

Annexes des Travaux Dirigés de l'UE 2E102 « Sources d'énergie électrique et capteurs »

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Les textes de TD sont à préparer avant la séance.

Apporter en TD calculatrice et petit matériel (crayon, règle, etc.)

ainsi que ce fascicule d'annexes.





1. PRODUCTION D'ÉNERGIE ÉLECTRIQUE

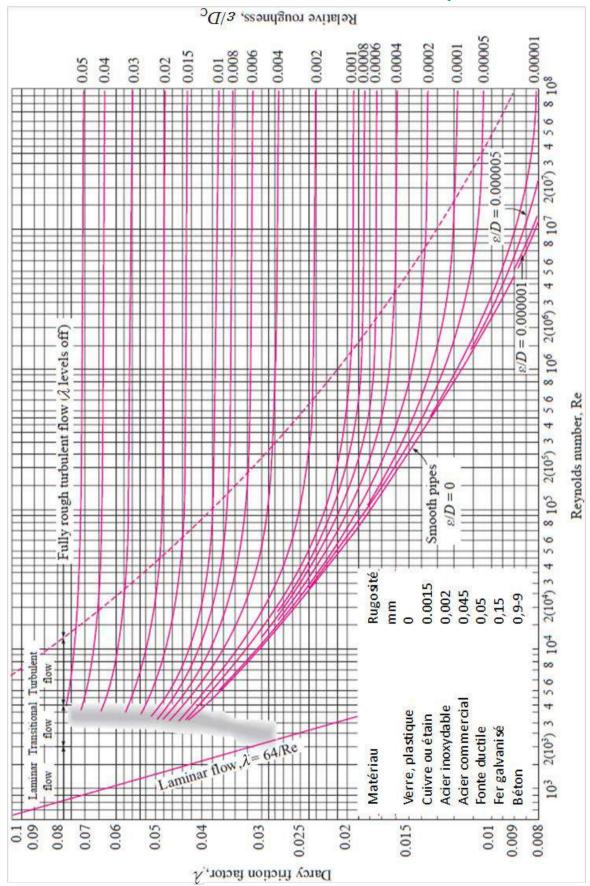


Figure A.1.1. Abaque de Moody donnant le coefficient de frottement λ pour des flux définis par leur nombre de Reynolds Re circulant dans des conduites circulaires de diamètre $D_{\rm C}$ et de rugosité ε (rugosité relative $\varepsilon/D_{\rm C}$). Source : Y.A. Çengel and J.M. Cimbala, *Fluids mechanics: fundamentals and applications*, 1st Ed., McGraw-Hill (2006)

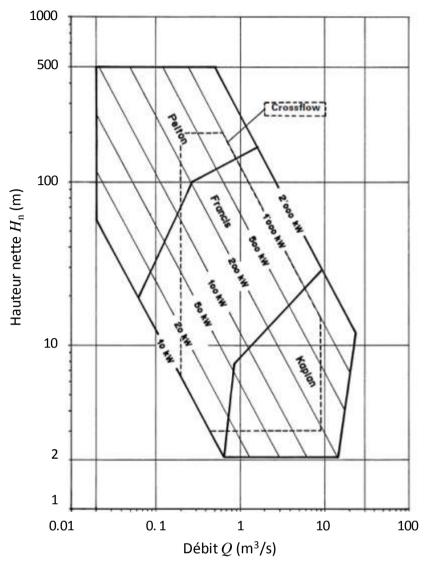


Figure A.1.2. Diagramme de sélection de mini-turbines.

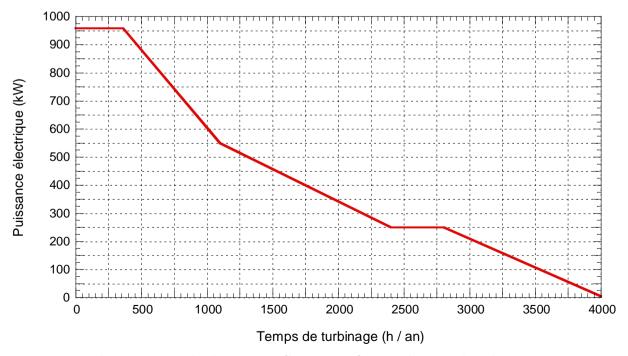


Figure A.1.3. Courbe de puissance électrique en fonction du temps de turbinage.



2. ÉNERGIE SOLAIRE ET SYSTÈMES PHOTOVOLTAÏQUES

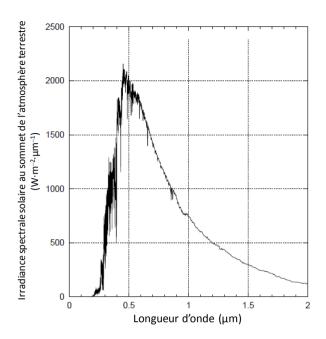


Figure A.2.1. Spectre solaire AM0 extraterrestre.

- ✓ Latitude Φ ; Longitude L.
- V Déclinaison δ : $\delta(^{\circ}) = 23,45 \sin \left[\frac{360}{365} (j + 284) \right]$, où j est le rang du jour dans l'année (cf. tableau page 4).
 - $\cos h \cos a = \cos \delta \cos H \sin \Phi \sin \delta \cos \Phi ;$
- Hauteur h et azimut a: $\begin{cases} \cos h & \sin a = \cos \delta \sin H ; \\ \sin h = \cos \delta \cos H \cos \Phi + \sin \delta \sin \Phi. \end{cases}$
- ✓ Hauteur au point de culmination (midi solaire = zénith solaire) : $h_z(\circ) = 90 \Phi + \delta$.
- ✓ Distance zénithale : θ (°) = 90 h.
- \checkmark Éclairement direct sur le plan horizon : $E_i = A \exp(-k AM)$, où

$$A = 1160 + 75 \sin \left[\frac{360}{365} (j - 275) \right], k = 0,174 + 0,035 \sin \left[\frac{360}{365} (j - 100) \right] \text{ et } AM = \text{nombre de masse d'air.}$$

- \checkmark Éclairement diffus sur le plan horizon : $E_{\rm d} = CE_{\rm i}$, où $C = 0.095 + 0.04 \sin \left[\frac{360}{365} (j 100) \right]$.
- $\not \leq \text{ \'eclairement direct } E_{\mathrm{ip}} \text{ et \'eclairement diffus } E_{\mathrm{dp}} \text{ sur un panneau inclin\'e d'un angle } \beta_{\mathrm{p}} \text{ avec le plan horizon : } \\ E_{\mathrm{ip}} = E_{\mathrm{i}} \cos \theta_{\mathrm{p}} \text{ , où } \cos \theta_{\mathrm{p}} = \cos h \, \cos \left(a a_{\mathrm{p}} \right) \, \sin \beta_{\mathrm{p}} + \sin h \, \cos \beta_{\mathrm{p}} .$

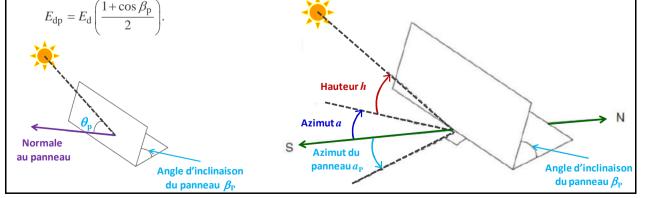


Figure A.2.2. Données et expressions utiles pour l'exercice n°2.

Rang j du premier jour de chaque mois de l'année

Mois	j	Mois	j
Janvier	1	Juillet	182
Février	32	Août	213
Mars	60	Septembre	244
Avril	91	Octobre	274
Mai	121	Novembre	305
Juin	152	Décembre	335

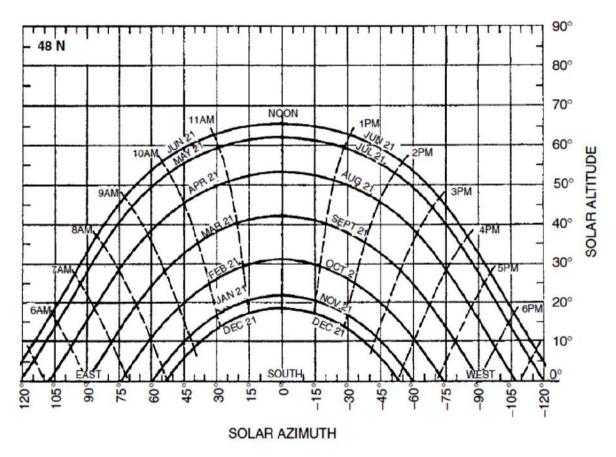
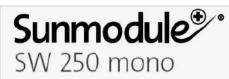


Figure A.2.3. Diagramme hauteur h – azimut a de la course du Soleil pendant une année (latitude Φ = 48° N). Source: © John Wiley & Sons, Inc., Hoboken, New Jersey (2004).





