

Sûreté de fonctionnement & Retour d'Expériences

Dependability and Feedback Data Collection

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Contents

Introduction

Reliability and failure rate function

Basic Reliability models

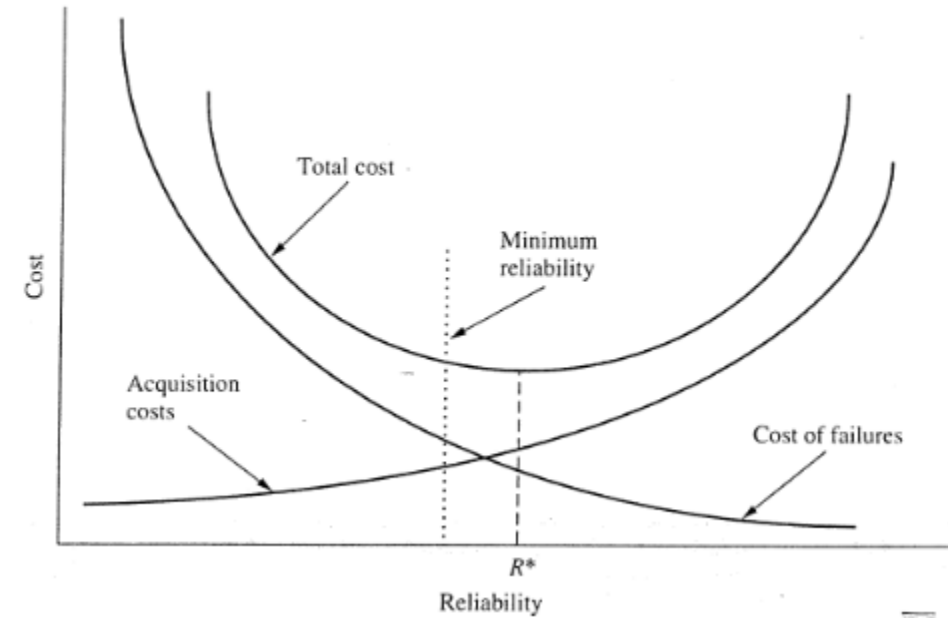
Data Collection & Empirical Methods

Identification of Failure distribution

Feedback data collection methods

Need for failure and repair data (Reliability and maintainability R&M Data)

- life cycle costing
- evaluating warranty programs
- computing spare part inventory levels
- optimal maintenance resources,
- analyzing trends
- identifying areas for engineering: design and modification.
- proper preventive maintenance
- failure characteristics.



Nature of Data resources

Product Phase	Primary sources of R&M data	R&M Tasks
Conceptual and Initial Design	Historical Databases (see Examples later)	R&M Goals and specifications, Life Cycle Costing
Detailed Design and Prototyping	Reliability Testing, Product testing, Maintainability demonstration	R&M Predictions R&M plans: Design methods
Production	Environmental Stress testing, Burn-in testing Acceptance Testing, Sequential Testing, Inspection.	R&M demonstrations, Redesign, modifications
Operations	Field Data	Construct Preventive maintenance, Predictive maintenance Programs, Determine spare and part levels, Maintenance resources Levels



Objectives and Challenges of Feedback Data collection (REX)

Objectives:

Collect, archive, analyze, specific information the behavior of installations and equipment.

- **Feedback (REX)** : All technical facts observed over the entire lifespan

REX functions:

- Analyze events, failures
 - Integrate technical knowledge in the form of analysis reports, expert opinions-!
- Archiving data
 - Memorizing knowledge
 - Ensure the sustainability of knowledge
- Restore the data
 - Provide quantified parameters
 - To restore to the user the knowledge of the past (field practices...)
- Administer the data
 - Organize, manage and update this knowledge
 - Integrate REX as it happens
- Adding new knowledge!!

Field Data:

- Difficult to obtain accurate information from operational failures, than under controlled conditions.
- Operational failures (actual conditions) → valuable information
For example, maintenance induced errors and operator errors: → not found in controlled environments.
- Type of data collected depends on :
 - objective,
 - system-specific
 - product specific
 - R&M policy specific....

Feedback Data (REX) elements:

- **Data element:**
sequential number identifying a failure record (combination of date and time)
- **Date and time:**
Date and time when failure recorded [may be different from actual failure time]
- **Part ID:**
specific component or part that has failed.
- **Failure time:**
The age of the part at the time of failure (not when it was discovered).

Measured in failure units of operating hours, cycles.

For repairable components, time is measured from a specific reference point (beginning of current cycle)
- **Failure mode:**
Exact nature and type or nature of failure (short, overload, power failure, etc.)

- **Failure cause:**
Event or situation that caused the failure, excessive vibration, fatigue corrosion, excessive loading, human error, humidity, etc.
- **Start repair:**
Date and time when hand-on corrective maintenance began
- **Stop repair:**
Date and time when all restoration is completed, comprises of verification, validation, return of system to operational status.
- **Action taken:**
Type of maintenance action performed to correct failure-removal, replacement, calibration, rebuilding.
- **Location of failure:**
Parts needed during repair Delay times waiting for pads, repair resources
- **Codes:**
standard codes are defined for identification of failure made, cause,...

Challenges:

Uniformity:

- Different ages of products and components.
- Unit of time to measure failure time
- Reference point to measure time between failures
- Products are manufactured and enter service at different dates
- Investment-profit tradeoffs.

What to control/optimize (Motivation)?

- Control of availability
- Control of maintenance costs
- Life cycle management
- Design assistance

Who is playing?

- Database Administrator
- Engineers
- Experts
- Analysts

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Spreadsheets and Databases

- Data-collection schemes can be manually transferred
- Data-collection done automatically (Industry future 4)

ITTE Failure Report and Action Form				
	System	Sub-system	Module/ sub-assembly	
Type				Report number:
Serial number				Report date:
Location/identification				Report completed by:
On-time (cumulative)				Company:
Down time (this failure)				
Active repair time				
System status: Field service Field trial Production prototype Model				Details of symptoms, diagnosis and failure:
Effect of failure on systems: Complete system failure Major degradation Minor degradation None				
On-site diagnosis: No defect found Part failure Installation defect Manufacturing defect Design defect Program defect On-site human error Other				Details of action taken:
Action taken: Replace module Repair Modification Program reload Other				
Project engineering action: - Consolidate with field data - For immediate analysis/action by				
	Name	Company/Dept	Signature	Date completed
Engineering				
Manufacturing				
Quality assurance				
Purchasing				
Other				
Analysis and action taken:				Engineering change no.:
				Date:
				Follow-up report Ref. no.:
				Date:
	Name:			
	Signature:			
	Date:			
For information to:				



Spreadsheets and Databases

- Facilitate data-sorting, data analysis : Uniform Codes!
- Code database Needed :

Equipment code :

Code	Meaning
R	Southampton plant
C1	Compression system
66	Power generation
03	Switchgear
5555	Actual item

Action taken

Code	Meaning
01	Item replaced
02	Adjusted
03	Item repaired
etc.	

