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Applicable to more study committees. – SCOT TO consider.

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FIGURES

1. INTRODUCTION

The review of piping and instrument diagrams (P&ID's) forms an integral part of engineering activities in the Definition phase (DRA) and Execution phase (ERA) of the design in the Project Life Cycle Model (PLCM) [1]. In the context of Eskom, the P&ID's issued during the DRA and ERA of the PLCM are subjected to different depths of review. According to the Design Review Procedure [2], the review of P&ID's falls under the day-to-day review classification. For the DRA phase typically a functional review is required to ensure that the intended function of the process is achieved. However for the ERA phase a detailed review of the P&ID's needs to be undertaken.

In summary reviewing a P&ID in itself is quite difficult if you do not understand the main objective of the process or unit operation described in the diagram, and which engineering level it belongs in (basic or detailed engineering) in the Design Review Procedure [2]. The current procedure is intended to provide a general guideline to reviewing P&ID's (basic or detailed engineering) and could be used to supplement the existing knowledge of experienced reviewers.

2. SUPPORTING CLAUSES

2.1 SCOPE

2.1.1 Purpose

The purpose of this guideline is to define the principles and essential steps which must be taken to ensure a structured and uniform approach when reviewing P&ID's within the framework of the Engineering Design Review [2] procedure.

The purpose of P&ID review is firstly to ensure that the P&ID description will perform the intended operation as described in the concomitant operation philosophy document. Secondly compliance with ESKOM standards and legislation (viz. OSH act) is verified. In principle the P&ID review provides an opportunity (especially at the basic design phase) to correct the baseline before the detailed design basis is established. As indicated, the RAM, HAZID/HAZOP, FMECA are complementary studies that influence the P&ID review before the design is ultimately frozen.

2.1.2 Applicability

This guideline is applicable to staff, as well as all contractors and seconded personnel, performing engineering work in the DRA and ERA phases of the PLCM.

2.2 NORMATIVE/INFORMATIVE REFERENCES

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] Eskom Group Capital Division Enterprises Programme Management Office EPMO: Capital Projects Lifecycle Model Ver. 9.0 16 February 2011

[2] Design Review Procedure 474-1325

[3] Reliability Engineering Manual 474-37

[4] Hazard and Operability (HAZOP) Study Guideline 200-4397-PGZ 45-24 Rev 0A

[5] Failure Mode Effects (and Criticality) Analysis (FME(C)A) Guideline 200-4393-PGZ 45-25 Rev 0A

[6] Eskom Standards-Appendix A

[7] ESKOM Drawing Symbology

2.2.2 Informative

None

2.3 DEFINITIONS

2.3.1 Classification

Controlled Disclosure: Controlled Disclosure to External Parties (either enforced by law, or discretionary).

2.4 ABBREVIATIONS

Abbreviation	Description
DRA	Definition Release Agreement
ERA	Execution Release Agreement
HAZID	Hazard Identification
FMEA	Failure Modes Effects Analysis
FMECA	Failure Modes Effects and Criticality Analysis
HAZOP	Hazard and Operability
HMB	Heat Mass Balance
MSD	Material Selection Diagram
P&ID	Piping and Instrumentation Diagram
PFD	Process Flow Diagram
PLCM	Project Life Cycle Model
RAM	Reliability, Availability and Maintainability