COMPORTEMENT LORS DE CONDITIONS DE TEST STANDARD (STC*)

		SW 250	
Puissance au point de puissance maximale	P _{max}	250 Wc	
Tension à vide	U _{oc}	37,8 V	
Tension au point de puissance maximale	U _{mpp}	31,1 V	
Courant de court-circuit	l _{sc}	8,28 A	
Courant au point de puissance maximale	Impe	8,05 A	

*STC: 1000W/m2, 25°C, AM 1.5

COMPORTEMENT À 800W/m², NOCT, AM 1.5

		SW 250
Puissance au point de puissance maximale	P _{max}	183,3 Wc
Tension à vide	U _{oc}	34,6 V
Tension au point de puissance maximale	U _{mpp}	28,5 V
Courant de court-circuit	l _{sc}	6,68 A
Courant au point de puissance maximale	Impp	6,44 A

Faible réduction du rendement en conditions de charge partielle à 25 °C: à 200 W/m2, la puissance est égale à 95 % (+/- 3 %) de la puissance en condition STC.

MATÉRIAUX UTILISÉS

60
monocristallin
156 mm x 156 mm
verre trempé (EN 12150)

GRANDEURS CARACTÉRISTIQUES THERMIQUES

NOCT	47 °C
CT I _∞	0,042 %/K
CT U₀c	-0,33 %/K
CT P _{mpp}	-0,45 %/K

GRANDEURS CARACTÉRISTIQUES RELATIVES Á INTÉGRATION OPTIMALE DANS LE SYSTÈME

Tension de système maximale classe II	1000 V
Valeurs limites de courant inverse	16 A
Charge neige et vent selon IEC 61215	5,4 kN/m²
Nombre de diode bypass	3

AUTRES DONNÉES

Tolérance de mesure	+/- 3 %
Boîte de jonction	IP65
Connecteur	MC4
SolarWorld: tri Plus ¹⁾	P _{Flash} ≥ P _{max}

Figure A.2.4. Caractéristiques du module photovoltaïque Sunmodule® SW 250 mono fabriqué par SolarWorld. <u>Source</u>: www.solarworld.de.

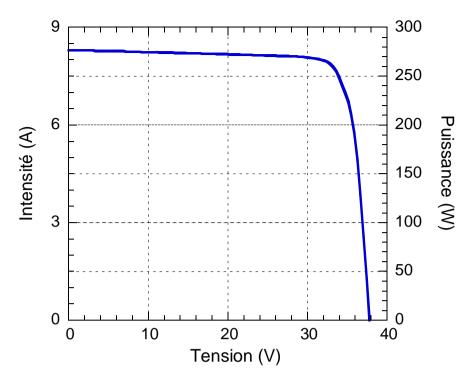


Figure A.2.5. Caractéristiques courant-tension (courbe tracée) et puissance-tension (à tracer) du module Sunmodule® SW 250 sous conditions de test standard.

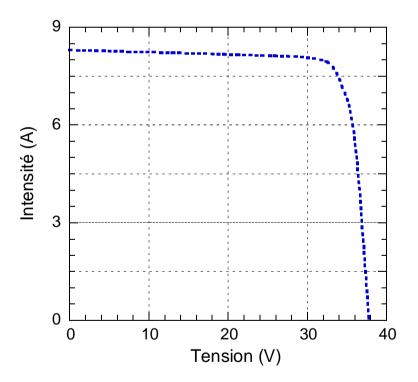


Figure A.2.6. Caractéristiques courant-tension du module Sunmodule® SW 250 :

- courbe en traits pointillés : sous conditions de test standard ;
- courbe a, à tracer : lorsque l'éclairement diminue de 50% à température constante de 25°C ;
- courbe b, à tracer : lorsque la température est de 70°C à éclairement constant de 1000 W/m².



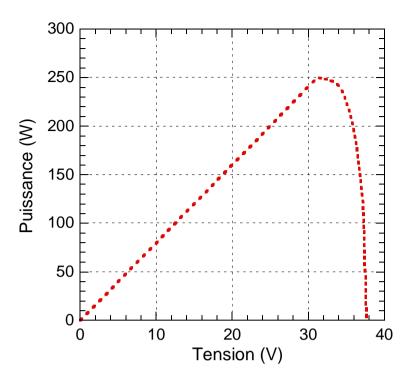


Figure A.2.7. Caractéristiques puissance-tension du module Sunmodule® SW 250 :

- courbe en traits pointillés : sous conditions de test standard ;
- <u>courbe c, à tracer</u> : lorsque l'éclairement diminue de 50% à température constante de 25°C; <u>courbe d, à tracer</u> : lorsque la température est de 70°C à éclairement constant de 1000 W/m².



Caractéristiques techniques (VDE 0126)

Caractéristiques d'entrée (CC)					
Puissance maximale du générateur photovoltaïque(1)	5400 Wc				
Plage de tension MPP®	125 V à 700 V				
Tension maximale à vide	750 V				
Courant maximal	3 x 8,5 A				
Raccordement sur connecteurs MC3 Multi-contact®	3 paires				
Caractéristiques de sortie (CA)					
Puissance nominale	4600 W				
Puissance maximale	5100 W				
Tension nominale	230 V				
Tension mini (paramétrage par défaut)	198 V				
Autres paramétrages possibles de la tension mini	180 V à 251 V				
Tension maxi (paramétrage par défaut)	251 V				
Autres paramétrages possibles de la tension maxi	198 V à 300 V				
Fréquence nominale	50 Hz				
Fréquence mini (paramétrage par défaut)	49,81 Hz				
Autres paramétrages possibles de la fréquence mini	48 Hz à 52 Hz				
Fréquence maxi (paramétrage par défaut)	50,19 Hz				
Autres paramétrages possibles de la fréquence maxi	48 Hz à 52 Hz				
Courant nominal	20 A				
Courant maximal	26 A				
Facteur de puissance	~1				
Facteur de distorsion	<3 %				
Caractéristiques internes					
Rendement maximal	>96 %				
Rendement européen	>94,5 %				
Consommation propre en service	~9 W				
Consommation propre à l'arrêt (la nuit)	0 W				
Caractéristiques mécaniques					
Boîtier	Métallique				
Refroidissement	Par convection naturelle (sans ventilateur)				
Masse	27 kg				
Dimensions (longueur x hauteur x profondeur) en mm	430 x 530 x 130				
Température ambiante de fonctionnement	-20 °C à +55 °C				
Humidité relative (HR)	0 % à 95 %, sans condensation				
Indice de protection	IP65				

Figure A.2.8. Caractéristiques de l'onduleur SunEzy 600E. <u>Source</u> : www.schneider-electric.com.



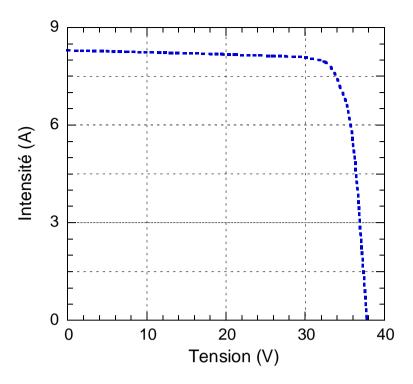


Figure A.2.9. Caractéristiques courant-tension du module Sunmodule® SW 250 :

- courbe en traits pointillés : sous conditions de test standard ;
- courbe e, à tracer : lorsqu'une cellule est ombrée à 60%.