Found why?

Code	Meaning
01	Plant shutdown
02	Preventive maintenance
03	Operating problem
etc.	

Which maintenance ?

Code	Meaning
01	Electrical
02	Instrument
03	Mechanical
etc.	

Type of Fault:

Code	Meaning
01	Short circuit
02	Open circuit
03	Leak
04	Drift
05	No fault found
etc.	

Comments:

Material safety Datasheet (Fiche Signalétique)

- Choice of materials and sample size
- Taking into account the company's resources
- Presentation and writing
 - Identification key: factory code - system code - hardware code - order number
 - General characteristics for all materials: common codes - pre-defined answers
 - model number - serial number
 - date of manufacture - date of commissioning
 - collection start date - collection end date
 - date of withdrawal from operation
 - update date
 - external environment
 - operating mode
 - maintenance
 - tests
 - documentation references
 - material manager

Material safety Datasheet (Fiche Signalétique du matériel)

FICHE SIGNALÉTIQUE DU MATÉRIEL

CODE OPERATION

A AFFICHAGE
M MODIFICATION

E EMISSION
S SUPPRESSION

LIBELLE MATERIEL SUIVI :

Clé d'identification :

Constructeur :

N° de marche :

REFERENCES CONSTRUCTEUR

Date de construction :

Date de mise en service :

Date début collecte :

Date fin de collecte :

Classe de sûreté Ans

Classe de sûreté IEEE

Classe CPFC :

Classe d'exploitation :

ENVIRONNEMENT EXTERNE :

LOCALISATION GEOGRAPHIQUE :

MODE DE FONCTIONNEMENT

C CONTINU

S A LA SOLLICITATION

I INTERMITTENT

V VEILLE

PERIODICITE DE MAINTENANCE :

PERIODICITE DES ESSAIS :

REFERENCES DOCUMENTATION :

Material safety Datasheet (Fiche Signalétique du material)

FICHE SIGNALÉTIQUE DE LA POMPE	
TYPE DE POMPE	
01 VOLUMÉTRIQUE	02 CENTRIFUGE
03 HELICOÏDALE	99 AUTRE
POSITION GÉOMÉTRIQUE	
A VERTICALE	B HORIZONTALE
C VERTICALE IMMERGÉE	X AUTRE
NATURE DU FLUIDE	
A EAU CONDENSÉE	B ACIDE < 2000 PPM
C ACIDE ≥ 2000 PPM	D EAU DÉMINÉRALISÉE
E EFFLUENTS	F EAU DE RIVIÈRE
G EAU DE MER	H FUEL OIL
I HUILE	J GAZ
K FLUIDE DE RÉGULATION	L RÉACTIF CHIMIQUE
M EAU DE NAPPE	N EAU BRUTE FILTRÉE
O EAU DE CIRCULATION	P AIR
X AUTRE	
TYPE D'ENTRAÎNEMENT POMPE	
A MOTEUR ÉLECTRIQUE	B TURBINE À VAPEUR
C DIESEL	D ARBRE ÉLECTRIQUE
X AUTRE	
MODE DE VARIATION DE DÉBIT DE POMPE	
A COUPLEUR	B TURBINE
C MOT. ELECT. A VITESSE VARIABLE	D SOUPAPE RÉGLANTE
E LAMINÉ ET VARIATION VITESSE	F PAS DE VARIATION DÉBIT
X AUTRE	

FICHE SIGNALÉTIQUE DE LA POMPE	
ORGANE DE TRANSMISSION	
A VARIATEUR DE VITESSE	B VARIATEUR
C REDUCTEUR	MULTIPLICATEUR
E TRANSMISSION DIRECTE	D MULTIPLICATEUR
X AUTRE	
POMPE NOURRICIÈRE	
A AVEC	B SANS
TYPE DE GARNITURE	
A PRESSE ÉTOUPE	B MÉCANIQUE
C HYDRAULIQUE	D LABYRINTHE
E ANNEAUX FLOTTANTS	F SANS
X AUTRE	
VITESSE DE ROTATION NOMINALE : (TR/MN)
PUISSANCE NOMINALE : (KW)
DÉBIT NOMINAL : (M ³ /H)
HAUTEUR MANOMÉTRIQUE : (MCE)

Operation sheet (Fiche de fonctionnement)

- Collect data to calculate failure rates
- Presentation and writing
 - Key of the form
 - identification of the equipment
 - year of collection
- Operating time
 - notion to be defined
 - electrical, electronic, computer and automation equipment: full year
- Number of requests
 - number of hardware status changes
- Means of obtaining data
 - hourly or solicitation counter
 - automatic reading
 - flat-rate estimate
 - information from other materials
- Comments (free text)

Operation sheet (Fiche de fonctionnement)

FICHE DE FONCTIONNEMENT DU MATERIEL	
CODE OPERATION	
A AFFICHAGE	E EMISSION
M MODIFICATION	S SUPPRESSION
REPERAGE :	
(usine – année – code matériel)	
MOYEN D'OBTENTION DU TEMPS DE FONCTIONNEMENT	
01 RELEVÉ AUTOMATIQUE	02 COMPTEUR HORAIRE
03 ESTIMATION FORFAITAIRE	04 INFORMATION AUTRE USINE
99 AUTRE	NOTA :
TEMPS DE FONCTIONNEMENT : (h)	
MOYEN D'OBTENTION DU NOMBRE DE SOLLICITATIONS	
01 RELEVÉ AUTOMATIQUE	02 COMPTEUR SOLLICITATIONS
03 ESTIMATION FORFAITAIRE	04 INFORMATION AUTRE USINE
99 AUTRE	NOTA :
NOMBRE DE SOLLICITATIONS :	

Failure record sheet (Fiche de défaillance)

Describe the failures according to the parameters to be estimated

Presentation and writing

- Identification key: link between the record
 - factory code - system code - component type - component number
- Circumstances of the failure
 - Condition of the equipment
 - System status
 - Physical conditions of the system
 - External conditions of the system
- Description of the failure
 - Discovery of the anomaly - Start of failure - Degree of failure - Appearance of failure
 - Failure mode - Internal component affected - Cause of failure
 - Repair time - Labour time
 - Duration of unavailability - Consequence on the system - Duration of unavailability of the system
 - Actions taken
 - Summary of the failure
- Additional documentation
 - Work order
 - Related documentation
- Analysis report
 - Failure detection means
 - Editor
 - Auditor

Failure record sheet (Fiche de défaillance)

FICHE DE DEFAILLANCE DU MATERIEL

CODE OPERATION

A AFFICHAGE
M MODIFICATION
E EMISSION
S SUPPRESSION

CLE TRANCHE – ANNEE – NUMERO (TAANNNN) :

REPERAGE FONCTIONNEL :

NUMERO DE MATERIEL :

NUMERO CONSIGNATION :

REPERAGE DOCUMENTATION :

DATE DECOUVERTE DEFAILLANCE (JJMMAA) :

DATE DEBUT INDISPONIBILITE (JJMMAA) :

ETAT DU MATERIEL

A ARRET
F FONCTIONNEMENT
S SOLLICITATION

SITUATION DU MATERIEL

E ENTRETIEN / REQUALIF.
N SERVICE NORMAL
T ESSAI PERIODIQUE

DEGRE DE DEFAILLANCE : C COMPLET D PARTIEL

APPARITION DEFAILLANCE : A SOUDAIN E PROGRESSIVE

DESCRIPTION SOMMAIRE DE LA DEFAILLANCE :

.....
.....
.....
.....

