarding waste material, especially if it may be contaminated.
  - Outline requirements related to in-plant working.
  - Identify foreseen design and construction safety reviews.

See also sections 16.2, 18.2 on SHE.

8. Project staff and labour resources

It is often stated that for all projects perhaps the most important influences upon the implementation success are the quality, availability and motivation of all those individuals involved in development and implementation. Within this overall need there are some issues which are of specific applicability and/or importance to retrofit projects.

8.1 Project definition resourcing

The project definition phase itself will often require considerable technical input. Insufficient resource in this phase is common and leads to either delay in completion or progressing to detailed design with an inadequate definition. Retrofit projects often require proportionately more work in the definition phase than new build projects. In particular, the role of the process engineer in this phase is usually very significant as up to 50% of the total process engineering work may need to be carried out in the definition phase (this is much greater than for a typical new build project). Therefore, early in the development of the project it will be necessary to identify:

- What specific skills and knowledge are required for project definition? The areas requiring specific knowledge (of existing plant/facilities) are most commonly process design and instrumentation/process control. However, other elements of specific knowledge must not be ignored and may be vitally important for a given project.
- Which individuals have these specific skills and knowledge and how can they be made available? Their availability may well be a determinant of the time needed to complete the definition phase of the project.
- What other more general resource requirements are needed and in particular who will manage the definition phase?
- Is it intended that these individuals will continue to be part of the project team through project implementation?

It is then necessary to obtain commitment of the needed resources in order to progress project definition.

8.2 Planning of resource requirements

For any project an assessment of (people) resource requirements to cover the whole exercise through definition, design and engineering, procurement, construction, handover, precommissioning and commissioning (and possibly through ongoing operation) should be made during the project definition phase. As the project progresses it is likely that the resource plan will need to be revisited and possibly revised. Where a consultant or contractor is involved in the engineering and management of the project then he or she must be actively involved in the planning as all the issues are equally valid in respect of the staff he or she employs. Aspects to be considered for a retrofit project include:

- In determining the composition of the core team to engineer and manage the implementation of the project it is again necessary to look at specific knowledge and skill requirements. Preferably those with specific knowledge will be included in the team, even if only on a part-time basis. In any event, there is a strong preference that the project manager and other lead engineers are all experienced in the specific needs of retrofit projects even if they do not have specific knowledge of the plant associated with the current project.

- It is common for many individuals assigned to a retrofit project (especially if it is a relatively small project) to be on a part-time basis with other concurrent obligations. In such cases it is vital to carefully assess the potential for conflicts of priority and resolve them. However good the project scheduling is, it is rarely possible to exactly determine the timing of required contributions many months in advance. A firm commitment should be gained from line management as to the availability of required staff as and when the project dictates, as well as the importance the project has as part of the individuals overall workload. If a satisfactory agreement cannot be achieved then the use of that individual should be reconsidered.
- Identify specialist skills needed and how they will be provided. It is important to gain assurance that the personnel required will be available when needed.
- Consider the benefits/consequences of multi-skilling. Whilst on one the hand this provides the individual with a wider range of experience and the benefit of greater involvement in the project, on the other hand it may not optimise use of the individual's key expertise and he or she may not have the optimum skills in other areas.
- The interface with plant operation and engineering staff will be significant (see section 20). The requirements for contribution from plant staff needs to be identified and a clear interface process with the project team agreed.
- Where the retrofit project forms part of a portfolio of (small) projects, a key element of overall portfolio management is to address resourcing needs when considering priorities and schedules for each individual project.
- There needs to be management (both client and contractor) recognition that retrofit projects often generate a disproportionately high requirement for engineering and project management. The reasons are the many additional complexities, most of which are the subject of this handbook.
- The issue of construction labour resource should not be forgotten. Again, use of contactors whose labour and supervision are already familiar with the site/plant/facilities has many benefits. See also section 15.

8.3 Managing and motivating the team

No single project team organisation structure will be appropriate for all retrofit projects. In many cases the structure will be determined by the nature of the particular project, the likelihood of ongoing work after it is complete, the availability of personnel (full-time and part-time) and the extent of use of consultants and contractors. Some aspects particularly relevant to retrofit projects are:

- Establish the criteria for determining that personnel are suitably qualified – this may include interviews/CV appraisal etc. This not only includes technical skill, but also the understanding of the needs of retrofit projects and their ability to interact effectively with others both within the team and outside it (in particular the interface with the plant operations and engineering staff).
- Ensure that the project manager has the necessary leadership skills and is familiar with the particular needs of retrofit projects and of the specific project.
- Ensure that all of the team are fully apprised of the project objectives and priorities and that there is "buy-in" from the whole team. For larger projects, a presentation from the business management will be of value.
- Ensure all team members are clear as to their roles, responsibilities and authorities.
- Ensure that there is scope for innovation where appropriate. Retrofit projects present many challenges and, hence, scope for innovative solutions. Appraisal of innovative ideas should

be by means of risk/benefits assessment. Where potentially good ideas are not adopted there should be an explanation of the reasons so that the originator and others understand the decision and are not demotivated in future.

- Aim for a sensible level of empowerment, but be mindful of individuals' level of experience and the need for assessment of the broader implications applying to certain types of decision.
- Emphasise the need for the team members to communicate and interact with others. They must be pro-active in identifying where a problem may need the involvement of others. The potential for this is much greater in retrofit projects. Regular review meetings focussing on issues can help, provided meetings are kept short with the aim of identifying, rather than solving the issues except where this can be achieved very rapidly.
- Aim to co-opt a plant operations focal point onto the team to assist in the interface with plant operations and engineering.
- Encourage team members (especially those that are part-time) to regularly review their workload and priorities. If they believe there may be a problem they should highlight this to the project manager as soon as possible.
- Identify training needs and ensure necessary training is provided. Training should generally only be provided if the project has special needs. The project must not become a major provider of general training.
- If there is an ongoing programme of projects, make every effort to maintain the core team. This assists development of skills, knowledge and effective working relationships. If it is provided by a contractor, consider an incentive scheme to limit team turnover. This will ensure that the resource provider has the necessary incentive to provide the project with the needed skills and resource level it requires at the time it requires it.

8.4 Integrated project team

One structure which can yield excellent results is the integrated team, a single team drawn from the management/engineering contractor and the client (in some cases also involving representatives from key construction contractors). For this approach to work there is, however, a need for an alliance or partnership type contractual relationship (see Section 15). Typically, the engineering contractor provides most of the team but the client inputs staff with the needed specific skills and knowledge. The benefits of this approach include:

- Additional expertise available for the development and definition stages.
- Continuity of involvement, avoiding learning curve errors.
- Reduction in the overall workload.
- Commitment to the project definition.
- Design and construction processes can be developed together.
- Optimisation of the project schedule.
- Commitment to achieve the project schedule.
- Avoidance of contractor and supplier selection delays during the course of the project.
- Reduction in the need for in line approvals.
- Removal of dual roles and man to man marking.

When operating an integrated team it is essential that:

- Those within the team understand the concept and accept it.
- There is a clear identification and acceptance of the boundaries of the team's responsibility and authority.

- There is acceptance by senior management of the parties (client and contractor(s)) involved in the integrated team, that the team must be able to take and implement decisions within the agreed boundaries of responsibility and authority.

8.5 Training

It is vital that those involved with retrofit projects have the appropriate knowledge and skills for their role. Inevitably it is not always possible to ensure that all team members have such knowledge and skills at the time they are considered for involvement in the project, but for other (good) reasons it may still be desirable to utilise them. Hence, there will be a need for training. In all cases, training needs should be identified as soon as practicable and effected before the individual needs to utilise the skills and knowledge provided. Training specifically relevant to retrofit projects includes:

- Provision of a general understanding of important retrofit issues. This is applicable to engineers who have not previously been involved with significant retrofit work.
- Detailed understanding of discipline retrofit issues - as above but more detailed for the relevant discipline.
- Familiarisation with the existing plant/facility - project team members who are not familiar (particularly contractor staff).
- Detailed understanding of plant process and control systems - process and instrumentation engineers on team (particularly contractor staff).
- Site and plant specific safety induction training.
- Specific training for handling of any hazardous materials which may be present on the plant. (e.g. asbestos, toxic liquids).
- Electrical technicians working within live control cabinets.
- Plant operator training for modified plant/facility.
- Maintenance technician training for new/modified equipment.

9. Estimating and cost control

The quality of any estimate is limited by:

- The quality of the scope of work and specification

  How well has this been defined? This includes:
  - The extent of design and engineering work needed.
  - The physical content of the materials (quantities and specifications) to be supplied.
  - The construction work to be done.
  - The circumstances under which the parts of the project will be implemented (time pressures, working conditions etc).
  - Other items such as temporary works, temporary facilities for construction labour, insurances, cleaning, waste disposal, document updating, training, first fill process materials, transportation, project team travel and other expenses, import duties, project specific medical and security provisions.
  - An assessment of the quantity of management required in order for the project to be developed and successfully implemented.

- The quality of cost data available.

  - How accurate is the pricing data for each element of the identified scope?
  - What are the vulnerabilities to changes in rates and prices?

The above is true for all projects. It is also true that the later in the overall development and design of the project that an estimate is carried out, the more accurate it is likely to be. This, however, has to be weighed against the legitimate business need to have a projected cost against which the project can be evaluated and authorised prior to irrevocable commitment of significant expenditure. It is essential that the project team, the business and those authorising the budget understand and appreciate this trade-off.

The ability to provide high accuracy estimates for retrofit projects faces additional challenges for a number of reasons.

9.1 Scope quality

Some significant elements of the scope of work required are often not identified or quantified until well into the detailed design process or in some cases into construction. Some examples include:

- Detailed requirements for excavations in locations where old plant has previously been located. Issues such as contaminated soil, extent of dewatering, unforeseen buried objects, poor ground requiring shoring, temporary support of adjacent structures etc.
- Need to remove/relocate existing plant/piping, not because it is redundant but because it needs reconfiguration to allow fit of new components.
- Safety reviews/condition assessments identify additional requirements for modification/ replacement of existing equipment.
- Checkout of existing structures indicates need for strengthening to carry extra loads.
- Discovery that new instrument cabling and cabinets are required as those existing do not have sufficient usable spare capacity.

- Detail design shows that control system modification/extension is more complex/extensive than foreseen.
- Discovery that process control/safeguarding system will need replacement rather than modification.
- The extent of work which must be done in plant shutdown (turnaround) is greater than initially assumed. This work will be at higher cost due to overtime payments and possibly lower productivity.
- Inspections identify need for remedial works to existing piping/equipment.
- The extent of scaffolding and scaffolding modification is often much greater than foreseen.
- The extent of temporary lighting needed is often much greater than foreseen.
- Collateral damage to existing insulation requires replacement.
- The scale of provision of utilities and temporary facilities for contractors (offices, toilets, mess huts, storage etc) is often underestimated.

9.2 Unit cost accuracy

Even where a requirement for materials and work has been identified, for some items it is difficult to accurately assess the level of unit cost. Some examples are:

- Cost of design and engineering work. How much effort will the designers need to put into discovery of existing plant/facilities, and how much of the existing plant will need modification to fit the new? How much more difficult will design be as a result of restrictions imposed by existing plant? This will be an issue not only on reimbursable contracts but also on fixed price as the vulnerability to change orders is significant.
- Modification of existing equipment. Cost will depend on detailed design, installation method, existing condition and required preparation, accessibility and time available. A contractor can only give a reasonable estimate when all of the above are known. It is entirely feasible that the cost could be up to 10 times that which would apply to the provision of similar work in a manufacturer's shop applied to new equipment.
- If materials are required to be supplied to a tight time schedule, premium payments may be required as well as the cost of express shipment. This can result in cost levels very significantly higher than for supply to normal delivery schedule.
- Productivity related to removal work is extremely difficult to estimate.
- General level of productivity for retrofit construction work is lower than for a new build project. However, accurately determining the level which will be achieved is difficult as it is affected by a number of factors and the extent to which each will occur is unlikely to be known at the time of estimate. See tables 9.2A and 10A.

Type of working	Increased cost
Overtime on normal working days	30 - 40% for additional hours up to 4 additional hours per day
Saturday working	40 - 50% for all hours
Sunday and holiday working	80 - 100% for all hours
Shift working (8 hour shifts)	20 - 30% for all shift hours
Shift working – supervision	80 - 100% (covers additional personnel and premium rates)

Table 9.2A - Hourly labour cost levels for construction work outside normal working hours (UK)

Above costs are for general guidance only and do not account for any loss of productivity associated with overtime and shift work.

9.3 Overall estimate accuracy and contingencies

For the reasons stated above it is essential that the declared accuracy for any estimate be carefully considered. In addition to provision of general contingency, it may well be prudent to list those areas of significant uncertainty/risk and allocate specific contingencies to each element. Additional considerations include the following:

- It is generally accepted that in order to be able to prepare an estimate where there is a 90% probability of the net estimate within ±10% of final cost, the following level of information is required:
  - A full set of detailed process engineering and utility engineering flowschemes against which an initial safety review has been carried out.
  - A complete list of instrumentation requirements.
  - Detailed survey of ground conditions.
  - Full functional requirement specification for buildings together with overall layout plans and specification of fit-out requirements and finishes.
  - At least 25% progress of the detailed design and engineering.
  - Firm tenders for all significant equipment items.
  - A firm project schedule, including assessment of needs for overtime/shift working.
  - Indicative tenders from construction contractors for at least the main disciplines involved.

  These requirements are essentially the same as for new build projects.

- A retrofit project also potentially has many other features which make accurate estimation more challenging. Given the timing at which the estimate required for project authorisation is usually required then it is highly unlikely that the available quality will be better than 90% probability of being within ±20%, and in some cases will be not better than ±30%. It is important that both the project management and the business (authorising party) recognise this limitation.

- An estimate is only valid for the assumed programme of the project. If (as often occurs) the programme is compressed then there is significant vulnerability to additional cost in order to achieve the shorter programme. Equally, if a project is stopped part way through and then restarted, additional cost will be incurred.

- There is a natural reluctance of management to provide the project manager with a large contingency for his use. However, failure to provide a sensible level of contingency presents a significant risk that at some stage there will be a need to request additional funding for the project. This is usually an unpleasant and difficult diversion from the ongoing management of the project. Possible approaches to this problem include:
  - In addition to provision of a general project contingency, separately identify those aspects of the project where there is perceived to be a high degree of cost uncertainty. For these aspects, individual aspect-specific contingencies can be allowed. These may be high as a percentage of base cost for the individual item, but reduce the need for a high overall project contingency. Such items should be identified as part of an initial project risk assessment.
  - The authorising party may retain apart of the contingency which can only be used if its release is agreed. It is not sensible to withhold the whole of a project contingency from the project manager; this only results in padding of the base estimate, particularly for retrofit projects, and there is a high probability of some cost growth.

- Identify and agree how any emerging works and scope changes will be funded. If they are to be within the overall project budget then a separate contingency should be considered for such items.

- Project cost is always important; however a small cost over-run is (usually) preferable to not achieving primary objectives. If the validity of a project is so cost sensitive that even a small overrun cannot be tolerated, then the whole justification is questionable. It makes sense for management to test a project's validity at higher cost levels and hold a reserve in order to provide for such events.

9.4 Project cost control

As the estimate for a retrofit project is likely to have some additional cost vulnerabilities, then effective cost control is even more important than normal. For cost control systems to be effective and allow some measure of control (rather than simply recording) it is necessary both to record costs as they arise (at the time commitments are made) and to carry out a frequent appraisal of outstanding potential costs against a budget of remaining work elements. It cannot be overemphasised that this activity requires a significant ongoing effort throughout the life of the project by suitably trained staff, even for projects of a modest size. For retrofit projects the following should be adopted:

- Regular review of the physical scope of the project to identify any materials or work which had not been included in the estimate or where the specification has changed. Include for such items in forecast cost.
- Checking that the original commitment figure remains valid. Change could occur for several reasons including volume of work, unit cost, need for remedial work, claims etc.
- Whenever the timeframe for any work changes, assess the likely cost impact.
- For construction work, make an early check on actual productivity against that assumed in the estimate and project cost impact. Re-check regularly as work progresses.
- For fixed price contracts (or unit rates), if it is apparent that the contractor is experiencing poorer productivity than he anticipated, then it is likely that they will make claims for extra costs and/or there will be a need to fund cost of schedule recovery.
- Identify any emerging additional work. Ensure that there is agreement as to whether such work will be funded from the existing project budget, a scope change is needed or that it will be funded from a separate budget (e.g. maintenance or a separate project).
- Provide early warning to management of any foreseen overruns and advise intended remedial action if possible.

10. Planning and progress monitoring

10.1 <u>Planning</u>

The amount of detail required for a schedule is dependent upon the scale, complexity and time sensitivity of the project. It is sensible to provide more detail in those areas which are on, or close to, the critical path for the project and/or those parts where there is a multiplicity of different resources interdependent upon one another's work in order to achieve general overall progress. Activities within the project schedule which on initial planning are not critical may become so as a result of events and in such cases it is likely that further detailing of these activities will be required. It must be emphasised that planning and progress monitoring may itself constitute a significant workload throughout the life of the project even for those of modest scale, but failure to provide adequate skilled resource is likely to lead to a lack of the quality data needed for effective control. Proportionately, retrofit projects are likely to require a greater planning effort than new build.

The following are some aspects of particular importance for retrofit projects. They should be addressed as early as possible within the planning process and revisited as appropriate as the project progresses.

- *Responsible parties and detail required.* Identify which party is responsible for the various parts of the overall project planning. This may include several different parties, such as the client for the broad overview plan; the management contractor for detailing the design, procurement and overview of construction; and the individual construction contractors for the construction detail plans. In each case, the more detailed plans need to be based upon the higher level plan and appropriate checking of compatibility must be carried out. Contracts must identify the specific requirements for planning, both in terms of detail expected and the required time for their presentation.

- *Co-ordination of plans.* It is essential that the plans prepared by each party are compatible with the overall plan and those of other parties. For retrofit projects, due to their complexity, higher risk of emerging works and likely constraints on construction work, this is even more important than for new build. It is vital that the plant/facility operations group are involved in the agreement of plans and are consulted in detail where this impacts upon plant operation. Specific planning co-ordination reviews should be carried out involving all relevant parties, and when changes to a part of any plan occur, checks must be made to assess the possibility of knock-on effects to other plans.

- *Time for collection of existing plant data*. Recognise the need and allow time for collection of required data covering the existing plant. This may in some cases include the development of a 3D CAD model for parts of the plant.

- *Design and safety reviews.* All the reviews intended must be identified along with the proposed timing and what information must be available. Participants in such reviews must be identified. It is likely and highly desirable that representatives from the operating plant are involved. Ensure that they are aware of timings and confirm their availability to attend. Review requirements will depend upon project specific needs and on client and engineering contractor procedures. Checks should be made that each review will sensibly add value. In some cases a single review can be made to serve multiple objectives. See Appendix F for listing of typical reviews.

- *Time critical design*. Identify which elements of the design are likely to be time critical and assess why. This will vary from project to project. Having identified the critical elements ensure that the plans are sufficiently detailed in this area. For example, if the production of piping isometrics is critical, it may be appropriate to list every isometric, identify the relative priority of each one and set individual target dates. Additionally, it will be necessary to identify all of the input information required to allow isometric production and set compatible targets. It will then be necessary to ensure that there are sufficient skilled design resources to meet the target dates, including contingency to cope with (inevitable) revision work.

- *Pre-shutdown work*. Determine what work must be carried out at plant shutdown and what work within the plant may be allowed with the plant in service. It is usually beneficial to minimise the shutdown work content as far as is practicable. However, live-plant work is likely to require additional safety precautions and may result in lower productivity. It is well worth holding detailed discussions with plant operations to determine exactly what is, and is not, possible. The following are possible items of work (within the plant) which may be allowed with the plant in service provided suitable precautions are taken:
    - Installation of new foundations at the edge of the plant.
    - Dismantling work on selected parts of the plant.
    - Excavation of cable trenches and installation of cables.
    - Installation of new cable racks and cables on the racks.
    - Installation of new field junction boxes for instrumentation.
    - Erection of new permanent lighting
    - Installation of tie-ins where needed isolations are possible (and no hot work is required). However, contingency plans should always be made to allow for the case where the isolation proves not to be possible.
    - Installation of new small bore pipework and tubing where no hot work is required.
    - Selected construction of scaffolds in the weeks prior to shutdown start, provided they do not significantly restrict operator access.
    - Preparatory removal of insulation provided it does not present an operational risk or safety hazard.
    - Installation of temporary lighting.
    - Modification works on spared equipment items.
    - Modification/extension works on items such as chemical additive systems, conveying systems or packaging systems which are often intermittently used and where use can be scheduled to allow the work to progress when not in use.
    - Work associated with new cabling and new cabinets in instrument auxiliary rooms.
    - Reconfiguration of control software, provided there is an offline workstation and the system has the capability to store information offline.
    - Work in electrical sub-stations associated with isolated sections of panels.

- *Shutdown scope*. The scope of the work within the shutdown needs to be determined in considerable detail, including work sequence requirements, who is responsible for executing each task and the resource requirements. This scope needs to include (at least to the extent it interfaces with) other work such as decommissioning, isolation, maintenance and cleanout which may be outside the scope of the project.

- *Shutdown timing and duration*. Identify the timing and duration of shutdown(s). Try to identify how firm timings are and what would be the implication of extended duration of shutdown. Shutdown durations may be negotiable, dependent upon foreseen market demand and possibilities for product (and feedstock) storage and alternate sourcing. It is usually the case that where a plant shutdown results in loss of business, then to minimise that loss considerable extra expenditure may be justified in order to minimise shutdown duration. However, it is important to remember that:

- This is only valid if the business is truly lost.
- There are practicable limits to the reduction of shutdown duration and attempts to further shorten this can result in major added expenditure for no gain.
- Shutdowns where significant retrofit project work is the time critical element are highly vulnerable to being extended due to the need for emerging work, unless there is some contingency in the time/resource plan.
- Shutdown plans need to be agreed on, and committed to, by all the parties involved

- *Shutdown work planning (scheduling).* For the reasons mentioned above it is often the case that the work to be done within a plant/facility shutdown related to retrofit project(s) is the determinant of the overall period required for that shutdown. Occasionally, this is as a result of a single sequence of activities requiring a certain duration (i.e. a discrete critical path) and in this case investigation into means of duration reduction can be undertaken. More often, however, it is the sheer volume of work required in the shutdown period which is likely to determine the overall time required. In theory this could be reduced by the allocation of more labour, but there are practical limits due to congestion, safety considerations (including issue of permits) and the need to recommission in a particular sequence. Use of overtime and shift working can be adopted but this will be at the expense of loss of productivity and increased costs (see tables 9.2A and 10A). It is almost always the case that the detail of work planning and sequencing appropriate for a shutdown is far greater than for most of the rest of the project. It is important that those responsible for shutdown work planning understand the detail of the planning work required and provide the appropriate skilled resource to enable it. An example (from a real project) is given in Appendix G illustrating the extent of detailing needed for a time-critical work element within a plant shutdown.

- *Emerging works.* It is almost inevitable that as a retrofit project proceeds the need for additional work will emerge. This could occur in the detailed design phase as a result of plant inspections or during construction. Clearly it is important to minimise such work as it can be extremely disruptive to project progress (see section 14). However, it would be wrong to ignore that it is likely to occur to some extent and, even where it is accepted that the additional work is outside the project scope, and will be funded separately it remains that the work will need to be done and, hence, must be planned and resourced. It is always prudent to ensure that all contractors have the capability to cope with a modest amount of such additional works and such assurance/commitment should be included in the contracts. A prudent overall plan will include some time/resource allowance to provide for emerging work.

- *Construction labour productivity.* Recognise that labour productivity for in-plant work will be significantly lower than for new build construction work. This can add significantly to the construction resource requirement and its cost. The amount of loss will depend upon many issues, including access, congestion, safety requirements and distance from contractor's facilities.

Type of working	**Productivity loss**
Work on existing off-plot facilities	10 - 20% loss
Work within existing process unit (in-service)	20 - 40% loss
Work within existing process unit (shutdown)	15 - 30% loss
Work in areas of difficult access (additional loss)	10 - 30% loss
Overtime working - up to 45hr/week	5 - 10% loss on all hours
Overtime working > 45 to 60hr/week	15 - 20% loss on all hours
Shift working	15 - 20% loss on all hours

Comparison with normal productivity for 39 hour working week on new build projects.

Table 10A - Construction productivity levels for retrofit projects in the UK

It should be noted that the above figures are for general guidance only and assume ongoing working for a period of at least a week, and that losses are, to a considerable extent, cumulative.

- *Handover and precommissioning plan.* A separate plan will often be required for the management of handover, precommissioning and commissioning based upon sequential completion of identified process systems. This plan is typically prepared by the management contractor (or by the client project team) with substantial input from plant operating staff up to completion of precommissioning and by the plant operations function themselves for the commissioning (see also Section 19).

10.2 Progress Monitoring and Control

- *Progress monitoring.* As for initial planning, progress monitoring should to be tailored to the needs of the specific project with a strong focus on those areas which are time-critical or near to it. However, non-critical elements of the project must not be ignored, for if overall progress significantly lags the schedule it is inevitable that elements which were non-critical will become so with a high risk of overall project delay. It is essential that progress monitoring be based upon measurement of output not input. How many hours of work have been done is only of secondary interest, the key issue is what has been delivered against the plan. The frequency and detail of monitoring might typically be as follows:
  - *Monthly.* Overall measurement of progress for whole project, broken down into each discipline of design and engineering, procurement, construction.
  - *Weekly.* Detailed assessment for those elements of the work which are critical or near-critical.
  - *Twice weekly.* Any elements of design or procurement which are super-critical.
  - *Weekly.* Any critical or near-critical pre-shutdown construction work.
  - *Twice Weekly.* Overall construction progress for shutdown works.
  - *Daily.* Critical and near-critical shutdown works.
  - *Daily.* Handover and precommissioning status.

- *Progress review meetings.* Meetings can easily become institutionalised consumers of huge amounts of staff time for very limited benefit. However, effective meetings can be a valuable method of agreeing needed actions. The principles of an effective meeting aimed at ensuring required progress for a retrofit project are no different from those for any other project. Key elements are:
  - Except in an emergency, ensure adequate notice of the meeting has been given to all invited parties (this is one of the values of a regular periodic meeting - all concerned are aware of timing).

