

APPLICATION OF QUALITY CONTROL PROCEDURES FOR CONVEYOR BELT INSTALLATIONS

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1. INTRODUCTION

The purpose of this paper is to outline the evolution of a conveyor installation from design through to installation, and the practical application of quality control procedures through the various phases required to make it a success. There is anecdotal evidence that the importance of quality control and record keeping is often overlooked and in some instances considered to be a hindrance to progress during an installation. This thinking often leads to unsafe conditions during installations and also poses a safety hazard during operations leading to injury or death of personnel. These incidents, despite being avoidable, can have a severely negative impact on operations or projects in the form of financial loss, strikes and even closure. Safety and quality control are not mutually separable and treating them as such may have far reaching consequences.

Figure 1 illustrates the basic steps in the development of a conveyor system and forms the basis of the topics discussed in the paper.

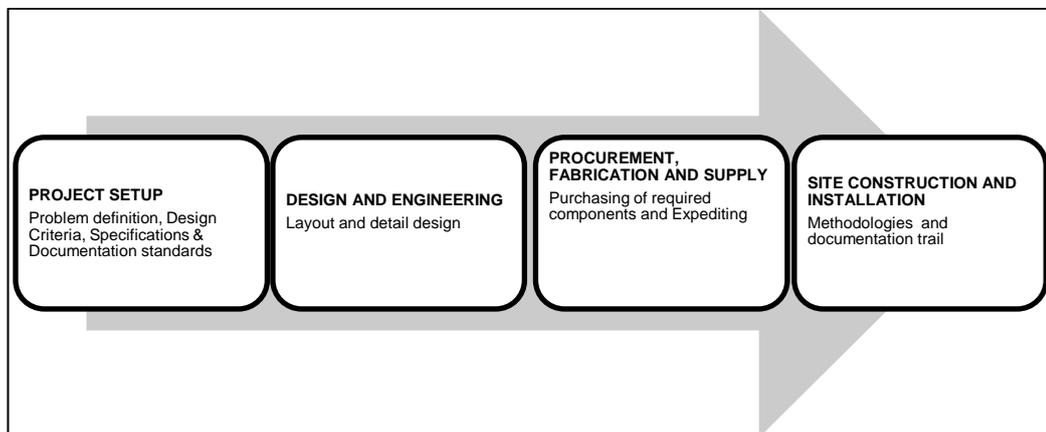


Figure 1. Overall process flow

Firstly, the paper focuses on the design of conveyors and the specification that initiates a successful installation, including the record keeping thereof.

Secondly, the procurement phase of conveyor components is discussed, highlighting in particular, the link between client specifications and practical quality control implications for manufacturers and suppliers.

Thirdly, site construction and installation of conveyors is presented with an emphasis on installation methodologies of all elements as well as the quality control and documentation trail that is compiled.

Finally, since every installation is a project on its own, the paper discusses the project management and the people management aspect of all the phases from concept inception to handover of a successful installation. The focus is on the roles and responsibilities of various parties (clients, engineers, designers, vendors, installers, etc.) in the process within a project environment.

2. PROJECT SETUP

The requirement of material handling systems such as conveyors is often borne out of the necessity to reduce labour-intensive operations and increase efficiency when moving large amounts of material. It is therefore critical at this inception stage that the problem is well-defined and recorded to enable optimum conveyor design and good team communication.

The following is required to enable clear and concise communication between all parties:

1. A *Design Criteria* document must be compiled, approved and signed by both client and design consultant and should clearly define, as a minimum, the following:
 - Operational parameters such as continuous or shift operation, maintenance days, type of loading, etc.
 - General design principles and considerations that often have cost and layout implications such as clearances required over roads, number of walkways, sheeting, access provision, maintenance principle (overhead cranes or by mobile crane), etc.
 - Also included are design principles for other disciplines, like civils, electrical, instrumentation and control.
2. *Project specific* specifications for each conveyor equipment component such as drives, idlers, belting, belt cleaners, pulleys, etc.) must be compiled, reviewed and approved by all parties. These specifications provide guidelines for the conveyor designer and contain information design factors (safety factors, load factors, thermal factors, etc.), and also information on prescribed equipment.

