Mining in a Day Seminar Balikpapan

2nd September 2015

Exploration Test Program Design

Exploration Test Program Design

Factors to be considered when designing test program

Existing databases.

- Little or no existing data – complete freedom
- Significant data already available – need to try and be consistent unless there are fatal flaws with existing data

Deposit factors

- Rank of coal and potential utilisation
- Potential mining methods and working sections
- Potential washing methods
- Particular coal quality issues, sulphur, phosphorus, rank, mineral characteristics etc.

Exploration Test Program Design

Requirements of the users of the data

- Geology – resource modelling and reserves
- Mining – production schedule
- Coal Preparation – plant design, product schedule
- Coal Technology and Marketing – product specifications, product schedule
- Environmental – reject and overburden emplacement

It is best to consult the specialist from each area to ensure the data generated from the exploration program meets their needs. QCC can however make recommendations based on our experience when this is not possible.

Exploration Test Program Design

Test programs can be divided into four broad categories based on sample types

- Slimcore – grid of cores over the deposit to provide the data for the geological model and provide the coal quality information. A simple test program is required
- Large diameter core (100-200mm) – provides data for coal preparation plant design and larger coal samples for specialised test work e.g. coke oven testing. Provides data for estimates of practical yield.
- Channel or Bulk Samples – similar test programs to large diameter cores but can provide larger samples for market samples or pilot scale testing
- Chip samples – LOX line definition or delineation of intrusion zones

Exploration Test Program Design

Slim Core Test Programs

- **Stage 1** – Simple raw ply testing
- **Stage 2** - Is the coal likely to be processed in a coal preparation plant?
    - **YES** or **NOT CERTAIN** - simple float and sink testing required with basic analyses on density fractions.
    - **NO** - no additional testing required
- **Stage 3** – Product coal Testing – Simulated product coal samples are prepared for testing by combining density fractions or raw ply samples if float sink testing was not performed. The samples combined should be from likely working sections to represent a product coal.

Exploration Test Program Design

Large Diameter Cores Samples – Essential Data for Preparation Plant Design

- Broken to provide an estimated plant feed sizing using drop shatter and dry tumbling
- Wet tumbled to simulate the breakdown the coal will receive in a coal preparation plant. Coal will breakdown by attrition and non-coal material (mudstone, claystone) will break down by interaction with water.
- Float sink testing on a range of size fractions to provide information for density based separation processes
- Froth Flotation testing
- Density and flotation fractions can be recombined to produce product coal samples

Exploration Test Program Design

QCC input will reduce the risk and costs of the test programmes to the project:

- Green fields exploration programs require data be collected in sufficient detail to allow the full range of mining, processing and product options to be investigated to maximise the potential value of a deposit, both now and in the future
- Premature decisions regarding mining, processing or products during an exploration program may result in the collection of inadequate data which will require additional drilling and testing in the future
- Test programs should not be fixed but must be reviewed in the light of results received to avoid unnecessary testing
- Test data needs to be validated. It can not be assumed that the results from the laboratory are correct. Sample, analytical and transcription errors often occur

Selecting Tests for Each Sample Type

There is a wide range of analyses that can be performed on coal samples. The costs of these analyses vary significantly and ensuring appropriate level of analysis is performed is an important part of exploration program cost control. Important considerations:

- Precision of the result required – if the analysis result is important and/or variable then more points of observation will be required
    - Calorific Value is a critical value for a thermal coal and will be tested for most samples, particularly if there are rank changes across the deposit
    - If sulphur is high or variable ply samples will be routinely analysed but if it is low and consistent may only be required on product coals
- Test such as ash analysis, ash fusion, Hardgrove grindability and trace elements should be performed on likely working section/product coals. Results should be carefully reviewed to ensure excessive testing is not performed.

Selecting Tests for Each Sample Type

Density

Density is an essential result for reserve and resource estimates but is often incorrectly used.