- If possible, only invite those who may have something to contribute. Make sure that all needed advisors and decision makers are present.
- Ensure that all needed status information to allow effective review and decision making is available. Ideally, prior to the meeting to allow pre-evaluation by participants.
- Focus strongly on key issues where decisions are needed.
- Make sure that those who can contribute do so (invite comment from those who have not spoken).
- Make a point of inviting participants to raise any other relevant points which may impact on project progress. This is especially important in retrofit projects where there is always a possibility of emerging issues.
- Ensure, where possible, that decisions are acknowledged as agreed by all present.
- Where the right information or people are not present to allow a decision to be made, cut discussion short and note how and when the issue will be resolved.
- Ensure notes of meeting are issued promptly, that they are concise and focus on points agreed, action items with stated responsibility and target completion.

- *Planning and progress monitoring – contractual obligations.* Make sure that contracts clearly spell out requirements in terms of planning detail required, requirement for first issue and requirements for updating. For progress monitoring, there should be an agreed basis for measurement of physical progress and an agreed frequency of reporting. Once the contract is in progress, ensure that the contractor complies with their obligations as this information is vital to effective planning and progress control.

11. Regulatory requirements and approvals

Regulatory authority approval requirements vary from country to country, both in terms of what must be approved, who provides such approvals, what information must be provided and timing. Required approvals can often be sub-divided into those necessary to allow construction and those required to operate. For retrofit projects the following should be determined:

- What approvals are needed? In some cases where only relatively minor changes are involved, certain approvals may not be required.
- In some countries (notably USA) there exists legislation which requires an operator to generally update the environmental performance of plant to current standards at the time any significant plant modification is undertaken. This obligation could significantly increase the scope and cost of a project.
- If the process and or operation of the plant has been significantly changed, then it is likely that operation safety case (COMAH Regulations in UK) will need to be revised and re-approved. This may also generate a need to update certain safety features within the plant which may not otherwise have been replaced.
- Current UK health and safety legislation requires plant operators to maintain and update plant design data so that it is available and valid for use by anyone having a future need for such information in order to assist in the management of safety related issues (e.g. for plant operation, maintenance and for future projects). This imposes an obligation on the operator to retain certain design data. It is also likely to influence the extent of requirement for the provision of as built documentation from the project and its integration with existing plant documentation.

12. Fast track projects or part projects

Many retrofit projects need, in part or whole, to be carried out on a fast track basis. There are many possible definitions for the term “fast track”. The following is a good simple definition:

“Reduction of the schedule to the minimum practicable is the principal driving force for one or more stages of the project.”

It is not intended within this document to describe extensively all the issues, risks and management techniques applying to fast track projects, but to point out that they need to be considered when applicable. If the fast track implementation is to be successful then the appropriate measures must be planned during the project definition phase and acceptance gained from the client’s senior business management of the techniques to be adopted and the additional risks involved.

Appendix B contains some overview guidance on the subject of fast track projects. Most of the content is taken from the ECI publication, “The Fast Track Manual – A guide to schedule reduction for clients and contractors on engineering and construction projects”, by Gerry Eastham. This contains comprehensive guidance on the subject of fast track projects and their management.

13. Risk management

In almost all projects there are risks that unplanned events will occur (and that planned events will not occur as planned). Experienced managers and engineers should be able to identify in advance the great majority of those risks which have potential significance and then develop a strategy to address them. However, this does not mean that all risks can be avoided nor does it normally make sense to adopt a strategy which aims to do so. Available risk management methodologies for retrofit projects are essentially the same as for other projects, except that it is essential that the additional risks arising from the fact that the project is a retrofit are recognised, as these are likely to be some of the more significant.

Risk responses may be classified as:

- Avoidance or reduction: Pre-emptive action is required, including, if necessary, changes to the project plan or implementation strategy. Preventative measures should be identified and additional information sought for an improved understanding of the risk.
- Transfer or allocation: Transfer or allocate the risk to the party who is best able to quantify and manage the risk. However, do not transfer risk simply as a means to place responsibility onto another party.
- Retention: Acceptance of the risk accompanied by determining the best measures to control and manage it. Contingency planning is necessary in this circumstance.

Organisations must accept that staff will occasionally not make the right decisions when they are required to work with limited information; this is especially relevant for fast track projects (which retrofit projects often are, at least in part). Without this acceptance of failure risk, the decisive behaviour that is at the heart of effective project management will be inhibited and a defensive approach will emerge. The inappropriate allocation of risk, i.e. that those best able to deal with it are not given responsibility for its management, will inhibit the successful management of that risk.

Many of the risks specifically applicable to retrofit projects are identified within this document and should, where applicable, be managed.

For all projects it is important that identified risks are categorised so that those which are perceived to have a potentially higher negative impact on the project and have a reasonably high probability of occurrence are those which receive the focus of management attention and, for which, prevention or mitigation plans are developed. For retrofit projects it is probable that some of those risks which are retrofit-specific are also those which require attention based upon the above criteria. (It is wholly impractical to actively manage every conceivable risk pertaining to most projects; the numbers are far too great.)

Whilst not absolutely essential, it is normal good practice to handle the assessment of risks related to construction SHE and their management separately from the general risk assessment exercise. It is likely that some of the most important construction SHE issues are those arising from the retrofit nature of the project. The parties needing to be involved to assess and manage the construction SHE issues will probably be different from those associated with more general project risk management.

A listing of some of the risks specific to retrofit projects is given in Appendix E.

14. Management of change

There is no doubt that effective change management is significantly influential in determining the overall achievement of project objectives, particularly those related to cost and schedule. It is undoubtedly true that imposition of changes is disruptive to the general progress of a project and that this disruption and the resulting cost of the change will increase significantly as the project progresses. Hence, change occurring in the project definition phase is generally acceptable (indeed to be welcomed if it is an indication of getting the definition right).

Retrofit projects generally have an increased risk of requests for change. Reasons for this include:

- Retrofit projects are rarely repeat projects, so there is limited previous experience to build upon.
- The detail of the interfaces between the existing plant/facility and the new project has not been sufficiently addressed in the definition phase.
- Safety and constructability reviews identify requirements for upgrading or replacement of elements of the existing plant not identified in project definition.
- Plant operations staff develop additional ideas to improve the plant.
- Items of work such as repairs to existing plant emerge as inspection and construction progress.

Every effort should be made to discourage and reject changes proposed after completion of the project definition phase. A well-defined change procedure supported by client senior management will assist in this. It would, however, be perverse to reject all proposed changes regardless of their merit. Changes which fall into the following categories merit serious consideration:

- The project will not fulfil one or more of its primary objectives without the change. There is no point in completing a project to time and budget if it does not fulfil the purpose for which it was intended.
- The proposed change will provide significant benefit to the project, e.g. a significant cost or time saving. However, against the benefits must be offset the cost and disruption of the change.
- The proposed change will provide significant benefit to the business which will utilise the project, e.g. a significant and valuable enhancement in plant output or efficiency. In such cases, it is essential to challenge the claimed benefits in order to confirm that they are assured. Challenge should also be made to check that the change cannot be sensibly implemented at a later date after project completion.
- The change is required for safety or environmental reasons which cannot tolerate delay even for a limited period which would allow later implementation.

There is a vital need to ensure that assessment of any requested changes be addressed urgently as the longer they are outstanding the greater the uncertainty and potential for delay, disruption and additional cost. For all but the simplest proposed changes, it is suggested that a two stage appraisal be considered:

1. A rapid overview to assess the order of magnitude of additional work, cost and schedule impact and the possibility of later implementation. This first stage should normally be completed within one week and should be immediately followed by a management decision

whether to proceed to stage two. If the decision is positive, it may also include authorisation to start any needed design and engineering.

2. A full review to assess in detail the requirement for additional work cost and the impact upon schedule. This should provide all the needed information to allow approval by the client and agreement of any contractual change orders. This stage two should also be completed as rapidly as practicable, but not at the expense of an inadequate assessment.

Notwithstanding the above, it must be made clear to the designers that they have an obligation to provide a design that can be practicably implemented and fulfils project objectives. Hence, for example, the need to re-design the details of a tie-in due to the client rejecting the original as it could not be safely constructed, would not normally constitute a change.

15. Use of contractors

Historically, many retrofit projects were designed/engineered and managed by the plant owner/operator's own staff, with only construction work being contracted out. Plant owners employed staff for the purpose of engineering and managing small works based projects, which included most retrofit projects. This was because detailed technical knowledge of the existing plant and management of construction work therein are important aspects of retrofit projects and were seen as areas of difficulty for an engineering contractor. Such a contractor would require substantial supervision and support from the owner's staff, which in turn would result in additional project cost.

More recently, many owners have downsized their engineering departments, and there remains little or no capacity to carry out the detailed engineering and management of projects. Hence, although the issues associated with retrofit projects have not changed, it is now common practice for them to be engineered and managed by a contractor.

15.1 Contracting strategy

In the definition phase for every project, the proposed contracting strategy should be developed as an integral part of the overall strategy (see Section 7.6). This strategy should include:

- Identification of work packages and responsibilities intended to be contracted out.
- Identification of those works the client intends to carry out themselves.
- Time frames for tender preparation, tendering, bid evaluation and contract award. Alternatively, identification of the use of existing term alliance contractors and the timings for scope preparation and agreement of job-specific terms for the work.
- Identification of forms of contract to be adopted (see Section 15.5). In particular, this needs to reflect the quality of the information to be provided to the contractor(s) and the risks they will be responsible for managing.
- Identification of key interfaces between client and contractor(s) and between any management and other contractors.
- Identification of key skills/resources needed from contractors for the project.
- Identification of contracting companies likely to be considered for the various packages of work.

15.2 Use of contractor for engineering and management

Most of the criteria for selecting a contractor to engineer and manage a retrofit project are the same as those for other projects. There are, however, a number of additional aspects which should be considered.

- Does the contractor have an established record of successfully managing retrofit projects? Do not simply accept a listing of projects carried out, check the detail and if possible contact the owners of one or two of the more recent examples.
  - Request the contractor to identify specific issues and the techniques they will use to manage the retrofit aspects of the project.
  - Check that they will provide key staff who have the relevant experience and request CVs. Where appropriate, interview proposed key staff.

- There are many advantages to utilising a contractor who has previous recent experience of working for the client, and even more so if that experience includes the plant or facility where the retrofit project will now be carried out. This advantage is, however, substantially reduced if the project team does not include individuals with that specific experience. When offering a contract on the basis of previous experience, the client should check on the individuals being offered (especially in key positions) and aim to persuade the contractor to offer the appropriate people.

- A long-term alliance arrangement between client and contractor can be beneficial provided there is a reasonable ongoing workload (see also section 15.6). Use of an alliance facilitates the involvement of the contractor in some elements of the project definition work. This allows the contractor to make a better assessment of their likely work content in project implementation and also allows them to make a flying start on detailed design once the go-ahead is given.

- If a new contractor is to be used, there will be a learning curve, where they operate inefficiently and make mistakes. This is not a sign of an inherently poor contractor, but simply reflects a lack of knowledge of the plant and the client's specific needs.

- Ensure that the contractor's project manager has the significant relevant experience.

- Aim to have other lead engineers with retrofit experience. This is of particular importance for the process engineer and (if there is significant content) the instrument engineer.

- If the project involves significant multi-discipline construction work during a plant shutdown, ensure that the contractor will be providing a high-calibre, experienced planner capable of the detailed activity planning needed to manage the shutdown.

- Consider carefully the form of contract to be adopted. Retrofit projects have an increased vulnerability to unforeseen requirements arising both in terms of additions and changes to scope and changes to the circumstances under which the work must be done. This makes the use of lump sum contracts risky for both parties. Lump sum should only be considered if the scope definition is of a very high standard with a low risk of changes and there is a genuine belief that the schedule is firm (and does not require a fast track approach). Imposing a high level of risk onto the contractor is likely to result in either higher tender prices and/or an adversarial relationship.

- With retrofit projects, it is often difficult at the tender stage for the contractor to accurately assess the amount of design and management effort needed to properly fulfil their duties. High quality design and management is vital to the achievement of challenging cost and schedule targets and hence some additional expenditure in this area will often result in a lower overall project cost than would otherwise be the case. A contractor who is genuinely under-recovering their costs is unlikely to be focussed on best project outcome.

- Regardless of the form of contract, every effort should be given to ensure that the contractor(s), when tendering for the work, have every opportunity to understand fully what is expected of them. There are many complexities and risks associated with retrofit projects and it is in the interest of all parties that they are understood by the contractors when preparing their bids. In order to facilitate this, the following should apply:

  - Ensure best practical quality of work scope and required timings.
  - Ensure that required specifications are clear.
  - Ensure that a site visit is carried out and that the tendering contractor includes key discipline staff in the visit.
  - Provide for, and encourage, questions from tendering contractors.
  - Advise the primary objectives of the project and the background to it.
  - Identify known key issues and constraints.
  - Allow a sensible time period for tendering to facilitate a proper understanding of the work content.
  - Clarifications will arise during the tender period. Ensure these are properly documented and transmitted to all bidders.
  - Do not award a contract based upon a tender where there is evidence that the tendering contractor has not fully understood the scope or other requirements.

- Are incentives to be applied? If so, they should be linked to key deliverables and should only be linked to the profit element within the contract (this will require a degree of open book exposure as to the make-up of contractor’s costs).

- Clearly identify the extent to which the contractor will be responsible for managing construction contractors, i.e. commercially, technically, SHE compliance, schedule compliance.

- Identify the individual discipline interfaces between design contractor and client. There is no question that the design and management contractor of a retrofit project will need support from the client’s technical and operations staff who have the detailed plant-specific knowledge. Equally, there is a duty on the client to make appropriate staff reasonably available to provide the information and support that is needed.

15.3 Use of construction contractors

The use of contractors to carry out construction work is well established and the great majority of work is undertaken by them. When required to carry out works related to retrofit projects, there are a number of additional issues and requirements which must be addressed. Most of the comments made in 15.2 above equally apply to construction contractors but there are other issues that need to be considered:

- In addition to those checks applicable to any specific work the following retrofit-specific issues must be addressed prior to contract award:
  - Check that the construction contractor understands the requirements of the permit to work system which will apply and have made proper provision to ensure that they make the needed applications in a timely manner to avoid delay to their work.
  - Ensure that any requirements for task-specific risk assessments/method statements are identified and they understand the safety requirements related to in-plant work.
  - If any of the materials they are to provide must be from a specific vendor; ensure that this has been included.
  - The contractor must understand their responsibility to complete and hand over work on a process systems basis in the sequence required by the precommissioning plan. Testing and precommissioning work may include work on elements of the existing plant as well as that installed by the contractor.

- During the execution of contractor's work carry out regular checking (both physical checks and reviews with contractor's supervision) to ensue that:
  - The contractor converts their tender planning into the required detailed job planning as a first priority task. Do not accept delay to this; without an acceptable detailed plan there is no effective means to monitor and control progress of their work.
  - The contractor is following agreed practices for safe working in-plant.
  - The contractor has provided resources (labour and supervision) to meet the needs of the required programme, even if this is greater than foreseen at time of tender.
  - Not only is the contractor generally progressing work to schedule, but specifically they are progressing those items which release work for others as stated in the overall plan.
  - There are no known issues which will potentially delay the contractor's further work.

15.4 Specialist contractors

In addition to the general construction contractors, there may be a need to employ certain specialist contractors or sub-contractors. These might carry out tasks such as installation and commissioning of complex equipment which must be conducted by equipment vendor staff. In addition, there may be a need for software programmers, specialist inspection and NDT services, specialist heat treatment service for work on pressure vessels, industrial cleaning, building specialist services such as HVAC, floor finishers and many more. Employees of such companies may be fully competent at their specific job, but they are likely to need considerable guidance if they are to be able to work safely and efficiently in a plant area. In some cases it is unrealistic to insist on them being able to fully manage all needed aspects when they comprise one or two persons working for a few days only. They therefore need support. Aspects needing attention include:

- Ensuring they are available at exactly the right time to do their task(s), in order to avoid delays to others.
- Ensuring that they understand the hazards associated with in-plant work, the required safe working practices and that they have the appropriate personal protective equipment. This will require some form of safety induction.
- Checking whether they will be using any hazardous materials which may present a risk for others.
- Assisting them with obtaining needed permits to work.
- Providing them with required safe access to their workplace.
- Providing facilities for washing, changing, toilets, messing, reviewing documents, telephone etc.
- Making sure they know who their primary contact is and how they can be contacted.

15.5 <u>Form of contract</u>

No single form of contract is always appropriate for retrofit projects. Form of contract should always be decided such that it is compatible with the overall project objectives and matches the nature of the work or service intended, including the circumstances under which it must be executed. For retrofit projects the following issues are often applicable:

- Whatever the form of contract, aim to provide the best quality information possible to the contractor. Where information provided is not firm, clearly indicate so and when and how it will be made available.

- Advise the contractor of what work (that interfaces with their work) will be carried out by others (e.g. scaffolding by scaffolding contractor, plant isolations by client's operators) and emphasise the need for active co-operation in planning of work flow.
- Good practice indicates that any risks associated with a contract should be borne by the party best able to manage them. It is disingenuous to impose risks upon those who have neither the capability nor capacity to bear them. For example, where it is reasonable to require a contractor to remedy their own defective work at no cost but it is not reasonable to expect them to bear the full cost loss of business from an extended plant shutdown. Imposing risk beyond a contractor's capacity is likely to cause the contractor to add a risk premium to their price and to act in a defensive manner, neither of which is conducive to the best achievement of project objectives.
- In many cases the scope of work and/or the circumstances under which it must be executed will not be sufficiently firm to allow a lump-sum contract. Use of lump-sum forms where significant changes are probable will invite disputes.
- Work in-plant has a much higher risk of delays occurring due to actions of other parties, not least due to permit delays.
- If reimbursement on a man-hour basis is utilised there will need to be some means of controlling productivity, possibly through the use of targets and incentives. Additionally, there will need to be close monitoring of man-hour trend. For the construction work associated with large projects the use of earned value analysis (EVA) is an effective means of both measuring the physical work done and identifying productivity trends (however, the work needed to set up an EVA monitoring system should not be underestimated).
- If reimbursement is on a unit rate basis, ensure that the rates are valid for all of the conditions the contractor is likely to encounter on the project. Alternatively, include specific provisions for how the rates may be adjusted if certain conditions apply. For instance, provide an adjustment which would apply if overtime working is required.
- Ensure that the contract includes a clear requirement for the contractor to provide regular progress, manpower data etc. and take necessary steps to ensure this is fulfilled (see also section 10). This information is vital to control progress and to address any claims for delay, disruption etc. Frequency of data provision will depend on the nature and criticality of the work. During a plant shutdown, it may be appropriate to require daily progress reports.

15.6 Alliances/Long-Term Agreements

It is not within the scope of this document to explore in depth the features and detail of alliances and long-term agreements between clients and contractors. It must, however, be noted that these forms of relationship are beneficial in the development and implementation of retrofit projects.

In order to be successful, alliances and other forms of long-term relationships require a considerable number of specific conditions to be in place and require substantial (and usually time-consuming) effort to set them up. It is therefore unlikely that such a relationship could sensibly be developed for a single retrofit project.

Some of the benefits which may result are as follows:

- Avoiding the repeated cost and time of tendering.
- Achieving better price levels as individual small contracts generate disproportionate set-up and overhead costs.
- Allowing contractors to effectively participate in project development and definition.

- Allowing joint development of a sensible work schedule both for individual projects and for programmes.
- Contractors are more willing to “go the extra mile” to solve arising problems.
- Sensible terms and conditions will engender a co-operative relationship and encourage innovation.
- Facilitating communication and transfer of knowledge.
- Avoiding repeated learning curves. Contractors become familiar with client requirements and gain knowledge of the plant/facilities. As a result they become more efficient.
- Providing additional security of employment for contractor labour, who are therefore better motivated.
- Offering the possibility to share in success.

15.7 Confidentiality

The very nature of a retrofit project means that engineering contractors are likely to gain a detailed insight into the design and operation of the plant. In many cases this will not be a great concern, but if the existing facility/plant and/or the new project design include technology which is secret, provides the client with competitive advantage and/or is licensed technology, then there is a legitimate concern. All contracts should include a confidentiality clause, but in certain cases it may be prudent to additionally require individuals (particularly those who will be directly working on the technology) to sign confidentiality agreements.

Additionally, in certain circumstances a requirement that the contractor returns all information and data concerning the project upon completion of their work may be included.

15.8 Guarantees, warranties, liabilities

The difficulty with a retrofit project is that the end product is not, by and large a separate entity, but is a modified/extended pre-existing plant or facility. Given this, the only guarantees which are sensible are those which are clearly identifiable as relating to the work, services or goods provided by a specific party. Attempts to impose guarantees and warranties more broadly will simply make the provider wary and defensive. In some cases there will be refusal to accept such conditions, which is not surprising as the party will consider that they are being exposed to risks over which they have no (or very limited) control.

In the process industry the business cost related to a plant not being able to produce in line with its expected capability may be very high. It is, however, recommended that a client (plant operator) should think very carefully before trying to include, within the conditions of contract, the ability to claim such costs from a contractor or supplier. The reasons are as follows:

- This imposes a potential major liability which may be disproportionate to the value of the contract. Many contractors will either refuse such exposure or will add a risk premium to their tender price.
- Smaller contractors or suppliers would be unable to meet such a liability and could not realistically insure themselves against it.
- The inclusion of such an obligation will inevitably make the contractor act more defensively right from the start of the contract. It will not engender a co-operative relationship aimed at best performance in the interest of project objectives.

- For retrofit projects, it will often not be straightforward as to why there is a performance deficiency and it may well not be due to the failure of a single party but for much more complex reasons. If a contractor is exposed to a possible large liability claim they will focus on arguing their position rather than assisting the client to remedy the situation.

The obligation for a supplier, consultant or contractor to promptly rectify their own defective work must be retained, and few will not object to this obligation.

15.9 Construction insurance

Unlike new build projects, retrofit projects are constructed within or adjacent to existing plant, facilities and infrastructure. Hence, if an incident occurs as a result of the retrofit project construction work, it may well cause loss or damage to the client’s existing plant, facilities or personnel as well as the project hardware and construction personnel. Similarly, there is the possibility that an incident within the existing plant could impact upon the project works and construction personnel.

There is therefore considerable merit in ensuring that each party involved carries insurance which covers for all possible injury, loss or damage to their own employees and property at the construction site, regardless of the cause. This is known as construction all risk (CAR) insurance and has several benefits including:

- This policy avoids the need to establish clear liabilities for any incident before being able to claim from the insurer. Each party’s insurer is responsible for the costs for the party regardless of the party causing the incident.
- The client will insure the existing plant and infrastructure and their employees. They will also insure the project materials and work at the construction site. This means that the level of risk (and hence premiums) is significantly reduced for contractors.

For this to work it is of course essential that all parties who will be present on the construction site comply with the requirements for insurance and, therefore, the client (and managing contractor) will need to impose the requirement.

16. Design and engineering

16.1 Design and engineering – general

The key issue is to recognise that the design and engineering of retrofit projects will be influenced by:

- The design of the existing plant/facilities.
- The constraints imposed by carrying out construction within or adjacent to the existing plant/ facilities.

It is vital that all those involved with the design are aware of this, have assessed how it will influence their part of the design and have identified their needs for relevant information. To this end, the design team will have a requirement to carry out extensive checking of existing installations and liaise with plant-based staff. It is essential that this need is facilitated and the location of the team is therefore an important issue which must be addressed when developing project strategy. See section 7.5.

The design for a project should be subject to review by all relevant parties and this is normally achieved by a series of design reviews. The number and extent depends upon the needs of the project and also the philosophy of both the client and design contractor. Timing of such reviews requires careful consideration and is usually a trade off between:

- Earlier review, based upon less-complete design, but the implications of any recommended changes are likely to be easier to accommodate.
- Later review, based on a more complete design, but any changes required are likely to have a greater impact on the project.

It may be necessary to carry out the main review at one time and recognise that there are certain specific items where the quality of information available at that time is inadequate. See Appendix F which shows a listing of typical design and safety reviews.

Whenever practicable, the existing plant dimensional datum for location identification should be utilised. This will eliminate the risk of confusion between old and new co-ordinates.

16.2 Safety, health and environmental (SHE) considerations in design

The design of a retrofit project, like any other project, must consider the safety, health and environmental issues associated with both the construction and the operation of the facility. For retrofit projects, the following additional aspects should be addressed:

- How to ensure safe access to the plant for designers and engineers in order to carry out surveying, design checks, marking of existing plant etc.
  - Ensure that all those who will visit regularly have undergone appropriate safety induction/training that is valid for the plant which they will visit.
  - Ensure that they have the required personal protective equipment and understand its mandatory use.
  - Ensure that they understand the requirements for “sign-on” and “sign-off” for each plant visit.

- Ensure that they are aware of restrictions related to the use of electrical and telecom equipment.
- Ensure that they are aware of the plant alarms and assembly locations in event of emergency.
- Agree a process for visits by occasional visitors who have not been inducted. The general requirement is that they should be accompanied.
- Advise the allowed locations for parking of vehicles.

- Are there any issues arising related to the compatibility of engineering standards used for the retrofit project against those used for the original plant?

- There is a need to check existing safety related systems to ensure that they have the capacity, specification, locations and compatibility for the facility on completion of the retrofit project. Examples are :
  - Review of capacity of existing flare and vent systems and of individual relief devices.
  - Firewater supply capacity, nitrogen purge systems capacity.
  - Locations of fire and gas detectors, emergency push buttons, safety showers, fire monitors, sprinkler systems etc.
  - Compatibility of existing process safeguarding systems (hardware and software) with any new installation. Identify competency issues relating to the design of changes to IPF systems.

- Identify required design safety reviews (e.g. HAZOP, IPF) and highlight to what extent they will need to address the existing installation as well as the new. See Appendix F.

- The design team have an obligation to design for safe construction (Ref. Construction Design and Management (CDM) Regulations in the UK and equivalent legislation in other countries). This will include :
  - Identifying how SHE will be managed throughout the project, including identification of responsibilities.
  - Involving those with detailed knowledge of the existing plant/facility to identify any existing hazards and how these may impact upon design and construction work.
  - Considering design options which will reduce construction (and later maintenance) risks.
  - Advising the constructors in respect of any (unusual) hazardous materials which they may encounter and the required safety measures.
  - Where appropriate, providing constructors with assembly/construction method advice to minimise risks.

- Consider how on-plant construction work can be minimised, but recognise that this may be limited by installation access space and the need to "field fit" due to inevitable limitations in dimensional accuracy at tie-in points. Can modular sub-assemblies be prefabricated offsite and then installed and hooked-up?

- Consider layout for safe maintainability and for safe access and egress. Ensure retrofit design does not compromise existing facilities.