2.5 ROLES AND RESPONSIBILITIES

None

2.6 PROCESS FOR MONITORING

None

2.7 RELATED/SUPPORTING DOCUMENTS

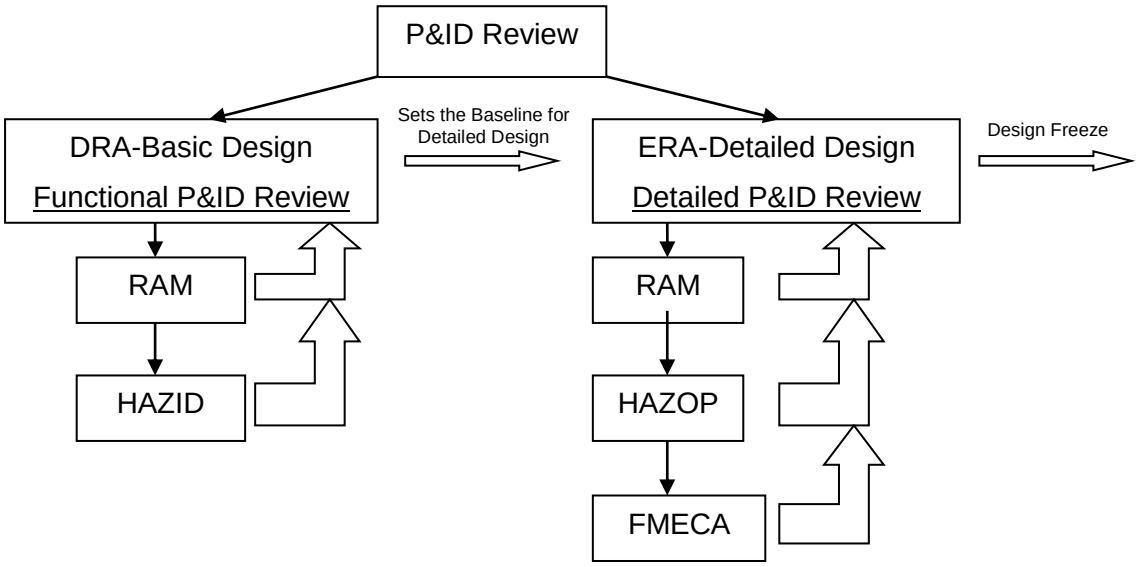
None

3. DOCUMENT CONTENT

3.1 CLASSIFICATION OF P&ID REVIEWS DURING DIFFERENT PLCM PHASES

P&ID reviews may be classified depending on the phase in which the review is carried out in the PLCM. Figure 1 shows the classification with the complementary studies.

Figure 1: Classification of P&ID reviews and associated activities



The P&ID"s issued during the basic design phase are conceptual and are not for construction. Given that the P&ID is not issued for construction a detailed review of it would not be beneficial. For this reason, a functional P&ID review is warranted where the aim of the review is to verify that the P&ID description agrees with the function and safety requirements of the entire system/process. With the Design Review Procedure borne in mind, Figure 1 indicates that during the basic design phase a functional review of P&ID's is adequate. In the DRA phase, the Reliability, Availability and Maintainability (RAM) [3] and Hazard Identification (HAZID) [4] reviews naturally follow the functional P&ID review. All issues raised in the RAM and HAZID needs to be incorporated into the P&ID description. The revised P&ID's, conceptual RAM assessment and the findings of the HAZID will form part of the documentation for the end of phase review for the basic design. Acceptance of the basic design will then set the baseline to develop the detailed design.

The P&ID's issued during the detailed phase are issued by the contractor, so a detailed P&ID review is warranted. In the detailed design phase (ERA), the RAM and Hazard and Operability Study (HAZOP) [4] can follow the detailed P&ID review of the contractor's detailed designs. In addition to the RAM study, the Failure Modes Effects and Analysis (FMEA) or Failure Modes Effects and Criticality Analysis (FMECA) [5] follow the RAM study. The HAZOP, RAM, FMECA or FMEA serve as important gatekeepers to ensure a safe and operable plant that complies with legislation, Engineering Standards [6] and Drawing Symbols [7] (where applicable) prescribed by ESKOM. All of the P&ID's that make up the contractors detailed design package will then in principle be subjected to a design freeze in

readiness for construction. Any changes downstream of this freeze will result in a compensation event, the quantum of which is dependent on the degree of rework.

3.2 CONDUCTING A P&ID REVIEW

There are key steps that need to be performed in a P&ID review, and these are detailed with descriptions below. The classification level is indicated in parenthesis at each step.

3.2.1 Step 1: Classify the P&ID review (Functional and Detailed P&ID Review)

Using Figure 1, determine whether the P&ID review is at the basic design or detailed design level. For example at the basic design stage the P&ID may not show some obvious equipment like drains etc. It would not be beneficial for the reviewer making suggestions/comments on details when the aim of the review is to verify the function of the entire process against the operation philosophy of the system/process. In many instances, the availability of an operating philosophy at the basic design level is limited, in this case the P&ID's should be reviewed in order to verify the system functionality in accordance with the process flow diagrams (PFD's) and the heat and mass balance (HMB's).