FICHE DE DEFAILLANCE DU MATERIEL

ETATS STANDARDS DU SYSTEME :

02 ATTENTE A CHAUD	01 EN PUISSANCE > 2%
04 ARRET INT. BIPHASIQUE	03 ARRET A CHAUD
06 ARRET INT. MONOPHASIQUE	05 ARRET INT. SUR RAA
08 ARRET A FROID CUVE OUVERTE	07 ARRET A FROID NORMAL
	09 ARRET POUR RECHARGEMENT

CONSEQUENCE DE LA DEFAILLANCE :

01 DECLenchement GTA	02 CHUTE DE BARRES
04 ILOTAGE	06 PASSAGE ATTENTE/ARRET A CHAUD
07 RETARD AU COUPLAGE	08 AUCUNE CONSEQ. SUR LA PUISSANCE
11 PERTE PARTIEL. SYSTEME OU VOIE	12 PERTE TOTALE SYSTEME OU VOIE
30 REDUCTION DE CHARGE	40 APPLICATION IO
41 PASSAGE A L'ETAT DE REPLI (IO) NOTA :	

MODE DE DEFAILLANCE :

COMPOSANT INTERNE AFFECTE :

CAUSE DE DEFAILLANCE :

DUREE DE REPARATION (H) :

DUREE INDISPON. MATERIEL :

DUREE INDISPON. TRANCHE :

INDISPO. TRANCHE (MWH) :

MESURES PRISES :

04 MODIFICATION MATERIEL	01 REMPLACEMENT TOTAL MATERIEL
20 CHANGEMENT CONSTR. OU REF.	06 CONTROLE MATERIEL IDENTIQUE
	21 REPARATION PROVISoire

NOMBRE D'HEURES M.O. :

DOSE ABSORBEE (H-MREM) :

REDACTEUR :

VERIFICATEUR :

Le recueil DEFIA d'EDF

Recueil DEFIA

RECUEIL DE DONNEES DE FIABILITE

Mise à jour: Juillet 1993

Taxonomie : 1.1.1

Fonction générale..... : Coupure

Famille de matériels..... : Disjoncteurs postes sources

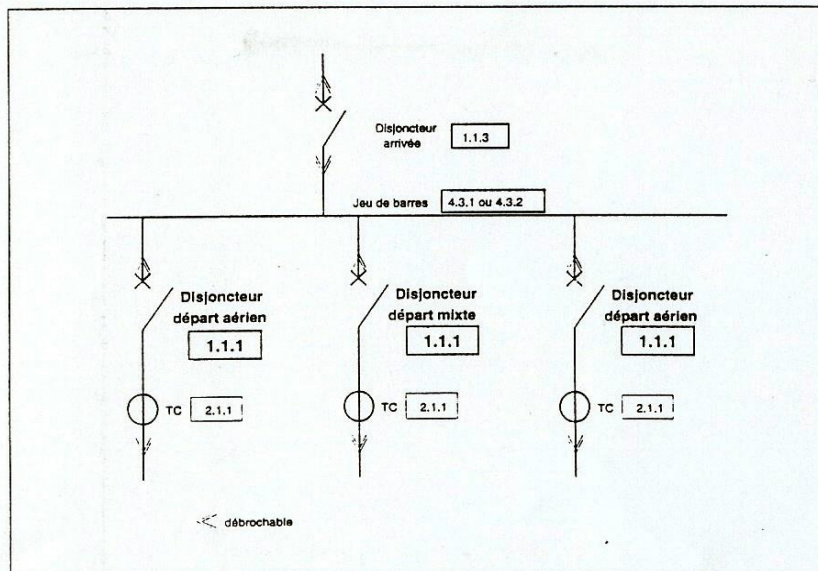
Matériel..... : Disjoncteur SF6 départ aérien ou mixte

Caractéristiques : Norme HN 64 S 40
Débrochable

Taux de défaillance spécifié(s) : $\lambda_{O\text{ int.}} = 0,01 \cdot 10^{-6}$ $\lambda_{F\text{uite}} = 0,68 \cdot 10^{-6}$ $\lambda_{\text{amov.}} = 0,05 \cdot 10^{-6}$
 $\gamma_O = 0,25 \cdot 10^{-3}$ $\gamma_F = 0,35 \cdot 10^{-3}$

Limite(s) du matériel : Disjoncteur + commande

Fonctionnement : A la sollicitation



Recueil DEFIA

RECUEIL DE DONNEES DE FIABILITE

Mise à jour: Juillet 1993

Taxonomie : 1.1.1 Matériel : Disjoncteur SF6 départ aérien ou mixte

PARC	PERIODE OBSERVATION	Nb. DE DEFAILLANCES		DUREE CUMULEE DE FONCT. en 10 ⁶ h	Nb. DE SOLL.	Obs.	Réf.
		fonct.	sollicitation				
	1988				743 300	(1)	[14]
	1988		193		701 000	(2)	[14]
15 000	1990	6	190	139,4		(3)	[4]
20 000		125/an		175,2		(4)	[4]
20 000		2/an		175,2		(5)	[4]

DONNEES DE FIABILITE

DEFAILLANCES (description, nature, siège, mode)	TAUX DE DEFAILLANCE						DUREES		Obs.	Réf.
	en fonctionnement 10 ⁻⁶ /h			à la sollicitation 10 ⁻³			Répar.	Indispo.		
	Inf.	Moy.	Sup.	Inf.	Moy.	Sup.	(h)	(h)		
Refus O				0,23	0,26	0,29			(1)	
Refus F				0,24	0,27	0,31			(2)	
Amorçage	0,02	0,05	0,09						(3)	
Fuite SF6	0,61	0,70	0,83						(4)	
O intempestive	0,002	0,01	0,036						(5)	
F intempestive		e					4h/an	4h/an	(6)	
									(7)	[4]

OBSERVATIONS :

- (1) Données sur les refus d'ouverture à la sollicitation
- (2) Données sur les refus de fermeture à la sollicitation
- (3) Données sur les amorçages, années de collecte non précisées
- (4) Données sur les fuites SF6, années de collecte non précisées
- (5) Ouverture intempestive par dire d'expert
- (6) Fermeture intempestive négligeable d'après [4]
- (7) Indisponibilité pour entretien et consignation d'après [4]

REFERENCES :

- [4] Analyse des points critiques de la partie MT du poste source (HT/MT).
[14] Comparaison sous l'angle de la fiabilité d'architecture de systèmes de protection et contrôle commande (PCCN) de la partie HTA des postes sources HTB/HTA.