- For instrumentation, consider alternatives of new marshalling/interface cabinets against the hazards of trying to use spare space in existing. Use of existing cabinets is likely to constrain the timing of construction work and may lead to an illogical layout of wiring within the cabinets.

- Check the design of tie-ins for ability to be safely installed in the conditions foreseen.

- If excavations are intended adjacent to existing structures, check that they will not affect the stability of the structure.

16.3 Availability of existing design data

In order to design the retrofit project it is necessary to have information concerning the existing installation. The extent of requirement will depend upon the scale of the retrofit project and the extent of the integration of new plant elements into existing. If the required information is not available, then an alternate strategy to cope without it is needed. This strategy will depend upon the type of information missing, but may require a complete re-calculation of loads/stresses for existing plant components in order to verify their ability to meet requirements imposed as a result of the new project. For instance, installing an additional vessel onto an elevated floor will increase loading.

The process design of the new project must take into account the process conditions pertaining to the existing facility (both normal operation and abnormal). Therefore, the availability of process data is a key requirement. This should have been addressed in the project definition stage (see sections 7.2 and 7.3).

Information is required for every point of interconnection (of new to existing), as well as the layout of the existing plant. Layout includes hidden items such as foundations, underground piping and cabling. Where existing drawings are not available, it will be necessary to draft, to some extent, the existing plant (piping, structural concrete, steelwork, equipment etc.) at each interconnection point and if part of an extensive design it is desirable to incorporate accurate plant location data (northing, easting, elevation). It is also valuable to know the original design codes used for the existing plant in order to check compatibility with those to be used for the current retrofit project.

In addition to the documentation available it is highly desirable for the design team to have access to individuals who have a detailed technical knowledge of the existing plant. It is inevitable that a number of queries will arise during design that can best be answered by those with detailed plant knowledge. In many cases, such knowledge contributes significantly to achieving optimum design for the retrofit project. Every effort should be made to ensure that such personnel are available and also that they participate in design reviews.

Whilst availability of existing drawings is usually the single most important component of existing design data, it is not the only one. Items such as process system calculations, equipment and instrumentation data sheets, civil and structural calculations, piping line lists and piping stress calculations can also provide valuable information. It is strongly recommended that a detailed assessment of existing information requirement and its availability is carried out before the detailed design work commences.

It is important to discover the status of all drawings and documents referred to. Unless the plant has only recently been constructed it is unlikely that there will be a single set of drawings and documents which fully reflect its current "as-built" status. In many cases, clients/plant operators do not ensure updating of all the original plant drawings and documents. Where earlier retrofit projects have been executed, they have often been implemented utilising a largely separate set of drawings and data sheets, with only limited integration on project completion. Drawings and documents which are not certified as up to date are still valuable to the design team, as much of the information remains valid. However, the information must be treated with additional care and a checking system implemented to ensure that invalid data is not used.

More commonly, clients update selected documents which are considered operational/safety critical. Typically, this may include process engineering flowschemes, instrument data lists, piping line lists, electrical one-line diagrams, overall equipment layouts, underground services layouts and hazardous area classification drawings. However, even where drawings are claimed to reflect current as-built condition this should not be totally relied on, and field checks should be made.

It is strongly recommended that a data survey/audit covering all relevant existing drawings and other existing design data is carried out as an early project activity in order to confirm the status (accuracy) of such documents. Such a survey will significantly improve the confidence level in respect of existing documentation and allow a strategy to be confirmed for their use. This survey/audit should always include an element of physical checking on site.

16.4 Updating of existing documentation

The owner of the plant needs to decide the extent to which they require existing plant documentation to be updated to reflect the addition of the retrofit project within a single integrated set of documentation. This decision will normally follow the owner's existing policy for such documentation and also needs to comply with regulatory requirements. The documents most commonly requiring to be updated to provide integrated document sets are:

- Process engineering flowschemes, utility flowschemes, safeguarding flowschemes.
- Instrument process data sheets.
- Instrumentation logic diagrams.
- Instrument loop diagrams.
- Safeguarding narrative.
- Control system documentation .
- Alarm and gas detection schematics.
- Equipment data sheets.
- Piping line lists.
- Electrical one-line diagrams.
- Electrical switchboard layouts.
- Cabinet wiring/termination diagrams (Instrumentation and electrical).
- Overall equipment layouts.
- Instrument location drawings.
- Underground services layouts.
- Hazardous area classification drawings.
- Operating instructions and emergency manuals.
- Equipment maintenance records.

It is important that the designer knows their obligations in this area at an early stage so that they can plan their work accordingly.

16.5 Modification of existing drawings for new design

Decisions must also be taken as to whether to carry out the design for the project utilising revisions (or mark-ups) of existing drawings and documents or to provide new documentation and then carry out integration upon completion of the project. Which option is chosen will depend upon a number of considerations, including the status of existing drawings both in terms of how up-to-date they are and whether or not they can easily be adapted to the CAD system the designer will use. Different decisions can be taken for different classes of document.

If new drawings and other documents are provided for the project, then a decision needs to be taken as to which party will carry out later integration work. This could be included in the design contractor's scope or alternatively the client (owner) may choose to do this work with their own staff or a contractor separately engaged to maintain the updating of plant records.

16.6 Drawing and document formats

Many clients have adapted standardised formats for their drawings and certain other documents. If such standards exist then it is highly likely that the client will require that the formats currently used for the plant drawings and documents also be used for the retrofit project. This requirement must be agreed before the start of detailed design and wherever possible the client should provide CAD templates for each type of drawing/document. Where existing drawings are being re-used (updated/modified), then conventions already on the drawing should continue to be used unless specifically agreed otherwise. Common aspects where standardisation may apply include:

- Drawing numbering.
- Layout of information boxes and notes on drawings.
- Use of standardised symbols for the various components on a drawing.
- Scales to be used for different types of drawing.
- Format of data lists such as line lists, instrument lists, cable lists, valve lists, material lists for isometrics.
- Format and symbols on logic diagrams.

16.7 Use of computer aided design (CAD)

Almost all detailed design work for engineering works is now carried out using CAD systems, and this brings many benefits of productivity, accuracy and the ability to easily exchange data between different designers. For new build projects, it is now common that a 3D multidiscipline intelligent model is developed. Such models are able to layout the plant for all disciplines avoiding clashes and retaining space for access as well as providing dimensionally accurate design details (e.g. piping isometrics collate total requirements for standard materials - material take off - MTO) and ensuring that any addition or change made on one drawing (screen view) is reflected on all other relevant drawings. For instance, if a line size is changed on a flowscheme it will amend the line list, the piping isometric, the material list, the MTO, the layout and also highlight any potential clashes with other parts of the design.

Where a retrofit project is to be carried out, the use of a full 3D interdisciplinary model can only be adopted if the data covering the existing plant is input into the model. If the plant is relatively new, then it is possible that there is an existing CAD model which can be used as start point for

the project. However, if the plant was designed before about 1995, then it is highly unlikely that such a model exists even though (less sophisticated) CAD design may well have been used.
If the extent of work projected for the retrofit project is extensive within a given area of the plant, then it may be worth considering the development of a 3D model for that part of the plant. Such a model will not have all the capabilities described above but will provide the ability to review the practicality of installing new equipment into the area, accurately dimensioning the new installations including connections to existing plant and the avoidance of clashes. It will also be able to provide material lists and MTOs for the new elements. The key to being able to develop such a model is the input of accurate dimensions covering all the existing plant and structures in the area to be modelled. This can be achieved by the use of photogrammetry or laser surveying coupled with use of specialised software which converts data into a CAD model. It must be recognised that development of a model using these techniques is both time consuming and costly (though costs are reducing). A careful assessment of cost versus benefit should therefore be undertaken before committing to this approach.

Where the extent of addition/modification to the existing plant (in a given area) is only moderate it is unlikely that the development of a CAD model will be justified. Of course, CAD can still be used as a design tool. However, it will probably be constrained to use as a single discipline tool with no automated transfer of data between disciplines. It will also be necessary to manually input plant co-ordinates and location data for connections to the existing plant and clash checking will probably require site visits by the designers.

This lower level of CAD use may have some benefit in that it is more likely that the existing plant drawings can be re-used where appropriate. If CAD files for existing drawings are available, then it is likely that they can be used by the CAD system adopted for the retrofit project as conversion software is available. Even drawings where only a paper copy exists can be scanned into the CAD. The scanned image will not be fully “intelligent” but can be modified by erasing and drawing new information onto it, which may be adequate. This also provides the capability to update existing drawings to provide the integrated design data for the plant (see section 16.4). It is, of course, essential when using existing drawings to be aware of their status in reflecting the current as built plant.

Where a retrofit project includes a discrete stand alone section (e.g. a new process unit or physical extension to an existing one) then it may well be sensible to develop a full 3D interactive model for the new part whilst using less sophisticated single discipline CAD design for the work in existing areas.

Regardless of which route is chosen, it is important that, when complete, the designs are usefully transferable to the end user (client). Hence, a CAD system must be used which will provide an output compatible with the client’s design record system. The client should indicate as part of the project definition which system(s) they use and obtain assurance from the design contractor that their design output will be in fully compatible formats or easily translated into such.

16.8 Photography

Photography (especially digital photography) is an extremely useful tool to provide visual information at a number of stages of project definition and implementation. Digital photographs allow input to be annotated, easily transmitted to other parties via email or as part of larger information files and can be retained long-term as a part of both project and plant records. Some particularly valuable uses in the context of retrofit projects are listed below:

- As part of a project definition package to show both the existing overall plant/facilities and to identify proposed locations of new. Photographs may include general area pictures and specific details. Annotation should be included to confirm what the picture is, i.e. location, orientation etc.
- For piping tie-in design, to show locations in detail. Annotate with location, orientation tie-in number and mark any removals needed.
- For work on existing buildings both externally and internally, to annotate where modifications will be made. For instance, new openings such as doors, windows, installation of new ductwork etc.
- For work inside existing instrumentation cabinets, to indicate where new instrument connections may be installed.
- For location of new equipment within existing plant areas, including the indication of any removals needed.
- For underground works to provide a detailed record before covering with paving etc. Particularly useful where multiple different items are adjacent to one another (e.g. cables, foundations, pipes, drains etc).
- As a record of construction progress. In such cases it is vital that photographs are dated.

The following security/safety points must be noted:

- Cameras are electronic instruments. They must never be used within a live plant area except with the specific agreement of plan operations staff. A clearance or permit to work certificate will usually be required.
- Many companies have security concerns in respect of the use of cameras. Use must therefore always be cleared by the plant/facility owner, who may also wish to approve each individual photograph and limit its use.

16.9 Plant numbering

Almost all process plants and facilities apply a numbering system to identify individual components of the plant or facility. For the retrofit project there will be a requirement to continue the existing numbering system. The principles to be applied to numbering should be identified as part of the project definition and (to a considerable extent) shown on the engineering flowschemes which form part of the definition package. This requirement will normally include:

- Process unit/building numbering.
- Equipment numbering.
- Pipe line numbering.
- Instrument numbering.
- Valve numbering.
- Cable numbering.
- Switchgear numbering.

Where redundant equipment or other items have been removed from the plant it is generally good practice not to re-use its number unless the new item is in fact a replacement in essentially the same duty. Where this is the case a note should be included in the plant records.

16.10 Process design

For any process plant, the process design is the key building block from which most of the rest of the detail design is developed; this is no different for a retrofit project. For the retrofit project, the process design, when complete, must form an integrated extension/update of the process design of the plant before the new (retrofit) project.

The whole of the process design work for the retrofit project must take account of the process design of the existing facility. This includes not only the process conditions which apply for steady-state normal operation, but the parameters which may apply during start-up and shutdown or other credible but abnormal conditions. The detail of the process design can be carried out by the design contractor's engineers, but it is important and highly beneficial that the process design work involves advice and review from both a process engineer with good plant-specific knowledge and operations staff who are able to articulate the various operating scenarios.

For any project it is highly desirable that a significant portion of the process design is carried out in the project scope definition phase and this is even more important in the case of retrofit projects (see section 7.3). That part of the process design not carried out in the definition phase should be completed so far as is practicable very early in the detailed design phase. However, it is inevitable that there will be a certain amount of iteration of the process design required as a result of the development of the rest of the detailed design and, again, this is likely to be proportionately greater in the case of retrofit projects. Examples are:

- Detailed design reveals that a tie-in physically cannot be located as shown on the flowscheme. Re-location will require the process design to be reviewed.
- Safety review shows existing relief valve and associated piping is inadequate.
- Detailed pressure drop calculation shows that a proposed new line must be a larger size.
- Proposed safeguarding specification needs modifying to allow plant start-up.

Prior to completion of the project it will be necessary to ensure that all new process data has been transferred onto the plant master documents which show the current overall status of the plant. This will include the updating of the master set of process engineering, utility engineering and safeguarding flowschemes, the piping line lists, instrument data sheets, relief and safety valve data sheets and any logic descriptions relating to control and safeguarding systems. It is important to make it clear at the outset of the design who has responsibility for the execution of this updating work. Is it in the contractor's scope or will it be done separately by the client?

Some organisations will also wish to separately retain a document set which reflects the process engineering and other design work specific to the individual project.

16.11 Layout

Consideration of layout for a retrofit project is very much influenced by the existing facilities and the spaces available. The following lists some considerations:

- It is essential that space remains to provide safe access and egress for plant personnel (this is a legal obligation); therefore walkways and access platforms must not be blocked by the installation of new plant, unless new routes are created to replace them.

- Sufficient space should be left to provide for maintenance access, especially around items where maintenance is expected, e.g. heat exchanger bundle pulling, control valves, relief valves, pumps, mixers, manways on vessels etc. Additionally, the provision of lifting beams/pulling posts should be considered where appropriate.
- Where it is unavoidable that a pipe or beam crosses a walkway at less than head clearance height (usually taken as 2.1m), then ensure that the pipe/beam is highlighted by painting it brightly; yellow/black stripes or equivalent. Consider attaching 50mm of insulation material so that any head impact will be with a softer material.
- Where it is unavoidable that a pipe crosses a walkway just above floor level, then provide either a ramp or step. Ensure that the ramp or steps are highlighted by painting them brightly; yellow/black stripes or equivalent.
- There may be cases where the preferred space exists for the new equipment but it is impossible to install. This then requires an assessment of how to create a route in by means of temporary removal, typically of piping, steelwork, flooring and sheeting. Assessment needs to address the technical feasibility (can such items be safely removed?), the cost and time involved for removal and re-installation and what alternative locations are available.
- Space can be created by the relocation of existing small equipment items and piping. However, before this option is confirmed there must be process engineering checks to ensure that features, such as required elevations relative to other equipment, are not compromised. Again, the additional engineering and construction work must be accounted for.
- Proposed locations for new equipment and piping must be checked to ensure that they can carry the additional loads. These include not only deadweight but also any imposed lateral loads.
- When routeing new piping, it is ideal if it can follow existing pipe routes, but this may not always be practicable. Consideration must be given to provision for expansion and contraction (hot and cold services), for continuous falls where needed, for use of long radius bends on slurry and solids transport lines and for carrying thrust loadings imposed by lines such as relief valve discharges.
- If part of the project includes a new process area, check whether it must be constructed immediately abutting the existing process area. If it can be located a little way apart (typically 15m or more) then there are likely to be considerable construction benefits arising from reduction in the safety constraints imposed by the proximity of the operating plant. In many cases this will more than offset the cost of extra interconnecting pipe work.
- Layout of new sewers and drains must be such that they allow the appropriate falls to ensure that they operate correctly.
- Layout considerations also apply in the installation of additional instrumentation within cabinets in the control building. This is addressed in section 16.15.

16.12 Civil and structural engineering

There are a number of issues specific to retrofit projects. These include:

- *Existing underground objects*. If new foundations, drains, cables or other project elements are to be installed below grade, there must be a check on the locations of any existing underground structures or services. The first check should be the existing design data, including that related to the facilities no longer used and including those which may have been demolished. However, lack of evidence from existing designs cannot be taken as absolute confirmation of the fact that there is nothing present, unless it is clear that the area has never been previously used for any plant or infrastructure. If existing drawings do show evidence of underground foundations or services, there is no guarantee that they are located exactly as per the drawings. It is strongly recommended that trial digs (by hand digging) are carried out to ascertain locations of suspected underground objects and that this is carried out during the design phase to allow design to accommodate findings if needed (see also section 18.6). It is also of value to locate metallic objects (including cables) are scanners which, when swept over the ground, identify magnetic anomalies.

- *Piling.* If any significant new structures or heavy loads are proposed, there may be a requirement for piling. It is unlikely that driven piling will be acceptable in any location within the vicinity of operating process units as the resulting vibrations present a significant risk of affecting sensitive instrumentation. Augured piles must therefore be used. Even with their augured piles, location should be such that the piling rig will not need to operate too close to existing process units unless this is absolutely unavoidable. Where piling is to be carried out on a site where old (demolished) facilities have been located, it will be necessary to have determined the location of old foundations including their piles and either remove them or arrange the new piles to avoid them. Piling layout may need some flexibility to allow alternate positions in the event that previously-undiscovered obstructions are encountered.

- *Drains.* Any new drains must be designed with levels and falls that are compatible with requirements at points of interconnection to existing drains. Existing drains need to be design-checked for capacity to meet new flow requirements. There may be a need to design any tie-ins bearing in mind that it is often impracticable to take the existing drain temporarily out of service.

- *Additional loading on elevated floors.* If any significant additional loads are to be imposed upon elevated floors, it is essential that the floor load bearing capacity is checked. If floor strengthening is required then the design must consider the practicality of installation, including possible requirement for fireproofing of steelwork.

- *Additional openings in elevated concrete floors and walls.* Other than for very small holes, it is likely that the cutting of a hole in a concrete floor or wall will result in cutting through reinforcing bar. If only one or two bars are cut this may be acceptable as there is normally considerable redundancy in the amount of reinforcement within the floor or wall, but if a large hole is required then it will be necessary to check the loss of strength. If necessary, a reinforcing ring will be required around the opening, which may necessitate the concrete being further chipped away to allow connection of existing rebar to the new. A ring located on the upper side of a floor will also act as a barrier to personnel putting a foot through the opening and to prevent water running through, off the floor. If the floor or wall has been designed as a fire or blast barrier then there will be a need to seal the opening. This can be achieved by a variety of methods; if necessary this will need to address the fact that a pipe passing through the hole may need some movement (e.g. for thermal expansion). Where rebar is exposed, it should be coated with a suitable paint or other coating in order to prevent corrosion, especially into the crevice between the rebar and the concrete.

- *Additional openings in steel floors and platforms.* If possible the holes should be located such that only the floor grating is cut out, in which case it is unlikely that any strengthening is needed beyond providing an upstanding steel lip welded onto the grating around the opening. If any of the floor braces must be removed then they will require replacement with a new arrangement of braces avoiding the opening. The flooring will then need to be clipped to the new braces.

- *Additional connections onto steel columns and beams.* If additional steel is to be added to existing structures, then new connections will be needed. In order to design these connections, it will be necessary to have calculated the forces and movements imposed from the new steel. It will also be necessary to determine the ability of the existing steel to carry these additional loads and moments. If the existing steel is fireproofed, this will need to be locally removed and then re-instated after installation of the new connection; this is a time-consuming activity. If existing steel has been galvanised, then before any welding is carried out the galvanising must be locally removed to avoid the creation of toxic fumes and contamination of the weld. After welding is complete, the affected area should be thoroughly cleaned and a zinc-rich coating applied.

- *Modifications to concrete water (or other fluid) storage tanks/interceptors.* If such tanks are extended or internally modified, it is vital that the connections between new and old are, and will remain, watertight. This requires careful design of the connection and steps to ensure that there is no differential settlement in the future. If a small opening is made for a new pipe to pass through, it is essential that there is a seal between the pipe outer surface and the wall. This can be achieved by various means. One method is to weld a puddle flange onto the pipe at the point where it passes through the wall and cast this into the wall to ensure no movement of the pipe relative to the wall, then filling any remaining gap with a waterproof grout. Where the tank has a corrosion-resistant lining, it is essential to address how the joint between new and existing will be sealed.

- *Modifications to buildings.* There are a huge range of modifications which may be contemplated and each will have its own issues to be addressed. Some of the common issues are listed below:
  - Check that any large openings made will not render the building structure unsafe during the period of the work. If needed, design and install temporary bracing.
  - Modification work is likely to cause dust, noise and vibration. What is the impact upon the normal occupants of the building (people, instrument systems, computer systems, electrical systems)? Specific provision may be needed to minimise this.
  - If during modification works, certain parts of the existing building must be cleared is temporary accommodation required? If so, this needs to be provided in advance of the commencement of work on the modification. This temporary accommodation may itself need design and specification.
  - If the building is to be extended, design must ensure that there is no differential movement between old and new.
  - If the building is to be extended then the building services (mechanical, electrical, heating and air conditioning, fire alarms, water supply, drains etc) required for the new section must be considered. In particular, how will they be interconnected to those of the existing building and do the existing facilities have the capacity to accommodate the extension?
  - If any new openings are required below ground level (e.g. for cable access into a control building basement), then it is vital that design provides for a good water seal. See also section 18.9.

16.13 Mechanical equipment

- *New equipment*. In most cases, the specification of new mechanical equipment items will not differ as a result of the project being retrofit. However, consideration should be given to:
  - Checking that the proposed item can be physically installed in one piece. If not, delivery will be required as components. In such cases a trial assembly should have been carried out prior to delivery to site.
  - Pre-assembly should be carried out prior to installation as it is far more efficiently done in a workshop or even on-site but away from the plant, than having to assemble in-situ. Examples are installing the stirrer into a reactor before lifting in or taking delivery of a compressor as a skid unit including items such as motor and gearbox, coolers, oil circulation systems and local instrumentation.

- *Existing equipment.* Where the foreseen operating conditions of an item of equipment will be changed as a result of the retrofit project then it is essential that an assessment of the item is carried out to confirm that it is suitable for the new duty. Assessment must address all normal and abnormal conditions. It must include higher temperatures and pressures, higher flow-rates and should also include:
  - Lower operating temperatures which could result in increased risk of corrosion under insulation.
  - Lower operating temperature which could increase the risk of brittle fracture.
  - Introduction of cyclic (temperature and/or pressure) conditions which could lead to increased risk of fatigue failure.
  - Changed specification of fluids (or solids) inside the equipment could result in increased corrosion, erosion or fouling.

- *Modification of existing equipment.* This work requires very careful planning as to its feasibility and the methodology to be applied. Considerations include:
  - Whether the work should be done in-situ or the equipment item removed to a workshop. It may be worthwhile even for large items to consider moving to a workshop as this facilitates much more efficient working and (in some cases) the utilisation of better tools and equipment.
  - If the item to be modified is a pump, compressor or other machinery item, then it may well be appropriate to involve the original supplier in the design and installation of modifications.
  - If new nozzles are to be installed onto a pressure vessel or tank, then a detailed design and installation procedure will need to be developed. As with piping tie-ins, if the service is liable to corrosion, then checks to ensure that there remains sufficient wall thickness are essential.
  - If a new head (or large nozzle) is to be installed, there needs to be recognition that the existing vessel may well not have been fabricated exactly as per the design drawings and the connection between new and old needs to be able to compensate for this. Typical examples are:
    - Wall thickness differs from design.
    - Shell is out of round.
    - Location/orientation of existing fittings is not as per design.
  - If work inside vessels is required, aim to design so that this is minimised.

- *Maintenance provision.* Where new equipment is installed, provision for maintenance should be considered. For example:
  - Lifting beams for rotating equipment and for vessels with removable top heads where use of cranes is not practicable.
  - Provision of sufficient space to allow bundle removal on heat exchangers, also pulling posts to assist especially when the exchanger is located on a elevated platform.
  - Are any long delivery spare parts needed?

- *Mechanical locks and interlocks.* On some plants mechanical locks are fitted to prevent actions such as erroneous opening or closing of a valve or safety cover or starting/stopping a motor. In some cases these locks form a suite whereby they can only be opened or closed in a certain sequence (for example, the cover for opening a stirred vessel can only be unlocked after the stirrer motor switch is locked off). This is interlocking. Typically, these locks are supplied from a specialist vendor and normally all those fitted on a plant are from one vendor with keys not captive in the lock located in a key box within the control room. The key box is generally locked with a master key. In a retrofit project there may be a need to add additional locks and/or change the interlock sequence. It will therefore usually be necessary to engage the services of the original supply vendor.

16.14 Piping design

There are many additional constraints and issues associated with piping design for retrofit projects and the designer must take account of them. They include:

- *Existing piping design data.* Recognise that even where drawings for the existing plant are available, they cannot be assumed as entirely accurate. Hence, field checking will be needed. Even when field checks have been carried out there is a limit to the practicable accuracy of measurements at connection points between new and existing (tie-in points). It is therefore necessary to incorporate within the piping details some allowance for the constructor to make "field-fit" adjustments. Where possible, these should allow for adjustment in each plane.

- *Fitness of existing piping for revised duties*. Where the foreseen operating conditions of existing pipework will be changed as a result of the retrofit project, it is essential that an assessment of the item is carried out to confirm that it is suitable for the new duty. Assessment must address all normal and abnormal conditions. This must cover higher temperatures and pressures, higher flow-rates and should also include:
  - Lower operating temperatures which could result in increased risk of corrosion under insulation.
  - Lower operating temperature which could increase the risk of brittle fracture.
  - Introduction of cyclic (temperature and/or pressure) conditions which could lead to increased risk of fatigue failure.
  - Changed specification of fluids (or solids) inside the piping which could result in increased corrosion or erosion or fouling.

- *Piping Tie-ins*. Tie-ins are the connections made between new elements of a plant or facility and existing elements. They occur in nearly every engineering project, but in the case of some retrofit projects the number of tie-ins can be very large relative to the overall scope. Typically, they require considerable design and management input relative to their overall contribution to the project. Tie-ins also occur when a new plant or facility is pre-assembled in several modular sections and there is then a need to connect the modules to each other. Tie-outs are where an existing connection is to be disconnected. Tie-ins may be permanent or temporary. Considerations for design include:

- A tie-in schedule should be produced. This document should be originated by the process engineers in the process design phase, but its completion will require considerable involvement from the piping design group. This listing should include, in addition to pipe-to-pipe connections, new connections of pipework to equipment, new connections of drainage systems, new connections to ventilation ductwork, any new connections to pipe or equipment required for instruments (e.g. pressure connection, analyser connection, thermowells). An example of this schedule is shown in Appendix C.
- The design of tie-ins should be treated as a high priority activity which should be progressed as early as is practicable in the overall design process. Design of tie-ins will require:
  - Review by the process engineer and plant staff to confirm the validity of the design and the practicality and detailed requirements to allow installation (e.g. what isolations and other preparations are needed?).
  - Identification of need for stress checks associated with the design.
  - Identification and agreement of testing requirements.
  - Identification of location and checking the integrity of the existing pipes or vessel at that point to ascertain that it is suitable for the proposed tie-in. If this is shown not to be the case, then either remedial work will be needed or an alternative tie-in location found.
  - Check compatibility against the drafting of the route for the new pipework which connects at the tie-in.
  - Procurement of any long-delivery items associated with the tie-in. Certain types of valve may have delivery periods of 16 weeks or even longer.
  - If a hot tap is required, engagement of the services of the specialist contractor.
  - If possible, design to allow for the possibility of tie-in installation at an earlier opportunity if one should arise.