3.2.2 Step 2: Material required for Proper P&ID Review (Functional and Detailed P&ID Review)

In order to make a meaningful review of a P&ID (irrespective of the classification), additional information coming from previous engineering levels is required. These include (as a minimum) but are not limited to:

- The Basic Engineering Design Basis (BED) document,
- The Process description,
- The Heat and Mass Balances (HMB's),
- The Material Selection Diagrams (MSD's),
- The key to materials used in piping,
- The level of redundancy typically assumed for instrument systems,
- The Operation Philosophy Document.

3.2.3 Step 3: Understand the System (Functional and Detailed P&ID Review)

Regardless of the classification of the P&ID review (according to Figure 1), prepare a simple start-up, shut-down and emergency procedure summary for the system and check if all the piping, valve types and instrumentation are on the P&ID to cater for these normal or abnormal operations. Keeping in mind equipment maintenance requirements like spares, draining to closed and open drain systems, and the fact that instruments and exchangers may require purging from time to time. Lastly, look for what is not provided but for this you might need to prepare an inventory of what is required at different stages of operation in the field as well as control room apart from Emergency shutdown procedures. You might also want ask questions like, what happens if a trip occurs, or what happens if instrument air fails or over-pressure occurs and so on. One could argue that this would normally fall into a HAZID/HAZOP but often there are some simple things to pick e.g. A missing pressure relief valves (PRV's), or non-return valves (NRV's) located (not located) where they should not (should be) located etc.

3.2.4 Step 4: Does the P&ID reflect Safe Operation and Outage Contingencies (Detailed P&ID Review)

According to the OSH act, the employer must identify any hazards on the plant and the mitigating actions required to reduce or eliminate the identified hazards. Furthermore, the employer must do everything possible to provide a safe working environment. This needs to be in the reviewer/designer's mind from the very outset. As an example, consider alternatives when the isolation you want is not present. What options are possible? For example, is there an interlock/isolation valve further upstream/downstream or would you be forced to a plant outage? You need to take a look at each situation regarding "what happens if this fails" and incorporate a design that can remedy the "what if it fails" question. It appears that almost every heavy industrial facility upgrade is installing "double redundancy" for safety purposes. Bear in mind however that redundancy is equated to increased cost. These suggestions will need to be traded off in the RAM and FMECA and Hazop studies.

3.2.5 Step 5: Essential Information Checklist (Detailed P&ID Review)

The following equipment requires the following essential information:

Equipment Number, Power rating, Temperature, Pressure, Flowrate

Temperature sensors and transmitters, pressure sensors and transmitters, flow meters and transmitters, tanks, vessels, vents, drains, purges, all safety features, heat exchangers, pumps, meters, Filters, valves-major block check valves, control, safety relief, valve actuator type, heaters, pipe with sizes (line number and line specification), flow directions, control set point (pressures, flow, temperatures), signal type (electrical or pneumatic and routing), interconnects, process permissions and interlocks

3.2.6 Step 6: Key Questions (Detailed P&ID Review)

The final step in the P&ID review really comes with experience. However the steps indicated below are designed to assist a first time reviewer and to make a better experienced reviewer. In general, one should question the P&ID and typically a good P&ID should answer adequately. The typical questions include (but should not be limited to):

a. Tagging: Is it consistent with the legends?

b. Symbology: Is it consistent with the supplied sheets/line types?

c. What is the process or unit operation designed for?

d. Against the backdrop of the process conditions, can the intended function/operation be performed with the selected equipment?

e. Can the mechanical design of the pipeline contain the fluids at the design flow rate, pressure, temperature and corrosion due to contained fluid? Do the tags associated with the lines contain this information with symbols defined in the consultants/contractors attached symbology?

f. Can the process be safely controlled with the selected instruments (or control systems)?

g. Can the Operator/DCS monitor what is happening in the process units or do you need more field mounted sensors with feedback via DCS to Control room?

h. How do valves fail: Fail Open or Fail Close?

i. Do you require heat tracing on the line?

j. What if there is a process excursion e.g. High temperature, high pressure or high flow

k. These deviations must be considered and recorded in the HAZOP study.

l. Contingencies for maintenance/emergency shutdowns?

m. Relief Devices-Pressure Relief Valve (PRV): Is the set/relief point indicated?

n. What happen months or years of operation? Will there be fouling or deposits? Will a purging system be required?

o. Review storage tank capacities and determine if these are sufficient for the system to operate in a practicable manner

p. Review flaring systems for safety and the incorporation of many vent/flare lines into a main header

q. Review pump selection and suitability for the application

r. Based on the category of fluids being processed, designate the plant according to relevant area classification zones. SANS 10108 Hazardous area classifications.