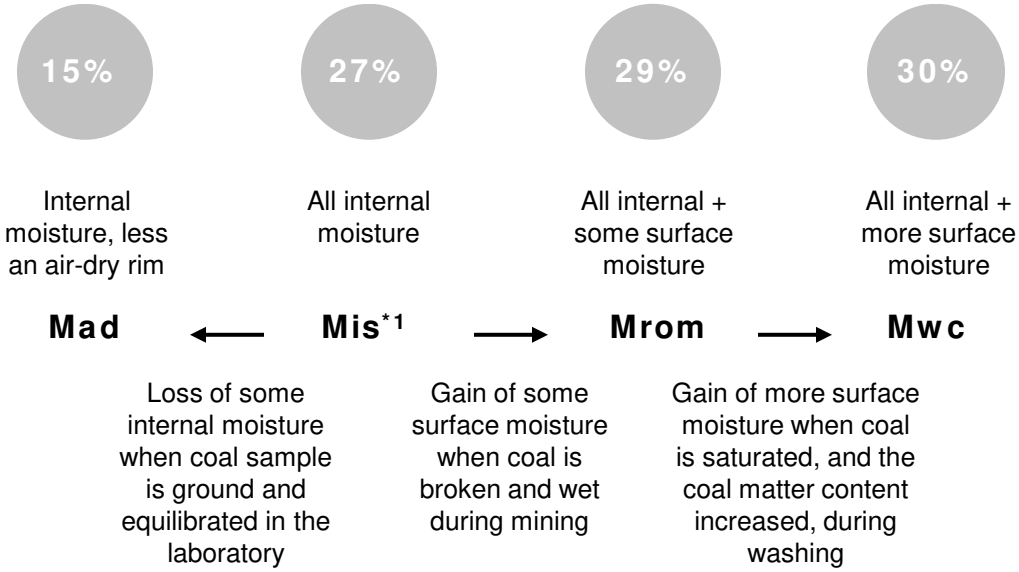
- The density required is the density of the in-situ coal. Density varies with the moisture content of the coal and the in-situ density must be at the in-situ moisture level. Two methods can be used:

1. Determine density of the normal analysis samples at a known moisture level and calculate the density to the in-situ moisture level using Preston-Sanders equation. The in-situ moisture level must be determined.
2. Determine the density by water displacement (apparent relative density method). The core must be taken carefully stored to keep the sample at the in-situ moisture level.

Selecting Tests for Each Sample Type

Moisture

Moisture in coal is present in a number of forms and its measurement is critical as it impacts on quality as well as product tonnes.



ad = air-dry; is = in-situ; rom = run-of-mine; wc = washed coal

*1 Mis = moisture in-situ, or bed moisture. For values below about 20%, it is about 0.5 to 1% greater than the moisture holding capacity value.

Selecting Tests for Each Sample Type

- **Moisture in the analysis sample Mad** (inherent moisture, air dried moisture). Moisture in the analysis sample after coming to equilibrium with the laboratory atmosphere
  - Result varies depending on ambient temperature and humidity
  - Essential to be performed when all other tests are performed (ash, volatile, sulphur, CV etc.) as these results vary as the moisture level changes
- **Free Moisture** (air dried loss) moisture lost when a sample is air dried.
  - Result varies depending on ambient temperature and humidity
  - Can be the first stage of a two stage total moisture determination

Selecting Tests for Each Sample Type

- **Total Moisture** (as received moisture) The moisture in the coal as sampled.
  - Can be a single stage or two stage determination
  - Low rank coals can oxidise if heated at 105ºC in air
  - Always required on shipment samples for adjustment of prices and care must be taken in sampling and preservation of samples

Practical Yield and Quality

Practical Yield and Quality Estimates

For deposits where coal washing will occur the expected yield must be known for reserve calculations. The yields can be overestimated or underestimated if the correct procedures are not used.

- Laboratory float and sink testing provides theoretical yields and qualities. These theoretical yields will always exceed those that will be achieved from a coal preparation plant.
- Practical yields and qualities can be estimated by processing washability data through a preparation plant simulator. QCC uses the LIMN program.

Practical Yield and Quality Estimates

- Feed data for processing through the LIMN simulation of a preparation plant can only be produced from pre-treated samples that simulate a plant feed size distribution and the breakdown of the coal during washing.
- In a deposit these points of observation are limited. To provide a wide distribution of points of observation for practical yield and quality, the results from the LIMN simulation are used to generate correlations with theoretical yields and qualities from slimcore samples.

Practical Yield and Quality Estimates

Practical yield and quality estimates from theoretical data can be generated by two approaches:

- Practical yield and quality is generated for each point of observation and is included in the geological quality model
- Theoretical washability is included in the geological model and is generated against the production schedule. Practical yield and quality is then generated for direct inclusion in the production schedule. This is the preferred option as data can be checked for internal consistency and different product options can be reviewed

Managing Coal Quality

Managing Coal Quality

In a competitive market reliability of supply and quality will assist in maintaining market share. Maintaining reliable coal quality is a combination of prediction and control.