  It is not uncommon that one or more of the above may cause a need to reconsider the detail design or location of the tie-in.
- Tie-ins may result in a change to the process conditions and stresses within the piping system. It may therefore be necessary to re-check the design integrity of existing piping as well as the new.
- If the existing piping is in a corrosive or erosive service (including external under-insulation corrosion), checks must be made to ensure that there is sufficient remaining metal to allow a safe tie-in to be constructed. Ideally, these checks should be made as part of the design process. If there is a significant loss of wall thickness then it may be necessary to replace a section of the existing pipe or to move the tie-in location.

• *Design of new piping*. This should aim to follow routes already established for piping where practicable. Where new routes must be used, there is a need to consider pipe supporting and care must be taken to avoid blocking routes for personnel access or space needed for maintenance of equipment (see also section 16.13). Design of new piping must take account of the need to physically install the pipes. If they are located within the core of an existing unit, there is likely to be limited space to manoeuvre and the possibility that cranes cannot be used; therefore, there will be a need for smaller spools to ease the ability to move the pipes into position.

- *Piping material requirements*. An effort should be made to identify as early as possible any piping items which may be on extended delivery and estimates of required quantities made so that procurement can be initiated. Typically, valves are the most likely long-delivery items, and in most cases valve requirements can be taken from the flowschemes. However, long deliveries can also occur for certain of the less-common pipe fittings, especially if they are in exotic materials (see also section 17). It is often impossible to gain an accurate set of requirements for pipe fittings until isometrics have been prepared, so if exotic materials are involved, those isometrics should be given priority.

- *Redundant pipework and equipment.* For existing piping which is to be removed, a separate set of drawings should be prepared (possibly a mark-up of existing plant drawings) showing what is to be removed. These drawings must be clearly marked as dismantling drawings. Additionally, the designers should (with the agreement of plant operations) physically mark all pipework and other equipment to be removed with red (or other bright colour) spray paint two to four weeks before removal work commences. The project process engineer or another separate party should check the accuracy of this marking.

- *Piping and equipment removed for re-use.* Where piping items are to be removed and then re-used, it is essential that this is marked on both the removal drawings and on the new installation drawings. Additionally, the item should have a durable label attached to it which specifically identifies it and indicates that it will be required for re-use. It should not be spray painted in the manner of redundant items.

- *Preparation of piping isometrics*. It is often the case that issue of piping isometrics is time-critical to the overall project schedule. In such cases, it may be desirable to make available preliminary versions of the isometrics to the construction contractor. However, if this is done it is vital that:
  - This process is clearly discussed and agreed with the construction contractor.
  - The exact status of every isometric is clearly marked on the drawing (e.g. for planning, for material procurement, for fabrication, for construction).
  - Similarly, if an isometric is generally issued for construction but a small part is still not finalised, then this “hold” must be clearly marked.

- *Fixed fire-fighting systems.* The project definition package may specify requirements for extension of these systems. However, if the retrofit project involves significant modifications to layout, or extensions to process systems which have specific fire-fighting requirements, then a review should be carried out to verify whether or not the existing installations are sufficient. The review should cover the following questions:
  - Have any process systems which have pressurised plastic fire detection tubing attached been extended or otherwise modified? If so, then the detection system may need to be similarly modified.
  - Do existing fire water deluge systems need extension or are new deluge systems needed?
  - Do existing fixed monitors provide adequate coverage?
  - Are there adequate fire hose connection points?
  - If there is a change to the maximum firewater demand, can the supply systems provide the additional water at required pressures? Note, if upgrading is needed the cost could be significant.

- *Design support in construction*. It must be recognised that even high-quality piping design will not result in every single piece of pipework fitting perfectly first time. There are several reasons for this and the probability and extent to which this will occur is significantly higher in the case of retrofit projects. It is important that piping designers are available throughout the piping fabrication and installation process to rapidly address and resolve problems as they arise. Piping installation is a critical activity for most projects; therefore delay will impact upon the overall project completion.

16.15 Instrumentation design and engineering

The requirements for the design and engineering of instrumentation and control systems for retrofit projects are likely to differ significantly from those for a new stand-alone plant. This is because in almost every case there will be a requirement for a degree of integration of the new installations with existing, in many cases with the objective of providing a single integrated control system. Considerations include:

- *Availability and quality of existing plant data.* If there is to be integration of the new installations with the existing then it is essential to know what is existing. In the ideal situation, there will be a complete set of drawings including instrument lists, functional logic diagrams, loop diagrams, wiring diagrams, cabinet and junction box termination diagrams, field hook-up drawings etc, which are up to date. Unless the client (operator) can give a definitive assurance that these are fully up-to-date, then it must not be assumed that they are. Field checking should be carried out to verify status. If they are found to be valid (or close to) then there are significant benefits to be had in modifying these drawings as needed to represent the additional installations required for the retrofit project. Benefits include:
  - Existing wiring and spare capacity information is immediately available to the designer.
  - Showing new alongside existing is useful for the installing electrician to ensure they install correctly.
  - Any minor errors discovered in depiction of the existing installation can be corrected.
  - Any removals to be carried out as part of the project can be shown on the same drawing.
  - The output can be used to provide a set of designs which show the total instrumentation/ control system for the plant/facility.

  It is, of course, essential where existing drawings are revised, that the revisions are clearly identified to leave no doubt what is existing, what is new, and what is to be removed. Where necessary, explanatory notes may be added.

- *Existing data not available and/or not valid.* There will be instances when the existing design data for the plant is not available or is substantially not up-to-date or is otherwise not valid as a basis for the retrofit project instrumentation design. It will then be necessary to prepare the design for the project on a stand-alone basis, but there will need to be substantial cross-checking to ensure compatibility with what is physically present in the existing plant and, where appropriate, to make notes on the designs. In this case, all design documents must_carry a clear note indicating that they show only the elements of the instrumentation and control system provided as a part of the retrofit project.

- *Plant re-instrumentation projects.* Occasionally, a retrofit project is carried out where one of the objectives is to replace existing obsolete instrumentation. Typically, this might involve the replacement of pneumatic instruments with electronic versions and the provision of a distributed control system (DCS) or programmable logic computer (PLC) for control. It is usual that these projects do not simply mirror the existing control capability but also aim to enhance it. Indeed, the possibility of improved control or even advanced process control (APC) often forms a key component of the justification for re-instrumentation. There is therefore a need for a full user requirement specification as per any other control/ instrumentation project. Additionally, if APC is intended, there will be a need for significant input from a process control engineer and this involvement is likely to continue for several months after plant recommissioning in order to optimise the system performance. Such projects require the development of a definitive instrumentation drawing/document set covering the whole of the plant. This can utilise the latest smart CAD systems (such as Intools) where data for a given loop need only be input once to provide all needed documentation. If the re-instrumentation is not total, there will be a need to depict the existing (retained) instruments.

- *Use of CAD for design work.* Instrumentation was probably the first category of design where the use of CAD was adopted. Hence, most (but not all) plants/facilities instrumentation drawings are now CAD-based. However, for many of the older plants, the CAD system used will have been a simple drafting tool which produced individual drawings not electronically linked to other drawings and documents. For the retrofit project, a decision will be needed on whether to continue with the simple system, which has the benefit of being able to re-use existing documents and revise them (see comments in section 16.7), or to start a new stand-alone document set for the project which can utilise the now-available smart CAD tools. This decision is likely to be based upon the quality of existing documentation and the scale of the instrumentation design work needed for the retrofit project. The decision regarding which way to go must be taken before the start of the design work and preferably should be addressed jointly by the client and design contractor as part of the overall strategy for the project. A third option is available which would be to agree to "back in" all existing plant instrumentation design information into the smart CAD system. This would achieve an excellent dataset for the plant but requires additional, possibly significant, design effort which in turn entails additional time and cost

- *Use of spare capacity in existing cabinets and junction boxes.* Most plants when constructed are provided with interface/marshalling cabinets and field junction boxes (JBs) where not all of the terminations have been used. The volume of spares provided will vary and subsequent small retrofit projects may have used some of the initially spare capacity. An early decision is needed in the instrumentation design as to whether new instrumentation will use spare capacity, or new junction boxes and cabinets are needed. There are a number of points to be taken into account:
  - If the number of new field instruments is small and there are comfortably sufficient spares, including spare capacity in cabling from JBs to the control building, then normally the use of these spares will be adopted. This is a straightforward and lower-cost option.
  - If the number of field instruments is such that new cabinets/junction boxes are needed, then it may be easier to route all the new instruments via the new JBs and cabinets as this will make construction work more straightforward and allow more work to be done with the plant in-service. However, there may be cases where because of physical location and/or interface with other existing instruments, it is still preferable to utilise some of the spare capacity in existing JBs.
  - When new cabinets and junction boxes are specified, it is always sensible to include some spare capacity beyond the net identified requirement. It is rare that during the progress of detailed design there is no growth in the number of instrument cabling/ termination needs. The extent of spare provision is something to be agreed between the

designers and the client; the latter may wish to make some allowance for future small projects.

- If the project includes general plant re-instrumentation it is now possible to consider the field-bus approach where signals from all instruments in a given area are transmitted along a single digital highway cable (usually there are two cables in order to provide redundancy). In this case, the requirement for junction boxes and cabinets is substantially reduced.

- *Additional instrument cabling.* If new field junction boxes are installed, then it is almost certain that additional cabling from the JBs to the control building will be needed. Installation of new cables into an existing plant is often not straightforward. Ideally, the routing will largely follow that of existing cables, but there may be significant difficulties in the installation of such a route. In designing the route, both the cost of materials and cost and feasibility of installation must be carefully considered.
    - If cable routing is underground it is highly desirable that excavation and cable pulling is done before plant shutdown, as it is a time consuming task and also restricts access whilst it is ongoing (definitely not something wanted during a shutdown). However, for the very same reasons the plant operations staff may be reluctant to allow such work with the plant in-service.
    - Where road crossings are intended, it is normal practice to install ducts. If an existing cable route is being followed, it is possible that there are already ducts in place and that there is spare space to provide for the new cables. If not, and new ducts are to be installed, it normally makes sense to install a few extra as the cost of ducts is very low. A merit of ducts is that their installation requires the road being crossed to be out of use for only a few days.
    - Above ground, routing is fairly straightforward if there is existing racking with spare capacity for new cables. However, if there is no available racking then the cost of material and installation could be substantial and, again, it would need to be determined whether such work could be done before the plant shutdown. In some cases, above ground cabling will require fire-retardant wrapping. New racking must be routed not to block access ways.
    - Digital highway cables, which typically carry all the signals for the whole or a substantial part of a plant, may require to be duplicated and if so, they will probably need to be routed separately to significantly reduce the risk of common cause failure.

- *Commonality of components*. There is often a desire from the plant operations and engineering staff that additional instrumentation is of the same type as that already installed on the plant. Where the existing equipment is modern, this is a reasonable approach, but it must be made clear before the start of the detailed engineering works. For certain items, such as capacity increase to a DCS system, there is of course no other option but to purchase from the original equipment supplier.

- *Modification/extension of safeguarding systems.* The requirement to modify or extend an existing safeguarding system should be based upon a clearly written user requirement specification (URS) which states all of the required functions of the safeguarding system on completion of the project (the URS should be an output from the process design). There should also be a safeguarding narrative which lists all of the cause and effect requirements for the proposed system. For a retrofit project, this should also identify where any existing cause/effect requirements are to be modified or deleted. A number of issues will need to be addressed and before the detailed design proceeds the approach to be adopted must be agreed. It is normally highly desirable to closely involve an instrumentation engineer who has a detailed knowledge of the existing system. There are commonly three generic types of system:

- Relay based wired system. This type was the norm for systems up to approximately the early 1980s. Their main deficiency is degradation of the performance of the individual relays.
- Solid state logic system. Solid state components hard wired on circuit board. These have a very high level of reliability, but modification is often difficult. These were adopted from the 1980s onwards.
- Programmable logic computers (PLCs). These systems utilise industrialised versions of personal computers (PCs) connected to the field instruments and controllers via interface cabinets. Usually, they are duplicated or even triplicated to provide redundancy in the case of single processor failure. It is relatively easy to modify/extend the software-based logic. PLCs have been used for process control since the 1980s, but their use for critical safeguarding service is more recent.

Selection of the approach for modification/extension should consider the following:

- The extent of the modification/extension intended.
- The extent of interfacing between new and existing.
- Need to categorise these instrumentation protection functions (IPF) by criticality and, hence, the level of reliability required. (Ref. IEC61508 Functional safety of electrical/ electronic/programmable safety related systems and IEC61511 Safety instrumented systems for process industry sector).
- If existing equipment is relay-based, its general condition and the availability of similar-type additional relays (there may be a case for total replacement).
- Availability of valid wiring diagrams and logic information in the case of relay or solid state logic systems.
- Identify and agree when the modifications can be carried out. Generally (but not always), modifications to existing system can only be done when the plant is out of service.
- Decision as to who (design contractor, original vendor, specialist contractor or client staff) will carry out the programming of a PLC system and whether that party or another will develop the functional logic diagrams and programme algorithms. Note that, unlike the UK, the IEC codes impose specific competency requirements on designers of critical systems.
- The need to re-test the modified/extended system, including who will be responsible for this.

- *DCS/PLC extension and update.* Any retrofit project which includes modification or additional instrumentation will almost certainly also require some work associated with the DCS or PLC control system. In planning and carrying out such work, the following need to be considered:
  - The required additional capacity/capability needs to be fully defined by listing all additional instruments and a statement of required functionality. This can then be analysed to assess hardware requirements for the DCS/PLC. Assessment must be carried out by personnel with specific knowledge of the existing system. If the outcome indicates marginal capacity availability it is recommended to provide additional hardware as in most projects there is some growth of requirement as the design progresses. Similarly, a lack of required functionality will require additional/replacement hardware.
  - Determination of the spare capacity in existing interface cabinets (see above) and interconnecting highway cables.

- Decision as to who (design contractor, original vendor, specialist contractor or client staff) will carry out the programming of the DCS/PLC system and whether that party or another will develop the functional logic diagrams and programme algorithms.
- Arrange for the supply of additional hardware (processors, memory etc) and arrange for its installation. Supply must normally be from the original equipment supplier and installation is usually carried out by the supplier.
- Determine when the installation and programming work can be done and make arrangements for the required personnel to be available as required.
- The configuration and functionality of the control system displays is an aspect in which the plant operators may wish to be involved. Such involvement is greatly beneficial to their acceptance of the design and for the training of operators in its use. Such involvement should occur early in the design phase when requested changes to screen layouts does not impose significant rework.
- Identify how the modifications will be tested/validated and who will be responsible for this.

- *Fire and gas detection/alarm systems.* The requirement for extension of these systems may be stated in the definition package. However, if the retrofit project involves significant modifications to layout, then review should be carried out to verify whether the existing installations are sufficient and remain correctly located. If new process chemicals will be introduced as a result of the project, the existing gas detectors may not be suitable for the new fluids (e.g. hydrocarbon detectors generally do not detect inorganic gases). If additional gas/fire alarms are needed the following should be considered:
  - Can existing field cabling be used or will new cables be needed?
  - If there is a discrete alarm panel in the control room can this cope with the extra points or will a new panel be needed?
  - If alarms are input to DCS/PLC, then these will require some reconfiguration.
  - If alarms will be input to the safeguarding system, determine how additional inputs will be achieved.

- *Quality measurement instruments (QMIs).* If new quality measurements are required the following should be considered:
  - If new measurements are similar in type to the existing on the plant, can the same instruments be used? Many instruments can be adapted to sequentially measure/analyse different streams.
  - If new instruments are required, it may be worthwhile to provide additional capability to replace existing QMI instruments. The most modern instruments have greatly enhanced capability in terms of both accuracy and speed of response. In particular, if the instrument is part of a closed loop control system this can yield significant benefit at minimal cost where a single instrument is used to measure multiple streams.
  - Check the requirement for any new off-line (laboratory-based) instruments. If these are required, are they within the project scope and do they need supporting infrastructure such as power supplies, other utilities etc?

16.16 Electrical design and engineering

For the great majority of retrofit projects, the aim will be to integrate the new electrical equipment with the existing installations. To provide complete new power supply and control systems could be very costly. The following aspects should be considered when carrying out the electrical design:

- *Identification of new power consumers and overall power requirements.* The project definition package will should identify the intended new significant consumers, such as electric motors, heaters etc. However, there can be many other new consumers which may not be directly identified. One of the first tasks for the electrical design group, working closely with other discipline engineers, should be to aim to identify all new consumers. These may include:
  - Auxiliary motors on large machines (e.g. lube oil pumps, conveyor drives etc).
  - Auxiliary heaters on machines (e.g. lube oil heaters).
  - Electrically actuated valves.
  - Additional plant lighting.
  - Upgrade of domestic power supply to buildings.
  - Upgrade of HVAC system resulting in increased power consumption.
  - Change-out of motor driver to up-rate a machine.
  - New or up-rated uninterruptible power supply (UPS).

  In some cases, the exact power needs will not be known until vendor information is available. However, a conservative first pass of requirements should be made to check-out the capacity of existing transformers, switchboards, cables etc. to cope with the new loads. Ability to supply the overall power needed is not the only consideration; the number of new or up-rated consumers must be addressed as each needs a supply complete with switchgear and possibly other controls. Checks should therefore include:
  - For up-rated consumers check whether existing cabling and switchgear can handle the increased load.
  - Check what spare cables are available. Obviously, they need to be routed close to the proposed consumer location.
  - Check what spare switchgear is available. This should also look at the ability to install additional switches into existing panels and to extend them (assuming there is physical space to do so). Modifying/extending existing panels is usually only practicable if they are of a fairly modern design.

- *New switchgear.* If new switchgear is needed, it is essential to check that for installation into an existing switch-house, the supply has sufficient capacity at the required voltage and that there is physical space for the new panel. If the latter is a problem, it may be overcome by replacement of one or more of the existing panels as new switch panels are much more compact than old designs. The downside of this approach is that much of the changeover work can only be done during a plant shutdown.

- *Additional lighting.* Any new process areas will require lighting, but existing areas may also require additional lighting if the layout of equipment changes. Decisions will need to be taken as to whether additional lighting can sensibly be connected into the existing supply circuit. This will depend on both the load capacity of the circuit and the physical location of the existing circuit relative to intended new lights. New light fittings are an item where the plant owner is likely to require use of a common type of fitting with those already installed, particularly where these are of modern design.

- *Cable routing for supply to new consumers.* A first check should always be made to investigate the use of existing spare cables. It is not uncommon for certain cables to have become spare as a result of a consumer being no longer used. If adequate capacity exists, then its re-use can result in a significant saving. If new cables have to be installed, then careful consideration to routing must be given. The following should be considered:

- It is usually preferable to aim to follow the routeing of existing cables. However, a major consideration must be given to the constructability of the route within existing process areas, particularly as for scheduling reasons it is usually impossible to leave this cable installation work until a plant shutdown.
- Routing of new power cables should be considered in conjunction with that for instrument cables.
- The need for control cables between the switch-house and control building must be addressed.

- *Supply segregation.* For certain critical consumers, there may be a requirement for segregation of supplies in order to minimise the risk of single failure causing multiple shutdowns. For instance, two instrument air compressors will often be supplied from separate switchboards so that failure of supply at one board will result in only one compressor being shut down. Lighting is sometimes divided so that a part (typically 20 – 25%) is supplied via the UPS. This philosophy must not be compromised by the design of the retrofit project and specific requirements must be advised by the client.

- *Variable speed (VS) electric motors.* The use of VS motors is becoming increasingly popular given the availability of thyristor controlled alternating current (AC) systems which are highly efficient at a reasonable cost. For retrofit projects, such motors can be appropriate both as a means to:
  - Increase capacity without need to replace the pump or compressor.
  - Provide the ability to control and vary flow rate without the use of control valves and their associated energy loss.

  However, when retrofitting a VS motor the following points need to be addressed:
  - Is the existing motor suitable for VS use? This may require checking with the original supplier, but many AC induction motors are suitable.
  - Is the whole pump/motor or compressor/motor assembly suitable for the whole speed range intended? Ensure that no critical frequencies are encountered, that casings are fit for any higher pressures and that bearings can take additional loads.
  - Is there space to install the thyristor control unit in, or immediately adjacent to the existing switch-house?
  - Is the existing power supply cable able to cope with additional electric current flow?
  - How will the control signal be delivered to/from the thyristor controller?

- *Uninterruptible power supply (UPS).* Many process plants include a UPS which is able, in the event of main power failure, to provide sufficient power to critical consumers for sufficient time to allow safe shutdown of process units. Typically, this includes supplies to instrumentation, control and safeguarding systems, to critical motorised actuators to allow them to operate to move into safe status (e.g. reactor depressurising valve), to critical motors to allow orderly shutdown (e.g. lube oil pump on a compressor, reactor) and sufficient lighting to allow operators to do essential tasks. It is essential that as part of any retrofit project that adds to the loading on the UPS, an assessment is made of its continued sufficiency. If the required upgrading is modest, this can often be achieved by adding to the number of installed storage batteries.

- *Lightning protection.* Where a retrofit project will result in new buildings or other structures which are of similar height or taller than existing nearby structures, the need for lightning protection must be addressed. If the structure is essentially metallic, such as an open steel frame or a distillation column, then probably no special measures, other than ensuring adequate earthing, are needed. However, if the external elements of the building or structure are non-metallic then the installation of lightning rod(s) at the highest point(s), connected to earth by a suitable conductor, will probably be necessary.

17. Procurement of materials

Most requirements for procurement of materials are essentially the same as those applying to new-build, but some aspects become more important in the case of retrofit projects. Items which have special emphasis for retrofit projects include:

- *Preferred and mandatory vendors*. The plant engineering staff may have strong preference that the retrofit project provides certain items from the same vendor as that already present on the plant. In the case where an item is being modified or extended (e.g. DCS) then it is essential that the new components are from the original vendor. This listing should be prepared at the beginning of the design phase and should also identify model types, where needed, to ensure that engineers are fully aware of requirements.

- *Vendor agreements*. Where the client or the design contractor has long-term procurement agreement with certain vendors, it is often beneficial to agree that they will become the preferred vendor for the project. They can often provide best pricing and technical advice before order placement which can assist in optimising requirements; when the items they are supplying are time-critical, there is a greater incentive for them to give best possible delivery performance.

- *Critical delivery materials*. The project planning process needs to identify which procured items are likely to be time critical. This criticality may relate to the delivery of the material and/or to delivery of design data relating to it. In such cases, the following measures should be considered:
  - Early enquiry based upon a preliminary specification. This can be used to identify the preferred vendor and provide better delivery advice.
  - Negotiate with one vendor to agree firm price and delivery.
  - Provide incentives for timely performance. Note that cash flow is a significant incentive to many smaller companies.
  - Ensure that a portion of payments are linked to the delivery of key design documents.
  - Try to get a feel for how well the vendor has performed historically against their schedule promises. Take into account their current work load. Usually, a supplier who is reasonably busy (but not overloaded) performs best.
  - Focus expediting effort on critical materials, but do not neglect others as they can end up being critical.
  - Consider carefully what materials are to be procured by construction contractors. Such contractors may be good at procurement of standard “off the shelf” items, but they rarely have good technical procurement capability. For critical delivery materials, it will usually be desirable that orders be placed earlier than would be possible if left to the construction contractor.

- *Electronic data transmission.* There are major benefits in exchanging design and engineering data with vendors by electronic means. To ensure that this occurs smoothly, it is necessary to identify protocols for such transmission at the time of ordering. There is a need to be realistic; it is not reasonable or sensible to require a small vendor to carry out their design using software they are not familiar with. The main design contractor or client are better positioned to make any needed format conversions.

- *Factory acceptance tests (FAT).* Use of factory acceptance testing is beneficial to the whole project and should be applied not only to single items (individual instruments, pumps, vessels, valves etc) but also to more complex complete assemblies such as skid units, instrument cabinets, safeguarding systems, PLCs etc. The benefit is that testing occurs earlier, in a better environment and any deficiencies can be rectified at the factory. This will also significantly reduce the needed site testing. There should always be the opportunity to witness FAT and in some cases to combine it with training for plant-based personnel.

- *Vendor's engineers at site.* For certain items, it will be deemed necessary for representatives of the supplier to be present at site to assist with site assembly and installation, software programming, testing and commissioning. Wherever this requirement is anticipated, it should be included in the original order for the materials, even where the extent of requirement cannot be firmly stated. The following should be addressed:
  - Prices and rates for such work.
  - Timing and notice requirements.
  - Contacts for site work.
  - Safety, health and environment requirements for work at site.

- *Spare parts.* Enquiries for materials should, where relevant, include a request to identify and price recommended spare parts. However, in the case of a retrofit project the selection of spares to be purchased needs additional advice from the plant engineering staff. Purchase of spares will not only need to account for the client's spares philosophy but also what spares they already hold for similar equipment already on the site.

18. Construction

One of the most significant ways in which a retrofit project differs from a new-build or greenfield site project is the very fact that construction will occur (at least in part) within, or immediately adjacent to, existing plant or facilities. This has a major influence upon the construction work. Virtually all of the good practices which apply to general project construction remain applicable, but there are also a number of additional constraints and challenges, mostly related to SHE issues and labour productivity, which must also be managed. The following focuses on these additional issues and requirements.

18.1 Planning the construction work

The plans for construction should form an integral part of the overall project planning, and therefore, the overview strategic plan should initially be developed as a part of the project definition. The fundamental issues are:

- When must the various elements of the work be done?
- Who will carry out each element of the work?
- What are the key requirements to allow each element to be executed?
- What are the significant risks?
- Who has managerial responsibility for SHE?
- What are the required resources (labour, supervision, construction equipment etc)?