International Telephone and Telegraph Corporation

ITTE Failure Report and Action Form					
	System	Sub-system	Module/ sub-assembly		
Type					
Serial number					
Location/identification					
On-time (cumulative)					
Down time (this failure)					
Active repair time					
System status:		Details of symptoms, diagnosis and failure:			
Field service					
Field trial					
Production prototype					
Model					
Effect of failure on system:					
Complete system failure					
Major degradation					
Minor degradation					
None					
On-site diagnosis:					
No defect found					
Part failure					
Installation defect					
Manufacturing defect					
Design defect					
Program defect					
On-site human error					
Other					
Action taken:		Details of action taken.			
Replace module					
Repair					
Modification					
Program reload					
Other					
To be completed at Designated Centre	Project engineering action:	Name	Company/Dept	Signature	Date completed
	- Consolidate with filed data				
	- For immediate analysis/action by				
	Engineering				
	Manufacturing				
	Quality assurance				
Purchasing					
Other					
To be completed at Designated Centre	Analysis and action taken:		Engineering change no.:		
			Dated:		
			Follow-up report Ref. no.:		
			Dated:		
		Name:			
		Signature:			
		Date:			
For information to:					

A General , recommended form

SERIAL NUMBER

DATE (and time) OF INCIDENT/EVENT/FAILURE

DATE ITEM INSTALLED (or replaced or refurbished)

MAINTENANCE TECHNICIAN (Provides traceability)

DISCIPLINE (e.g. Electrical, Mechanical, Instrumentation)

FAILED COMPONENT ITEM DESCRIPTION (e.g. Motor)

SUBSYSTEM (e.g. Support system)

DESCRIPTION OF FAULT/CAUSE (Failure mode, e.g. Windings open circuit)

'TAG', 'SERIAL NUMBER' (HENCE DATE OF INSTALLATION AND REFURB)
e.g. System xyz, Unit abc, Motor type zzz, serial no. def,

DOWN TIME [if known]/REPAIR TIME
e.g. 4 hrs repair, 24 hrs outage

TIME TO FAILURE (COMPUTED FROM DATE AND TAG NUMBER)
e.g. This date minus date of installation
e.g. This date minus date of last refurbishment

PARTS USED (in the repair)
e.g. New motor type zzz, serial no. efg

ACTION TAKEN (e.g. Replace motor)

HOW CAUSED
Intrinsic (e.g. RANDOM HARDWARE FAILURE) versus extrinsic (GIVE CAUSE IF EVIDENT)

HOW FOUND/DIAGNOSED
e.g. Customer report, technician discovered open circuit windings

RESULT OF FAILURE ON SYSTEM
e.g. Support system un-usable, process trip, no effect

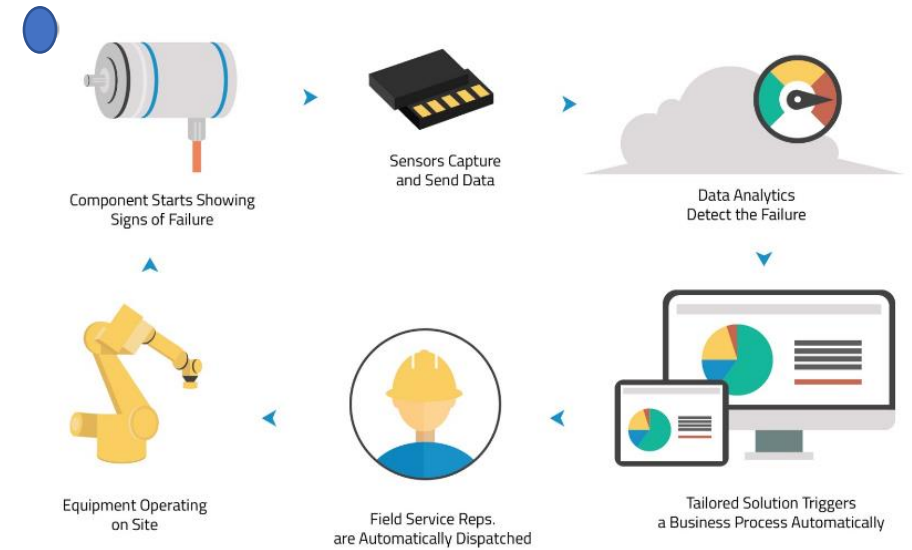
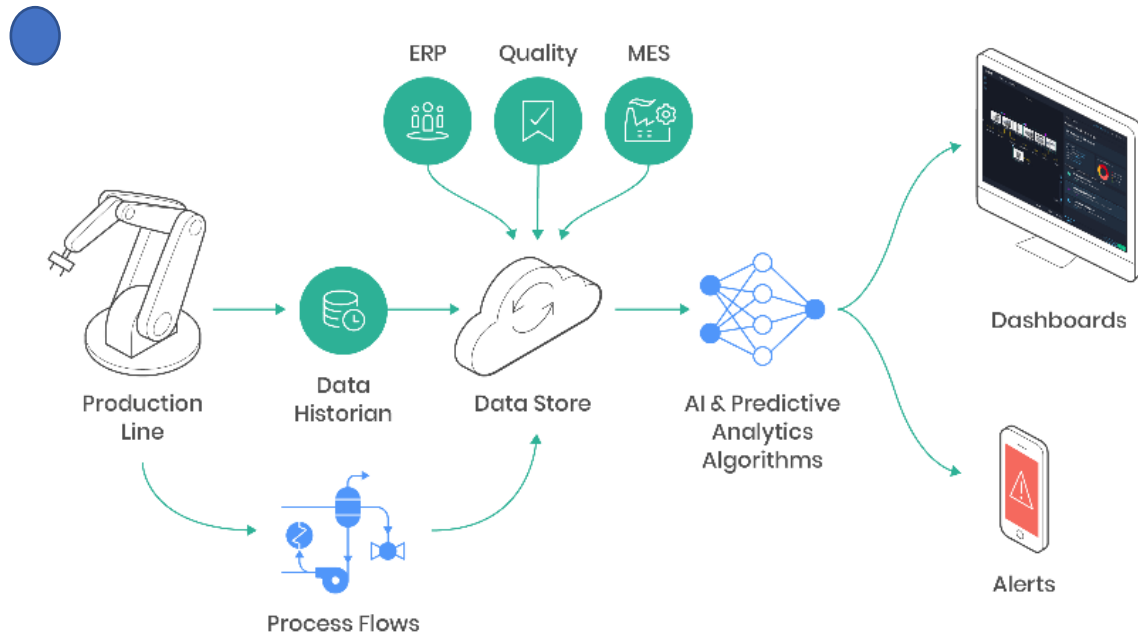
COMMON CAUSE FAILURE e.g. redundancy defeated
time between CCFs
attributable to SEPARATION/DIVERSITY/COMPLEXITY/HUMAN FACTOR/ENVIRONMENT