3. CONVERSION D'ÉNERGIE (1) : EFFETS THERMOÉLECTRIQUES

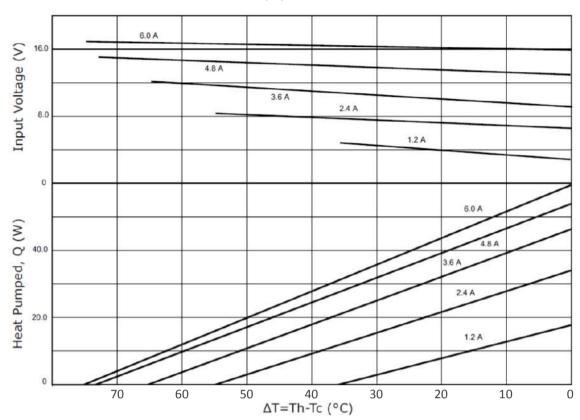


Figure A.3.1. Diagramme fonctionnel de performance pour le module CP60440 (à $T_{\rm h}$ = 50°C). <u>Source</u> : www.cui.com

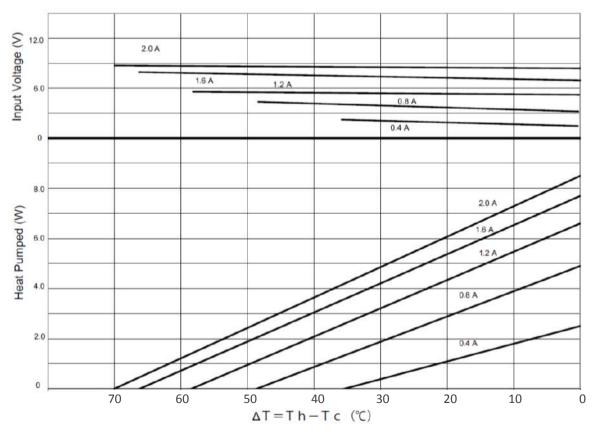
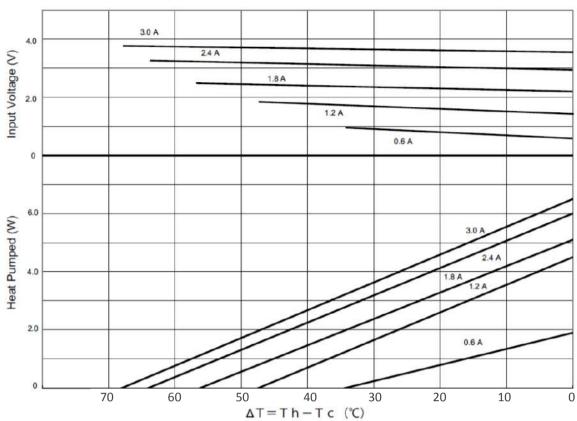
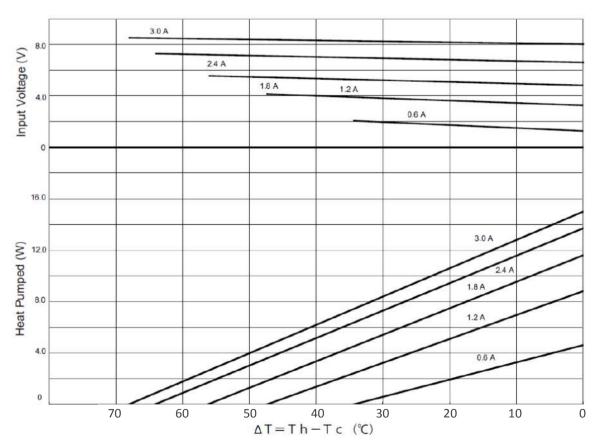


Figure A.3.2. Diagramme fonctionnel de performance pour le module CP20251. Prix : 17 $\frac{\text{Source}}{\text{Source}}$: www.cui.com







4. CONVERSION D'ÉNERGIE (2) − ÉNERGIE MÉCANIQUE → ÉNERGIE ÉLECTRIQUE : ÉNERGIE ÉOLIENNE

Expressions utiles:

- ✓ Influence de la hauteur et de la rugosité du paysage sur la vitesse du vent : $\frac{v}{v_0} = \frac{\ln(H/z)}{\ln(H_0/z)}$, où v est la vitesse à la hauteur H, v_0 la vitesse à la hauteur H0 et z la longueur de rugosité.
- \checkmark Tip-Speed Ratio: TSR = Vitessedurotor / Vitesseduvent.
- ✓ Densité de probabilité liée à une distribution de Weibull : $f(u) = \frac{k}{A} \left(\frac{u}{A}\right)^{k-1} \exp\left(-\left(\frac{u}{A}\right)^{k}\right)$.
- Fonction de survie (fonction cumulative d'une distribution de la vitesse du vent supérieure à une valeur u_0): $Q(u>u_0)=\exp\left(-\left(\frac{u_0}{A}\right)^k\right).$
- ✓ Fonction de répartition complémentaire de défaillance (fonction cumulative d'une distribution de la vitesse du vent inférieure ou égale à une valeur u_0) : $F(u \le u_0) = 1 \exp\left(-\left(\frac{u_0}{A}\right)^k\right)$.

Figure A.4.1. Expressions utiles pour les exercices du TD.

Classe de rugosité	Longueur de rugosité (m)	Coefficient énergétique (%)	Type de paysage
0	0,0002	100	Surface d'eau
0,5	0,0024	73	Terrain complètement dégagé avec une surface lisse, p.ex. une piste d'atterrissage en béton ou de l'herbe fraîchement coupée.
1	0,03	52	Terrain agricole dégagé, sans clôtures ou haies vives, et avec très peu de constructions. Seulement des collines aux pentes douces.
1,5	0,055	45	Terrain agricole avec quelques constructions et des haies vives de 8 m de haut situées à environ 1250 m les unes des autres.
2	0,1	39	Terrain agricole avec quelques constructions et des haies vives de 8 m de haut situées à environ 500 m les unes des autres.
2,5	0,2	31	Terrain agricole avec beaucoup de constructions, arbrisseaux et plantes, ou des haies vives de 8 m de haut situées à environ 250 m les unes des autres.
3	0,4	24	Village, petite ville, terrain agricole avec de nombreus es de hautes haies vives, des forêts, terrain très accidenté.
3,5	0,8	18	Grande ville avec de hauts immeubles.
4	1,6	13	Très grande ville avec de hauts immeubles et des gratte-ciel.

Figure A.4.2. Tableau des classes et longueurs de rugosité.

Source: d'après Atlas éolien européen, 1991, Laboratoire National de Risø, Danemark.



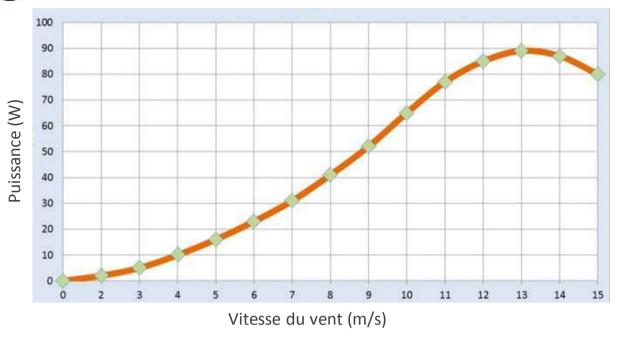


Figure A.4.3. Courbe de puissance de l'éolienne *ASE Energy* M80 en fonction de la vitesse du vent. Source : www.ase-energy.com

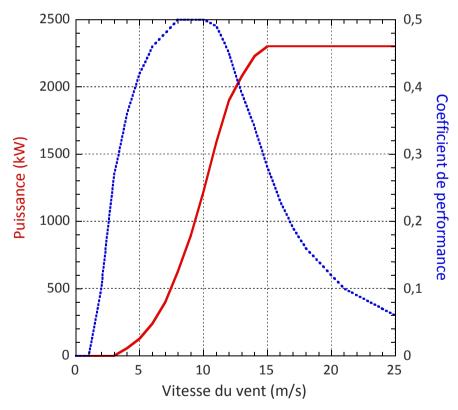


Figure A.4.4. Courbes de puissance (en trait continu rouge) et de coefficient de performance (en traits pointillés bleus) de l'éolienne *Enercon* E70 en fonction de la vitesse du vent.