The initial views in respect of this will be the basis for the construction strategy. However, further work as the design and detail planning progresses may result in some changes aimed at risk reduction and productivity improvement. Generally, it is beneficial to:

- Aim to minimise work that has to be done within, or immediately adjacent to, the plant or facility.
- Identify whether the volume of project construction work planned to be carried out during shutdowns is critical to the shutdown duration. If so (as it often is), look at ways in which this work can be reduced. Some work may be possible with the plant in-service.
- Recognise the likely level of productivity for in-plant work and ensure that resourcing levels and planned durations reflect this (see also section 10.1).
- Recognise that in certain areas of the plant there will be (potentially significant) limitations on how many people can work at any one time. Work prioritisation and scheduling will need to reflect this.
- If there is any significant other work, such as maintenance, industrial cleaning, other project work, being carried out concurrently, then likely interfaces must be addressed and provision made for active co-ordination with those responsible for managing the other works. In some areas, especially scaffolding, the need for co-ordination of requirements is crucial.

In respect of tackling the above it is essential to actively involve plant operations personnel in the decision making. See also section 10.

18.2 Responsibilities for construction site safety, health and environment (SHE)

There can be no doubt that the client, the plant operations staff, the management contractor, the project design team, each individual contractor and all labour and supervision at the construction site all have a responsibility to ensure health and safety at the worksite.

Notwithstanding this, there is a need to ensure that it is clear who has overall managerial responsibilities for the construction work, including the facilities and services associated with it. On a new build construction site, overall safety management and co-ordination can normally be straightforwardly allocated to the management contractor (if one has been appointed) or to the main construction contractor. The individual contractors will retain responsibility for safe management of their own work.

Retrofit projects are less simple. A significant portion of the SHE issues are related to the fact that work will be carried out within, or adjacent to, an existing plant or facility. The party who has the best detailed knowledge of the plant or facility is likely to be the client/plant operation staff. Additionally, the client has both a legal obligation in respect of SHE at site and a strong business incentive to maintain safe working. It is therefore appropriate to carefully consider who has what managerial responsibilities. What is appropriate will need to be judged upon the needs of each project, the circumstances under which the construction work is carried out and the capabilities of each of the parties involved. The following may be appropriate:

- *Overall supervision of SHE management.* The client (operator of the plant or facility) may well wish to retain this role in order to ensure that plant-specific SHE considerations are fully identified and properly addressed. Alternatively, a management contractor may fill this role provided they maintain a close advisory link with the plant operator.

- *General site SHE Management and co-ordination.* This would normally be allocated to the management contractor (if one has been appointed) as one of their key responsibilities. If there is no management contractor it may be appropriate to appoint one of the construction contractors if their work represents the dominant element of the total construction. Alternatively, the client may retain this role, but if so must recognise the need for day-to-day managerial involvement (and hence resource). If this role is to be allocated to a contractor, then it is essential that before this commitment is made the client properly assesses their competence to carry out the role and in particular their understanding of the specific issues related to working on existing plant.

- *Contractor SHE management.* Each contractor is responsible for the management of SHE related to their work. This includes responsibility for all their own employees and anyone else who may be affected by their work. This responsibility cannot be abrogated.

- *Regulatory notification of construction works.* Other than minor works, all construction activity must be notified to regulatory bodies controlling construction SHE (In the UK, the Health and Safety Executive do this through their Construction Design and Management (CDM) regulations). It is essential that the required timing and the party who will be responsible for notifications are clear. Additionally, tracking must be carried out so that any needed revisions to notifications are not omitted. These may occur due to a material change in the scale, nature or timing of the work or in identification of the organisations involved. Requirements as to what must be notified and the required timing of such notifications vary from country to country.

- *Preparation and issue of permits to work.* In the great majority of cases, most physical construction work will only be allowed within existing plant areas when authorised under a permit to work scheme. Exact requirements will differ depending upon the plant operator's requirements, the nature of the work to be done and the status of the existing plant at the time it is to be carried out. It is vital that all parties involved in the construction work fully understand the requirements of the permit to work system that apply and their obligations in this respect. Permit to work systems can be the cause of (significant) loss of productivity to construction work, but this can be substantially reduced by effective planning and management, including:

    - Preparatory review with plant operations personnel of construction work foreseen and agreement of precautions needed for safer working.
    - Detailed understanding of how to prepare permits. If necessary, provide training to contractor supervisors.
    - Early submission of permits, accompanied by agreed method statements where appropriate.
    - Ensuring plant operations have sufficient resource for permit review and authorisation. If needed, arrange for extra resource by use of "off shift" personnel or hire in retired operators who know the plant.
    - Negotiate a possible relaxation on the number of permits required when plant is in shutdown.

A listing of key UK legislation relevant to construction work is provided in Appendix D.

The UK Health and Safety Executive provides many useful leaflets and guidance documents to good practice and assistance in compliance with UK legislation relevant to construction work. A full listing is available at www.hse.gov.uk. These will also provide excellent guidance for work outside the UK, though they may not fully meet local legislation.

18.3 Safety training for construction site labour and supervision

It is now common that labour and supervision employed by major construction contractors have undertaken industry-approved training and, as a result, carry certification (often known as a safety passport). However, it is inevitable that this training is mostly focused upon the general hazards and good practice related to working on a construction site. It is unlikely to have focused upon the additional issues related to retrofit projects and cannot have addressed site-specific and plant-specific issues. Employees assigned from specialist companies may not even have undergone general training related to safety on a construction site.

It will be necessary for the client and/or management contractor to develop a procedure to ensure that all persons who will work on the construction site or visit it for other reasons have appropriate knowledge and training. The requirements may differ depending upon the duration the individual will be on the construction site and the nature of what they will be doing. For retrofit projects, the following will need to be addressed:

- Understanding of the permit to work procedures. Additional training may be needed for those who will be requesting and signing for such permits.
- Advising the plant/facility specific hazards and what special precautions may be needed.
- Advising requirements for personal protective equipment.

- Advising immediate actions to be taken in the event of an accident or other emergency.
- Advising accident/incident reporting procedures.
- Advising on limitations such as carrying of matches, carrying and use of portable electric equipment, carrying and use of radios and mobile phones etc.
- Identification of first aid facilities.
- Advising of alarms and where muster points will be.
- Advising security requirements for the site.
- Advising car parking locations and restrictions on vehicle usage.
- Advising requirements for maintaining cleanliness of the work site.
- Advising requirements for waste disposal.

The above items and any other relevant points are usually covered at an induction course at the site which should be attended by all those who will work on the site.

A further issue can arise when foreign labour is employed. If such labour does not speak the language commonly used on the site, then special arrangements must be made to ensure that they have a proper understanding of the rules and requirements. The following should apply:

- Ensure that at least the supervisor has a reasonable understanding of the site language.
- Use the supervisor or another bilingual person to interpret during an induction course.
- If there are significant numbers of such labour, consider producing and issuing a booklet covering all the key points in the relevant language.

Where persons are simply visiting the site for a period of a few hours (and not carrying out any physical work), it is often impracticable to insist on an induction course. However, they should still be made aware of key requirements and be logged onto the site. A short induction can be given through the use of a video. An alternative is to insist that they are accompanied by someone who has undergone the needed induction training at all times.

18.4 Offsite prefabrication and modularisation

Carrying out fabrication offsite is far more efficient, sometimes allows work to be done earlier, presents fewer safety hazards and often leads to improved quality. It is therefore advantageous to maximise the amount of work which can be done in this way. The following should be done:

- Investigate whether new elements of the project can be constructed in modules, which can be lifted or skidded into position virtually complete, requiring only tie-ins/hook-ups. This kind of assessment must be carried out early in the project as it has a significant impact upon design detail.
- Consider the temporary removal of existing pipes, steelwork etc to allow installation of larger components fabricated/assembled offsite. This, however, has limitations as the temporary removals themselves add to on-site work.
- Allow the piping contractor flexibility in deciding the extent to which they prefabricate pipework.
- Consider where equipment items have to be modified, removing them to a workshop for the modification work.

18.5 Temporary facilities

There is a legal obligation to provide certain facilities for labour at construction sites. Additionally, the location and quality of facilites provided can significantly impact upon construction productivity. Considerations for retrofit projects include:

- Temporary facilities should be located as close as is practicable to the construction site in order to minimise lost time in transfer between the sites. However, the temporary facilities area should be located such that there are no limitations on activities in that area imposed by the proximity of process plant.
- There should be sufficient space for all users to locate offices, mess facilities and storage, and to carry out preparatory work.
- Space required for temporary storage of materials may need to be extensive as it must include access for trucks and lifting equipment. Materials should be stored off the ground on wooden sleepers unless delivered in packing boxes. Fabricated pipe spools in particular require extensive space.
- The material storage area must be secure and additional security measures may be required to avoid theft of valuable items. Small items should be placed in containers or (if present) buildings which can be secured and locked.
- Consider provision of multi-use (available to all labour) washing and toilet facilities and common provision of skips for waste disposal.
- The temporary facilities site should be secure when not in use.
- A specific location should be designated for car parking for staff and labour. This must recognise that road traffic accidents are a significant hazard (for many companies accidents involving vehicles are the single most common cause of injuries).
- Consider whether the issue of permits to work for the construction site should be based at the temporary facilities location rather than in the plant control building. If there are going to be a large number of permits, it is worth aiming to get dedicated operations staff to handle them. This is especially relevant at plant shutdowns.

18.6 Trial excavations

When construction work includes work below grade on a site where there have been previous installations of any kind, it will be necessary to positively locate all existing underground non-natural objects. Existing drawings are helpful, but they should not be relied upon as a complete and accurate record unless the site owner can give categorical assurance that this is the case. The normal method for providing additional assurance is to carry out trial digs. The number and depth of such digs will depend upon the nature of the new construction work contemplated. Some guidelines for digs are as follows:

- Digs will normally need to be carried out with hand tools, though if the area is paved it may be acceptable to carry out initial break-out of the paving with machines.
- Where drawings indicate the presence of objects, locate digs aimed at verifying locations.
- If the water table is high be prepared for needed de-watering.
- Generally, trial digs need not exceed 1 metre in depth unless deep foundations are contemplated and/or there is reason to believe that there are objects, the highest points of which are located a little more than 1 metre below grade.
- Where cables are discovered, there is a need to check whether they are live. Specialist devices will detect a voltage even if there is no current flow.

- Where pipes are discovered it is possible to detect any flow by acoustic devices. However, no flow in itself does not provide assurance that it is safe to cut the pipe. Unless the condition of the pipe can be confirmed, the use of a hot tap type procedure may be needed to drill a pilot hole in order to determine whether the pipe is pressurised or contains hazardous material.
- Where a pipe is to be cut, unless it is known that it was in a benign service, it should be taken into account, that there may be residues remaining in the pipe.
- Carrying out trial digs provides an opportunity to determine whether the local earth and ground water are contaminated. If this is the case then special arrangements will be needed for disposal when the main excavations are carried out.

Another means of detection for metallic objects is a scanner which detects magnetic anomalies. Having identified a potential object it will then be necessary to dig for identification. Use of such scanners is valuable to trace complete routes of cables and pipes without the need to dig the whole length.

18.7 Piling on existing plant sites

- *Piling close to existing operating plant.* This requirement is fairly common as a new unit associated with an existing plant or extension to an existing unit cannot normally be remotely located. The required timing for piling installation is unlikely to be concurrent with a planned plant shutdown. Provided that the piling rig is at least 15m from the existing plant, the required precautions will probably be confined to the following:
  - Use of augered, cast in-situ piles rather than driven piles. Pile driving causes significant vibration which is liable to affect sensitive instrumentation with resultant risk of plant trip.
  - Regular gas testing in the area between the plant and the piling rig.
  - Requirement of cessation of work in the event of a plant emergency alarm.

  Where it is necessary to pile immediately adjacent to existing plant, there may be a need to build a separation screen to segregate the rig from the plant. The purpose of the screen will be to:
  - Reduce the risk of any gas leak reaching the rig before it is shutdown.
  - Provide a physical barrier in the event that the jib of the piling rig inadvertently swings towards the process unit.

The requirement will be for a substantial barrier which will typically be at least 5m tall. Such barriers can be constructed from scaffold, boarding and sheeting. The barrier will need to be braced and anchored to ensure its stability both in the case of being hit by the rig jib and from wind loading.

- *Old foundations and piles*. When piling is intended on a site where plant has previously been located, there is always the possibility of encountering the old foundations and piles. This risk can be reduced by carrying out trial excavations (see above); however, consider also carrying out a general excavation of the area to be piled down to a depth of 800mm– 1m. This is not the significant extra cost it may at first appear to be as there will always be a need to cut back the new pile caps and to lay out the forms for new foundations which would in themselves require excavation. Additionally, the civil designer should be prepared to advise alternate locations for the new piles if the desired location is occupied by an old pile.

18.8 Excavations within existing plant area for new foundations, drains and cable routes

The easiest and safest time to carry out excavations within the plant is when it is shut down. However, this is often not practicable as excavations are carried out as a precursor to other work and not to start excavation until plant shutdown would inevitably delay such work and probably significantly extend the whole shutdown and project duration. Dependent upon the location and other hazards presented by the plant it may be possible to carry out excavation with the plant in-service. The following need to be addressed:

- Identify locations of existing underground foundations and services, use design documents where available, plus trial digs as appropriate.
- Develop a detailed method for the work including safety precautions and agree this with the plant operations function.
- Having broken out surface paving, hand dig to positively locate existing services.
- Digging adjacent to existing live cables will need to be entirely by hand as the risk of an excavator damaging the cables is too high.
- Arrange for removed spoil either to be disposed of immediately or stored in a location that does not restrict access.
- Ensure that the excavation is properly barriered, and that there is sufficient lighting to ensure that it is visible at night.
- The excavation may be at risk from flooding due to rainwater run-off from nearby paved areas. Depending upon the rate at which water soaks into the ground, it may be necessary to provide de-watering.

18.9 Work inside existing buildings

In many cases, process plant is located within buildings. This is the norm for food processing, pharmaceutical plant and is also common for fine chemicals, water treatment, waste processing, power generation and packaging facilities. Even for major oil and petrochemical plant, certain elements may be located within buildings. When it is intended that work be carried out within such buildings, a number of issues must be considered which will influence both the design and how the construction is carried out. The first consideration is whether operation of the plant will continue during the construction period. Points to be addressed include:

- What are the sensitivities to dirt, dust, solvent fumes, welding fumes, abnormal temperatures? This could be a crucial issue and may require specific measures to avoid any possible contamination of the manufacturing process or product. Protection must be afforded to personnel who need to be present in the building to carry out construction or are there for operational reasons. These considerations are likely to determine what work can or cannot be carried out with the plant in-service. Measures such as installation of plastic sheeting to isolate the construction area, regular vacuum cleaning etc may be needed.
- If the building is air conditioned, an assessment of what influence the air flow may have on the spread of undesirable contaminants should be carried out. Whilst in most cases it will be preferred to keep the heating ventilation air conditioning (HVAC) system in service, it may be necessary to temporarily block individual air outlets or to install temporary ducting to relocate the air outlet. Is the construction work likely to compromise its performance and if so is this acceptable? The answer to this may depend upon external climatic conditions, and hence it may be acceptable at certain times and not at others.

- Instrumentation and control systems are sensitive to dust, vibration and high humidity. Hence, if any of these are likely to occur it will be necessary to protect the instrumentation. This protection will be needed even if the instruments concerned are temporarily out of service. Protection can often be achieved by placing individual instruments in plastic bags and sealing them and cabinets and control panels can be covered in plastic sheeting and taped. With the latter however, consideration must be given to heat dispersion if in-service and also any hazardous area certification requirements.
- Unless the building has been taken out of service, any interruptions to existing services such as electric power and lighting, telecoms, datacoms, water supplies, drains and HVAC systems must only occur by specific arrangement with the building users and must be timed to cause least disruption.

18.10 Modification works to buildings

When modification of an existing building itself is contemplated (see section 16.12), the considerations stated in section 18.9 apply, but the following must also be addressed:

- Is the building occupied and if so is it intended that it will remain occupied during modification works? If occupants must be temporarily moved then the sequence of moves must be planned and this may influence the timing and sequence of the construction work. It may also require temporary accommodation to be arranged.
- If the building contains sensitive instrumentation, computer systems, switchgear or laboratory equipment, then considerations similar to those for an occupied building will be needed.
- Temporary openings in external walls may render HVAC system ineffectual even if still in service. It may be necessary to ensure that the opening is sheeted to provide a reasonable seal at all times other than the minimum time where unavoidable work dictates otherwise. This situation may also apply at openings between the existing building and a new extension, prior to the HVAC being reconfigured to include the extension.
- Cutting openings into blast-resilient concrete walls is a significant task; the concrete is likely to be thick and the reinforcing bar density high. Typically, diamond drilling is the method of carrying out such work and this will cause noise, vibration and some dust. It is also a time consuming activity. The use of sensitive equipment must be considered to minimise the impact on building occupants. Large, temporary openings may compromise the blast resilience.
- If, during construction works, normal means of building exit are not available then alternate safe means must be provided.

18.11 Isolation/spading

In order to carry out parts (in some cases the majority) of the construction work there will be a requirement to isolate parts or all of the plant or other infrastructure items. Requirements for isolations will generally be determined by the plant operating personnel, but in order to do this they require a good appreciation of the work to be done and the preferred timing of such work. Clearly isolation/spading needs are different when the overall plant or facility is in service compared to shutdown with overall plant isolations already in place. Requirements for isolations are a key determinant of what work can sensibly be done with the plant in-service. Additional considerations are:

- In many cases, isolation can only be made when it has been positively confirmed that the plant or element of the plant or facility is in the required status (condition). This can only be confirmed by plant operations. Similarly, the sequence in which isolations are installed is important.
- Determining who will execute the installation of spades and locks. In some cases, plant operators will do this themselves; in others a contractor will be used working under the supervision of plant operations.
- In many cases, even when a plant is out of service it may not be fully isolated. Therefore, if work is contemplated there may well be a need for specific isolations.
- On completion of shutdowns, de-spading will occur. This equally will need to be done in a specified sequence to reflect the progress of plant recommissioning.
- For work on electrical systems, it is common practice to install locks on the isolation switches within the switch-house. Typically, the plant personnel will switch off and install a lock. The person(s) then working on the isolated item (e.g. a motor) may then also install their own lock as a double safeguard.

18.12 Dismantling/demolition work

Where there is a need to remove items from existing plant or infrastructure, but the main part will be retained for continued use, it is often necessary to apply a different approach. In particular, the dismantling/demolition work must be planned and managed as part of the overall construction work. Requirements typically include:

- Identify what techniques will be allowed. These may be different when the plant is out of service (shutdown) against those acceptable with plant in-service. This in turn may influence the timing of this work.
- Identify which is the best party to carry out the work. In many cases there will be no point in engaging a demolition contractor as the techniques allowed will be dismantling (reverse construction) rather than demolition. In some cases, especially for retained items, plant engineering staff may wish to do the work themselves.
- Identify cases where there is a risk that the items being removed may be contaminated with hazardous fluids or residues. Develop an appropriate work method including safety precautions for such items. Identify how they will subsequently be disposed of.
- Where cutting into pipes or other containers which have contained flammable material, an assessment should be made as to whether there is any risk of residue remaining. If such a risk exists then initial cutting should use a cold process followed by testing to verify the absence of any residue. A similar procedure should also be adopted for other, potentially hazardous residues, and if they are potentially toxic there may be a need to wear special PPE and a procedure adopted for final cleaning and residue disposal.
- Where insulation is being removed from plant which is more than 15 years old, the possibility that it is of an asbestos-containing material should be addressed. If there is any doubt, then tests must be made and if asbestos is present then removal must be carried out by a contractor who has the appropriate capabilities whilst using specified procedures. (UK – Control of Asbestos at Work Regulations, 1999).
- Requirements for isolations must be identified. In some cases, there will be a temporary isolation to allow the work to be carried out, then a permanent isolation or alternatively a new connection to achieve the final new configuration. Permanent isolations (e.g. blank flange, cap) and new connections must be included in the tie-in listing.

- The philosophy for redundant cabling needs to be agreed. Normally, such cables are left in-situ as they have potential future use. If they are left, then the ends need to be positioned so that they are not an obstruction or trip hazard and should be securely taped with a waterproof insulating tape. At the cabinet or switchgear end, they should either be physically disconnected or the switchgear locked in the isolated position. Local instrument cables from the (removed) instrument to the local junction box should be removed where practicable.
- As part of work planning, there is a need to identify and agree with plant operations what work will be done with the plant in-service and what must await a plant shutdown.
- All items to be removed must be shown on marked-up drawings which will be given to the contractors carrying out the work. This should be done not only for pipework but for all types of removal (civil, structural, equipment items, instruments, electrical equipment, and also fireproofing, insulation where their removal is needed separately). Where possible, detailed drawings should be marked in addition to flowschemes. Drawing marking can either be by hand or by CAD using a discrete colouring. Where useful, add advisory notes to the drawings.
- For items which will be temporarily removed but are required for re-installation or use elsewhere, drawings should also be marked but in a different colour and a remark added that the item is to be retained.
- For items to be removed, it is beneficial, in addition to the drawings, for a designer to physically mark the items in the field using a waterproof spray paint applied shortly before the work is required to start. This must, of course, only be done with the permission of plant operations. For items to be removed but retained, they should either be sprayed a different colour (this may not be acceptable) and/or tagged with strong plastic tag wired onto each item.
- Arrangements for disposal of redundant materials must be agreed. Identify who is responsible and what procedures apply. The plant owner has a legal responsibility to ensure that all such materials are disposed of in accordance with legal requirements.

18.13 Piping tie-ins

Tie-ins occur in all elements of engineering projects, including foundations, concrete structures, drains, roads, rail tracks, steelworks, piping, conveying systems, electric power systems, electric control systems, equipment modifications, HVAC systems and others. However, those related to piping systems make-up the majority.

Tie-ins (and tie-outs) need special consideration both in their design and engineering and in their installation. Design and engineering issues are addressed in section 16.14 and an example tie-in schedule is shown in Appendix C.

Construction issues include the following:

- Every tie-in location should be tagged with the relevant tie-in number. It is suggested that a strong plastic label marked with waterproof ink and wired into each location is used. These should be placed by the designer or another person with a detailed knowledge of the plant piping layout using a strong metal wire. Tagging should not be done too far in advance as this increases the risk that the tag will disappear before the arrival of the construction team carrying out the work. Where it is impossible to attach directly to the pipe, the tag may be wired or taped to adjacent steelwork or sheeting.

- Initial development of the tie-in schedule should have included identification of timing for execution. However, regular review with plant operations may identify an earlier window of opportunity which should be taken whenever practicable.
- At the time of the design detailing for the tie-in, the requirements for testing should be addressed. Normal practice for pressure piping systems is to carry out a hydrotest; however, in certain cases this may be impracticable due to an inability to spade the section to be tested. In other cases, hydrotest may be undesirable due to product contamination. In every case the tests to be applied must be agreed with the plant inspection authority as failure to do so is likely to lead to rejection at handover. The following alternate tests may be appropriate:
  - In-service test for benign services such as air, water, lube oil.
  - Hydrotest with the process fluid. Useful for services such as hydraulic oil, lube oil, certain solvents where water would be a serious contaminant.
  - Where installed pipe is fully flanged consider testing before installation.
  - 100% radiography of welds.
  - Full ultrasonic defect detection of welds.
  - Magnetic particle inspection on stainless steel.
- Before the construction contractor starts work on tie-ins, a detail review should be carried out with them, using the tie-in schedule as a guide, in order that they understand the timing requirements and safety issues for every tie-in.
- Special consideration must be given to proposed hot taps (tie-ins carried out where the existing element to be connected into remains in-service). Hot taps should be avoided where possible as they involve safety hazards and are likely to be more expensive to execute. If they are to be considered, the following should be addressed:
  - Is this the only practical means of execution?
  - What are the safety issues and how will they be managed?
  - What specialist resources will be needed to carry out the work?
- Tie-outs (removal of existing connections) should be handled exactly as tie-ins.

18.14 <u>Pipework installation</u>

Where pipework must be installed into existing plant and facilities some additional considerations may apply. These include:

- Interconnections between new and existing. This is addressed in section 18.13 above.
- It is usually preferable to maximise the extent of prefabrication carried out off-site as this is more efficient. However, consideration must be given to the practicality of transporting to the installation site and the need to make adjustments to provide correct fit (field fitting). The correct balance will depend upon the complexity of the pipework, the extent of congestion of the existing plant and the difficulty of making modifications at site. This decision is best left to the party (piping contractor) who will carry out the work. For them to carry out this evaluation properly they must have possession of the piping drawings (layout and isometrics) plus access to the installation locations to allow a proper assessment before fabrication work commences.
- It is unlikely that the pipework contractor will fabricate the pipework in exactly the sequence they would wish to install. Therefore, it is important to provide a lay-down area fairly close to the plant where they can temporarily locate the fabricated spools. Additionally, they may wish to carry out some limited fabrication/modification work at this location and this should be facilitated if possible. Hence, the location needs to be such that hot work can be carried out without any concerns about hazards from the process plant or other sources of flammable

fluids. If welding is to occur in a lay-down area, the contractor must take adequate steps to protect construction workers from welding flash (arc eye).

- Where pipework is to be steam or electric-traced, it may be practicable to attach the tracers before installation. This needs to be assessed against the risk of damage to the tracers.
- In-situ welding and flame cutting of piping will only be allowed under controlled conditions. This is addressed in section 18.17.
- Certain types of connections require specific techniques to be applied to ensure their proper installation (e.g. alignment, bolt tensioning etc). If this is the case, it must be highlighted in the scope of work given to the contractor. It must then be ensured that they have the required equipment and labour with the appropriate training.

18.15 Installation of cables

If new cables are required, it is essential that there is detailed planning of their installation. This requires that information covering all cables to be installed and their proposed routings is available. This may include cables for:

- Electric Power.
- Earthing.
- Instrumentation and control.
- Telecoms.
- Datacoms.

Typically, a project schedule will demand that cable laying must be largely completed before any plant shutdown, as the shutdown period is likely to be required for final termination work, testing and commissioning. However, as cable laying can be disruptive to ongoing plant operation and presents certain safety hazards, it is vital that the installation methodology and schedule is carefully considered and then agreed upon with plant operations. The following will need to be addressed:

- If excavations are needed, can this be done with plant in service and if so will certain locations need to be boarded over to provide access ways? What form of barriers will be installed to protect locations of excavations? Ensure that the spoil is either immediately disposed of offsite or, if to be re-used, placed in such a way that it is not an obstruction.
- Excavations will often need to be carried out by use of hand tools only. Use of machine tools will be constrained by both the risk of damage to existing cables and/or other underground services and also by general limitation of use of machines in operational areas.
- If underground road crossings are needed, the installation of ducts is usually preferred as this reduces the time that the road must be out of use. In any event, the timing of any road closure must be agreed, and if needed, diversionary routes posted. Note that if the road is a public access road then additional requirements will apply. See section 18.32.
- If scaffolds are needed to provide access for cable installation, there will be a need to agree locations and avoid blocking of access ways.
- There are constraints to the pulling of cables in cold weather. If the temperature is below 5ºC there becomes a risk of cracking insulation when bending the cable. Furthermore, cracking may not be identified until the cable is in service.
- The free length of cable at either end must be tidily coiled and placed where it will not be an obstruction until such time as termination is carried out. The cable ends must be wrapped for protection until they are terminated. Where cables are routed to a new junction box/cabinet/

switchboard/other equipment, it is preferable to carry out termination as soon as possible after cable laying. Where termination is to an existing item, then the timing of termination will depend upon operational requirements and may have to await plant shutdown.