ENVIRONMENT/OPERATING CONDITION
e.g. temp, humidity, 50% throughput, equipment unattended

NARRATIVE

Age of IOT , Automatic data collection

Data-collection done automatically (Industry future 4)



Kiezo : Online platform for data collection

The screenshot displays the Kiezo online platform interface, which is used for creating and editing data collection forms. The interface is divided into two main sections:

- Form Editor (Left):** This section shows a form being edited. It includes a header with the 'logo arcelor' and a paragraph of text: "En remplissant ce formulaire, vous déclarez être l'intervenant ayant participé à la maintenance de l'appareil concerné. Merci de le remplir de manière sincère et appliquée. En cas d'incompréhension de certains renseignements demandé ou éventuels apport technique, merci de vous renseigner auprès de votre responsable." Below the text are several form fields, each with a blue edit icon: "Informations sur l'intervenant", "Intervenant *", "ID_Intervenant", and "Equipe de maintenance".
- Widget Palette (Right):** This section contains a grid of 20 different widget types that can be added to the form. Each widget is represented by a blue button with an icon and a label: "Champ de saisie", "Zone de texte", "Date et Heure", "Case à cocher", "Slider", "Compteur", "Liste", "Choix", "Géolocalisation", "Contact", "Adresse", "Référence", "Photo", "Audio", "Dessin", "Pièce jointe", "Signature", "Code-barres", "Tag NFC", "Séparateur", "Tableau", "Texte fixe", "Image fixe", "Fichier fixe", and "Calcul".



ArcelorMittal

En remplissant ce formulaire, vous déclarez être l'intervenant ayant participé à la maintenance de l'appareil concerné. Merci de le remplir de manière sincère et appliquée. En cas d'incompréhension de certains renseignements demandé ou éventuels apport technique, merci de vous renseigner auprès de votre responsable.

Informations sur l'intervenant -

Intervenant

* >

Enregistrer Brouillon

En remplissant ce formulaire, vous déclarez être l'intervenant ayant participé à la maintenance de l'appareil concerné. Merci de le remplir de manière sincère et appliquée. En cas d'incompréhension de certains renseignements demandé ou éventuels apport technique, merci de vous renseigner auprès de votre responsable.

Informations sur l'intervenant -

Intervenant

* >

ID_Intervenant

Equipe de maintenance

Enregistrer Brouillon

Informations sur l'intervenant -

Intervenant

* Marc Danor >

ID_Intervenant
Intervenant03

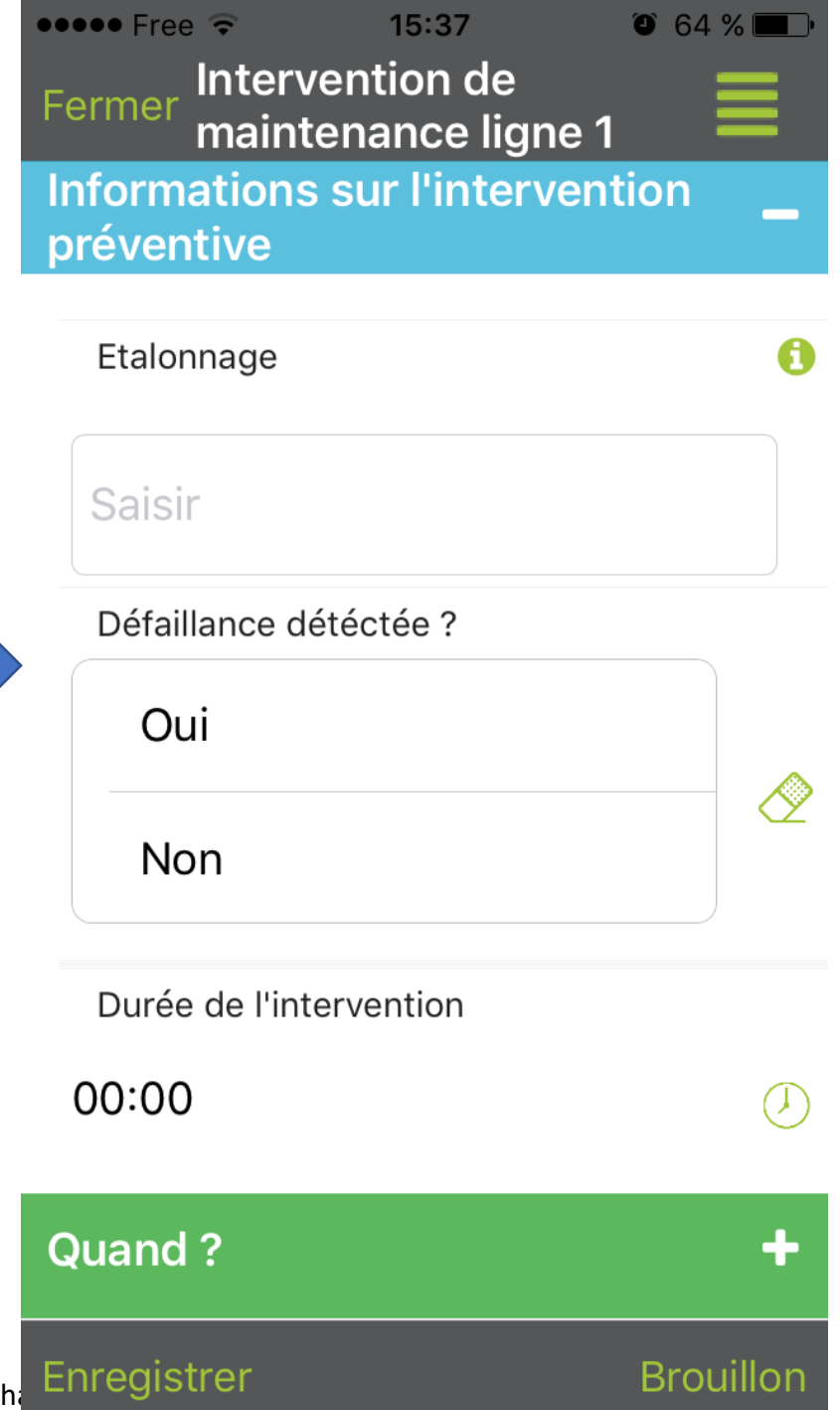
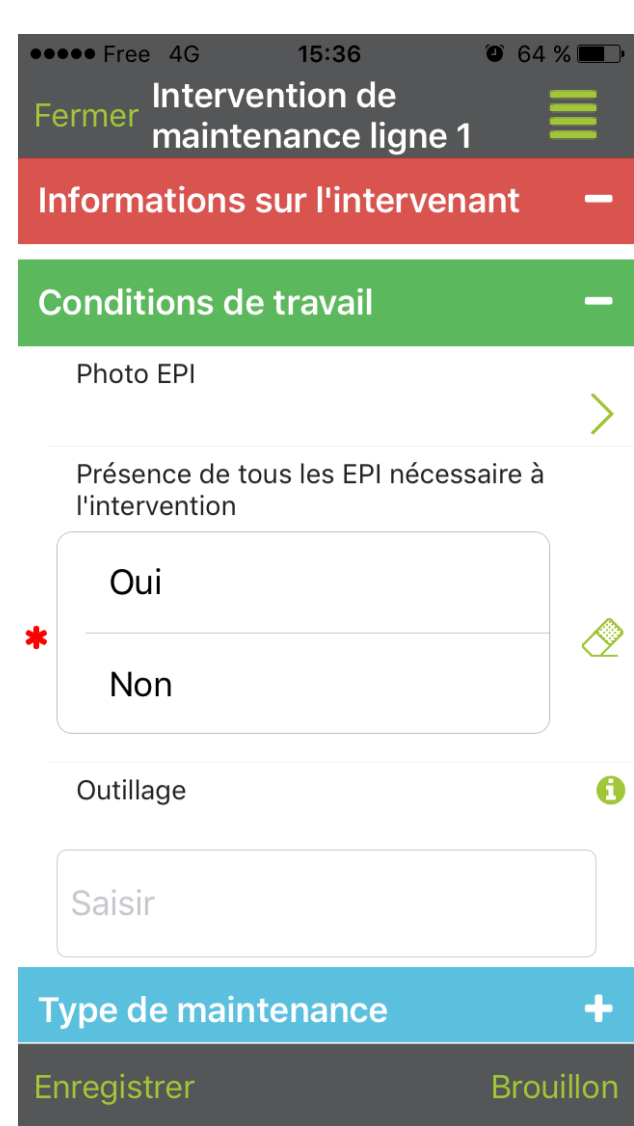
Equipe de maintenance
Equipe1