It is of great importance that care and diligence is applied when compiling the documentation above to make it client specific, taking into account factors such as capital and life-of-mine operational costs. Cognisance must be taken that these documents will govern every aspect of the process from design to suppliers, the installer and eventually the client.

| Legend | G | Generates | Project Manager | Project Engineer | Conveyor Designer | Drawing Office | Team Supervisors/Managers | Contractor / Supplier | Client |
|---------------|--------------------------|-----------------------|-----------------|------------------|-------------------|----------------|------------------------------|-----------------------|--------|
| | A | Approval | | | | | | | |
| | I | Input into Generation | | | | | | | |
| | R | Recipient | | | | | | | |
| | | | | | | | | | |
| PROJECT SETUP | Design Criteria | I | G | I | R | | | | I, A |
| | Technical Specifications | I, A | G | I | | R | R | | A |
| | Project Procedures | G | R | R | R | R | R | | A |
| | Acceptance Criteria | G | I | I | | | | | A, I |
| | Drawing Office standards | I, A | I | | G | | | | |

Table 1. Responsibility matrix, Project setup

3. DESIGN AND ENGINEERING

A simplified process chart for this phase is illustrated in Figure 2. Some of the stages are interlinked. However, for ease of illustration, a linear path of design evolution is depicted.

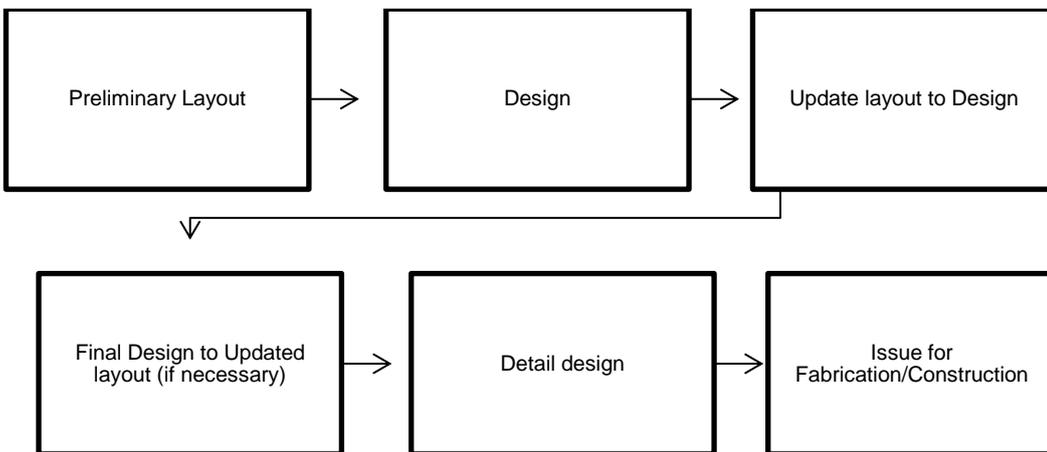


Figure 2. Design and engineering process flow

In design phase, an iterative approach to the conveying problem is taken where the conveyor is laid out to deliver material via the shortest route and lowest lift possible. The conveyor designer then utilises this information to produce a compliant design within the confines of the approved design criteria and specifications. Critical design information that influences the layout such as

minimum radii required is communicated back to the draughtsman who updates the layout to satisfy the minimum design requirements.

Often on engineering projects, the detailed design phase is the most time consuming step in the process due to the enormous amount of man hours required to produce the necessary drawings for fabrication and/or construction. Therefore to minimise rework and costly loss of time, it must be ensured that the quality of information in the layout and design phases is well controlled and documented for traceability.

At this stage, quality control procedures are required to regulate and record the flow of information for future reference.

The following is required for traceability:

1. Revision control for both design and drawing, with cross-referencing between each document. The design sheet from the designer should contain as a minimum, the drawing number and revision of the layout upon which the design is based.
2. General arrangement (GA) drawings for free-issued equipment must be checked, commented on and approved by the engineer.
3. All fabrication drawings must be stamped and signed by the engineer and other relevant parties prior to being issued to contractors. As tedious as this process may be, it encourages accountability on the part of the managing engineer.
4. A system of transmittals should be implemented to ensure that each party is in receipt of relevant information.