- The geological model together with product schedule will provide predicted coal quality. Include in this will the need for consideration of practical yield, dilution and coal loss. Predictions from the model and schedule need to be regularly reconciled against actual quality and yields and prediction process continually validated.
- Sampling and analysis of the product coal through the coal chain is essential to verify quality.
- Coal washing provides a very high level of product quality control

Sampling and Analysis

It is not possible to control quality if it can not be reliably measured.

- Errors in coal quality results come from three areas. In order of importance:
    1. Sampling
    2. Sample preparation
    3. Analysis
- Sampling audits are required to confirm that samples have been taken representatively.
- Laboratory audits address sample preparation and analysis competence of the laboratories.
- This applies along the coal chain from exploration to shipment

Sampling Audit

Poor sampling is the major source of errors in coal quality results.

- Manual sampling is commonly used for intermittent sampling or in the field where automatic samplers are not available. The availability of properly designed equipment and appropriate levels of training and supervision are critical
- Automatic samplers provide more reliable results but need to be properly designed and maintained.
- All sampling programs need correct design
- An audit will determine if sampling is being performed properly and make recommendations to remedy deficiencies. Objectives of an audit are to review:
    - Purpose of sample being collected
    - Users of the information from the samples
    - Is the sample the most appropriate to provide the information required?
    - Frequency of sampling

Laboratory Audits

Laboratory audits review the sample preparation and analytical operations of the laboratories. Systematic errors in analysis generally results from problems with equipment calibration and maintenance or with incorrect or poorly performed analytical methods. This is often the result of poor training or supervision.

A laboratory audit will have the following objectives;

- Safety – safe working practices and control of hazards
- Quality system – accreditation and its operational status
- Staff – adequacy of staff levels, supervision and experience
- Training systems - including safety and work procedures
- Equipment – conformance with standards, capacity and availability of backup
- Calibration and maintenance systems – review of schedules and confirm systems are in use. Confirm traceability of standards
- Facilities
  - Sample preparation and analytical areas size and setup
  - Dust and fume extraction
  - Power backup if appropriate

Laboratory Audits

- IT infrastructure – network and backup protocols, LIMS (laboratory information management systems
- Proficiency test programmes and use of quality control samples
  - Review the level of participation in external proficiency test programmes, review results and investigations when results are outside the acceptable levels
  - Review the use of internal check testing, results and actions when results fall outside control limits.
- Traceability of results from the analyst to the final report together with processes used to validate results prior to reporting

Why is a Coal Preparation Plant Required?

Coal preparation plants represent a considerable capital investment and a ongoing significant operational cost and are used only as necessary.

- Metallurgical coals (coking coals) almost always require washing to meet the lower ash levels (and increased vitrinite levels) required for coking coals and to ensure a consistent product quality.
- Lowering the ash of thermal coals will increase energy levels and sale price and make them more attractive in a tight market
- In times of market oversupply higher ash thermal products may not be easy to sell and washing may be required
- Coal that has significant level of dilution may normally need to be discarded but washing may recover additional product coal. This coal can be considered to have zero mining costs.
- May reduce undesirable coal properties e.g. sulphur if the problem material is concentrated in the higher density fractions.

Coal Preparation Plant Design

Considerations for Coal Preparation Plant Design

Each coal resource provides its own mix of sizing, washability, quality

Factors which can impact on selection of a CPP process

- Mining and raw coal handling methods
  - Impact on size distribution
  - Ability for selective mining
- Dilution and coal loss
  - Nature of dilution material
- Seam mix (by period)
  - Are the washability characteristics of the seams different?
- Washing strategy (batch versus blend washing)
  - Can the blend of different coal sources be controlled or will the plant wash coal as delivered and need to cope with the variability?
- Product specification(s)
  - Are multiple products required?

Considerations for Coal Preparation Plant Design

An important part in evaluating a new coal resource is to consider the practical implications of washing i.e. undertake a process study.

- **Processing options i.e. Jig, DMC, DMB, Spirals, TBS, Flotation**
- **Product options – Primary secondary products, products from different size fraction**

Need to consider CPP requirements from a 'whole of project' perspective. The optimum process is not always selected, due to other issues, such as:

- **Mine life**
  - **short mine life will require lower capital inputs**
- **capital expenditure and payback period**
  - **What are the investment criteria required by the client?**
- **Client preference**
  - **Ultimately the client will need to approve a specific design**

Preparation Plant - Design to Operation

The major stages in design and construction of a coal preparation plant are:

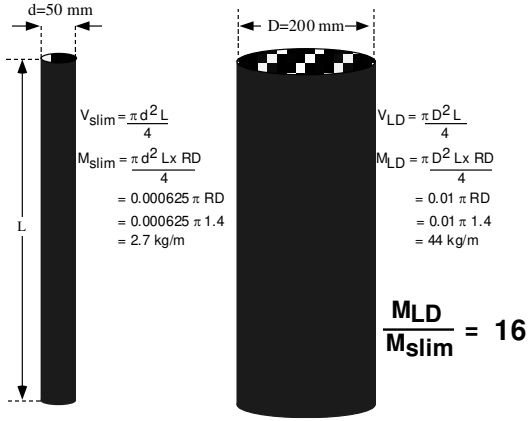
- Acquisition of design data
- Process studies to determine the plant flowsheet
- Equipment selection – type and size
- CAD modelling to layout out the plant
- Client Review
- Preparation of engineering drawings for construction
- Construction
- Commissioning

Project Scale

Preparation plants can range is capacity for 100 t/h to 4,000 t/h and the complexity of the studies, design and engineering varies accordingly.

- Appropriate design data necessary to confirm suitability of any plant design

Design Data



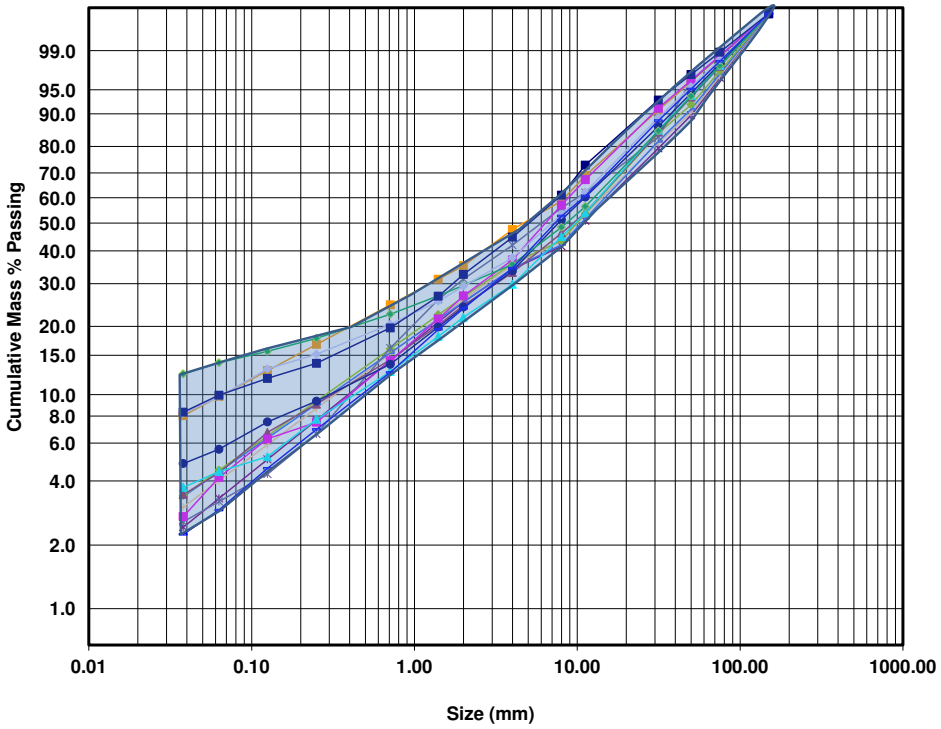
Slim cores provide

- **simple float sink and coal quality and show the variability of coal washability across the deposit**