Conditions de travail +

Type de maintenance +

Quand ? +

Enregistrer Brouillon



Free 15:37 64 %

Fermer Intervention de maintenance ligne 1

Type de maintenance

Informations sur l'intervention préventive

Fréquence de cette intervention

- Journalière
- Hebdomadaire
- Mensuel
- Trimestriel
- Annuel

Type d'intervention préventive

Enregistrer Brouillon

Free 15:37 64 %

Fermer Intervention de maintenance ligne 1

Informations sur l'intervention préventive

Durée de l'intervention

01:30

Quand ?

Date et Heure

* 21 février 2018 15:36

Où

Lieu de l'intervention

*

Récapitulatif +

Enregistrer Brouillon

Free 15:38 64 %

Fermer Intervention de maintenance ligne 1

Quand ?

* 21 février 2018 15:36

Où

Lieu de l'intervention

*

Récapitulatif

Problème(s) rencontré(s)

Saisir

Signature

*

Enregistrer Brouillon

Nom : Paté
Prénom : Mary
Date de réponse : 20/02/2018 17:15:56



En remplissant ce formulaire, vous déclarez être l'intervenant ayant participé à la maintenance de l'appareil concerné. Merci de le remplir de manière sincère et appliquée. En cas d'incompréhension de certains renseignements demandé ou éventuels apport technique, merci de vous renseigner auprès de votre responsable.

Informations sur l'intervenant

Intervenant : Marc Danor
ID_Intervenant : Intervenant03
Equipe de maintenance : Equipe1

Conditions de travail

Photo EPI :
Présence de tous les EPI nécessaire à l'intervention : Oui
Outillage : Marche escabeau cassée

Type de maintenance

Maintenance : Corrective
Etalonnage :

Informations intervention panne

Secteur défaillant : Peinture
ID_Machine : Tête de peinture 1
ID composant défaillant : Cylindre_3479
Cause de la défaillance : Casse pièce

Data Sources : Standard documents of Failure data collection

MIL-STD-2155	Failure Reporting, Analysis and Corrective Action System (FRACAS)	U.S. Department of Defense
IEC 706 PT3	Guide on Maintainability of Equipment: Verification and Collection, Analysis and Presentation of Data	International Electrotechnical Commission (IEC)
MODUKDSTAN 00-44	Reliability and Maintainability Data Collection and Classification	British Defense Standards (U.K. Department of Defense)
IEEE 500	Guide to the Collection and Presentation of Electrical, Electronic, Sensing Component, and Mechanical Equipment Reliability Data for Nuclear Power Generating Stations	Institute of Electrical and Electronics Engineers (IEEE)
IEC 362	Guide for the Collection of Reliability, Availability, and Maintainability Data from Field Performance of Electronic Items	International Electrotechnical Commission (IEC)
—	A Reliability Guide to Failure Reporting, Analysis, and Corrective Action Systems.	American Society for Quality Control (ASQC)

Sources of Failure Data

Organisations:

- **Reliability Analysis Center (RAC)** : Nonelectronic Parts Reliability Data (NPRD) reports by US Airforce.
- **Defense Technical Information Center** : Reliability data for defense equipment.
- **Parts Reliability Information Center (PRINCE)**: Reliability of systems related to space
- **Institute of Electrical and Electronics Engineers (IEEE)** : failure data concerning various electrical related items.

Data Banks:

- **Nuclear Plant Reliability Data System (NPRDS)**: Failure data on equipment used in nuclear power plants.
- **Equipment Reliability Information System (ERIS)**: failure data on equipment used in electric power generation.
- **SYREL: Reliability Data Bank**: failure data on equipment used in power generation (UK).
- **OREDA (Offshore Reliability Data) - version 4 (2002)** : recueil européen concernant les matériels des compagnies pétrolières.
- **IEEE Standard 500 - 1984 (États-Unis) - Guide to the Collection and Presentation of Electrical, Electronic, Sensing Component, and Mechanical Equipment Reliability Data for Nuclear Power Generating Stations**

Guide : Fides (reliability)

- reliability calculation for *electronic components and systems*.
- Fides is a DGA (French armament industry supervision agency) study conducted by a European consortium :

Airbus France - Eurocopter - GIAT Industries - MBDA Missile systems - THALES Airborne Systems - THALES Avionics - THALES Research & Technology - THALES Underwater Systems