It must be noted that the design and engineering phase is interlinked with the next phase, namely procurement. There is symbiotic relationship that can be described as follows: the design and engineering can only be completed when all the certified information from suppliers has been received and approved. And vice versa, the procurement of conveyor equipment is also dependent on design and engineering progressing to a high level of confidence before final equipment selection can be made.

Roles and Responsibilities

Below is a summarised matrix for roles and responsibility within a project team. Only key personnel have been included for illustrative purposes.

| Legend | G | Generates | Project Manager | Project Engineer | Conveyor Designer | Structural Engineer | Drawing Office | Site Team (Supervisors/Managers) | Contractor / Supplier | Client |
|------------------------|--|--------------------------|-------------------------------------|------------------|-------------------|---------------------|----------------|-------------------------------------|-----------------------|---------|
| | A | Approval | | | | | | | | |
| | I | Input into Generation | | | | | | | | |
| | R | Recipient | | | | | | | | |
| | | | | | | | | | | |
| ENGINEERING AND DESIGN | Conveyor Design | | | G | | | | | | R |
| | Conveyor Equipment Schedules | | R, A | G | | R | R | R | R | R |
| | Layout Drawings | | I, R | I, R | | G | | | | I |
| | General Arrangement Drawings | R, A | I, R, A | I, R | R | G | R | | | I, A, R |
| | Structural Design | | R | | G | R | | | | |
| | Fabrication and Construction Drawings | | I, R | | A | G | R | R | R | R |
| | Checking and Approvals Prior to Issue to Contractor(s) | | A | | A | A | | | | |
| | Shop Detailing and Checking of Generated Drawings | | Approval Only on Engineer's request | | A | R, A | | G | | |

Table 2. Responsibility matrix, Engineering and design phase

4. PROCUREMENT, FABRICATION AND SUPPLY

The success of this phase relies on the accuracy of the information produced during the design and engineering phase. Again, well defined technical specifications that lack ambiguity and are not open to interpretation ease the process of procuring conveyor components.

Quality Control Procedures

Standard procurement of equipment of a technical nature often requires that suppliers and contractors submit, for approval, their quality control procedures (QCPs) as part of the procurement process.

QCPs are often not carefully scrutinised and hardly ever amended to be project specific. It is of paramount importance that one takes factors such as project resourcing (personnel, time and cost) into account when approving the steps in the manufacturing or supply of item(s). More often than not, there are steps in the process that may require intervention or the involvement of the purchaser. Therefore, the purchaser must exercise professional judgement when adding intervention points in the process such as “holds” to avoid unnecessary delays and cost. However, since most conveyor equipment is of standard high-production type, interventions are rarely required.

Fabrication of structural steel for conveyors (or any other structure for that matter) and some complex platework items necessitate the inclusion of intervention points, such as “hold” and “surveillance” points, to ensure that the item has been fabricated to the engineer’s requirements. These intervention points should be strategically placed prior to a major manufacturing process to avoid costly rectification work. An example would be a “hold” point on critical platework items before full welding can commence followed by another “hold” prior to rubber lining.

Non-Conformances and Concessions

Also important is record keeping of all non-conformance and concessions. The former must be completed if a quality deficiency is picked up and rectification work is to follow. The rectification method statement must be included by the fabricator for approval by the engineer prior to work commencing.

The latter concessions are completed by the fabricator (for approval or acceptance by the engineer) in the event of deviation from the project specifications or quality requirements. Again, the engineer (in some cases in conjunction with the QA/QC inspector) must exercise professional judgement when making assessments and should consider only making concessions where the original operational requirements are not compromised and there are obvious benefits to approve the concession.

Data Books

In addition to QCPs, suppliers and fabricators must keep a data book containing records of material certificates, welding qualifications, etc., and this book must be kept from order placement until completion.

The requirement for such record keeping is often called into question, forgetting that in the event of failure or non-performance of a component whilst in operation, at least the source of the problem can be determined from this history.