Source: www.enercon.de/fr/home/

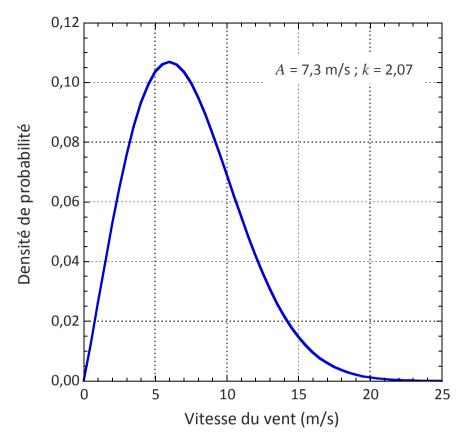


Figure A.4.5. Fonction de distribution de Weibull de la vitesse moyenne des vents à une hauteur de 55 m dans la région de Narbonne sur une année (courbe en trait continu). Le paramètre d'échelle A correspond à la valeur moyenne de la vitesse du vent et le paramètre de forme k-détermine la forme de la courbe de Weibull.



5. UTILISATION DOMESTIQUE DE L'ÉNERGIE ÉLECTRIQUE

Les interrupteurs différentiels dans le logement

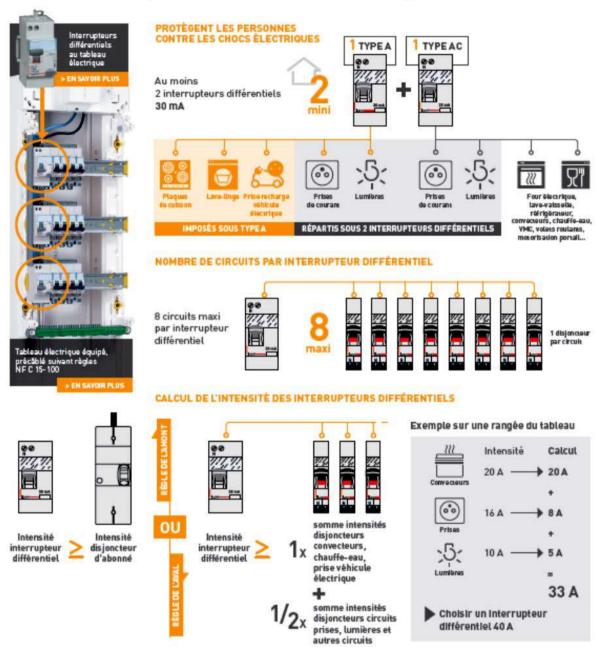


Figure A.5.1. Les points clés de la norme NF C 15–100. <u>Source</u> : www.legrand.com

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6. COMMENT CHOISIR UN CAPTEUR?



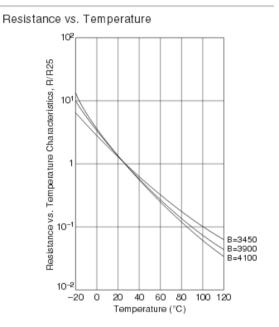
R=Ro expB (1/T-1/To)(1)

R: Resistance in ambient temperature T (K)

(K: absolute temperature)

Ro: Resistance in ambient temperature To (K)

B: B-Constant of Thermistor



Part Number	Resistance (25℃) (ohm)	B-Constant (25-50°C) (K)	B-Constant (25-80°C) (Reference Value)(K)	B-Constant (25-85°C) (Reference Value) (K)	B-Constant (25-100°C) (Reference Value) (K)	Permissive Operating Current (25℃) (mA)
NCP03XM102□05RL	1.0k	3500 ±1%	3539	3545	3560	1.00
NCP03XM152 D5RL	1.5k	3500 ±1%	3539	3545	3560	0.81
NCP03XM222□05RL	2.2k	3500 ±1%	3539	3545	3560	0.67
NCP03XM332□05RL	3.3k	3500 ±1%	3539	3545	3560	0.55
NCP03XM472□05RL	4.7k	3500 ±1%	3539	3545	3560	0.46
NCP03XH682□05RL	6.8k	3380 ±1%	3428	3434	3455	0.38
NCP03XH103F05RL	10k±1%	3380 ±1%	3428	3434	3455	0.31
NCP03XH103□05RL	10k	3380 ±1%	3428	3434	3455	0.31
NCP03XV103□05RL	10k	3900 ±1%	3930	3934	3944	0.31
NCP03XH153□05RL	15k	3380 ±1%	3428	3434	3455	0.25
NCP03XH223□05RL	22k	3380 ±1%	3428	3434	3455	0.21
NCP03WF333□05RL	33k	4250 ±1%	4303	4311	4334	0.17
NCP03WB473□05RL	47k	4050 ±3%	4101	4108	4131	0.14
NCP03WL473□05RL	47k	4485 ±1%	4537	4543	4557	0.14
NCP03WF683□05RL	68k	4250 ±1%	4303	4311	4334	0.12
NCP03WL683□05RL	68k	4485 ±1%	4537	4543	4557	0.12
NCP03WF104F05RL	100k ±1%	4250 ±1%	4303	4311	4334	0.10
NCP03WF104□05RL	100k	4250 ±1%	4303	4311	4334	0.10
NCP03WL104□05RL	100k	4485 ±1%	4537	4543	4557	0.10
NCP03WL154□05RL	1 50k	4485 ±1%	4537	4543	4557	0.08
NCP03WL224□05RL	220k	4485 ±1%	4537	4543	4557	0.06

 $[\]square$ is filled with resistance tolerance codes (E: ±3%, J: ±5%).

Rated Electric Power shows the required electric power that causes Thermistor's temperature to rise to 125°C by self heating, at ambient temperature of 25°C. Operating Temperature Range: -40°C to +125°C

Figure A.6.1. Caractéristiques de la sonde CTN de type NCP03.

Source: www.murata.com



Pt100 ELEMENTS, THIN FILM (100 Ohm) THERMOMETER INSERTS

- Pt100 elements to IEC 751 Class A & B in ceramic sheaths
- Sheath 5.2mm diameter x 35mm long
- For use from -50°C to +250°C
- Thin film construction
- Extension leads 7/0.2mm singles, copper, PTFE insulated
- Insulated leads rated -50°C to +250°C
- 2 or 4 wire configurations
- Vibration resistant

Specifications of elements

Sensor type: Pt100 (100 Ohms @ 0°C)

Construction: Thin film sensor in ceramic sheath

Temperature range: -50°C to +250°C

Ice point resistance: 100Ω

Fundamental interval

 (0°C to 100°C)
 38.5Ω (nominal)

 Self heating
 <005°C/mW</td>

 Stability
 ±0.05%

Sheath dimensions & tolerance class 5.2mm O/D x 35mm, Class B

Dimensions & codes

	Farnell code	LAB code
50mm x 2 wire 7/0.2mm PTFE	725-5731	01-412-RT/D
450mm x 4 wire 7/0.2mm PTFE	725-5743	01-412-RT/B



Data Ref: FAR 60

Figure A.6.2. Caractéristiques de la sonde Pt100 utilisée.

<u>Source</u>: www.labfacility.com

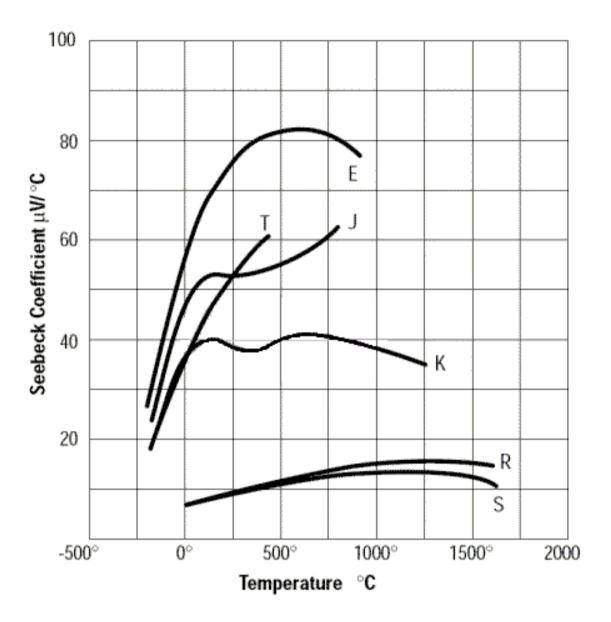


Figure A.6.3. Coefficient Seebeck de quelques thermocouples.



Figure A.6.4. Tableau des tensions d'un thermocouple de type K.