Standardized normal probabilities: $\Phi(z) = \int_{-\infty}^z (1/\sqrt{2\pi})e^{-y^2/2} dy$

z	$\Phi(z)$	1 - $\Phi(z)$	z	$\Phi(z)$	1 - $\Phi(z)$	z	$\Phi(z)$	1 - $\Phi(z)$
-4.0000	0.00003	0.99997	-3.5100	0.00022	0.99978	-3.0200	0.00126	0.99874
-3.9900	0.00003	0.99997	-3.5000	0.00023	0.99977	-3.0100	0.00131	0.99869
-3.9800	0.00003	0.99997	-3.4900	0.00024	0.99976	-3.0000	0.00135	0.99865
-3.9700	0.00004	0.99996	-3.4800	0.00025	0.99975	-2.9900	0.00139	0.99861
-3.9600	0.00004	0.99996	-3.4700	0.00026	0.99974	-2.9800	0.00144	0.99856
-3.9500	0.00004	0.99996	-3.4600	0.00027	0.99973	-2.9700	0.00149	0.99851
-3.9400	0.00004	0.99996	-3.4500	0.00028	0.99972	-2.9600	0.00154	0.99846
-3.9300	0.00004	0.99996	-3.4400	0.00029	0.99971	-2.9500	0.00159	0.99841
-3.9200	0.00004	0.99996	-3.4300	0.00030	0.99970	-2.9400	0.00164	0.99836
-3.9100	0.00005	0.99995	-3.4200	0.00031	0.99969	-2.9300	0.00169	0.99831
-3.9000	0.00005	0.99995	-3.4100	0.00032	0.99968	-2.9200	0.00175	0.99825
-3.8900	0.00005	0.99995	-3.4000	0.00034	0.99966	-2.9100	0.00181	0.99819
-3.8800	0.00005	0.99995	-3.3900	0.00035	0.99965	-2.9000	0.00187	0.99813
-3.8700	0.00005	0.99995	-3.3800	0.00036	0.99964	-2.8900	0.00193	0.99807
-3.8600	0.00006	0.99994	-3.3700	0.00038	0.99962	-2.8800	0.00199	0.99801
-3.8500	0.00006	0.99994	-3.3600	0.00039	0.99961	-2.8700	0.00205	0.99795
-3.8400	0.00006	0.99994	-3.3500	0.00040	0.99960	-2.8600	0.00212	0.99788
-3.8300	0.00006	0.99994	-3.3400	0.00042	0.99958	-2.8500	0.00219	0.99781
-3.8200	0.00007	0.99993	-3.3300	0.00043	0.99957	-2.8400	0.00226	0.99774
-3.8100	0.00007	0.99993	-3.3200	0.00045	0.99955	-2.8300	0.00233	0.99767
-3.8000	0.00007	0.99993	-3.3100	0.00047	0.99953	-2.8200	0.00240	0.99760
-3.7900	0.00008	0.99992	-3.3000	0.00048	0.99952	-2.8100	0.00248	0.99752
-3.7800	0.00008	0.99992	-3.2900	0.00050	0.99950	-2.8000	0.00255	0.99745
-3.7700	0.00008	0.99992	-3.2800	0.00052	0.99948	-2.7900	0.00264	0.99736
-3.7600	0.00008	0.99992	-3.2700	0.00054	0.99946	-2.7800	0.00272	0.99728
-3.7500	0.00009	0.99991	-3.2600	0.00056	0.99944	-2.7700	0.00280	0.99720
-3.7400	0.00009	0.99991	-3.2500	0.00058	0.99942	-2.7600	0.00289	0.99711
-3.7300	0.00009	0.99991	-3.2400	0.00060	0.99940	-2.7500	0.00298	0.99702
-3.7200	0.00010	0.99990	-3.2300	0.00062	0.99938	-2.7400	0.00307	0.99693
-3.7100	0.00010	0.99990	-3.2200	0.00064	0.99936	-2.7300	0.00317	0.99683
-3.7000	0.00011	0.99989	-3.2100	0.00066	0.99934	-2.7200	0.00326	0.99674
-3.6900	0.00011	0.99989	-3.2000	0.00069	0.99931	-2.7100	0.00336	0.99664
-3.6800	0.00012	0.99988	-3.1900	0.00071	0.99929	-2.7000	0.00347	0.99653
-3.6700	0.00012	0.99988	-3.1800	0.00074	0.99926	-2.6900	0.00357	0.99643
-3.6600	0.00013	0.99987	-3.1700	0.00076	0.99924	-2.6800	0.00368	0.99632
-3.6500	0.00013	0.99987	-3.1600	0.00079	0.99921	-2.6700	0.00379	0.99621
-3.6400	0.00014	0.99986	-3.1500	0.00082	0.99918	-2.6600	0.00391	0.99609
-3.6300	0.00014	0.99986	-3.1400	0.00084	0.99916	-2.6500	0.00402	0.99598
-3.6200	0.00015	0.99985	-3.1300	0.00087	0.99913	-2.6400	0.00415	0.99585
-3.6100	0.00015	0.99985	-3.1200	0.00090	0.99910	-2.6300	0.00427	0.99573
-3.6000	0.00016	0.99984	-3.1100	0.00094	0.99906	-2.6200	0.00440	0.99560
-3.5900	0.00016	0.99984	-3.1000	0.00097	0.99903	-2.6100	0.00453	0.99547
-3.5800	0.00017	0.99983	-3.0900	0.00100	0.99900	-2.6000	0.00466	0.99534
-3.5700	0.00018	0.99982	-3.0800	0.00103	0.99897	-2.5900	0.00480	0.99520
-3.5600	0.00019	0.99981	-3.0700	0.00107	0.99893	-2.5800	0.00494	0.99506
-3.5500	0.00019	0.99981	-3.0600	0.00111	0.99889	-2.5700	0.00508	0.99492
-3.5400	0.00020	0.99980	-3.0500	0.00114	0.99886	-2.5600	0.00523	0.99477
-3.5300	0.00021	0.99979	-3.0400	0.00118	0.99882	-2.5500	0.00539	0.99461
-3.5200	0.00022	0.99978	-3.0300	0.00122	0.99878	-2.5400	0.00554	0.99446