Large Diameter Cores/Bulk Samples

- **Detailed sizing and FS by size i.e. "CPP design data"**

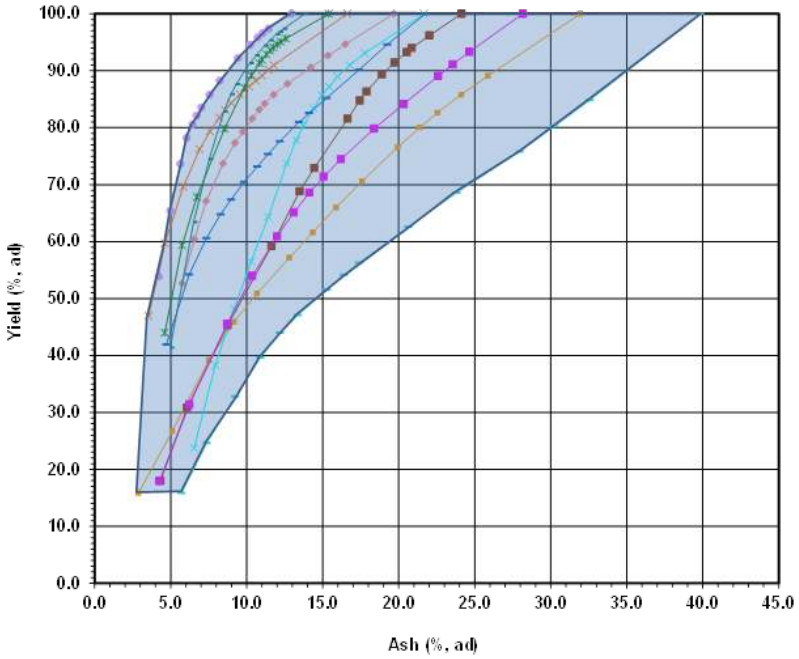
Design "envelopes"



Built up from LD core or bulk sample data

- **Allow for a range of CPP feed types. Samples must be selected across the mining area to represent the range of plant feeds**
- **Will be used to determine the capacity required for each circuit in the plant**
- **Underestimating the amount of fines has been a significant issue for coal preparation plants. Underestimating fines results in reduced plant capacity**

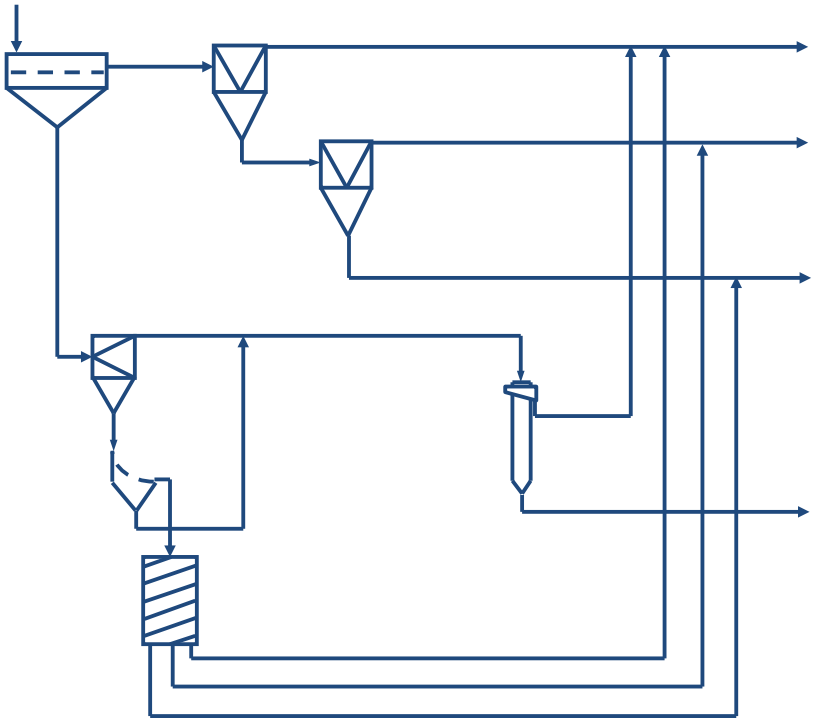
Design "envelopes"



Important to consider

- **Practical mining sections that will represent likely plant feeds**
- **Dilution and loss – may have a major impact on the plant yields**
- **Relative tonnages of the coal types**
  - **washed separately**
  - **proportions if combined**

Flowsheets



LIMN® "The Flowsheet Processor"

Inputs

- Feed files (within design envelopes)
- Product target quality

CPP simulation using LIMN

- solids only flowsheets for Concept/Pre-feasibility studies
- full material balance for Feasibility Study/Project Implementation

Outputs

- yield-ash for options & preferred process
- process flows (water, pulp, magnetics)
- mine planning practical yield/ash predictions

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Processing Equipment and Technology Trends

The 'standard' configuration of a modern coal preparation plant consists of

- **wet screening (desliming)**
- **dense medium processing of the coarse material**
- **water based processing of deslimed fines and**
- **froth flotation of all or part of the fine coal fraction (optional)**

Every deposit however needs to be considered individually to ensure that the minimum capital and operational cost plant is selected and the required capacity is achievable.