18.16 Modification to instrumentation/control/safeguarding systems

Modification and extension of instrumentation/control/safeguarding systems is a very common element of retrofit projects. Generally, the installation of new field instruments and controls is relatively straightforward and not significantly different from new build projects except where they are to be located onto existing equipment or piping, in which case it is likely that the work must await a shutdown. Work needed within existing cabinets, to computerised control systems and to safeguarding systems is much more complex. In some cases the volume of work required is far too great to be executed and tested all within a plant shutdown period. It is therefore necessary to devise and plan means by which some (most) of the work can be done with plant in operation. The following possibilities may be considered:

- Investigate possibilities of certain elements of the plant being taken out of service to allow work. On some plants, not all parts are used all of the time and partial shutdowns may be scheduled within the overall production programme. In many cases, particularly for instrumentation work, there will be no need to fully decommission the process.
- For wiring work in existing cabinets, investigate the possible implications of an error being made. A risk assessment should be carried out considering the following:
  - Is the loss of existing instruments/controls associated with the cabinet something plant operators can live with for a short period, especially if they are pre-warned of the possibility?
  - Is there any safety risk to the technician working in the cabinet? Voltages and currents are usually fairly low.
  - Are highly skilled technicians who are thorough in the checking of their work available? Ideally, use technicians who have previous experience on the plant.
  - This practice is not likely to be acceptable for work inside cabinets which include safeguarding systems.
- Control systems such as DCS, PLC may have engineering workstations which allow reconfiguration and updating work to be carried out independently of the active display and control functions. If this is the case then the risk of upset to the control system is low (but not non-existent) and there should be no objection to a suitably experienced person carrying out such work with the plant in service. Depending on the nature of the changes made, it may also be possible to commission them (i.e. command the active system to adopt the changes) and allow plant operators to test their validity with the plant in service.
- Modification of existing safeguarding systems with the plant in service, will in most cases not be permissible. For this reason (except for PLC-based systems), there is considerable merit in designing and supplying the required new elements of a safeguarding system as a separate module and separate interface cabinet which can then be cross-wired at the plant shutdown. See also section 16.14.
- For PLC-based safeguarding systems, the reprogramming will normally need to be carried out during a plant shutdown unless the consequences of safeguarding malfunction are acceptable.

18.17 Hot work (welding, flame cutting, grinding, heat treatment etc)

Hot work includes welding, flame cutting, grinding, heat treatment etc and always requires careful assessment of the associated safety implications. Many issues are common for all types of construction work, but for retrofit projects additional issues may apply. These include:

- If the process of an existing plant includes flammable fluids it is probable that there will be a prohibition or severe restraint upon carrying out hot work within a plant area even on items which themselves are part of the new project or are otherwise out of service. If there is a very strong need for such work, it may possibly be permitted with the provision of continuous gas testing.
- Where cutting into pipes or other containers which have contained flammable material, an assessment should be made as to whether there is any risk of remaining residue. If such a risk exists, then initial cutting should use a cold process followed by testing to verify the absence of any residue. Note a similar procedure should also be adopted for other potentially hazardous residues, and if they are potentially toxic there may be a need to wear special PPE.
- When working within a structure, steps must be taken to avoid sparks or hot debris flying or falling such that they may cause injury to others or ignite flammable materials. This issue also applies to new build projects, but for retrofit there is a higher probability of other personnel and/or flammable materials being in the vicinity. The problem can usually be addressed by use of floor matting and tarpaulin screens. Additionally, hand-held fire extinguishers should be provided.
- When it is intended to weld onto existing galvanised steelwork, it will first be necessary to grind away the galvanising in the area to be welded as the galvanising material will contaminate any weld and also produce unpleasant fumes when subject to high (flame) temperatures. If flame cutting of galvanised steel is contemplated then the person doing the work should wear appropriate PPE.
- Where welding or hot cutting is to be carried out within a building, it is essential that there is adequate ventilation to disperse the fumes and heat. If this is not available by natural circulation or from a permanently installed ventilation system, then use of a temporary extraction system should be adopted.
- It is essential that gas bottles are located in a safe position (where there is low risk of being accidentally damaged). If practicable this should be outside of any structure, though this introduces the hazard of longer gas supply lines. The bottles must be secured so that they cannot fall over. If the bottles are to be located within a building, checks is made to ensure that there is adequate ventilation at all times to avoid any risk that a leak could cause a build up of flammable gas. Routing of gas supply lines must be such that they cannot snag on any sharp object nor result in a trip hazard.
- Gas bottles must never be placed in a confined work space. Short period secure storage in a container or unoccupied store building may be acceptable provided that prior to storage a careful check should be made to ensure that there are no small leaks from the regulator assembly. The store must be adequately ventilated.

18.18 Location of construction machinery

Construction machinery such as cranes, excavators, personnel lifts (cherry picker), welding machines, air compressors, water jetting pumps, concrete pumps, trucks etc. must always be safely located. Safety must be considered in terms of hazard to people, hazard to the machinery itself, and hazard to process plant and infrastructure. In the case of retrofit projects, specific considerations include:

- Ensuring that the ground upon which the machine is located is firm when working close to excavations. Apparently firm ground can be rendered not so by vibration or by running water. If the machine is wheeled positive means should be used to prevent movement when in use. For heavy machines there is a need to check out ground load bearing capacity. Where the ground is vulnerable to slippage into the excavation, steps such as sheet piling of excavation or other wall support bracing will be needed.
- For heavy machines when it is intended to locate them on a paved area, there is a need to check load-bearing capacity of the paving. If necessary, use load-spreading beams or plates.
- Where machines are to be used within buildings or other plant structures, the hazards from noise vibration and their exhaust fumes must be addressed. In every case it should be looked at to see whether it is possible to locate the machines outside this area.
- Diesel engines can explode if they ingest a flammable gas; they therefore must be located such that any risk is negligible. Additionally, unless contained within an acoustic casing they are relatively noisy and therefore should not be located adjacent to work positions. Operating engines should always have a hand-held fire extinguisher available nearby. (Gasolene driven engines, other than within road vehicles, should generally not be used on construction sites).
- Ensure that air compressors are located such that the air intake will receive only clean air. If flammable gas is ingested there is risk of explosion of the machine. Additionally, contaminated air (flammable, toxic or asphyxiating) will present a hazard at the delivery point.
- Cranes must be positioned such that when the jib and cab rotates it will remain clear of fixed installations. The area of the cab rotation should be identified as being of hazard to passing personnel. At the time lifts are proceeding, all non-essential personnel should be kept out of the immediate area of the lift.
- Mobile construction equipment such as dumpers, excavators, backhoes and fork trucks should not be left unattended with their engine running.
- Water jetting is a hazardous activity. Ideally such work is carried out in a segregated area remote from other activities. However, in some cases it is unavoidable that equipment fixed in plant must be cleaned. In such cases, the area should be taped off with warning signs at all possible access points. Additionally, any delicate plant (such as instrumentation, electrical equipment) in the vicinity of the work should be protected. The extent of protection will depend upon the type of jetting. For low-pressure jetting, only protection against water ingress is needed, but for high pressure jetting the energy of the water jet is a significant hazard. For high pressure jetting the operatives carrying out the work must wear appropriate PPE.
- The routing of cables and hoses from machines to work locations must be carefully considered. They must not produce a significant trip hazard and must not be vulnerable to damage from chafing, things being dropped on them, or run over. Where they must cross roads or access ways, covers or ramps should be positioned to protect them. Where appropriate, they can be tied to steelwork in order to stop movement and chafing. Regular physical checking of cables and hoses (daily when in use) should be adopted.

18.19 Planning the use of cranes

Careful planning of the use of cranes must be undertaken. Their use is likely to restrict access to other work in the area of the lift, and the cost of crane hire (especially large ones) is significant. The following should be considered:

- Identify well in advance all foreseen needed lifts. Where appropriate, this should include lifts needed for other projects on the same site and for maintenance work. It is then possible to optimise the usage of cranes, though in some cases this may require some rescheduling of associated work.
- Decide on whether there should be a single supplier for all required lifts or whether individual contractors should make their own arrangements. Single supply can bring benefits in terms of pricing levels and efficiency of use, but requires collaborative planning.
- For all lifts, there is a need to consider the intended location of the crane and also the location where the item being lifted by the crane will be positioned (prior to installation or after removal). In some cases preparatory work may be needed to provide access and/or load bearing capacity.
- Lifts carried out within plant areas will need to consider the risks associated with lifting over existing facilities. If the plant is in service, the consequences of an accident could be far more serious than simply damaged equipment.
- Agree with plant operations and engineering the need for lifting at required locations in plant areas.
- For all lifts, identify who will be responsible for the management. For all but small routine lifts, a detailed method statement is likely to be required; this must be available and agreed before the permit to carry out the lift is signed.
- If major lifts are required using large cranes, there may be a need to order the crane well in advance, to ensure availability. Typically cranes up to 100 tonne rated are available at a few days notice, but for larger units or more remote locations the lead time may be greater.

18.20 Scaffolding

Scaffolding is extensively used in association with construction works to provide access, to provide local temporary storage of material and equipment, to provide weather protection and to provide temporary support for constructions prior to the completion of permanent support. Many scaffolds serve more than one purpose, but in every case it is essential that they are designed and constructed to fulfil the purpose(s) intended. For those scaffolds which must carry heavy loadings and those which include significant overhangs in their layout or other unusual features there may well be a need for a detailed design study prior to their construction. Retrofit projects may impose some specific needs n respect of scaffolding. These include:

- Scaffolding may need to be used by several different construction contractors as well as for maintenance work and for plant cleaning. If this is the case, it is essential to have a forward plan of all potential needs and is worth considering the use of a single contractor to install scaffolds for all users. This will have numerous benefits:
  - Use of a contractor who is familiar with the site.
  - Reduction in the overall scaffold needed as in many cases multiple uses will occur.
  - Provision of suitable forward planning with reduced conflicts over access requirements.

  Aim to require all users to submit their needs at least one week in advance (more for major requirements).
- The erection of scaffolds severely limits other work in the immediate area for safety reasons. If the construction schedule is tight, the following should be considered:
  - Discuss with plant operations which scaffolds may be erected with the plant still in service. Naturally, such scaffolds must not unduly limit operator access. Similarly, agree to what extent scaffolds may be dismantled after the plant re-starts.

- Consider the use of a team of scaffolders to work outside the normal construction working hours, specifically to erect and modify scaffolds in those areas where working during normal hours would most disrupt the work of others.

- It is essential that scaffolds do not unduly restrict access for plant operations and other workers. Where there is a problem, consultation with plant operations is essential. Scaffolding can itself be used to provide a temporary access when the normal access is blocked. If access is required frequently then consider construction of a stairway rather than relying on ladders.
- If there is a significant amount of scaffolding work required, aim to find a place close to the work location where the scaffold contractor may temporarily store material. This will significantly improve efficiency of the scaffolding work.
- Retrofit projects generate a significant need to modify existing scaffolds as the requirements of the users change. It is by no means unusual for a scaffold to require modification 3 or 4 times before final dismantling. The contract should contain an appropriate means of reimbursement for this type of work (modification work usually has to be on a hourly rate basis).
- Sheeted scaffolds can be used to provide weather protection, which in turn can significantly improve the productivity of other workers and protect delicate equipment. However, sheeting may result in a greatly increased loading on the scaffold from wind loading and rainwater (if used as a roof). In such cases, the scaffold must be designed for such loads. Sheeting is also usually made of a polyethylene material and hence is flammable.
- The stability of tall scaffolds must be considered (sheeting/wind loading are additional loads). Not only must the footings be stable, but also the scaffold will probably need lateral ties to permanent structures and/or spread footings.
- Consider the use of system scaffolds for many standard shape scaffolds; they allow much quicker erection and modification.
- Ensure that there is a system of scaffold checking and certification in place. However, it remains incumbent upon the users to satisfy themselves that scaffolds they use are fit for the use they intend.

18.21 Temporary lighting

Temporary lighting requirements for retrofit projects may be quite different from those for a new build project. Considerations include:

- Will permanent lighting in the work area provide sufficient light for the construction work or is temporary lighting needed? In making this evaluation the following need to be addressed:
  - Will permanent lighting always be available?
  - Will the construction work (including temporary installations such as sheeting, scaffolds, formworks etc) obscure light to work areas?
  - Can any new permanent lighting be installed early to provide for construction needs?
- If temporary lighting is needed, then there is a requirement to determine:
  - Is the area classified as hazardous in terms of possible flammable vapours? If so, then lighting provided must be suitable for this zoning, unless the plant is decommissioned to the extent that the hazard can be guaranteed to be not applicable for the period concerned.
  - If the lighting requirement is for very short periods then it may be possible to use battery powered lighting.
  - Can lighting needed be achieved by use of portable lighting towers? These are very effective for lighting fairly large areas.

- In plant areas, check whether there is a local power supply which can be used for the temporary lighting.
- If extensive cabling is needed to provide power for lighting, ensure that it is properly routed both to avoid risk of damage to cables and so as not to provide a trip hazard.
- Ensure that lights are firmly fixed, are located to provide needed illumination, but also that they are not restricting access or work space.

- Where temporary lighting is needed by several parties, consider provision by a single contractor to provide all needs. This will need planning similar to that for common-use scaffolding.

18.22 Painting

Painting is needed for the protection of certain metallic materials and, if not carried out properly, can result in severe corrosion. For retrofit projects there are many constraints and considerations as to when and how it is best to carry out painting works. These include:

- Painting quality is strongly influenced by the quality of surface preparation. It is essential that this is properly carried out in accordance with requirements for the type of paint to be applied.
- In-situ painting (other than minor touch-up) cannot be sensibly conducted when other trade works are being carried out in the immediate vicinity, especially if spray painting is used.
- Always seek to maximise the amount of painting that will be carried out offsite. This will ensure better quality work and allow work to be done earlier and more cost effectively. However, recognise that subsequent handling must aim to minimise any damage to the paintwork.
- If it is intended to carry out blast preparation of installed piping and equipment, then this work must be done at a time when the area is completely cleared of other personnel (i.e. plant will be shutdown) and all delicate equipment such as instrumentation or electrical equipment will need to be protected. This can be achieved by wrapping the equipment in heavy gauge plastic (use bags for small items). Following blasting, thorough cleaning to remove blast material and other debris will be needed. This will probably include the use of industrial vacuum cleaning.
- Recognise that during construction work some damage to paintwork will occur (both to new and existing equipment) so there will be a need for remedial painting, which, in the case of existing insulated items, may only be discovered as the construction work progresses.
- Ensure that the process for site painting is agreed. This will include the types of paint to be applied, the type of preparatory work, the necessary area protection needed and the timing of the work.
- Discuss and agree with plant staff which painting work may sensibly be left until after the plant is handed over for recommissioning.
- Recognise that the weather may have a significant impact upon the ability to carry out site painting works. Paint cannot be applied to wet surfaces and will fail if wetted before it has time to dry or in many cases if the air temperature is too low (typically +5ºC is the low limit). Spray painting cannot be carried out in windy conditions unless suitable protection for the area is in place.
- If spray painting is intended then protection must be in place to ensure that the spray does not drift onto objects not intended to be painted. This may require such objects to be protected (plastic wrapping) if in the immediate vicinity and/or area sheeting to be in place. Area sheeting will also assist in the elimination of draughts.

- Painting of equipment and piping which will subsequently be insulated requires particular attention. Areas of local damage to the paintwork will be especially vulnerable to corrosion and hence steps must be taken to ensure that these are eliminated. This is usually achieved by ensuring that a thorough examination is carried out prior to insulation. This activity will require careful planning and scheduling as the window of opportunity may be short.

18.23 Insulation

The scope of thermal insulation work associated with retrofit projects will cover the application of new insulation to newly installed equipment and piping, and removal of existing insulation and repair of damage to it as a result of construction work or earlier degradation. Considerations include:

- The need to positively identify which insulation which must be removed. This can be done by provision of listings together with marked up drawings and/or prominent marking of insulation to be removed. If paint marking is used, then a different colour should be adopted from that used to identify equipment and piping which is to be removed. In general where insulated equipment and piping is to be removed this can be done with insulation remaining attached unless the insulation is in such poor condition that there is a risk it will fall off during equipment removal.
- When contemplating insulation removal, an assessment must be made as to whether there is any possibility that the insulation contains asbestos. If it is not possible to determine beyond reasonable doubt that no asbestos is present, then a small sample should be taken for laboratory analysis prior to any further action. If asbestos material is present then the work must be done under specific controls utilising only contractors who have the required skills and equipment. Disposal must also be made to approved sites. See also UK legislation - Appendix D.
- Identify and agree with plant operations which insulation may be removed whilst plant is in operation and which may be installed after plant restart. Inevitably, insulation is one of the last construction activities and the ability to finish it after plant start-up will facilitate reduction in workload during the shutdown period.
- Identify and agree with plant operations those points (usually flanges) where they specifically require the insulation boxes to not be installed until after the plant is fully commissioned. These are points which plant operations may need to disconnect for spade removal and/or cleaning, leak testing etc.
- If polyurethane foam insulation (for cold service) is to be used, extra care should be taken to ensure that it is protected from any fire risk. It is not only inflammable but also generates toxic fumes when burning. Similarly, if hot work is intended on any existing pipe or equipment it is essential to ensure that polyurethane insulation is well clear of the area.
- If the total amount of insulation work is significant, aim to provide a local store for material. Storage can effectively be provided using standard containers.
- Ensure that the contract for insulation service includes the provision for repair of construction damage. This is almost inevitable to some extent.

18.24 Working in confined spaces

The need to work in confined spaces is much more common on retrofit projects and there are also some additional potential hazards. Confined spaces may include deep excavations, tunnels, small rooms, cellars, inside of vessels, inside of furnaces and boilers or even within confined areas of process plant. Issues to be considered include:

- Is it possible to carry out some or all of the work elsewhere (e.g. prefabrication)? Use of and such possibilities should be maximised.
- The need to ensure that the atmosphere for the workforce is safe at all times. This should include an assessment to identify any possible sources of contamination. In some cases, there will be a need for forced air delivery to ensure that the atmosphere remains acceptable including removal of heat, fumes and dust which may be created by the ongoing work within the space. If there is a positive air supply, it is necessary to ensure that the supply point is located where there is no possibility of contamination. If a compressor is used, it must be able to supply breathing air. If a safe atmosphere cannot be guaranteed, breathing equipment will required.
- A plan should be in place covering how persons can safely be removed from the confined space if they incur an injury or are otherwise incapacitated. A single individual must never work alone in a confined space.
- In locations such as excavations and tunnels, protective measures to effectively eliminate the risk of collapse should be addressed. This may include temporary propping, shuttering etc.
- When a confined space has been in a service involving materials which could be hazardous to personnel, it is essential that the space has been properly cleaned and positively isolated prior to allowing entry. Isolation must be by means which cannot be accidentally overridden (e.g. a closed valve would not be acceptable). Even utilities such as water, steam, nitrogen, electricity and air at elevated pressure, are potentially hazardous.
- Ensure that there is adequate lighting in the space.
- Never place gas cylinders in the confined space. They should be placed well away from the entry to the space and delivered by hose. In particular, be aware of hazards from gases which are heavier than air (e.g. carbon dioxide, liquefied petroleum gas (LPG)), as these will not readily disperse.

18.25 Work on roofs

Retrofit projects may have a requirement to access a roof in order to carry out work. If so, the following should be addressed:

- Is the roof designed to carry the loading of people and materials? If not, it will be necessary either to place additional support to spread the load, provide a scaffold platform or achieve the access by other means such as by personnel-lift (cherry picker).
- Does the roof have protection from the risk of falls from the roof edge and any other openings in the roof? If not, either temporary edge protection should be installed, or if access is only for a short period then personnel should use fall-arrest harnesses provided there is a suitable anchor point.
- Consider the additional risks posed by working on roofs in inclement weather. This may necessitate temporary cessation of work.
- If new openings are to be made into the roof, it is essential to check that this will not compromise the integrity of the roof during the execution of the work. Ensure that no-one is present directly under the area where such work is being carried out unless they are directly involved with such work.
- Ensure that all material and equipment is secure. It is potentially vulnerable to rolling or sliding especially on a pitched roof.

18.26 Working under HV power lines

Overhead electric power cables can provide hazard in several ways:

- If conducting material is allowed to come close to live cables there is a risk of flashover. With high voltages there is no need for actual contact and the minimum safe separation distance may be quite substantial, dependent upon voltage. If there is an unavoidable need to use this space it is possible to temporarily prop the cables to provide additional clearance. Specially designed props are available.
- If there is a regular need to cross under such cables, consider placing marker cables with bunting across the access way on both sides at the safe height as a warning.
- If there are pipelines running parallel to the HV overhead cables for any distance (typically 100 metres or more), there is the possibility of generation of an induced current within the pipeline unless it is well earthed. This can result in significant sparks when the line is touched by construction equipment. Hence there is a need to ensure earthing when carrying out work on such lines. It should be noted that many under ground pipelines have protective coatings and are connected to cathodic protection systems and, hence, are deliberately not earthed.

18.27 Hazard from motor vehicles

It must never be forgotten that one of the more significant causes of injury to personnel in and around construction sites is accidents involving moving motor vehicles. For retrofit projects, this issue may be more complex due to the need for vehicle access to the plant area for operational reasons as well as the fact that the area may well be more congested than a new build construction site. The following should be considered in order to reduce risks:

- Ensure that only essential vehicles are allowed in that area. Agreement upon what is allowed will need to involve plant management and the relevant contractors.
- Ensure that car parking is provided at a safe location within reasonable walking distance of the construction site for all site personnel. Ensure that the route from the car park to worksite does not in itself present any significant hazards.
- Consider one-way traffic routing around the construction site. If this is to be effective it must be clearly signposted.
- Place warning signs and consider flashing lights at points where pedestrians must cross a road which has frequent vehicle use.
- If the construction site is within a major complex, provide road signs so that visitors will follow the preferred route.
- Reversing trucks should use an alarm horn.
- Impose and enforce a low speed limit; 30kph is suggested.
- Fork-lift trucks present a particular hazard as they are relatively quiet and, especially when loaded, the driver may have a restricted view. Consider:
  - When construction work is being carried out immediately adjacent to a fork lift route see if use of the route can be temporarily discontinued.
  - If only occasional trips are needed, consider the use of an operative walking alongside the fork truck as a lookout.
  - Equip fork trucks with flashing lights and/or intermittent horn.

18.28 Inspection and testing

The principles determining requirements for inspection and testing to be applied should be identified in the project definition phase. This should cover the types and extent of inspection and testing required which will allow later inspection and testing listings/schedules to be produced. The following will need to be addressed:

- What inspection/testing is required?
- When will it be carried out?
- Who is responsible for its execution?
- Who will determine the acceptance of results?
- Who will additionally witness tests?
- What certification and other documentation are required?

For retrofit projects, requirements for inspection/testing is likely to include some work related to the existing installations as well as new construction work. The need to carry out much of this work within existing plant areas is also a major influence upon how and when the work is done. Some considerations particular to retrofit projects include:

- There is an early need to identify those inspections and tests required to determine whether existing elements of the plant/facility are fit for continued use. As this will affect the scope of work, it is important that this work is carried out as early as is practicable.
- Where inspections/tests discover a defect to existing plant, then there is a need to determine who is responsible for execution of remedial work and to ensure that it is done such that overall impact on the project is minimised.
- Use of radiography for inspection of welds and other defect identification in materials presents personnel hazard and generally should be carried out when a minimum of other personnel are in the area (i.e. at night or on the weekend). The area around the source must be taped off and warning signs placed at normal access points. The radius of the restricted area will depend upon source strength. Radiography can only be allowed under specific authorisation of plant operations for each individual event.
- If larger sources are used, there is also a risk that radiation may affect other sensitive instrumentation on the plant. Check should be carried out with the plant-based instrument engineer.
- Where hydro-testing is intended, there will be a need to agree the following with the plant operations:
    - Development of a set of hydro-test circuits. This will identify the equipment/piping to be covered in each test, positions of spading points and may include elements of existing plant.
    - Source of water. This should be reasonably clean, fresh water otherwise silt and other residues will be left in the pipe and equipment. If stainless steel pipework or equipment is to be tested then limitation on chloride content will apply.
    - Disposal of water. In many cases it will be possible to dispose of this to existing storm drains, but not so if the water is likely to be contaminated from residues within the equipment/piping being tested, or (in cold climates) antifreeze has been added. It is not normally acceptable to simply allow the water to spill onto the floor area, it should be specifically routed to drain

- For some tests, it will be preferable to use a fluid other than water for compatibility with the process fluid. This most commonly applies to oil systems where the oil may be used. In such cases it may be possible to leave the oil in place after testing.
- If hydro-testing is contemplated in low temperatures (potential for freezing) then a water/antifreeze mix should be used. This fluid must be recovered after use, initially for reuse on other tests and eventually for safe disposal as chemical waste. It must not be allowed to flow into storm drains.

- If the intention is to use pneumatic testing for systems which contain any significant volume, it is vital to recognise that the compression of the air (or other gas) will result in significant stored energy. Hence, the risks of such testing must be carefully assessed and carried out only when non-essential personnel are removed from the area.
- Testing of instrumentation systems will generally be as for new build projects, excepting that the control of such systems will usually remain with plant operating personnel. Hence, the system testing (testing the function of the loop) is likely to be controlled by them. It will also be necessary to include the re-test of existing instrumentation where any new interfaces have been installed.
- Testing of the process safeguarding systems may require test of the whole system not just the new elements. In any event safety-critical systems require proof testing at specified intervals and this is normally done at time of plant shutdown.
- Electrically powered inspection/test equipment (even battery powered) must be designed for use in hazardous areas if it is to be employed in areas of live plant where there is a risk of flammable gasses and/or dusts.