Table des tensions de Thermocouple Type K (Chromel/Alumel)												
Tension thermoélectrique en millivolts avec jonction de référence à 0°C												
°C	0	1	2	3	4	5	6	7	8	9	10	°C
-270	-6,458											-270
-260	-6,441	-6,444	-6,446	-6,448	-6,450	-6,452	-6,453	-6,455	-6,456	-6,457	-6,458	-260
-250	-6,404	-6,408	-6,413	-6,417	-6,421	-6,425	-6,429	-6.432	-6,435	-6,438	-6.441	-250
-240	-6,344	-6,351	-6,358	-6,364	-6,371	-6,377	-6,382	-6,388	-6,394	-6,399	-6,404	-240
-230	-6,262	-6,271	-6,280	-6,289	-6,297	-6,306	-6,314	-6,322	-6,329	-6,337	-6,344	-230
-220	-6,158	-6,170	-6,181	-6,192	-6,202	-6,213	-6,223	-6,233	-6,243	-6,253	-6,262	-220
-210	-6,035	-6,048	-6,061	-6,074	-6,087	-6,099	-6,111	-6,123	-6,135	-6,147	-6,158	-210
-200	-5,891	-5,907	-5,922	-5,936	-5,951	-5,965	-5,980	-5,994	-6,007	-6,021	-6,035	-200
-190	-5,730	-5,747	-5,763	-5,780	-5,796	-5,813	-5,829	-5,845	-5,860	-5,876	-5,891	-190
-180	-5,550	-5,569	-5,587	-5,700	-5,624	-5,642	-5,660	-5,678	-5,695	-5,712	-5,730	-180
-170	-5,354	-5,374	-5,394	-5,414	-5,434	-5,454	-5,474	-5,493	-5,512	-5,531	-5,550	-170
-160									-5,313	-5,333		-160
-	-5,141	-5,163	-5,185	-5,207	-5,228	-5,249	-5,271	-5,292			-5,354	
-150	-4,912	-4,936	-4,959	-4,983	-5,006	-5,029	-5,051	-5,074	-5,097	-5,119	-5,141	-150
-140	-4,669	-4,694	-4,719	-4,743	-4,768	-4,792	-4,817	-4,841	-4,865	-4,889	-4,912	-140
-130	-4,410	-4,437	-4,463	-4,489	-4,515	-4,541	-4,567	-4,593	-4,618	-4,644	-4,669	-130
-120	-4,138	-4,166	-4,193	-4,221	-4,248	-4,276	-4,303	-4,330	-4,357	-4,384	-4,410	-120
-110	-3,852	-3,881	-3,910	-3,939	-3,968	-3,997	-4,025	-4,053	-4,082	-4,110	-4,138	-110
-100	-3,553	-3,584	-3,614	-3,644	-3,674	-3,704	-3,734	-3,764	-3,793	-3,823	-3,852	-100
-90	-3,242	-3,274	-3,305	-3,337	-3,368	-3,399	-3,430	-3,461	-3,492	-3,523	-3,553	-90
-80	-2,920	-2,953	-2,985	-3,018	-3,050	-3,082	-3,115	-3,147	-3,179	-3,211	-3,242	-80
-70	-2,586	-2,620	-2,654	-2,687	-2,721	-2,754	-2,788	-2,821	-2,854	-2,887	-2,920	-70
-60	-2,243	-2,277	-2,312	-2,347	-2,381	-2,416	-2,450	-2,484	-2,518	-2,552	-2,586	-60
-50	-1,889	-1,925	-1,961	-1,996	-2,032	-2,067	-2,102	-2,137	-2,173	-2,208	-2,243	-50
-40	-1,527	-1,563	-1,600	-1,636	-1,673	-1,709	-1,745	-1,781	-1,817	-1,853	-1,889	-40
-30	-1,156	-1,193	-1,231	-1,268	-1,305	-1,342	-1,379	-1,416	-1,453	-1,490	-1,527	-30
-20	-0,777	-0,816	-0,854	-0,892	-0,930	-0,968	-1,005		-1,081	-1,118	-1,156	-20
-10	-0,392	-0,431	-0,469	-0,508	-0,547	-0,585	-0,624	-0,662	-0,701	-0,739	-0,777	-10
- 0	0,000	-0,039	-0,079	-0,118	-0,157	-0,197	-0,236	-0,275	-0,314	-0,353	-0,392	- 0
0	0,000	0,039	0,079	0,119	0,158	0,199	0,238	0,277	0,317	0,357	0,397	0
10	0,397	0,437	0,477	0,517	0,557	0,597	0,637	0,677	0,718	0,758	0,798	10
20	0,798	0,838	0,879	0,919	0,960	1,000	1,041	1,081	1,122	1,162	1,203	20
30	1,203	1,244	1,285	1,325	1,366	1,407	1,448	1,489	1,529	1,570	1,611	30
40	1,611	1,652	1,693	1,734	1,776	1,817	1,858	1,899	1,940	1,981	2,022	40
50	2,022	2,064	2,105	2,146	2,188	2,229	2,270	2,312	2,353	2,394	2,436	50
60	2,436	2,477	2,519	2,560	2,601	2,643	2,684	2,726	2,767	2,309	2,850	60
70	2,850	2,892	2,933	2,975	3,016	3,058	3,100	3,141	3,183	3,224	3,266	70
80	3,266	3,307	3,349	3,390	3,432	3,473	3,515	3,556	3,598	3,639	3,681	80
90	3,681	3,722	3,764	3,805	3,847	3,888	3,930	3,971	4,012	4,054	4,095	90
100	4,095	4,137	4,178	4,219		4,302	4,343	4,384	4,426	4,467	4,508	100
110	4,508	4,549	4,590	4,632	4,673	4,714	4,755	4,796	4,837	4,878	4,919	110
120	4,919	4,960	5,001	5,042	5,083	5,124	5,164	5,205	5,246	5,287	5,327	120
130	5,327	5,368	5,409	5,450	5,490	5,531	5,571	5,612	5,652	5,693	5,733	130
140	5,733	5,774	5,814	5,855	5,895	5,936	5,976	6,016	6,057	6,097	6,137	140
150	6,137	6,177	6,218	6,258	6,298	6,338	6,378	6,419	6,459	6,499	6,539	150
160	6,539	6,579	6,619	6,659	6,699	6,739	6,779	_	6,859	6,899	6,939	160
170	6,939	6,979	7,019	7,059	7,099	7,139	7,179		7,259	7,299	7,338	170
180	7,338	7,378	7,418	7,458	7,498	7,538	7,578	7,618	7,658	7,697	7,737	180
190	7,737	7,777	7,817	7,857	7,897	7,937	7,977	8,017	8,057	8,097	8,137	190
200	8,137	8,177	8,216	8,256	8,296	8,336	8,376		8,456	8,497	8,537	200
210	8,537	8,577	8,617	8,657	8,697	8,737	8,777	8,817	8,857	8,898	8,938	210
220	8,938	8,978	9,018	9,058	9,099	9,139	9,179	9,220	9,260	9,300	9,341	220
230	9,341	9,381	9,421	9,462	9,502	9,543	9,583	9,624	9,664	9,705	9,745	230
240	9,745	9,786	9,826	9,867	9,907	9,948	9,989	10,029	10,070	10,111	10,151	240
250	10,151	10,192	10,233	10,274	10,315	10,355	10,396	10,437	10,478	10,519	10,560	250
260	10,560	10,600	10,641	10,682	10,723	10,764	10,805	10,846	10,887	10,928	10,969	260
270	10,969	11,010	11,051	11,093	11,134	11,175	11,216	_	11,298	11,339	11,381	270
280	11,381	11,422	11,463	11,504		11,587	11,628		11,711	11,752	11,793	280
200	11,301	11,422	11,403	11,304	11,340	11,307	11,020	11,009	11,711	11,732	11,793	200