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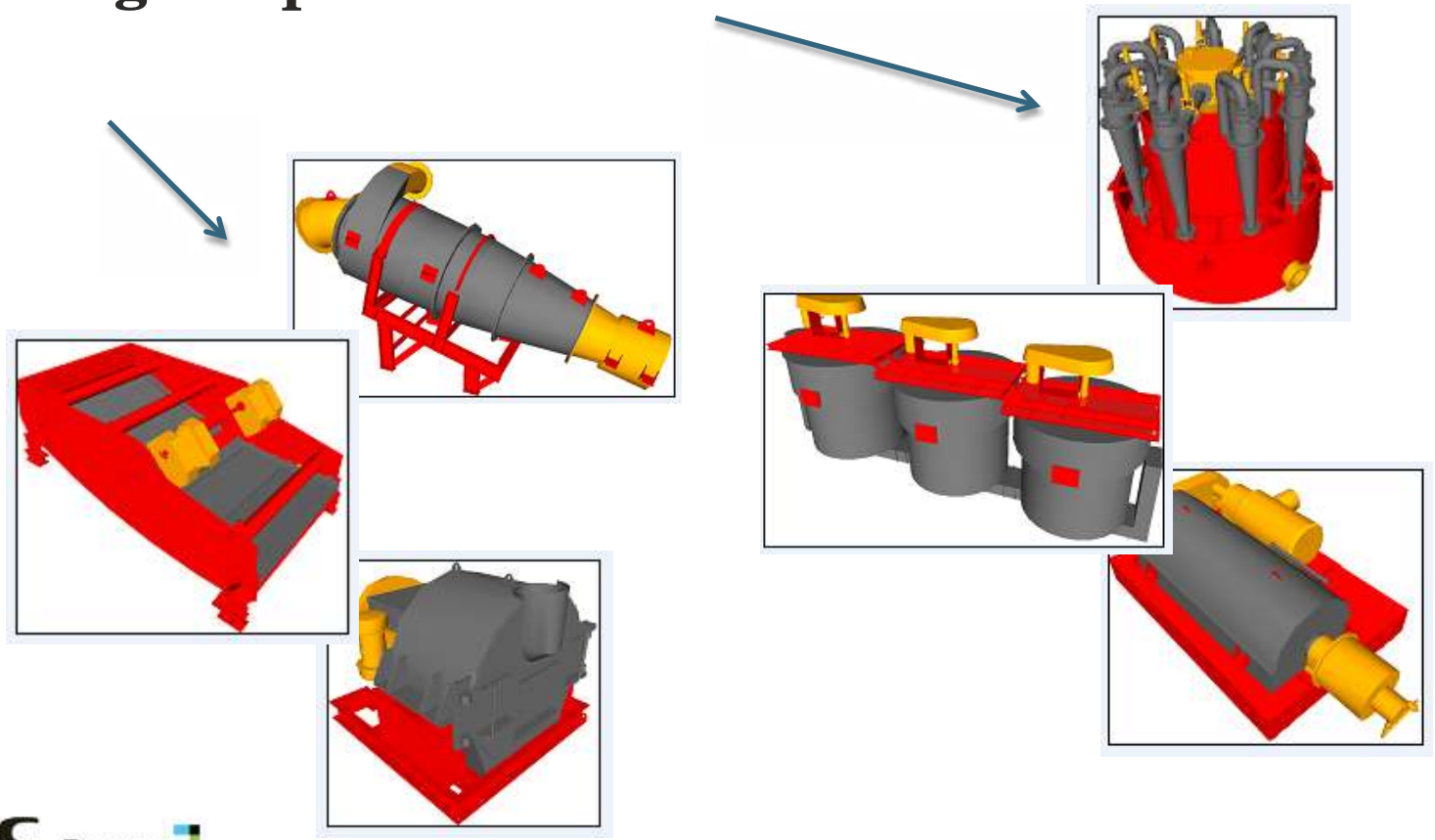
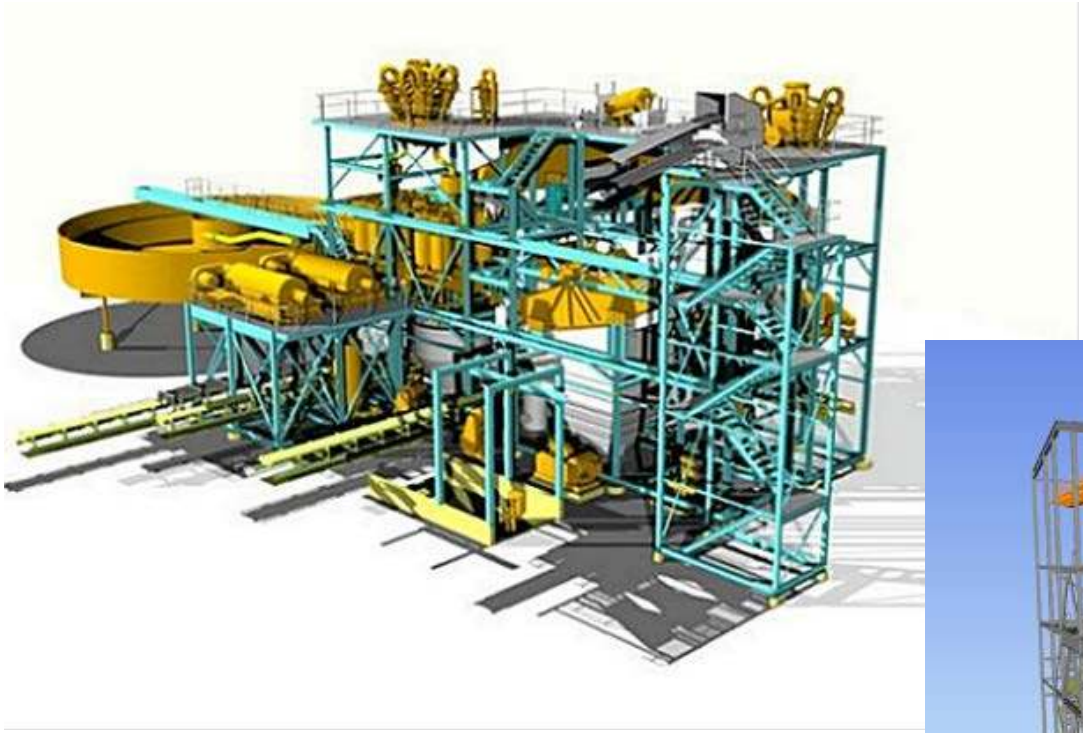
Equipment selection