Roles and Responsibilities

Below is a summarised matrix for roles and responsibilities in a project team. Only key personnel have been included for illustrative purposes.

| Legend | G | Generates | Project Manager | Project Engineer | Conveyor Designer | Structural Engineer | Drawing Office | Site Team (Supervisors/Managers) | Contractor / Supplier | Client |
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| | A | Approval | | | | | | | | |
| | I | Input into Generation | | | | | | | | |
| | R | Recipient | | | | | | | | |
| | | | | | | | | | | |
| PROCUREMENT, FABRICATION AND SUPPLY | Tender compilation and issue | I, A | G | | | | | R | I, A | |
| | Adjudication & Contract Placement | I, A | G | | | | | R | I, A | |
| | Certified Drawings | | I, A | | R | I, R | R | G | R | |
| | Quality Control Plans | | I, A | | | | | G | | |
| | Non-Conformances | R | G | | | | | G | R | |
| | Concessions | R | A | | I | I | R | G | | |
| | Data Books | | R | | | | | G | R | |

Table 3. Responsibility matrix, procurement, fabrication and supply phase

5. SITE CONSTRUCTION AND INSTALLATION

5.1 STRUCTURAL STEEL ERECTION

The quality control processes on site are always a team responsibility for they require that every engineering discipline (civil, mechanical, piping, electrical and instrumentation) adhere to and keep records of all quality aspects of their work. Quality deviations in any one discipline may have adverse consequences for follow-on disciplines, such as civil plinths of sub-spec concrete handed over for conveyor structural erection, leading to a risk of failure under load.

The following steps are recommended for successful installations:

1. Quality of concrete for construction must be checked, tested and records kept and made available for inspection at all times.
2. On large installations, a client surveyor may be appointed to work together with the contractor-appointed surveyor to cross-check and verify surveys including set-out points prior to major concrete pours. This is probably the single most important service one can put into place on any site, which goes

a long way to save any project from wasting time and money. The client surveyor also assists on the verification and checking of civils to be handed over to the structural steel erector.

3. It is recommended that the steel contractor also verify major or critical dimensional details on civils against the issued general arrangement drawings prior to accepting civils. This step, although often deemed to be a repetition of Step 2, has in the past proven to pick up discrepancies that would have led to costly rework or double handling if picked up during steel erection.
4. For elevated conveyors with gantries, it is strongly recommended that each fully assembled gantry is placed on level ground and a check made to confirm that all bolts are tight, the gantry is straight, and that it complies with the minimum project requirements for structural steel. The contractor's quality controller and the employer must sign it as acceptable before it is lifted into position.

The gantry in the picture below was eventually rejected upon completion due to the "bowing-in" of the chords and had to be rectified off-site at a workshop.



Figure 3. Gantry being pre-assembled

Figure 4 below shows a crane trying to straighten a gantry after installation. This is a result of quality processes being bypassed and thus leading to unsafe practices.



Figure 4. Rectification of a defective gantry

5. When all mechanical equipment and gantries have been erected and the conveyor made safe for access, then the levelling and alignment process can begin. Alignment must be done before the belt is pulled. The initial alignment of a conveyor should be done through the use of the traditional wire line from head to tail in straight sections. This alignment should be followed-up with the more accurate method of using a theodolite, an instrument that measures on the horizontal and vertical axis. This instrument is mounted such that the sight scope aligns with the centre rolls on the idler frames. (Figure 5).



Figure 5. Theodolite in position

The centres of each of the middle rolls within the line of sight are measured and visibly marked. These marks assist the operator with aligning individual idler frames until they all align with the vertical line in the scope. For a long

conveyor, this process is repeated along visible straight sections until the conveyor is completed.

5.2 MECHANICAL EQUIPMENT INSTALLATION

The following general guidelines must be adhered to during installation of conveyor mechanical equipment.

5.2.1 Conveyor Pulley Installation

Installation tolerances are often project or manufacturer specific and must be adhered to. Alignment of pulleys is perhaps one of the more critical areas that installers should pay attention to, as to rectify a misaligned pulley is both time consuming and costly. Table 4 is an example of differing tolerance requirements, all of which can be achieved through differing methods such as laser alignment, dumpy or feeler gauges. Tolerances may also be dictated by the type of sealing arrangement on bearings, such as taconite seals, and the engineer should apply expert judgement and not apply overly stringent tolerances where not applicable.