18.29 Use of radios, telecoms equipment

Radios and mobile phones are extensively used on construction sites. However, for retrofit projects it is vital to check whether their use poses a safety risk. Such risks are as follows:

- Electrically-powered equipment (even battery powered) must be designed for use in hazardous areas if it is to be used in areas of live plant where there is a risk of flammable gasses (i.e. zone 0, 1 and 2 classified areas).
- Radio signal transmitters (this includes mobile phones) can, if used adjacent to sensitive instrumentation, cause malfunction of the instruments.
- Interference with the radios used by plant operators.

Before any such equipment is used at the site there should be a clear agreement with plant operations as to what may be used in which locations. Equipment not authorised should not be allowed to be carried in such areas in order to obviate accidental use.

18.30 Damage to fire and gas detectors/alarms, accidental initiation

In many cases, the fire and gas detection/alarm systems will remain in service whilst construction work for retrofit projects is ongoing. This is generally desirable as there remains some risk of fire or gas leaks even in a plant shutdown situation. Push-button alarms should also be available to use in the event of a construction-related emergency. However, the following points will need to be addressed:

- If as part of the project the systems will be modified or extended it may be necessary to temporarily disable the system. If this is to be done it must be agreed with the plant operations management and with the relevant emergency services. An alternative means of communicating emergency needs may be needed.

- It is entirely possible that the systems may be activated as a result of the construction work. This can be from any number of sources. There is a need to plan and agree with the plant operations and emergency services how to a handle such alarms. The following should be considered:
  - How can the cause and needed response be quickly determined?
  - How, if no emergency action is needed, can all those who would respond be quickly informed that no action is needed? (It is highly embarrassing to have attendance from public emergency services when there is no need).
  - If detection systems automatically initiate fire-fighting systems, it may be acceptable that such automatic initiation is temporarily disabled. In such cases rapid manual initiation should still be available.
- If damage to systems does occur, then steps must be urgently taken to carry out repair and recommissioning of the system.

18.31 Site cleanliness, plant cleanliness, disposal of waste material

- *Construction site cleanliness and tidiness.* There is always a need to ensure that an area where construction work is being carried out is kept clean and free of debris in order to avoid tripping or other injury to personnel, whether they are construction workers, plant operators or others. On a retrofit project where there is an operating plant or facility, it is likely that the standard of cleanliness required will be higher than for a conventional new build construction site. The following should be addressed:
  - All parties must be responsible for clean-up of their own debris and this requirement should be explicitly included in work scopes. Any significant debris should be cleared on a daily basis and, specifically, any hazardous materials must be removed as soon as practicable.
  - Where it is desirable to leave material at the work site for future use, there must be an insistence that it is left tidily away from access ways. Hazardous materials (which include flammable material) should never be left unless properly contained, clearly marked and their presence notified to plant operations.
  - Spills of oil, water, powders, pellets etc can render floors extremely slippery and must be cleaned up as soon as is practicable. In some cases they also present a fire hazard.
  - Where cables and hoses are in place, they should be routed to avoid being a trip hazard.
  - Consider the provision of common-use waste skips for all contractors, located as close as is practicable to work locations. Skips should, of course, be clearly marked to identify the types of waste they are intended for. Such provision encourages regular clean-up as it is a simple task to place waste into nearby skips.
  - Regardless of quality of daily clean-up it must be insisted that every contractor cleans up properly on completion of their work in any area.

- *Process cleanliness.* There is often a requirement that the installed equipment be cleaned to certain standards to ensure that the process and/or products are not contaminated. Requirements will depend upon the processes and products involved, but in certain cases very high standards may be required which will involve special cleaning processes. The following should be addressed:
  - What is the standard of cleanliness required for each part of the process? This will normally be advised by plant operations and if it requires any special or time consuming process this should be explicitly identified within the project scope.

- What is the extent of cleaning required? How much of the existing plant will need to be cleaned in addition to the new construction elements.
- What is the procedure to achieve the required standard? Who will do this work? Is a specialist contractor needed?
- Who will manage the work? Is it the responsibility of the project team or is it an operational matter to be handled as part of commissioning?
- The recognition that water (even clean) may be a contaminant and if this is the case, systems will need air blowing which can be time-consuming if a very low moisture level must be achieved.

- *Disposal of waste materials.* In addition to the normal requirements for the disposal of material related to construction work, a retrofit project may include scrap from removed elements of the process plant. Before these are removed from site there is an obligation to certify that they are not contaminated with any hazardous material or that they be treated as hazardous waste and routed to a specifically-approved disposal site. The plant owner (client) is legally obliged to control the handling of such scrap material and must ascertain that it is disposed of in compliance with regulations. This obligation cannot be avoided by selling the scrap material.

18.32 Construction works in locations adjacent to public access

Where work must be carried out adjacent to areas where the public may be present (e.g. work on pipelines, power lines, entrances to buildings etc), it is essential that the public is protected from any hazard arising from the work. The following precautions should be taken:

- Install fencing so that the public cannot gain access to the work site. Fencing should be of a standard that physically prevents access rather than simply a warning barrier. Fences should be at least 1.8 metres high and of robust metallic construction with posts either driven into the ground or fixed into heavy concrete bases. Gates should be of similar construction and locked with good quality locks.
- Valuable materials and equipment should not be left overnight or during other non-working periods at such locations, even when locked within the fenced area, unless it is continuously guarded.
- If cabins are located within such compounds, they should be provided with high-quality locks on all doors.
- If excavations are involved, measures must be taken to prevent the collapse of side walls which could result in the hole being not contained within a fenced-off area.
- If excavations are in a location near to a route of motor vehicles, there must be adequate warning to divert the traffic around the excavation. The warning must be visible at night and at a sufficient distance to allow the traffic to easily avoid the hazard. If the excavations are to be within or immediately adjacent to a public road, then specific agreement may well be required from the local authority responsible for the road and also from the traffic police. Dependent upon the extent of interference with normal traffic flow, temporary traffic control measures may be needed. It may also be prudent to install a barrier of sufficient strength to prevent any vehicle falling into the excavation, both to safeguard vehicle occupants and those working in the excavation. Large interlocking concrete blocks are available for hire for this purpose.

19. Punch listing, handover, precommissioning, commissioning

The principles for punch listing, handover, precommissioning and commissioning are no different than for a new build project, but the retrofit project is more complex as it will involve not only the parts which are newly installed but to some extent, the existing plant/facilities as well. Additionally, the plant operations and maintenance personnel will be significantly involved, but will also have to continue to look after the operating plant. The following will need particular attention in respect of retrofit projects:

- *Planning the work.* It is vital that the requirements for this work are planned well in advance of the required time for it to be carried out. If the project is of a significant size (>€5M/$5M), it is recommended that this work should commence at least 6 months before projected start of handover. This work should include:
  - Identifying the sequence by which the plant should (ideally) be re-commissioned. This information will normally be provided by the plant operations personnel, but may need to be further detailed to ensure clear understanding by all parties who will be involved. Typically, individual process and utility systems are commissioned in a predetermined sequence. For this to occur, it is essential that the content of each process system is fully identified. This may be done by a detailed written listing and/or marking up of relevant drawings. Retrofit projects will very often include significant elements of the existing plant/facilities as well as all the newly constructed elements.
  - Identifying those components which cannot sensibly be included in individual process/utility systems because they form part of the infrastructure that is related to the whole plant/facility. Again, this may well include elements of existing plant.
  - Commissioning work will, for retrofit projects, almost always be carried out by the plant operations personnel, possibly with support from specialists including those with specific expertise in the type of plant involved and commissioning engineers from vendors where complex equipment, such as large compressors, are involved. A commissioning plan should always be prepared for all but the simplest of projects and must identify any requirements for external support.
  - Where the retrofit project will introduce the use of different feedstocks, additives, utilities and packaging materials, or significantly increased quantities of existing types, it is important to identify this and ensure that required supplies are available at the time the plant will be recommissioned. Similarly, if there are significant changes to plant production (quantity and/or modes of packaging/sale) then revised logistics provisions must be planned and in place.

- *Resources for the work.* As a part of planning there is a need to identify who will carry out each element of the work and who will manage the various sections and ensure that the needed resources are available. This is often, especially for retrofit projects, fairly complicated as there will be several types of work (plant operation, construction, handover, precommssioning and possibly commissioning) all occurring at the same time. If the resources to do and manage the work are not available or are overstretched between conflicting priorities, then there is a good chance that the overall time taken to get the plant/facility into service will be significantly extended. For management of the work, the following should be considered for all but very simplest of projects:
  - Appoint a named individual to manage the planning phase of the work. Ensure that this work is recognised as a high-importance task for the individual and that they have the skills and time available to do the work thoroughly. They must recognise the need to

work closely with contractors and plant operations in order to provide a detailed plan that can be accepted by all those involved.
- Ensure that all contractors involved understand the work required from them and in particular the required sequence. Check that contractors have sufficient resource (labour and supervision) to support punch listing, precommisioning and completion of construction and testing, all of which may need to be ongoing concurrently. For larger projects, it is often desirable the contractor has a separate team for punch list rectification work and precommisioning.
- Aim for plant operations to provide a nominated focal point to contribute to the planning and management of handover and precommissioning.
- Ensure that a team has been nominated to carry out the punch listing and that this team is sufficiently resourced for the expected workload. The workload includes follow-up to check the completion of punch list items.
- Appoint a named individual to be the manager for the execution of the handover and precommissioning work. Ideally, this should be the same individual who co-ordinated the planning, but there is a need to ensure that the individual has the necessary managerial skills to handle this intense multi-party work phase. For all but small projects, this is likely (for a limited period) to be a full-time job which will require liaison on a daily basis with all those parties involved in the handover, precommissioning and commissioning works. Ideally, this should be the same individual as coordinated the planning phase. Other than for small projects, it is generally not advisable to give such a task to the construction manager as it presents a conflict of priorities against the completion of construction.
- Commissioning is usually carried out and managed by plant operations. On retrofit projects, this is typically resourced from existing plant staff. If so, it is essential that those involved are not overloaded as a result of still having all their normal duties and responsibilities. This aspect should be carefully checked.
- Planning for commissioning, including the preparation of the commissioning procedures and pre-training of operators, can be a major activity which, if not carried out properly, is likely to result in problems during the commissioning and subsequent operation of the plant/facility. For retrofit projects, those involved are likely to be existing plant staff so there is a need to ensure that they have sufficient time to carry out such planning, preparation and training. In order to achieve this, it may be necessary to engage temporary staff to stand in for others whilst they carry out the preparatory work and training.

- *Timing of punch listing.* The time period over which punch listing is likely to be required is often much more compressed for a retrofit project than for a new build project. For retrofit projects, the following should apply:
  - As soon as the system is ready it is important that punch listing is carried out promptly as failure to do so will result in an overall progress delay. In order for this to be achieved there must be sufficient people available for punch listing and they must be given regular updates of forthcoming requirements.
  - Systems must not be presented for punch listing before they are essentially complete. Failure to do this will generate significant extra work for the punch out team, result in very long punch lists, and generally delay the overall progress. In the event that systems presented are not sufficiently complete, they should be rejected without detailed punch listing.

- In many cases, it is sensible to accept that certain finishing works such as painting, insulation and labelling will not be complete at time of punch listing and accept that these will be tackled later.

- *Documentation.* It is vital as part of the planning process to identify all of the documentation that will be required in order to achieve handover of the systems within the projects. Such documentation is likely to include design documents, vendor operating and maintenance manuals, QA documents for the construction work, testing certification and signed-off punch lists and lists of (acceptable) outstanding work. Again, for retrofit projects this will include to some extent requirements related to existing plant and facilities. There also needs to be an agreement with the plant staff as to whether they wish to take physical custody of such documentation progressively or wait until overall project completion and take the complete package of documents.

  Plant management has a legal obligation to retain certain documentation, and in any case it is valuable for reference related to plant operation, inspection, maintenance and future projects. There is a need to decide whether the information is retained as a separate discrete package associated with the project or is to be integrated into the overall data for the plant. If the former is adopted, it is essential that there is a clear notification system whereby future users of the data are made aware that the plant/facility has been modified by subsequent projects and, hence, there is a need to look at that data as well as that for the base plant/facility. Decisions must also be taken as to the extent to which existing drawings and other documents from the existing plant/facility should be updated to reflect the existence of the new installations. Some may have been used by the project and hence will have been updated, but others may not have been. They may now not fully reflect the current installed plant/facility. See also sections 16.3, 16.4 and 16.5.

20. Involvement of plant operations and engineering staff

It is undoubtedly true that the extent and quality of the involvement of staff representing both operations and engineering who have detailed knowledge of the existing plant/facilities will have a major influence upon the effectiveness of both the development and the implementation of the project and the probability of meeting its objectives. The need for, and extent of, this involvement is proportionately much greater in the case of retrofit projects than for new build projects.

It must be recognised that such plant-based staff, unless they are temporarily fully seconded to the project team, are likely to have many other concurrent obligations and there is potential for conflict of priorities. It is important for the project manager to obtain a commitment from the management of the plant to make plant based staff available when needed. Preferably, this should be identified and agreed as part of the project strategy (during the project definition phase). There is a need to specifically identify each of the persons who will need to be involved in the project and ensure that they are committed to the work and understand their importance to the overall success of the project.

Ideally, a member of the plant staff should be nominated as the co-ordinator/champion for their involvement. However, it is rarely practicable or sensible that this one individual can represent all of the needed input from plant staff. The following are the main areas where involvement of plant based staff will be needed:

- Agreeing the project objectives and priorities.
- Agreeing elements of the project strategy, particularly those related to safe in-plant construction, handover, precommissioning and commissioning.
- Review of the process design package (PDP), which forms the core of the project definition package or basic design and engineering package (BDEP).
- If required, leading the update of the plant operating safety case and it submission to regulatory authorities.
- Advising proposed shutdown timings and agreeing durations.
- Participation in design safety reviews.
- Participation in plant layout reviews including accessibility and maintainability.
- Tie-in detail design and identification of timing and requirements for installation (note that this applies not only to piping but also to civil, equipment, electrical and instrumentation).
- Participation in design/configuration of operator displays on DCS/ PLC control systems and of alarm displays.
- Assistance in identifying any hazards which are specific to the plant and how they should be handled.
- Agreeing what preparatory and construction work may be carried out with the plant in service, and what precautions will need to be taken to allow this work to proceed.
- Agreeing any demolition/dismantling work which can proceed before the plant shutdown and what precautions will be needed.
- Agreement of the overall construction plan and input to detail of the shutdown work plan. Ensuring that any potential clashes between project work and maintenance work are resolved.
- Participation in the development and implementation of the overall construction safety plan.

- Preparation of a detailed listing of required isolations and checking that all such isolations have been correctly installed and later correctly removed. In some cases isolations will be directly managed by plant engineering staff.
- Permits for construction work:
  - Advise the permit requirements for both plant in service work and plant shutdown work. It may be possible when plant is shutdown to agree a much simplified procedure where a single daily permit authorises a whole pre-identified list of work rather than require a permit for each task.
  - Ensure timely review and authorisation of permits for work. There is a need to ensure there will be sufficient staff to cope with the anticipated number of permits. Delays in the availability of a permit to work can be a major cause of low construction productivity related to in-plant work. However, a responsibility also lies with the contractors to provide the required information in accordance with procedures for permits to be issued.
- Ongoing gas testing as required on the permit to work. Where there is an extensive need for gas testing, it may be necessary to provide a dedicated person by bringing in an "off-shift" operator or hiring in a retired operator.
- Participation in the development and agreement of process and utility systems definition (the systems by which the plant will be handed over, precommissioned and commissioned). This needs to include every physical part of the installed project, so additional systems will need to be defined for common use elements such as a DCS system, safeguarding system, plant cabling, buildings, general civil works, steel structures etc.
- Participation in the development and agreement of a handover and precommissioning plan. This will include agreeing needed documentation for handovers.
- Providing staff for punch listing and contributing to handover management.
- Preparation of plant commissioning and operating/maintenance procedures.
- Training staff as needed to operate and maintain the plant.
- Witnessing as needed the testing of plant and equipment, e.g. hydro tests, electric and instrument circuit and loop tests, trip and alarms, etc. This may include factory acceptance Tests (FAT) before the delivery of equipment to site.
- Obtaining (where needed) a permit to operate from statutory authorities (often a joint responsibility with project manager).
- Carrying out plant re-commissioning.
- Preparing plant performance test procedures.
- Carrying out performance tests.
- Receiving and retaining project documentation (design books, as built drawings, calculations, vendor manuals, QA documentation) and their safe storage suitable for reference (compliance with regulatory requirements).
- Updating of plant maintenance records, including electronic databases (MMS).
- Procurement of any additional equipment spare parts that are required.

21. Associated (non-engineering) requirements

Some projects require, in addition to the engineering works, other changes within the organisation in order for the overall investment to achieve its business objectives. These changes may or may not fall within the responsibilities of the engineering project manager. It is recommended that the engineering project manager, even where they are not responsible for the implementation of the changes, ensures that they are clear as to where responsibility lies and that implementation is consistent with the overall project requirements. Similarly, it is important to ascertain whether the costs associated with such business changes fall within the engineering project budget or not. It is not within the scope of this handbook to address in detail the methodologies to be adopted for such changes, but the following is a listing of the more common items:

- Changed requirements for supply of feedstock, additives, utilities, and packaging.
- Revised logistics for transportation of additional product and/or different products.
- Disposal requirements for any new waste products.
- Training of operating staff.
- Updating of plant accounting and other information management systems.
- Revisions to product sales and marketing.
- Revisions to maintenance contracts to incorporate newly-installed elements.
- Closure of redundant plant (where demolition is not needed to allow new construction). This could possibly be at a different site remote from the retrofit project.
- Staff redeployment/redundancy.

22. Performance enhancement by learning from experience

- *Learning from experience.* For all projects, no matter how successful or otherwise, there is tremendous benefit to be gained by carrying out a review of what happened and why in order to take on board the lessons learned and thereby improve effectiveness and performance of future projects. This is entirely valid for retrofit projects and, given their additional complexities and challenges, the potential benefits are greater. In order to maximise benefit, the following steps are suggested:
  - Ensure, so far as is practicable, that all parties who had a significant input to the planning or implementation of the project are involved in the review. In practical terms, this will involve a series of separate small meetings or response to a questionnaire. Obviously, if there is a contractual dispute, it may not be possible to include certain contractors.
  - Ensure that the focus is not simply on aspects that were not considered to be optimal. There is just as much to be gained from building on successes, by investigating the reasons for success and ensuring they are followed in the future.
  - Allow some time (typically 3 months after handover) after the completion of the project to assist in an objective, unemotional evaluation.
  - Obtaining the opinions of the customer is crucially important. Consider using a standardised questionnaire, but follow up with a face-to-face review of the core reasons for successes and failures. Always remember that the ultimate test is whether the project fulfils its stated key objectives (the reasons for carrying it out).
  - There is little value in identifying learning points unless there is an effective means of passing on the information to others who will become involved in future projects. Given the specific issues surrounding retrofit projects, there may be value in having a specific section of any learning data bank dedicated to retrofit issues.

- *Key performance indicators (KPIs) and benchmarking.* Benchmarking is a useful tool for measuring project performance, and there is no reason why retrofit projects should not be included. Naturally, the benchmark norms used must be based upon data from other projects which are broadly of a similar nature. Nonetheless, it is inevitable that benchmark figures will be based upon a range of projects and hence care must be taken when comparing the KPI figures for any one project with the benchmark norms. Retrofit projects are inherently very diverse in terms of scale, complexity and the circumstances under which they are developed and executed. This will inevitably result in KPIs for the project diverging from the norms. Such divergence must not be simplistically used to assert good or poor performance, but as the starting point to analyse the reasons for divergence. It is the analysis which will yield the information to allow lessons learned to be taken on board and the enhancement of future project performance.

  The choice of KPIs to be used will depend upon the organisation. Generally they should only be of significance to the overall performance of the project and only measured if good (reliable and consistent) data is available for a significant number of projects.

APPENDIX A

Project definition checklist

The quality of front end definition is one of the key elements which will determine the success or otherwise of the overall outcome of any project. This is especially true for retrofit projects, where the extent of definition work required may be more extensive than for new build.

The following is a general project definition checklist. Items which are retrofit-specific or significantly more important for retrofit projects are shown in *italics*.

A Business objectives

A1 Have the key business objectives been identified, agreed and clearly communicated? These must identify the driving forces for the project and specify what is most important from the viewpoint of the business.

A2 Cost is always important, but for this project, what is the importance of cost relative to other key drivers? If unavoidable, will additional expenditure to achieve other objectives override the desire for low cost?

A3 Schedule (both general and any specific target dates)
Is there an overriding requirement to meet a fixed completion date? For instance, completion during a plant scheduled outage, or a market commitment or legal obligation.

A4 Quality (of product or performance of completed project)
Are there specific performance requirements in terms of capacities, product quality requirements, plant availability and reliability etc?

Answers to the above should aim to identify relative importance of various drivers. Simply stating that all are important is not useful. What are the critical success factors?

B General project data

In addition to the key business objectives, there are often a number of other aspects which will influence the detailed design and implementation of the project.

B1 To what extent is automatic control to be provided? What are the criteria for control and safeguarding systems redundancy?

B2 Is the required turndown capability stated? *In the case of a retrofit project, does this change the required turndown ratio?*

B3 Are there specific process/control requirements for start-up and shutdown?

B4 What are the criteria for equipment spares?

B5 What are the requirements for equipment access/lifting/pulling beams/cranes?

B6 *Has constructability been considered? What constraints on construction are imposed by access to existing plant?*

B7 *Have interfaces and compatibility with existing instrumentation/control systems been identified*?

B8 *Have permit requirements been identified? Is there a permitting plan in place?*

B9 *Has the overall project milestone schedule been developed and agreed upon by the major project participants, including plant operations?*

B10 *Is any dismantling or demolition required? If so, has the scope been identified in detail and what safety requirements will apply? Is the timing identified?*

B11 *Has the required existing plant information been identified? Are design documents covering existing facilities available and have they been assessed for their completeness and accuracy? If not, has a plan for required additional work been developed?*

B12 Have project documentation (including electronic) deliverables been identified? *Has the extent of re-use (new revisions) of existing drawings been agreed?*

C Technical standards and specifications

C1 Are the standards and specifications to be applied identified and recorded?

C2 *Is there a specific requirement for compatibility with existing plant standards*?

C3 Are any project specific specifications required?

C4 Is there a requirement to procure certain items from a specific vendor to ensure standardisation or to meet specific performance requirements (*or for compatibility with existing plant installation)?*

D Process design

D1 Is there a completed set of process and utility flow diagrams showing all new equipment, main piping and control systems *and interconnections with existing plant and facilities*? What is the development status of these drawings?

D2 Is there an operating philosophy document against which design should be executed?

D3 Is there a tabulation of heat and material balances? Does this cover heat input and output for major equipment items (including all heat exchangers) within the unit? Material balances cover material input and output for all equipment items within the unit

D4 Has a set of process (and utility) engineering flow schemes (PEFs or P&IDs) been prepared? What is the development status of these drawings? PEFs should show all equipment, all piping and valves (sized) and all instrumentation, together with any specific additional requirements such as tracing, line slopes, specific elevation requirements. *Where the project is retrofit, a clear separate identification of what is new* *and what is existing should be made.* In general, PEFs are considered to be a key element within the scope definition package of a project.

D5 Are there equipment data sheets which identify for each item of equipment design conditions, performance data, sizing data, nozzle sizes, energy requirements, sealing requirements metallurgy, applicable design standards, insulation requirements, internals details? *This should include modification of existing.*

D6 *Have existing equipment items and piping systems been checked out for their suitability for revised duties?*

D7 Is there a line list which identifies each pipe together with sizing, design conditions, piping class and connectivity? *For retrofit projects, has line numbering for new lines been agreed?*

D8 Are all utility requirements identified, including quantities, design conditions, etc? Are existing utility design conditions identified? For instance, temperature, pressure, quantities available ? *Have connection points been identified?* These should include any sewer connections.

D9 *Are all process and utility tie-ins identified? Have the requirements under which the tie-in must be executed been identified?*

D10 Is there an instrument list which provides process data for every instrument together with its location?

D11 Is there a requirement specification and/or logic description covering the control and safeguarding systems? *If these will be extensions of existing systems, how will this be achieved in both design and installation?*

D12 Are relief valves and bursting discs, vents and flare systems identified and sized? *Have existing been checked out for any revised duties?*

D13 Have all electric power requirements been identified? Have sources of power been confirmed?

D14 Is the area classification plot plan provided to show the environment in which electrical and instrument equipment is to be installed?

D14 Has a HAZOP or other design safety review been carried out? If not, will one be required? Will an instrumentation protective function (IPF) review be required? *For retrofit projects, has the extent of the safety review been defined?*

E Layout and piping

E1 Are there overall layout drawings showing locations of new equipment? Are locations defined and agreed with plant operations and maintenance?

E2 Are piping classes identified?

E3 Are any special valve requirements identified and detailed? Must these valves be from a specific supplier?

E4 *Are design requirements for all tie-ins available? For instance, type of tie-in/size, hot tap, cold cut, flange, screwed, weld, cut and weld. Have these been reviewed with plant operations to check installation feasibility?*

E5 Are piping layout special requirements identified? For instance, slopes, long radius bend, requirements regarding high or low points, jacketing, provision for pulsation, cyclic operation conditions?

F Civil and structural

F1 For new or modified buildings is there a preliminary layout and user requirement specification? Are there any special design requirements (e.g. blast resilience, special HVAC requirements, special temperature or humidity requirements, clean room specifications)?

F2 Is data available for existing ground conditions (e.g. soil survey, water table, contamination data)?

F3 Is design code environmental data available (e.g. design wind-speed, rainfall rate, snow loading, earthquake factor)?

F4 Are layouts and elevations for new floors and platforms identified?

F5 Where existing structures are to be re-used/modified are existing design details/ calculations available? If not, how will this issue be addressed?

F6 Are finish coating requirements for steel identified (e.g. fireproofing, galvanising)?

F7 *Are routings for sewers and underground fire mains identified including tie-ins to existing*?

G Instrumentation and control

G1 *Have all local standards, including plant specific requirements, been identified?*

G2 *Has the extent of interconnection and extension of existing systems been identified?*

G3 Is there a written control and safeguarding philosophy and user requirement specification covering normal operation, start-up and shutdown? Are redundancy requirements identified?

G4 Is there a detailed instrument listing covering all instruments required, together with full design data? Are locations of all instruments identified?

G5 Is there a listing of preferred vendors and, for special requirements identification of specific instrument model numbers to be used?

G6 *Where extension of existing systems, (e.g. DCS, SGS, PLC) is contemplated, has expandability been checked out? Can modification/extension work be done with the plant in service or must a shutdown be provided*?