Tension thermoelectrique en millivotts avec jonction de rétérence à 0°C 1	Table des tensions de Thermocouple Type K (Chromel/Alumel)												
Texas Texa													
1796	°C	0		-								10	۰c
1300 12,007 12,249 12,290 12,332 12,373 12,415 12,456 12,456 12,459 12,539 12,551 12,623 300 310 12,632 12,664 12,766 12,477 12,789 12,381 12,672 12,914 12,955 12,957 13,039 31,030	_					_							
340 13,039 13,080 13,132 13,132 13,146 13,205 13,247 13,289 13,331 13,372 13,141 34,565 320 330 13,456 13,467 13,593 15,581 13,623 13,665 13,766 13,748 13,790 13,832 13,874 33,931 33,31 13,872 13,414 34,565 320 330 13,874 13,915 13,957 13,999 14,041 14,083 14,125 14,167 14,208 14,250 14,250 14,292 340 350 14,712 14,754 14,796 14,838 14,880 14,922 14,964 15,006 15,048 15,090 15,132 360 14,712 14,754 14,796 14,838 14,880 14,922 14,964 15,006 15,048 15,090 15,132 360 10,1712 14,754 14,796 14,838 14,880 14,922 14,964 15,006 15,048 15,090 15,132 360 15,555 15,594 15,536 15,679 15,721 15,763 15,805 15,487 15,889 15,537 15,555 370 380 15,555 15,941 15,636 15,679 15,721 15,763 15,805 15,847 15,889 15,931 15,974 30,900 16,395 16,438 16,480 16,522 16,564 16,607 16,649 16,691 16,733 16,776 16,818 400 16,395 16,438 16,480 16,522 16,564 16,607 16,649 16,691 16,733 16,776 16,818 400 17,241 17,283 17,326 17,368 17,368 17,409 17,453 17,495 17,537 17,580 17,592 17,684 420 17,724 17,728 17,729 17,702 17,702 17,707 17,114 17,166 17,199 17,414 410 18,088 18,131 18,173 18,16 18,680 18,680 18,680 18,680 18,680 18,680 18,680 18,680 18,680 18,680 18,680 18,680 18,680 18,680 19,223 19,065 19,108 19,139 19,393 19,335 18,555 18,938 400 18,033 18,355 18,36	$\overline{}$	-	•	_	_	_		-		_			
320 13,039 13,080 13,122 13,164 13,205 13,247 13,269 13,331 13,372 13,414 13,456 320 330 13,466 13,467 13,559 15,861 13,623 13,665 13,766 13,748 13,750 13,837 433 340 13,874 13,915 13,957 13,999 14,041 14,063 14,125 14,167 14,208 14,250 14,292 340 13,874 13,915 13,957 13,999 14,041 14,063 14,125 14,167 14,208 14,250 14,292 340 350 14,292 14,341 14,756 14,796 14,838 14,880 14,922 14,641 14,566 14,628 14,670 14,712 350 360 14,712 14,754 14,796 14,838 14,880 14,922 14,946 15,006 15,048 15,090 15,232 360 370 15,132 15,174 15,216 15,256 15,300 15,342 15,304 15,006 15,048 15,909 15,513 32 360 370 15,132 15,174 15,216 15,256 15,909 15,721 15,753 15,805 15,847 15,889 15,931 15,510 15,552 370 300 15,974 16,016 16,058 16,100 16,142 16,184 16,227 16,269 16,311 16,353 16,395 390 15,974 16,016 16,058 16,100 16,142 16,184 16,227 16,269 16,311 16,353 16,395 390 15,974 16,016 16,058 16,100 16,142 16,184 16,227 16,269 16,311 16,353 16,395 390 14,041 15,041 14,041 14,041 14,041 14,041 14,041 14,041 14,041 15,041 15,041 15,041 14,041 14,041 14,041 14,041 14,041 14,041 15,041 14,041				_	_			-			_		
330 1 3,456 1 3,477 1 3,539 1 3,581 1 3,623 1 3,665 1 3,706 1 3,748 1 3,790 1 3,832 1 3,874 33 340 1 3,874 1 3,915 1 3,957 1 3,999 1 4,041 1 4,083 1 4,125 1 4,167 1 4,208 1 4,250 1 4,252 1 4,364 350 1 4,292 1 4,334 1 4,376 1 4,418 1 4,460 1 4,502 1 4,544 1 4,566 1 4,522 1 4,547 1 4,712 350 360 1 4,712 1 4,754 1 4,796 1 4,838 1 4,880 1 4,922 1 4,964 1 5,006 1 5,048 1 5,090 1 5,132 360 370 1 5,132 1 5,174 1 5,216 1 5,256 1 5,300 1 5,342 1 5,344 1 5,426 1 5,468 1 5,510 1 5,525 370 380 1 5,552 1 5,594 1 5,636 1 5,679 1 5,721 1 5,763 1 5,805 1 5,847 1 5,889 1 5,931 1 5,974 380 390 1 5,597 1 6,016 1 6,058 1 6,100 1 6,142 1 6,184 1 6,227 1 6,269 1 6,311 1 6,353 1 3,935 39 400 1 6,395 1 6,438 1 6,480 1 6,522 1 6,564 1 6,607 1 6,649 1 6,691 1 6,733 1 6,776 1 6,818 40 400 1 6,395 1 6,438 1 6,480 1 6,522 1 6,564 1 6,607 1 6,649 1 6,691 1 6,733 1 6,776 1 6,818 40 401 1 6,881 6 ,680 6 1 6,802 1 6,948 1 1,989 1 7,709 1 7,707 1 7,714 1 7,728 1 7,739 1 7,729 1 7,737 1 7,758 1 7,799 1 7,724 1 410 402 1 7,241 1 7,283 1 7,326 1 7,388 1 7,410 1 7,453 1 7,495 1 7,537 1 7,580 1 7,622 1 7,684 420 403 1 7,664 1 7,707 1 7,749 1 7,792 1 7,784 1 7,876 1 7,919 1 7,961 1 8,004 1 8,046 1 8,048 1 8,313 1 8,173 1 8,275 1 8,256 1 9,188 1 9,198 1 9,199 1 7,991 1 8,048 1 8,889 1 8,989		-					-			_			
340 1 13,674 1 13,915 1 13,957 1 13,999 14,041 14,083 14,125 14,167 1 4,208 1 4,250 1 4,227 1 3,00 30 14,712 1 4,754 1 4,766 1 41,836 1 44,801 4 15,90 1 45,681 4 15,90 1 5,132 360 14,712 1 14,754 1 4,766 1 41,838 1 4,880 14,922 14,964 1 5,006 15,048 15,090 1 5,132 360 370 15,132 15,174 1 5,216 1 5,258 1 5,300 1 5,342 1 5,364 1 5,426 1 5,468 1 5,510 1 5,552 370 380 1 5,574 1 6,161 6 16,058 1 6,100 1 6,142 1 6,164 1 6,227 1 6,269 1 6,311 1 6,353 1 6,393 1 6,040 1 6,355 1 6,438 1 6,460 1 6,525 1 6,544 1 6,607 1 6,649 1 6,691 1 6,311 1 6,353 1 6,395 1 6,438 1 6,460 1 6,525 1 6,544 1 6,607 1 6,649 1 6,691 1 6,733 1 6,776 1 6,818 400 1 6,363 1 6,400 1 6,363 1 6,400 1 6,508 1 17,400 1 7,453 1 7,455 1 7,527 1 7,530 1 7,522 1 7,540 1 7,520 1					_						_		
360 14,292 14,334 14,376 14,418 14,460 14,502 14,544 14,586 14,628 14,670 14,712 350 370 15,132 15,174 15,216 15,258 15,800 15,342 15,304 15,006 15,048 15,090 15,132 380 370 15,132 15,174 15,216 15,258 15,300 15,342 15,304 15,426 15,486 15,507 15,552 370 380 15,552 15,594 15,636 15,679 15,721 15,763 15,805 15,847 15,889 15,931 15,974 380 390 15,974 16,016 16,058 16,100 16,142 16,184 16,227 16,269 16,311 16,353 16,376 394 400 16,395 16,438 16,480 16,552 16,564 16,607 16,649 16,691 16,733 16,776 16,818 40 410 16,818 16,880 16,902 16,945 16,987 17,029 17,072 17,114 17,156 17,197 17,241 14,104 17,105 17,193 17,241 14,104 17,105 17,193 17,241 14,104 17,105 17,193 17,241 14,104 17,105 17,193 17,241 14,105 17,193 17,241 14,104 17,105 17,193 17,241 14,105 17,193	-			_						-			
360 14,712 14,754 14,756 14,838 14,880 14,922 14,964 15,006 15,048 15,090 15,132 360 370 15,132 15,174 15,216 15,258 15,309 15,342 15,342 15,342 15,458 15,501 15,552 370 380 15,574 16,016 16,058 16,100 16,122 16,142 16,144 16,227 16,269 16,311 16,353 16,395 390 15,974 16,016 16,058 16,100 16,122 16,544 16,227 16,269 16,311 16,353 16,395 390 14,974 17,235 17,326 17,384 17,107 17,027 17,114 17,156 17,199 17,241 140 140 16,818 16,860 16,902 16,945 16,997 17,029 17,072 17,114 17,156 17,199 17,241 140 140 17,374 17,326 17,388 17,410 17,453 17,459 17,577 17,580 17,627 17,664 140 18,086 18,131 18,173 18,216 18,258 18,301 18,343 18,385 18,428 18,470 18,513 140 18,088 18,131 18,173 18,216 18,258 18,301 18,343 18,385 18,428 18,470 18,513 140 18,183 19,485 19,485 19,928 19,028 19,023 19,065 19,108 19,150 19,199 19,235 19,276 19,330 19,405 19,481 19,873 19,946 19,539 19,056 19,108 19,150 19,199 19,235 19,276 19,300 19,363 14,004 19,788 19,831 19,873 19,946 19,599 20,001 20,044 20,066 20,129 20,172 20,214 480 19,788 19,831 19,873 19,480 19,533 19,576 19,618 19,661 19,703 19,746 19,788 17,000 12,109 21,152 21,194 21,237 21,200 21,322 21,355 21,407 21,450 21,493 21,555 21,578 21,621 21,664 21,207 21,205 22,555 20,586 20,412 20,575 20,768 20,811 20,851 20,868 20,938 20,981 21,024 21,066 500 20,404 20,683 20,725 20,768 20,811 20,851 20,808 20,938 20,981 21,024 21,066 500 21,199 21,152 21,194 21,237 21,200 21,322 21,355 21,407 21,450 21,439 51,556 21,470 21,515 21,578 21,621 21,664 21,576 21,766 21,769 21,769 22,775 24,000 22,042 22,042 22,042 22,042 22,042 22,042 22,045 22,040 22,047 22,0	-			_		-	_		_		_		
370 15.132 15.174 15.216 15.258 15.300 15.342 15.384 15.426 15.486 15.510 15.552 370 380 15.574 16.016 16.058 16.100 16.142 16.184 16.227 16.259 16.311 16.353 16.353 16.355 390 15.974 16.016 16.058 16.100 16.142 16.184 16.227 16.259 16.311 16.353 16.355 36.385 400 16.395 16.438 16.480 16.502 16.554 16.567 17.029 17.072 17.114 17.156 17.1353 16.376 14.401 16.818 16.860 16.902 16.945 16.967 17.029 17.072 17.114 17.156 17.136 17.1241 14.040 17.241 17.283 17.326 17.388 17.410 17.453 17.495 17.537 17.550 17.622 17.664 420 17.241 17.283 17.326 17.386 17.410 17.453 17.495 17.537 17.550 17.622 17.664 420 18.088 18.131 18.173 18.216 18.258 18.301 18.343 18.385 18.428 18.004 18.088 18.131 18.173 18.216 18.258 18.301 18.343 18.385 18.428 18.895 18.938 18.900 18.513 18.490 19.023 19.065 19.108 19.150 19.139 19.235 19.278 19.330 14.040 19.383 18.990 19.023 19.065 19.108 19.150 19.139 19.235 19.278 19.330 14.040 19.383 18.990 19.484 19.490 19.533 19.576 19.681 19.661 19.703 19.746 19.768 19.044 19.066 12.109 20.155 20.268 20.242 20.385 20.427 20.470 20.512 20.555 20.598 20.640 490 20.244 20.265 20.063 20.725 20.768 20.811 20.833 20.896 20.938 20.981 21.024 21.066 500 10.1066 21.109 21.152 21.154 21.237 21.200 21.322 21.325 21.407 21.452 21.495 16.505 16.00	-					_			_		_		
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HMC1001/1002 SPECIFICATIONS