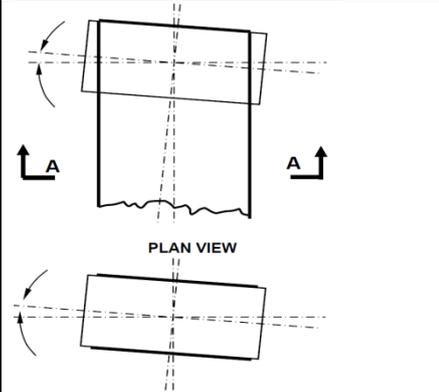
| | |
|--|---|
|  | <ul style="list-style-type: none"> • SKF allows 25 mm over bearing centres of 2 900 mm • CEMA specification allows 1/32 inches over bearing centres, i.e. 0.8 mm • Anglo American specification allows 1 in 1 000, i.e. 2.9 mm |
|--|---|

Table 4. Pulley alignment tolerances for bearing centres of 2 900 mm

Checking of machined pulley stool using feeler gauges prior to installation of sole plates is shown in Figure 6.

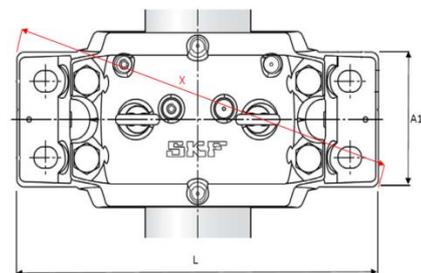


Figure 6. Flatness of pulley structure plates measured using feeler gauges

5.2.2 Conveyor Drive Installation

The drive must be installed according specific manufacturer's requirement with emphasis on ensuring that the drive is horizontal for effective lubrication.



Figure 7. Drive installation in progress

5.2.3 Conveyor Idler Installation

Although seemingly the simplest of installations on conveyors, there are cases where frames with off-set idler frames were installed in the opposite direction to that of the conveyor, so it is recommended that suppliers include directional arrows on frames.

Project specific installation tolerances should also be adhered to and checked using a theodolite where possible, as described previously, to minimise belt misalignment during commissioning.

On elevated sections where anti-roll-back idlers are installed, installation patterns provided by the supplier must be followed starting from the head end working towards the bottom.

5.2.4 Conveyor Belt Installation and Splicing

The belt must only be pulled once the installation is complete, safe and within tolerance in all aspects, i.e. structure and mechanical equipment. It is absolutely critical that the total belt length ordered includes length for splicing otherwise too short a belt will result in an inoperable conveyor.

There are two methods of splicing a belt, mechanical or vulcanising. This paper only focuses on hot vulcanising. In hot vulcanising, a press is used to apply heat and pressure to the belt resulting in a strong joint. The amount of pressure, heat and duration of application are specific to each size and type of belt and it must be ensured that the belt manufacturer's recommendations are strictly followed to ensure the integrity of the splice.



Figure 8. Splicing - hot vulcanisation in progress

Figure 8 shows splicing in progress. The belt is clamped in a special press and heat applied following the application of glue or gum between opposing ends of the belt. It is imperative that the splicing table is protected from the elements (moisture, dust, etc.) during the pressure heating process. Moisture and dust ingress often results in a compromised splice which manifests itself in delamination or “bubbles” in the spliced zone.

Following completion, each splice must be numbered and associated quality documentation completed and filed in the data pack. It is safer to use experienced and reputable splicing companies, as incorrectly spliced belting leads to mistracking belts and even an unsafe condition.

6. COMMISSIONING

In the case of new installations, prior to commissioning, suppliers of mechanical equipment such as drives, belt cleaners and belt scales must be invited to inspect the installation for acceptance. This also serves to preserve the validity of the equipment warranty. Only once all the vendor acceptances have been successfully completed can commissioning activities commence.

Provided the above steps have been diligently followed, commissioning of the conveyor should be completed with minimal problems, especially tracking and training. Taking into consideration the stringent laws with regards to moving machinery (conveyors included), an installation that has been aligned properly should require minimal adjustments and thus inherently enhance safe operation.