G7 *Has existing cabling infrastructure been checked out? Is spare capacity available or must new cabling, junction boxes, racking, auxiliary room cabinets etc, be provided? If new are needed is space and routing available?*

G8 *Will the existing DCS, PLC displays need to be reconfigured?*

G9 For safeguarding systems has instrumentation protective functionality rating been assessed?

G10 Are there any new *or extensions to existing,* gas detection or fire detection/alarm systems required?

H Electrical

H1 Have all requirements and locations for electric power been identified, including voltage levels, control requirements, UPS requirements, variable speed drive requirements?

H2 Have source(s) of new power requirements been identified, including any new switch house equipment needed? Have means of interconnection (tie-in) been assessed?

H3 Have the electrical single line diagrams been produced or existing ones marked-up?

H4 Are routes for new cabling identified?

H5 Have any requirements for electric tracing been identified?

H6 Have additional lighting requirements been identified?

H7 Are there any requirements for cathodic protection?

H8 Do grounding or lightning protection systems need to be installed *or extended*?

J Fire protection and safety requirements

J1 Is any additional fire prevention/fire fighting equipment required. This might include firemain extensions, deluge systems, fire monitors, fire extinguishers, foam systems, damper panels and fire doors.

J2 *Is any new safety equipment required (e.g. safety showers, specialised PPE for operators)?*

J3 *Have safe means of egress been addressed in the layout of new facilities?*

K Project management approach

K1 Has a project strategy been defined for the implementation of the project? This strategy must align with the business objectives and provide an overview of how the project will be implemented.

K2 Project execution plan (PEP). Has a detailed plan of execution been prepared? This should be agreed by all parties involved in the project especially the project sponsor. Ideally, it forms a part of the authorisation documentation. The PEP should include:
- Business objectives.
- Procurement and contracting strategy.
- SHE during implementation.
- Provision of overview project time plan, identifying critical activities and key hold points.
- Technical overview and any critical aspects.
- Identification of design standards and specifications.
- Outstanding issues remaining from definition package.
- Basis upon which cost control is to be managed.
- Identification of resource requirements (own staff and contractors).
- Identification of key risks and mitigation plans.

K3 Has the project time plan been checked to assess its overall validity and to identify critical and near-critical activities? Has this plan been accepted by business management and other key stakeholders? Have any significant schedule risks been identified and a management strategy for them devised?

K4 Has a project authorisation estimate been prepared? Has the accuracy level been agreed with those responsible for authorisation? Have any significant cost risks been identified and have appropriate levels of contingency been assessed and agreed?

K5 Have requirements relating to SHE been addressed, including legal requirements?
- Has provision for safety reviews been made?
- Have any specific/unusual hazards been identified and, if so, have risk assessment and remedial measures been identified?
- Which party will fulfil the roles of principal contractor and planning supervisor?
- Is notification to HSE under CDM Regulations required?
- Will one or more specific project health and safety plans be required? Who will produce these?

K6 *Have all staff resource requirements been identified? Have specific skills and knowledge requirements for the project been addressed? Has the availability of these resources at the times required been agreed? Have any potential resource conflicts been addressed?*

K7 Has the strategy for execution of the detailed design and engineering been identified?
- If a contractor is to be used, has sufficient time been provided to allow for tendering and negotiation of the contract?
- *For contracted-out design and engineering works, has consideration been given to the location where this work will be executed?*

- *If the work involves modification/extension of existing plant, has sufficient client resource been provided to assist in giving the contractor specific data and an understanding of existing facilities?*

K8 Is the procurement approach identified?
- Who is responsible for procurement of materials?
- Are sufficient resources available to ensure enquiries, orders and follow-up are carried out at required timings?
- Will the project require special effort to ensure required delivery of key items?
- Are time-critical items identified with the steps needed to ensure early ordering and timely delivery?

K9 Is the approach for provision of construction services identified?
- Who is responsible for procurement of construction services? Are they aware and able to provide contracts at the required timings?
- Have the means by which contracts are to be entered into been identified and agreed?
- Does the project schedule include time for development and tendering of contracts?
- If existing term/core contractors are to be used, have they been consulted and the availability of their resource been checked?

K10 Have the requirements for handover, precommissioning and commissioning been identified complete wit identified roles and responsibilities?

K11 *Have the required interfaces with the plant operating and maintenance team been identified and planned? These should include:*
- *Participation in development of the definition package.*
- *Requirement for comment on designs/vendor drawings.*
- *Participation in design safety reviews.*
- *Management of permits to work on existing plant.*
- *Requirement for plant shutdowns for construction, tie-ins etc.*
- *Process and responsibilities for pre-commissioning and commissioning and responsibilities.*
- *Operator training requirements.*
- Requirements for as built documentation.

K12 Have the requirements for cost control been identified? These should be looked at along with appropriate mechanisms for:
- Preparation of detailed estimate against an agreed scope.
- Identification of any special cost risk issues (e.g. sub-optimal time schedule, currency risk).
- Preparation of spreadsheet programme or equivalent to monitor costs.
- Scope change management system.
- Reporting requirements.

K13 Has a project risk assessment been carried out to identify any significant (scale of consequence and/or probability) risks to the achievement of the business objectives? If so have mitigation plans been identified and responsibilities assigned? Has a plan for revisiting identified risks been included?

K14 Have needed project responsibilities and authorities been agreed (commercial and technical)?

APPENDIX B

Some key aspects of fast track projects

This appendix contains a summary of some of the key features and issues affecting fast track projects. It is by no means a full guide. Much of the content is taken from the ECI publication, "The Fast Track Manual – a guide to schedule reduction for clients and contractors on engineering and construction projects" by Gerry Eastham (ECI, 2002). This document contains comprehensive guidance on the subject of fast track projects and their management.

The ECI Fast Track Manual gives the following definition of a fast track project:

"A project is considered to be fast track when the reduction of the schedule to the minimum practicable is the principal driving force for one or more stages of the project."

A fast track approach can be justified only where:

- The reduction of the schedule to the practicable minimum duration has significant benefits for the client who is therefore prepared to accept the risks that are introduced; and/or
- The contractor will benefit under the terms of the contract.

This will rule out the majority of projects which tend to be principally driven by cost considerations for the creation of the new asset rather than the maximum benefit to the client business.

Recent evidence suggests that fast track projects involve higher levels of risk and trade-offs with other requirements in order to achieve the shortest possible delivery schedule. In addition to the good business and project management practices normally used to ensure timely delivery, it is recognised that exceptional practices may have to be deployed to achieve fast track delivery targets. The use of such practices can result in greater risks.

A common cause of difficulty on projects concerns those that are initially intended to be delivered on a low risk basis, to a conventional schedule, but, due to delays in the development/ authorisation or a revised completion target, is left with no option but to take a fast track approach as there is insufficient time for conventional delivery. Project managers are warned against accepting such a brief. The slow decision-making at the front end of the project is likely to continue throughout the life of the project and will inevitably result in the schedule being exceeded.

The maximum reduction in overall schedule will be achieved when there is overlap of all stages of the project from concept through to beneficial operation. That can only occur when an integrated team is involved in the project from the start.

On fast track projects, some decisions will need to be made with only limited information available. This will require experienced judgement to ensure the correct outcome. It will be necessary to authorise and empower the team members to behave in this way, which may be contrary to their training and previous experience. The organisation must make it clear that it is prepared to accept that some decisions will be wrong or sub-optimal and that it is prepared to carry the risk that some decisions will need to be changed when the full information becomes available.

A consequence of scheduling activities in parallel rather than in a series is that more staff will be needed at peak periods if each of the parallel paths is to make the optimum rate of progress. It is therefore necessary to provide resource levels to deliver the plan rather than levelling the plan according to the resources available. The flexible provision of these additional staff should be taken into account when deciding the resource strategy.

One penalty that is most likely to be incurred is an increase in the amount of management, planning and control effort required for the successful delivery of a fast track project compared to a conventional project. Such costs will make up a greater percentage of total project cost.

Ensure that benefit to the client rather than cost of asset drives the client's thinking. However, it is doubtful if there are any projects for which early completion at any cost will be acceptable.

Contract arrangements are required that bring together the client's objectives with those of all the parties who need to co-operate. The intention must be to achieve a win-win situation so that everyone can concentrate on delivering the project critical success factors, confident in the knowledge that their best interests are being served by doing so. This requires that the project risks are fully understood and placed with the parties best able to manage them.

Alliances, term agreements and framework agreements help to ensure stability of working arrangements, so avoiding time lost while new staff become familiar with the required standards and procedures. If a client's forward investment plans have been shared with the contractors involved in an alliance or framework agreement then it is more likely that the necessary levels of resources will be available when required.

Arrangements for the payment of additional costs resulting from extra work or changed work conditions should be agreed up-front so that settlement can be effected quickly, thus maintaining motivation and avoiding diverting the focus away from the project objectives.

A fast track strategy, by definition, results in the introduction of greater risks, which then have to be managed to prevent them from damaging the project outcome. Risk-averse companies, especially clients who demand a certainty of outcome, will seek to limit their risk exposure and in so doing will constrain the project team that is attempting to deliver the new asset to a fast track schedule.

The inclusion of new and unproven technology and innovative design does not automatically rule out the possibility of executing a project to a fast track schedule. However, it is likely to increase the number of uncertainties and thus make planning and execution more difficult. It is recommended that the new technology and innovative design content be kept to a minimum and realistic allowances made in both time and cost for dealing with the issues introduced.

It is likely that a cost estimate to within plus or minus 10%, on which project funding would normally be approved, will not be obtained until well into the design stage of a fast track project. This will be some time after the procurement and construction stages have commenced. Approval will therefore have to be given on a lower level of definition and with a wider tolerance.

It has often been said that there are three things that are important in project management – definition, definition and definition – and the problem with some fast track projects is that detailed design has to proceed without total clarity of definition. There are limits as to what is possible and it is a matter of judgement as to which areas are sufficiently well defined to proceed with detailed design without incurring too great a risk, and which areas need to be held back until greater clarity of definition has been achieved.

Contracts will need to be set up with an appropriate balance of risk and reward. In the situation where the financial risk cannot be adequately defined, it will be necessary for the client to carry the risk and not try to pass it down a chain of unsuspecting contractors and suppliers. The increased risk of a fast track project needs to be effectively managed and this will only happen if the risk is identified and allocated to the organisation or person most able to deal with it.

References/further reading

1. ECI, The Fast Track Manual – A guide to schedule reduction for clients and contractors on engineering and construction projects, 2002

APPENDIX C

Example tie-in schedule

Tie-in tag no.	Existing Pipe or item tied into	New item connected to tie-in	Service	Detailed drawing no.	Flowscheme no.	Location	Party responsible for installation	Installation timing	Notes
T93-01	100-S93085	50-S93201	LP Steam	R450814 St 23	R450017	U9300 8M floor NW	Mechanical contractor	At plant shutdown	Possible at short opportunistic shutdown.
T93-02	200-P93126	80-P93245	Waxy hydrocarbon	R450814 St 78	R450008	U9300 ground floor S	Mechanical contractor	By arrangement with plant operations	Line will require removal of residues after cold cut.
T93-03	V9302	93 PR 053 (Instrument)	Ethylene	R450816 St 5	R450003	U9300 4M floor NE	Mechanical contractor	At plant Shutdown	New nozzle on vessel by specialist contractor
T93-04	100-P93057	None	Ethylene	R450814 St 82	R450007	U9300 ground floor N	Mechanical contractor	At plant shutdown	Blank flange installed replaces removed piping
TE-01	Switchboard E17A	New motor switch for P9355	415V 3ph	R452505	N/A	Switch house E17	Electrical contractor	At plant shutdown	

APPENDIX D

Listing of key relevant UK Safety, Health and Environmental (SHE) legislation

This listing identifies only the main items of UK HSE legislation which need to be complied with when developing, designing, implementing and commissioning a retrofit project.

There may, in certain instances, be a additional requirement to comply with planning legislation though this will normally only be a significant issue if the proposed retrofit project will result in either a major change in the scale or nature of use of the existing plant/facility.

It should be noted that the below only applies to the UK. It is not an exhaustive listing of all legislation which may apply.

	UK Legislation Mostly issued under the Health and Safety at Work Act 1974, and now harmonised with EC directives.
Process Safety	• Control of Major Accident Hazard Regulations (1999) (COMAH) • Control of Substances Hazardous to Health Regulations (1994) (COSHH) • Equipment and Protective Systems for use in Potentially Explosive Atmospheres Regulations • The Pressure Systems and Transportable Gas Containers Regulations (1989) • Dangerous Substances Regulations (1990) • Highly Flammable Liquids and Liquefied Petroleum Gases Regulations (1972)
Construction Management	• Notification of installations handling hazardous substances (NIHHS) • Construction (Design and Management) Regulations (1994) • Construction (Health, Safety and Welfare) Regulations (1996) • Provision and Use of Work Equipment Regulations (1992) (PUWER) • Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (1984) (RIDDOR) • Control of Substances Hazardous to Health Regulations (1994) (COSHH) • Manual Handling Regulations (1992) • Personal Protective Equipment at Work Regulations (1992)
Consents/ Authorisations	• Planning Permission • Building Control • Integrated Pollution Prevention Control (IPPC)
Design Management	• The Pressure Systems and Transportable Gas Containers Regulations (1989) • Construction (Design and Management) Regulations (1994) • Equipment and Protective Systems for use in Potentially Explosive Atmospheres Regulations • Machinery Safety Directive

References/further reading

1. Institution of Chemical Engineers, London, Project Management in the Process Industries, Chapters 11 and 13, 1999, ISBN 0 85295 406 9.
2. Institution of Chemical Engineers, London, Safety Management Systems, 1994, ISBN 0 85295 356 9.
3. HSE Books, London, HS(G) 150 – Health and Safety in Construction, 1996 (original edition, regular re-prints have topical amendments), ISBN 0 7176 1143 4.
4. HSE Books, London, HS(G) 166 - Formula for Health and Safety – guidance for small and medium-sized firms in the chemical industry, 1997, ISBN 0 7176 0996 0.
5. ECI ACTIVE Value Enhancing Practice No. 1.5 Safety, Health and Environment, October 1998.

APPENDIX E

Listing of risks specifically related to retrofit projects

This listing covers only some of the more common risks and it must not be assumed that every risk for a given project is addressed. No attempt has been made to include those (many) risks which are not specific to retrofit project. Many other risks are identified within the body text of this document.

- Resources with required specific knowledge are not available when needed to carry out feasibility and development phase work.
- Divergent project objectives/priorities from stakeholders (this can occur on any project, but is far more likely for retrofit projects).
- Documented information (drawings etc) relating to the existing plant/facilities is not available.
- Documented information (drawings etc) relating to the existing plant/facilities is not updated and, significantly, does not reflect current as built situation.
- Process design work identifies significant non-compliance of the existing plant/facilities with current process safety standards and/or it is unfit for revised duty (may arise as a result of HAZOP/process safety review).
- Risks associated with the use of unproven technology.
- Resources with required specific knowledge are not available when needed to advise and support detailed design work.
- Plant operations legitimate requirements are not addressed.
- Inspections of existing plant/facilities identify necessary remedial works to allow the project to be implemented.
- Project authorisation is delayed, yet project end date is fixed (e.g. shutdown date). This forces the project to become fast-track by default.
- Access dates for in plant construction works are revised (e.g. shutdown dates change).
- Availability of construction resource for fixed date works.
- Construction productivity is less than budgeted.
- Issuing of permits to work cause significant delay to construction works.
- Key materials are not available at the required (fixed) dates (e.g. items required for plant shutdown).
- Plant operations personnel are not available to support the project as needed.

Appendix F Typical design and safety reviews

The following chart lists the design reviews which should be considered. It is not suggested that all of these will apply to every project. The extent and detail of review will be dependent on project needs. In certain cases, a single review can be adapted to achieve several of the requirements. In addition to those due to attend each review, the project manager may wish to attend certain key reviews, and will certainly need to be consulted in respect of any significant changes arising as a result of the reviews.

Name	Review intent/purpose	Responsible discipline	Recommended attendees	
			Designer	**Client**
Hazard screening review/preliminary HAZOP	To assess potential hazards arising from the project and/or existing plant.	Process	Lead process engineer	Process engineer Operations representative
Basis of design review	Review process concepts, including levels of automation to set project scope.	Process	Lead process engineer	Process engineer Operations representative
Environmental screening	Review waste management system, environmental protection requirements (e.g. double containment, noise review).	Process	Lead process engineer	Process engineer Operations representative
Flowscheme (PEFS) review	Review process details, safety aspects, material selection.	Process	Lead process engineer E & I engineer Piping Engineer	Process engineer Operations representative
Control philosophy/ safeguarding review	Review control operations in all scenarios, methods of control, levels of redundancy, levels of interlock classification.	Process control systems/ instrumentation	Lead process engineer E & I engineer Piping engineer	Process engineer Operations representative
Plot plan review (may be included in 3D model review)	Review plant, location, logistics for transport/storage and evacuation, review overall construction sequence.	Piping	Lead piping engineer Lead process engineer E & I engineer Construction engineer	Operations representative Maintenance representative Construction engineer
Equipment location plan (may be included in 3D model review)	Review equipment location with respect to optimising layout based on process and/or material flow and overall maintenance requirements.	Piping	Lead piping engineer Lead process engineer E & I engineer	Operations representative Maintenance representative Construction engineer
Hazardous area classification	Review extent of hazardous area, zone classification, means of eliminating hazards.	Electrical & instrumentation (E & I)	E & I engineer Process engineer	Electrical engineer Process engineer
Layout and ergonomics review (3D model review no. 1)	Review overall layout of main equipment, critical pipelines and main structures to check accessibility, maintenance, safety in operation, ergonomics, evacuation and study of potential construction problems.	Piping	Lead piping engineer, lead process engineer, E & I engineer, civil structural engineer, construction engineer	Operations representative Maintenance representative Construction engineer

Name	Review intent/purpose	Responsible discipline	Recommended attendees	
			Designer	Client
Hazard and operability review (HAZOP or equivalent)	Review possible malfunctions, safety aspects and reduction of hazards. Identify operational requirements and possible need for training. Review relief streams.	Process	Lead process engineer Piping engineer E & I engineer Mechanical engineer	Process engineer Operations representative
Instrumentation protective function (IPF) review	Review of functions and criticality of safeguarding instrumentation. Determination of installed requirements.	Instruments	Lead process engineer	Process engineer Operations representative Instrument engineer
Alarm review	Review of required alarms and their display	Instruments	Lead process engineer	Process engineer Operations representative Instrument engineer
Fire fighting/protection	Review of fire-fighting philosophy, type of equipment needed, fire-fighting team requirements, fire exits, fire protection (e.g. on structures).	Mechanical	Mechanical engineer Piping engineer Civil engineer E & I engineer Mechanical engineer	Fire captain. Process engineer Operations representative
Detailed layout review (3D model review no. 2)	Review plant layout in detail to assess accessibility, ergonomics, maintenance and constructability.	Piping	Lead piping engineer Lead process engineer E & I engineer Mechanical engineer Civil structural engineer Construction engineer	Operations representative Maintenance representative Construction engineer
Paving and drainage review	Review maintenance and operational areas for need of paving, review separation and containment of process drains, storm water and firewater.	Civil	Civil engineer Process engineer	Civil engineer Process engineer
Mechanical and piping 100% design review	Review of mechanical and piping design for completeness, consistency of data, areas requiring action from construction as preparation for issue of subcontract scope of work.	Mechanical/ piping	Mechanical engineer Piping engineer Construction engineer	Mechanical engineer
E & I 100% design review	Review of E & I design for completeness, consistency of data, areas requiring action from construction as preparation for issue of subcontract scope of work.	E & I	E & I engineer/design	E & I engineer/designer
Construction safety risk review	Review of the design for potential risks to construction, operations and maintenance as a result of the design. Risk elimination or mitigation methods identified and residual risks documented.	Project manager/ construction manager	All discipline lead representatives Construction engineer	Discipline representatives Operations and maintenance representative

Name	Review intent/purpose	Responsible discipline	Recommended attendees	
			Designer	Client
Pre start-up safety review (PSSR)	Review of the completed plant with respect to the design intent, check of operational data/documentation and training adequacy.	Process	Process engineer Project engineer/Manager	Operations and commissioning team

Appendix G   Example of detailed planning requirement for shutdown works

The following is based upon a work element from a real project. The work consisted of the removal of an existing cyclone/bag filter vessel from within the main structure of a polymer plant, taking it to a vessel manufacturer's shop, removing the bottom cone section and replacing it with a longer cone. The vessel was then returned and re-installed. The whole project was carried out on a fast track basis and, at the time of planning, this was identified as one of the critical paths for the shutdown works, though (partly due to the detail of planning carried out), in the event, completion was achieved before certain other works. This detailed planning was carried out jointly by the client and managing contractor, with all needed information passed onto the several construction contractors involved. Note the extent of detail required for the shutdown element.

Task no.	Task Description	Party responsible	Preceding tasks	Other constraints	Length	Notes
1	Initial specification of required modifications to vessel.	Client Engineering contractor			4 wks	This had to be completed within 2 months of contract award to engineering contractor. However basic process requirements were identified in definition package.
2	Identification of preferred vendor for vessel modifications.	Client Engineering contractor				Decided on use of vendor who had good track record of vessel modification/repair work for client.
3	Review required work with preferred vendor and agree price.	Client Engineering contractor	1, 2		4 wks	Review resulted in some detail changes to how the modifications would be implemented.
4	Finalise specification and place order.	Engineering contractor	3	This had to be achieved at a timing of no later than 6 months before start of plant shutdown (i.e. within 3months of start of detailed engineering).	2 wks	Note that cost of this work (which was a significant element of overall budget) was only firmed up 3 months after project approval.
5.	Identify civil and structural modifications needed to accommodate revised vessel.	Engineering contractor	1		2 wks	
6	Develop total work scope for removal and re-installation.	Engineering contractor	5		2 wks	Scope development and agreed timings involved clients plant operations.
7	Detailed design and fabrication of new cone section for vessel.	Vessel manufacturer	4		5 mths	Design had to accommodate the potential need for adjustments for welded connection of new to old, where a flush and smooth internal finish was vital.

Task no.	Task Description	Party responsible	Preceding tasks	Other constraints	Length	Notes
8	Ensure required work is fully detailed in mechanical contractor's scope of work.	Engineering contractor	6	This had to be achieved at a timing of not later than 5 months before start of plant shutdown (i.e. within 4 months of start of detailed engineering).	2 wks	
9	Complete detailed design for required civil and structural modifications.	Engineering contractor	5		2 mths	(This was not a critical activity.)
10	Complete detailed design for new associated pipework.	Engineering contractor	6		2 mths	This activity was critical and became super-critical due to problems with overall piping design progress.
11	Supply material and fabricate new pipework.	Mechanical construction contractor	10	Pipework required to be at site no later than 2^{nd} week of plant shutdown period. Note material included long radius pulled bends in stainless steel.	8 wks	Special valves supplied by engineering contractor; also involved use of specialist sub-contractor for long radius pulled bends.
12	Arrange for lifting contract.	Engineering contractor		Needs to be agreed approximately 2 months in advance to ensure availability of 200 tonne crane and agree method statement.	4 wks	Needs close liaison between mechanical construction contractor and crane/lifting contractor.
20	Install scaffolds to allow stripping of insulation from vessel.	Scaffolder		Allowed to start 1week prior to plant shutdown.	3 days	Start prior to plant shutdown agreed with plant operations hence this activity became non-critical.
21	Remove steelwork above vessel to provide access to vessel top.	Steel contractor		Allowed to start 1week prior to plant shutdown.	3 days	Start prior to plant shutdown agreed with plant operations hence this activity became non-critical.
22	Remove insulation from vessel.	Insulation contractor	20, 21	Allowed to start as soon as plant stopped production, i.e. during decommissioning.	3 days	
23	Plant decommission/ spading and gas freeing.	Plant operations			3 days	
24	Remove instrumentation from vessel and piping.	Instrument contractor	23		1 day	Most instruments to be retained for re-installation.
25	Disconnect and remove pipework at vessel.	Mechanical construction contractor	20, 22, 23		1 day	
26	Set up crane at site.	Crane supplier	12		2 days	Required installation of load spreading timbers.

Task no.	Task Description	Party responsible	Preceding tasks	Other constraints	Length	Notes
27	Remove vessel top head, bag filters and cleanout polymer powder.	Plant maintenance	24, 25		2 days	Plant maintenance staff used as they have prior experience of this task.
28	Lift out vessel.	Crane supplier	26, 27	Area adjacent to the lift cleared of all personnel during this operation.	½ day	By agreement crane was left in-situ to await return of vessel. Crane also used for a number of small lifts from same location.
29	Remove scaffold at location of vessel bottom.	Scaffolder	28		1 day	Scaffold removed to allow modification of concrete floor. Also shape of revised cone on vessel will need different scaffold.
30	Open out concrete floor to provides space for new (larger) cone on vessel.	Civil contractor	29	No personnel allowed to work in area below this opening during this period.	5 days	Use of jack hammers causes considerable noise and dust. New larger opening required lip to give strength to the larger hole in floor. New rebar connected to existing.
31	Transport vessel to vessel shop.	Vessel manufacturer	28		½ day	
32	Cut off vessel bottom cone and fit new longer cone.	Vessel manufacturer	7, 31		8 days	Fitting new cone involved careful use of jigs and some grinding in order to achieve a smooth, flush connection internally.
33	Carry out hydro-test of vessel.	Vessel manufacturer	32		1 day	
34	Transport back to site.	Vessel manufacturer	33		½ day	
35	Re-install vessel.	Crane supplier	34	Area adjacent to the lift cleared of all personnel during this operation.	½ day	
36	Refit internals.	Plant maintenance	35		1 day	
37	Build new scaffold for insulation of vessel.	Scaffolder	35		2 days	
38	Install new pipework connecting to vessel. Carry out radiography.	Mechanical construction. contractor	35		5 days	Radiography carried out overnight.
39	Carry out piping hydro-tests.	Mechanical construction. contractor	38		2 days	
40	Blow dry piping and vessel to ensure no	Mech. construction.	38		1day	Initial drying. Further drying carried out in precommissioning phase to ensure no contamination when taken into service.

Task no.	Task Description	Party responsible	Preceding tasks	Other constraints	Length	Notes
	residual water.	contractor				
41	Install instrumentation to vessel and pipework.	Instrument contractor	36, 40		2 days	
42	Re-insulate vessel and pipework.	Insulation contractor	36, 40		3 days	
43	Re-install steelwork above vessel.	Steel contractor	36		2 days	
44	Punch-list system ready for precommissioning.	Mech. construction contractor	40, 41		1day	

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