Characteristics	Condition s [±]	Min	Тур	Max	Units
Bridge Elements					
Supply	Vbridge (Vb) referenced to GND	19	5.0	12	Volts
Resistance	Bridge current = 10mA per bridge	600	850	1200	ohms
Operating Temperature	Ambient	-55		150	°C
Storage Temperature	Ambient, unbiased	-55		175	°C
Field Range	Full scale (FS) - total applied field	-2		+2	gauss
Linearity Error	Best fit straight line ± 1 gauss ± 2 gauss		0.1 1.0	0.5 2.0	%FS
Hysteresis Error	3 sweeps across ±2 gauss		0.05	0.10	%FS
Repeatability Error	3 sweeps across ±2 gauss		0.05	0.10	%FS
S/R Repeatability	Output variation after alternate S/R pulses Vb =5V, I _{SR} = 3A		2)	100	μV
Bridge Offset	Offset = (OUT+) - (OUT-) Field = 0 gauss after Set pulse, Vb = 8V	-60	-15	+30	mV
Sensitivity	Set/Reset Current = 3A	2.5	3.2	4.0	mV/V/gauss
Noise Density	@ 1Hz, Vb=5V	8	29		nV/sqrt Hz
Resolution	10Hz Bandwidth, Vb=5V		27		μgauss
Bandwidth	Magnetic signal (lower limit = DC)	•;	5		MHz
Disturbing Field	Sensitivity starts to degrade. Use S/R pulse to restore sensitivity.	5			gauss
Sensitivity Tempco	T_A = -40 to 125°C, Vb=8V T_A = -40 to 125°C, Ibridge=5mA	-0.32	-0.30 -0.06	-0.28	%/°C
Bridge Offset Tempco	T _A = -40 to 125°C, No Set/Reset T _A = -40 to 125°C, With Set/Reset		±0.03 ±0.001		%/°C
Bridge Ohmic Tempco	T _A = -40 to 125°C		0.25		%/°C
Cross-Axis Effect	Cross field = 1 gauss, Happlied = ±1 gauss With set/reset		±3 ±0.5		%FS
Max. Exposed Field	No perming effect on zero reading			10000	gauss

Figure A.6.5. Caractéristiques du capteur magnétorésistif utilisé <u>Source</u>: d'après Honeywell Microelectronics & Precision Sensors

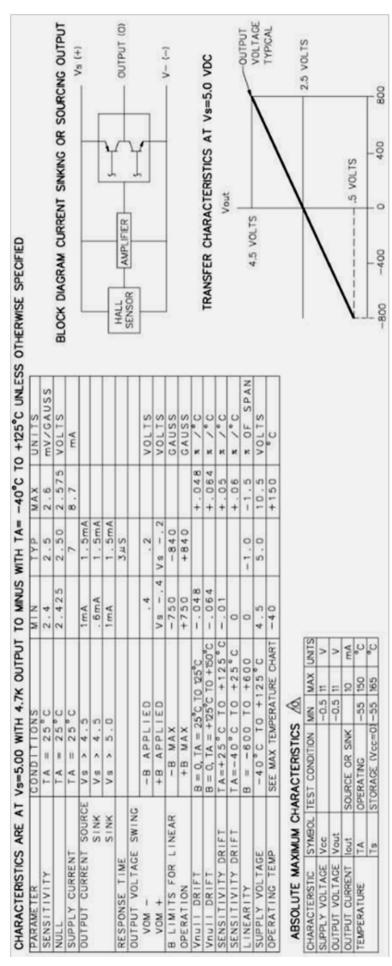


Figure A.6.6. Caractéristiques du capteur à effet Hall utilisé



7. COOL & QUIET

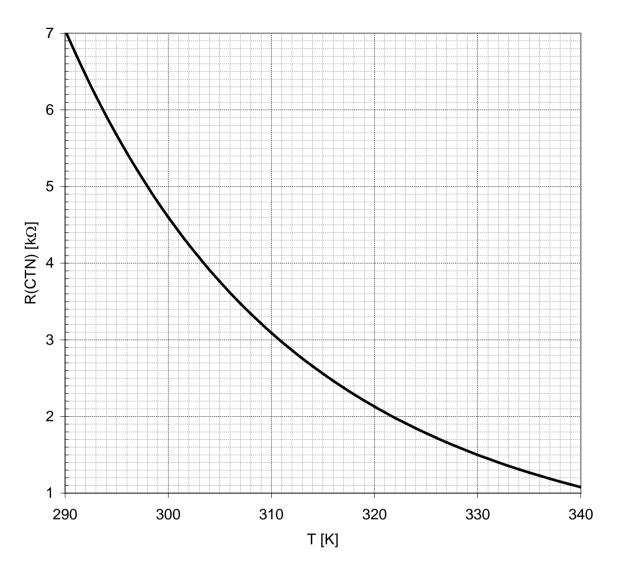


Figure A.7.1. Résistance de la sonde CTN utilisée en fonction de sa température.