4. AUTHORISATION

This document has been seen and accepted by:

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5. REVISIONS

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November 2012	0		Draft Document for review created from 474-171
May 2013	1		Final Document for Publishing

6. DEVELOPMENT TEAM

The following people were involved in the development of this document:

- Titus Mathe
- Chiraag Gokaldas
- Eugene Pininski

7. ACKNOWLEDGEMENTS

- Titus Mathe
- Chiraag Gokaldas
- Eugene Pininski

APPENDIX A

ESKOM STANDARDS REQUIRED FOR P&ID REVIEWS

Code	Description
0.00/1290	Cable tag numbering
0.00/1285	Cable terminations for PVC cables
0.00/10355 shts 1-4	Power & Control wiring termination standard
0.52/1037 - 0	MV and LV switchgear front panels pad lockable lever lock
0.52/1038 - 0	MV and LV switchgear rear panels fastener
0.52/1174 - 0	63 Amp and 125 Amp maintenance sockets outlets arrangements
0.54/430 - 0	Outdoor Isolators Padlock
0.54/03695 – 1985 sht 1	MV, LV and DC switchgear labels and name plate details arrangement diagram
0.54/03695 – 1985 sht 2	General labels and name plate details arrangement diagram
0.54/5609	Switchgear cable lugs standard dimensions
0.00/1310	Standard Power and Control Cable code
0.00/2713	Instrument cable code
0.54/393 – 22 Part 1	Earthing Standards (Common Section)
0.54/393 Part 2	Earthing Standards (General Section)
0.54/393 Part 3	Earthing Standards (General Section)
FM Global's Property Loss Prevention Data Sheet 7-79	FM Global's – "Fire Protection for Gas Turbine Installations"
ESKAMAAD1	Storage and handling of Flammable and Combustible Liquids
ESKASAA04	Electronic Protection and Fault Monitoring Equipment
ESKASAAU7	Quality requirements for the procurement of assets, goods and services.
ESKSCSAAD0	Specification For continuous analogue indicating instruments for electrical quantities.
GGG 0450	Guideline to Acceptance of Contractors Drawings
GGS 0182	Process flow diagrams and piping instrumentation diagrams
GGS 0317	Specification for storage Tanks
GGS 0183	Fire Barrier Seals for Electrical Cable Installation for Power Stations
GGS 0445	Drawing numbering system
GGP 0448	Procedure for On-site Inspection and pressure testing of pipelines constructed with steel pipes for duties up to 25 bar and

	100 ^{0}C
GGS 0853	List of Approved Relays
GGP 0349	Procedure for On-site Commissioning of Low Pressure Systems
GGSS 0423	Specification for low pressure valves
GGS 0690	Specification for medium pressure pipelines
GGS 0456	Specification for switch gear and associated equipment for voltages up to and including AC 1090 V and DC 1200 V
GGS 0462	Quality requirements for engineering and construction work
GGS 0802	Specification, power station electrical motors procurement
GGS 1030	Storage of power station electrical motors
GGS 1080	Transport of power station electrical motors
IEC 60071	Insulation Co-ordination
IEC 60034 – 1	Rotating electrical machines Part 1 – Rating and performance
IEC 60034 – 5	Rotating electrical machines Part 5 – Classification of degrees of protection provided by enclosures of rotating electrical machines
IEC 60044 – 1	Instrument Transformers Part 1 – Current transformers
IEC 60044 – 2	Instrument Transformers Part 2 – Inductive voltage transformers
IEC 60051	Direct acting analogue electrical measuring instruments and their accessories
IEC 60060 - 1	High voltage test techniques Part 1 – General definitions and test requirements
IEC 60269	Low voltage fuses
IEC 60529	Degrees of protection provided by enclosures (IP code)
IEC 60898	Electrical accessories – Circuit breakers for over current protection for household and similar installations
IEC 60947	Low voltage switchgear and control gear – Part 2 – (circuit breakers)
ISO 898 - 1	Mechanical properties of fasteners made of carbon steel and alloy steel: Part 1 – Bolts, screws and studs
NRS002	Graphic symbols for electric diagrams
GGR 0992	Eskom Plant Safety Regulations
GGS 0386 rev 4	Requirements for control and power cables for power stations
NFPA 85	Boiler and Combustion System Hazards Code
NRS 042	Guide for the Protection of Electronic Equipment against Damaging Transients
OPS 0002	Eskom Documentation Standard