Once the system is running satisfactorily, readings such as power draw and running temperatures of various components like pulley bearings and drives should be taken, if possible, over a duration of a few hours to provide a baseline for future reference. This information must also be included in the data pack. Below is a typical index of inclusions in a contractor's data pack which is kept in a library for a minimum of five years.

| Construction QC Dossier - Index | | | |
|---------------------------------|---|--------------------|--------------|
| Discipline: Mechanical | | | |
| Package Number: | | | |
| No | Index | Form Reference No. | Required (a) |
| 1 | Handover Documents | | |
| 2 | QCP | | |
| 3 | Access Certificates | | |
| 4 | Civil Survey Reports | | |
| 5 | Mechanical Installation QC Check Sheets | | |
| 6 | Welding Documentation and Certificates | | |
| 7 | NDT Reports | | |
| 8 | Test Certificates | | |
| 9 | Coating Repairs and DFT Reports | | |
| 10 | Site Engineering Queries | | |
| 11 | Site Instructions | | |
| 12 | Non-conformance Reports | | |
| 13 | Concession Requests | | |
| 14 | As-built Drawings and Weld Maps | | |
| 15 | Phase 1 Punch List | | |
| 16 | Phase 2 Punch List | | |
| 17 | Phase 3 Punch List | | |
| 18 | Construction Completion Certificates | | |
| 18.1 | Platework | | |
| 18.2 | Structural | | |
| 18.3 | Mechanical | | |

Table 5. Typical data pack index

7. PROJECT MANAGEMENT AND PEOPLE-SIDE OF CONVEYOR INSTALLATIONS

Conveyor installations are often done by multiple contractors, all with their specialities (civil, structural, mechanical, electrical, instrumentation and control) and the task of interfacing the different disciplines requires knowledge of the basics of project management.

Project Management Triangle

Figure 9 below illustrates The Project Management Triangle (called also Triple Constraint or the Iron Triangle), which is a model of the constraints of project management namely cost, time and quality.

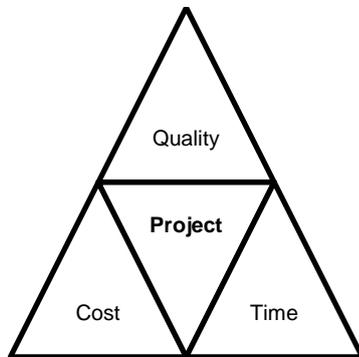


Figure 9. The Project Management Triangle

These three cornerstones of a project must always be considered at each development phase of a conveyor installation and calculated discretion should be used when one of the constraints is to be sacrificed for the success of the project. However, it must be stressed that while cost can be recovered and time made up, sacrificing on quality inevitably leads to more time and financial loss due to unreliable and poor performing installations.

Planning

Planning of design, procurement and site activities must be done thoroughly, especially with multiple contractors, as bad planning is often the cause of late projects resulting in increased cost.

Communication

One of the most important aspects of project management is good communication with all stakeholders, i.e. internal team, consultants, suppliers, contractors, site teams and most importantly, the client. It should be kept in mind that all the documentation compiled as part of the project quality control plan is a means of communication and therefore must be as complete and concise as it needs to be.

Direct means of communication is critical to the success of any project. Whether this may be to communicate technical information to the site team, project status to the client or contractual exchange with the contractor, the message must be clear, simple and concise.

People-side

The people-side of projects in the construction industry is a subject that has received little or no attention and more is required to be done to foster improved relationships between labour and management. One must bear in mind that conveyor installations are ultimately accomplished by people and given the vast cultural diversity in the construction labour sector, a concerted

effort is required from both management and labour to understand that the common goal is to safely deliver a quality product.

8. CONCLUSION

This paper presented general quality control measures to be implemented at each stage of the evolution of a conveyor system, from design through to commissioning. The objective is not to be prescriptive but to highlight key quality control measures to be considered for a successful conveyor installation and ensure traceability of data. As safety is the number one priority at any site activity, it is hoped that the practical considerations discussed during conveyor alignment will enhance the safety and wellbeing of those involved. Further success can be achieved by paying attention to the softer issues on site such as cross-cultural understanding and common courtesy among all people, labour and management alike.

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