8. UN OPACIMÈTRE POUR BEER & LAMBERT – APPLICATION : DÉTECTION DE GAZ

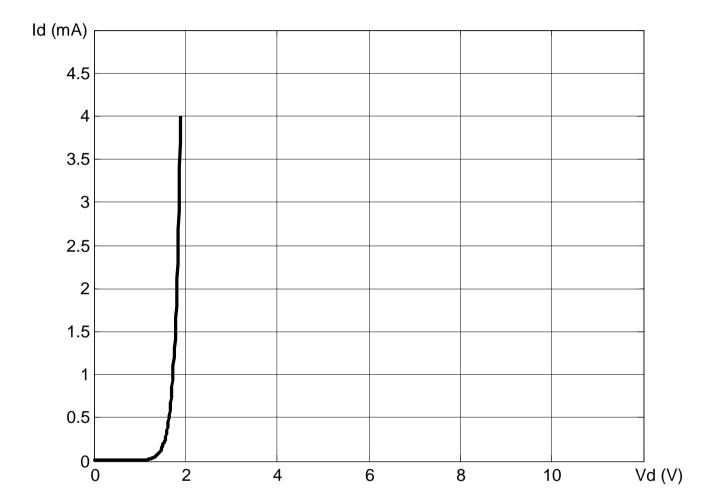
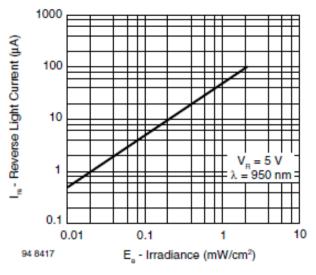
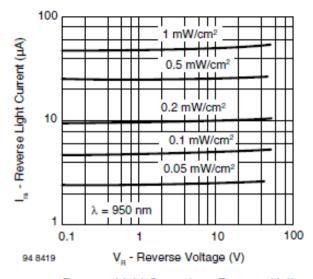


Figure A.8.1. Caractéristique de la LED utilisée







Reverse Light Current vs. Irradiance

Reverse Light Current vs. Reverse Voltage

a)

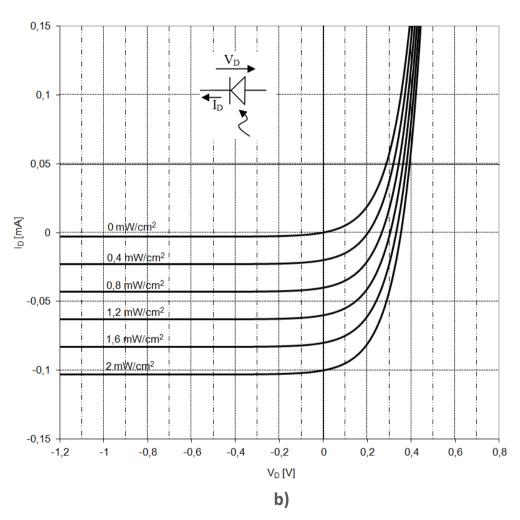
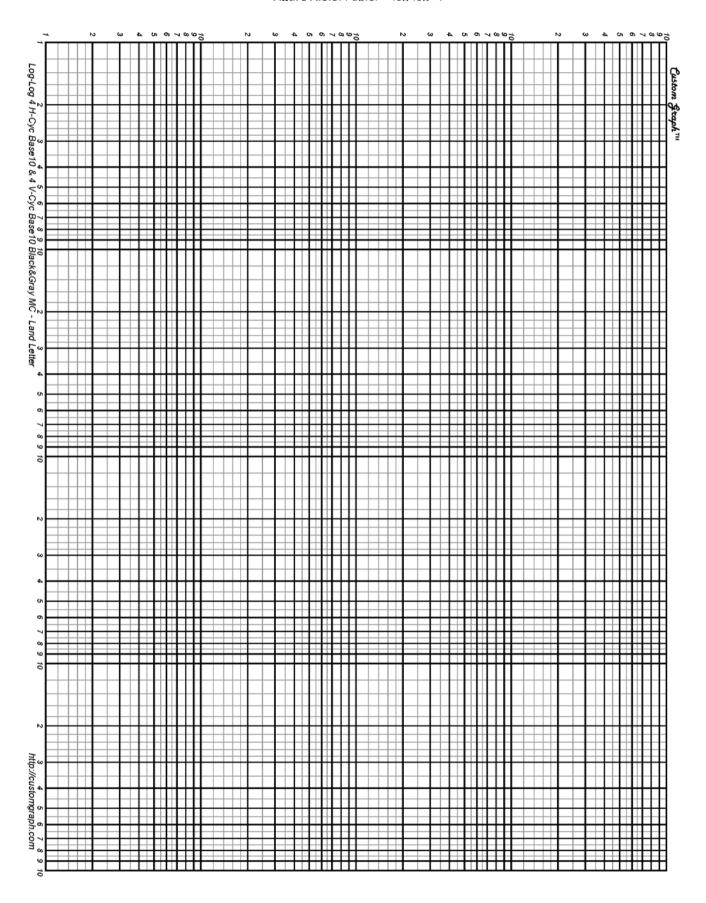


Figure A.8.2. Caractéristiques de la photodiode BPW34 (fabricant : Vishay)

- a) Extrait de la notice technique (datasheet) de Vishay
- b) Extrapolation libre de la notice technique.

NB: Les caractéristiques de la notice technique sont données à la longueur optimale 950 nm (infrarouge proche). Or la LED émet dans le rouge (environ 630 nm), les performances sont donc un peu moins bonnes tout en restant dans les mêmes ordres de grandeurs.

Figure A.8.3. Papier « log-log ».





9. CIRCUITS DE CONDITIONNEMENT POUR CAPTEURS DE DÉFORMATION

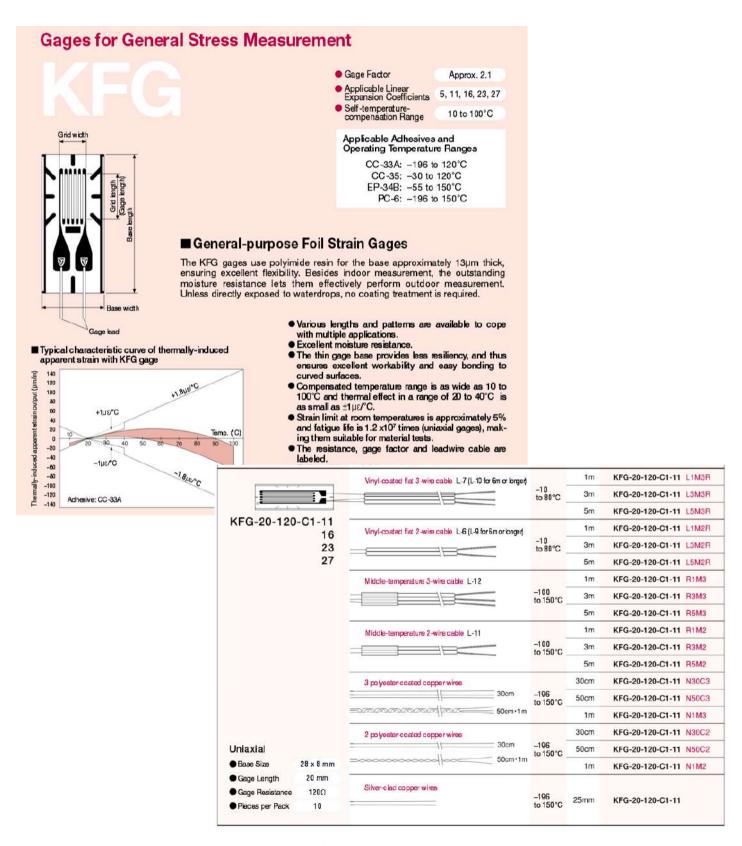


Figure A.9.1. Caractéristiques de la jauge KFG 20-120-C1-11. Source : d'après le fabricant Kyowa