OHSA no 85 of 1993	Electrical Installation Regulation under Occupational Health and Safety
SABS 62	Steel pipes and pipe fittings up to 150 mm nominal bore suitable for Screwing to SABS 1109 pipe threads
SABS 135	ISO metric black bolts, screws and nuts (hexagon and square)
SABS 0162	The structural use of steel
SABS 719	Electric welded low carbon steel pipes for aqueous fluids (ordinary Duties)
SABS 763	Hot-dip (galvanized) zinc coatings
SABS 974-1	Rubber joint rings (non-cellular) for use in water, sewer and drainage systems
SABS 1109	ISO pipe threads for pipes and fittings where pressure – tight joints are made on the threads.
SABS 1123	Steel pipe flanges
SABS 1411	Cable construction
SANS 152	Low voltage air break switches, air break disconnectors, air break switch disconnectors and fuse combination units
SANS 156	Moulded case circuit breakers
SANS 1019	Standard voltages, currents and insulation levels for electricity supply
SANS 1091	National colours for paint
SANS 1274	Coating applied by the powder-coating process
SANS 1507	Electrical cables with extruded solid dielectric insulation for fixed insulations (300/500V TO 1900/3300V)
SANS 1574	Electric cables – Flexible Cords
SANS 9000 to 9004	Quality Management systems and standards
SANS 10108	The classification of hazardous locations and selection of electric apparatus for use in such locations
SANS 10140-3	Identification Colour Markings
SANS 10142	Code of Practice for the wiring of premises.
SANS 10198 - 13	Part 13 – The handling and selection of electrical power cables of rating not exceeding 33kV
SABS 0199 – 1985	The design and installation of an earth electrode
SANS 60439	Low voltage switchgear and control gear assemblies
SANS 61136 - 1	Semiconductor power converters – Adjustable speed electric drive systems – General requirements Part 1 – Rating specifications particular for DC motor drives
IEC 60071	Insulation Co-ordination

IEC 60034	Rotating Electrical Machines
IEC 60044	Instrument Transformers
IEC 60076	Power Transformers
IEC 60079	Electrical apparatus for explosive gas atmospheres
IEC 60502	Power cables with extruded insulation and their accessories for rated voltages
IEC 60529	Degrees of protection provided by enclosures (IP Code)
IEC 60694	Common Specifications for High-Voltage Switchgear and Control gear Standards
IEC 60896-11	Stationary lead-acid batteries – Vented Type
IEC 60947	LV Switchgear and Control gear
IEC 61439	LV Switchgear and Control gear Assemblies
IEC 61649	Enclosed Low-Voltage Switchgear and Control gear Assemblies – Guide for Testing under Conditions of Arcing due to Internal Fault
IEC 62271	High Voltage Switchgear and Control gear
Eskom standard GGSS 0456 Rev. 4	Specification for LV Switchgear and Control gear Assemblies and Associated Equipment for Voltages up to and Including 1000V AC and 1500V DC
Eskom standard GGSS 1201 Rev. 0	AC Metal Enclosed (Metal-Clad) Switchgear and Control gear for Voltages Above 1kV up to and Including 52kV.
PGZ 45-24 Rev 0A	Hazard and Operability (Hazop) Study Guideline
PGZ 45-25 Rev 0A	Failure Modes Effects and Criticality (FMECA) Study Guideline
474-37 Rev 0	Reliability Engineering Manual