z	$\Phi(z)$	1 - $\Phi(z)$	z	$\Phi(z)$	1 - $\Phi(z)$	z	$\Phi(z)$	1 - $\Phi(z)$
-2.5300	0.00570	0.99430	-2.0300	0.02118	0.97882	-1.5300	0.06301	0.93699
-2.5200	0.00587	0.99413	-2.0200	0.02169	0.97831	-1.5200	0.06426	0.93574
-2.5100	0.00604	0.99396	-2.0100	0.02222	0.97778	-1.5100	0.06552	0.93448
-2.5000	0.00621	0.99379	-2.0000	0.02275	0.97725	-1.5000	0.06681	0.93319
-2.4900	0.00639	0.99361	-1.9900	0.02330	0.97670	-1.4900	0.06811	0.93189
-2.4800	0.00657	0.99343	-1.9800	0.02385	0.97615	-1.4800	0.06944	0.93056
-2.4700	0.00676	0.99324	-1.9700	0.02442	0.97558	-1.4700	0.07078	0.92922
-2.4600	0.00695	0.99305	-1.9600	0.02500	0.97500	-1.4600	0.07214	0.92786
-2.4500	0.00714	0.99286	-1.9500	0.02559	0.97441	-1.4500	0.07353	0.92647
-2.4400	0.00734	0.99266	-1.9400	0.02619	0.97381	-1.4400	0.07493	0.92507
-2.4300	0.00755	0.99245	-1.9300	0.02680	0.97320	-1.4300	0.07636	0.92364
-2.4200	0.00776	0.99224	-1.9200	0.02743	0.97257	-1.4200	0.07780	0.92220
-2.4100	0.00798	0.99202	-1.9100	0.02807	0.97193	-1.4100	0.07927	0.92073
-2.4000	0.00820	0.99180	-1.9000	0.02872	0.97128	-1.4000	0.08076	0.91924
-2.3900	0.00842	0.99158	-1.8900	0.02938	0.97062	-1.3900	0.08226	0.91774
-2.3800	0.00866	0.99134	-1.8800	0.03005	0.96995	-1.3800	0.08379	0.91621
-2.3700	0.00889	0.99111	-1.8700	0.03074	0.96926	-1.3700	0.08534	0.91466
-2.3600	0.00914	0.99086	-1.8600	0.03144	0.96856	-1.3600	0.08691	0.91309
-2.3500	0.00939	0.99061	-1.8500	0.03216	0.96784	-1.3500	0.08851	0.91149
-2.3400	0.00964	0.99036	-1.8400	0.03288	0.96712	-1.3400	0.09012	0.90988
-2.3300	0.00990	0.99010	-1.8300	0.03362	0.96638	-1.3300	0.09176	0.90824
-2.3200	0.01017	0.98983	-1.8200	0.03438	0.96562	-1.3200	0.09342	0.90658
-2.3100	0.01044	0.98956	-1.8100	0.03515	0.96485	-1.3100	0.09510	0.90490
-2.3000	0.01072	0.98928	-1.8000	0.03593	0.96407	-1.3000	0.09680	0.90320
-2.2900	0.01101	0.98899	-1.7900	0.03673	0.96327	-1.2900	0.09853	0.90147
-2.2800	0.01130	0.98870	-1.7800	0.03754	0.96246	-1.2800	0.10027	0.89973
-2.2700	0.01160	0.98840	-1.7700	0.03836	0.96164	-1.2700	0.10204	0.89796
-2.2600	0.01191	0.98809	-1.7600	0.03920	0.96080	-1.2600	0.10383	0.89617
-2.2500	0.01222	0.98778	-1.7500	0.04006	0.95994	-1.2500	0.10565	0.89435
-2.2400	0.01255	0.98745	-1.7400	0.04093	0.95907	-1.2400	0.10749	0.89251
-2.2300	0.01287	0.98713	-1.7300	0.04182	0.95818	-1.2300	0.10935	0.89065
-2.2200	0.01321	0.98679	-1.7200	0.04272	0.95728	-1.2200	0.11123	0.88877
-2.2100	0.01355	0.98645	-1.7100	0.04363	0.95637	-1.2100	0.11314	0.88686
-2.2000	0.01390	0.98610	-1.7000	0.04457	0.95543	-1.2000	0.11507	0.88493
-2.1900	0.01426	0.98574	-1.6900	0.04551	0.95449	-1.1900	0.11702	0.88298
-2.1800	0.01463	0.98537	-1.6800	0.04648	0.95352	-1.1800	0.11900	0.88100
-2.1700	0.01500	0.98500	-1.6700	0.04746	0.95254	-1.1700	0.12100	0.87900
-2.1600	0.01539	0.98461	-1.6600	0.04846	0.95154	-1.1600	0.12302	0.87698
-2.1500	0.01578	0.98422	-1.6500	0.04947	0.95053	-1.1500	0.12507	0.87493
-2.1400	0.01618	0.98382	-1.6400	0.05050	0.94950	-1.1400	0.12714	0.87286
-2.1300	0.01659	0.98341	-1.6300	0.05155	0.94845	-1.1300	0.12924	0.87076
-2.1200	0.01700	0.98300	-1.6200	0.05262	0.94738	-1.1200	0.13136	0.86864
-2.1100	0.01743	0.98257	-1.6100	0.05370	0.94630	-1.1100	0.13350	0.86650
-2.1000	0.01786	0.98214	-1.6000	0.05480	0.94520	-1.1000	0.13567	0.86433
-2.0900	0.01831	0.98169	-1.5900	0.05592	0.94408	-1.0900	0.13786	0.86214
-2.0800	0.01876	0.98124	-1.5800	0.05705	0.94295	-1.0800	0.14007	0.85993
-2.0700	0.01923	0.98077	-1.5700	0.05821	0.94179	-1.0700	0.14231	0.85769
-2.0600	0.01970	0.98030	-1.5600	0.05938	0.94062	-1.0600	0.14457	0.85543
-2.0500	0.02018	0.97982	-1.5500	0.06057	0.93943	-1.0500	0.14686	0.85314
-2.0400	0.02067	0.97933	-1.5400	0.06178	0.93822	-1.0400	0.14917	0.85083



Annex : Student t distribution Chart

TABLE A.2
Critical t values with ν degrees of freedom

ν	α				
	0.100	0.050	0.025	0.010	0.005
1	3.078	6.314	12.706	31.821	63.657
2	1.886	2.920	4.303	6.695	9.925
3	1.639	2.353	3.182	4.541	5.841
4	1.533	2.132	2.776	3.747	4.604
5	1.476	2.015	2.571	3.365	4.032
6	1.440	1.943	2.447	3.143	3.707
7	1.415	1.895	2.365	2.998	3.499
8	1.397	1.860	2.306	2.896	3.355
9	1.383	1.833	2.262	2.821	3.250
10	1.372	1.812	2.228	2.764	3.169
11	1.363	1.796	2.201	2.718	3.106
12	1.356	1.782	2.179	2.681	3.055
13	1.350	1.771	2.160	2.650	3.012
14	1.345	1.761	2.145	2.624	2.977
15	1.341	1.753	2.131	2.602	2.947
16	1.337	1.746	2.120	2.583	2.921
17	1.333	1.740	2.110	2.567	2.898
18	1.330	1.734	2.101	2.552	2.878
19	1.328	1.729	2.093	2.539	2.861
20	1.325	1.725	2.086	2.528	2.845
21	1.323	1.721	2.080	2.518	2.831
22	1.321	1.717	2.074	2.508	2.819
23	1.319	1.714	2.069	2.500	2.807
24	1.318	1.711	2.064	2.492	2.797
25	1.316	1.708	2.060	2.485	2.787
26	1.315	1.706	2.056	2.479	2.799
27	1.314	1.703	2.052	2.473	2.771
28	1.313	1.701	2.048	2.467	2.763
29	1.311	1.699	2.045	2.462	2.756
∞	1.282	1.645	1.960	2.326	2.576