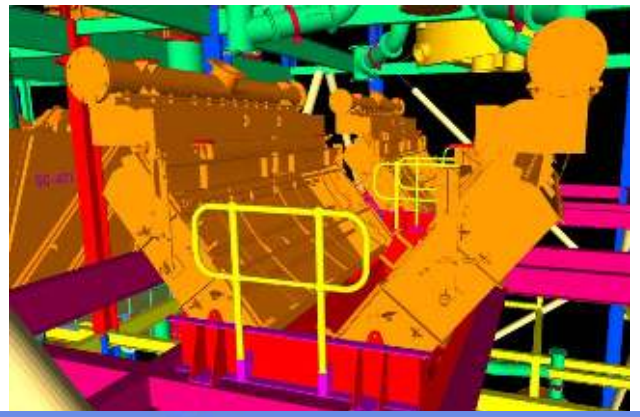
Equipment sizing and selection from the LIMN modeling output sheets



3D CAD Modeling

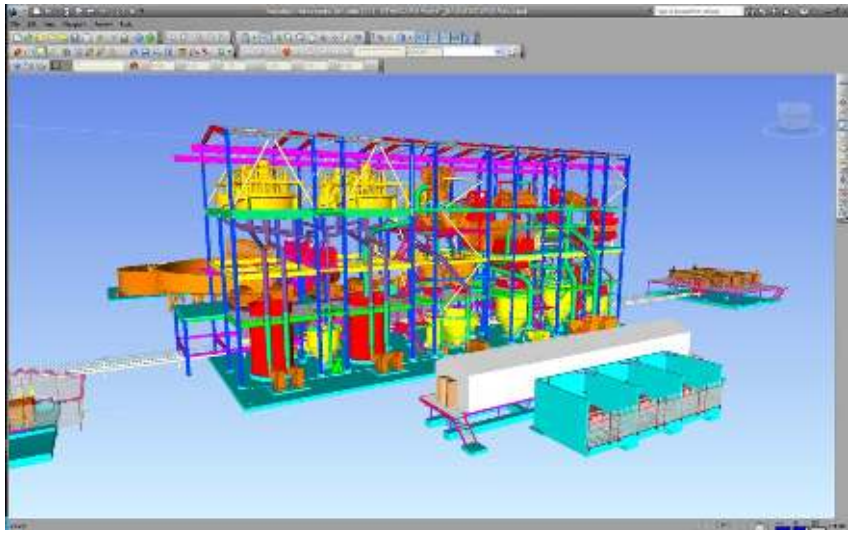
CAD modeling using AutoCAD V12, Prosteel, and Plant 3D

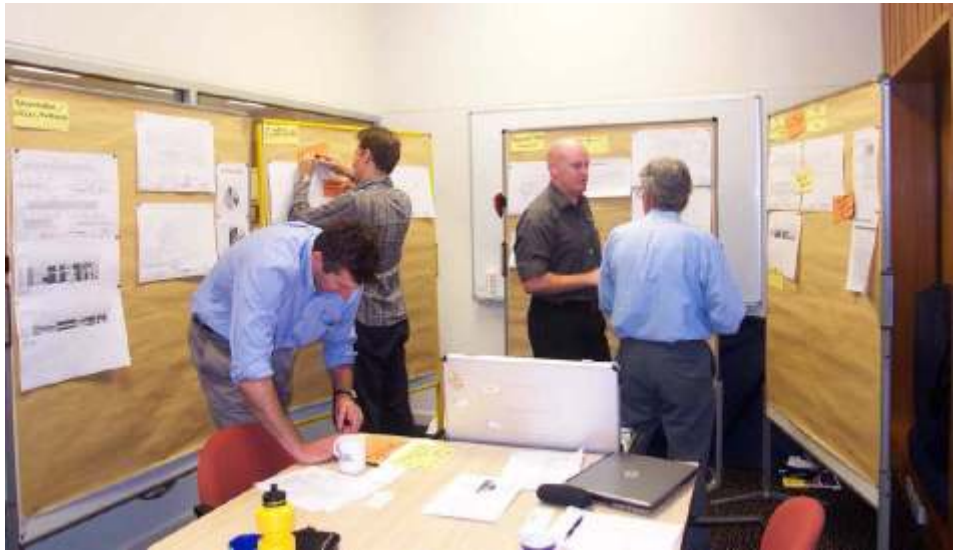




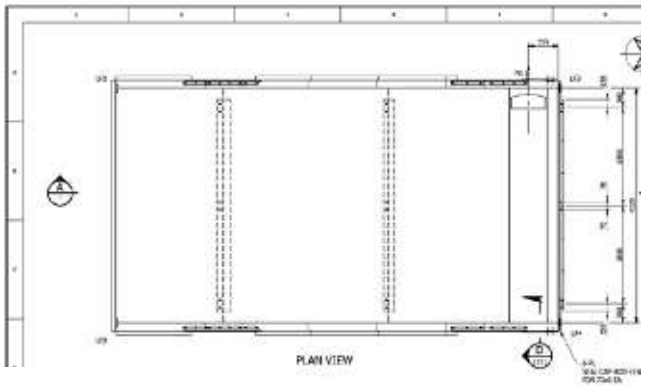
Client Review

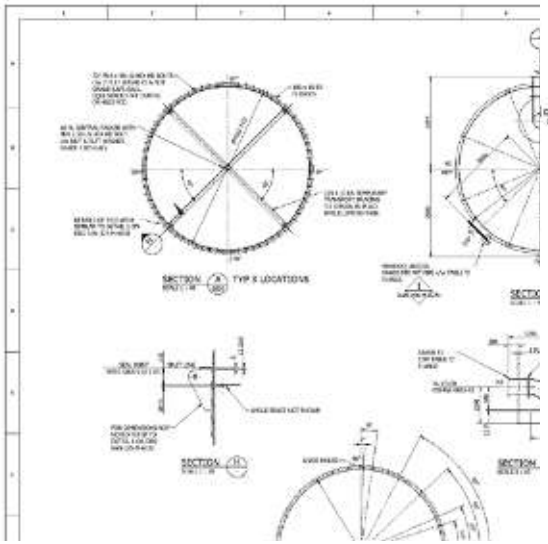
At all stages through the design process the client is involved. The clients input is critical as the plant must be integrated into the mine operations and the client may have specific operational and design criteria to be considered.

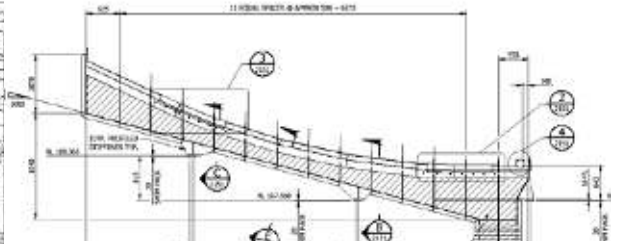




Engineering drawings







Construction

Mangoola (NSW, Australia) Coal Preparation Plant 1800 t/h

Jellinbah (Qld, Australia) Coal Preparation Plant 350 t/h

Stockton (New Zealand) Coal Preparation Plant 250 t/h

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Commissioning