



**MINISTÈRE
DE LA TRANSITION
ÉCOLOGIQUE**

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FRENCH CLASSIFICATION OF PENSTOCKS AND THE PERIMETER OF RISK ANALYSIS

Florent BACCHUS
PoNSOH (Bureau of Hydraulic Safety)
DPT OF RISK PREVENTION

Sources of the French Safety Regulation about Penstocks

2000 : 2 successive accidents occurred

- 12/12/2000 Cleuson-Dixense (Switzerland) 3 missing persons, disaster noted by the watch cell of the Ministry
- 14/12/2000 Licq Atherey (France) Technicians threatened + 2 HPP nearby struck by mudflow

The French administration focused about penstock accidents

2000-2010 1 or 2 incidents / year
mainly on ageing facility

Risks not under control

Objectives of the new Regulation

- **Improve / Guaranty penstock Safety**
for either existing penstocks and future ones
- **Designate the persons in charge**
 - The owner (*for legal, financial and organizational aspects*)
 - Accredited engineering offices (*for technical aspects*)
- **Inscribe specifically penstock Safety Requirements & State : How to satisfy such requirements ?**
 - Safety Review Risk Assessment
(*SaRRA, FR : étude de dangers - EDD*)

Existing penstocks may
be dangerous now

Same objectives as
dam safety regulation
inscribed in the law
2015-536

Why Safety Review Risk Assessment ?

- Each known accident/incident was analyzed
(cf. my last April 2021 presentation about the French data-base about incidents related to penstocks more than 60 cases)

- => Many reasons involved in failures

Ageing (corrosion, abrasion) of metal sheet, rivets, forged weld

Ageing of equipment (drifting, seizing)

Ice during winter ... Heat during summer

Geology (sliding)

Hydrology (mud flows)

Gate malfunction

Piping connections

Insufficient surveillance or monitoring or maintenance

Decreasing of skills ...

**Larger than a technical
standard,**

**Need to develop
Specific methodologies
New Law 2021-1902**

Which penstocks are interesting ?

1/4

- Each known accident/incident was analysed

The incidents locations (relevant perimeter and parameters)

=> Failures occurred **everywhere on the network** from the gallery to the turbine

- Both gallery and penstocks should both be included in the perimeter
- Main gallery weaknesses are geological faults and visit access
- All the Equipment (which may initiate or mitigate the risks) should be taken account
- Less failures occurred from steel lined pressure shafts
- “Luckily” (?) few chain failures of parallel penstocks, but may have been worse

Which penstocks are interesting ?

2/5

The consequences of incidents (relevant parameters)

- **Head**

- Increasing head = Increasing consequences

- Down : high pressure, locally very dangerous,
large flow, close to the river

short range effect

- Up : low pressure, locally “less” dangerous
large drop, far from the river

large range effect

*Never forget
the mud flow effect*

*(the French more dangerous recent incident concerned a gallery
containing 100m pressure for 1250m total head
spread over many kilometers long)*

- Intermediate : a combination of previous effects

Which penstocks are interesting ?

3/4

The consequences of incidents (relevant parameters)

- **Head**
- **Diameter**
 - Increasing diameter = Increasing consequences
 - Flow proportional to diameter

Parallel branching and potential chain failures

=> Define “Equivalent Diameter (De)” as “same total cross section”

Which penstocks are interesting ?

4/4

The consequences of incidents (relevant parameters)

- **Head**
- **Diameter**
- **Persons at risk**
 - More mobile people at risk from high head penstocks
 - More settled people at risk from medium and low head penstocks

Easy to estimate
before driving the
risk analysis

Difficult to estimate
before driving the
risk analysis

French regulatory definition of penstock

Arbitrations of law 2021-1902

*Code de l'environnement R214-112-1
+ Arrêté 29/12/2021*

- **Hydropower pipes... or other authorized water collection
if large and risky dimensions**

3 main purposes of penstock explicitly quoted :

- flow going downstream to the turbines
- flow go upstream from pumps
- pipes of water conveyance crossing a valley

French regulatory definition of penstock

Arbitrations of law 2021-1902

*Code de l'environnement R214-112-1
+ Arrêté 29/12/2021*

- **Hydropower pipes... or other authorized water collection if large and risky dimensions**

3 main purposes of penstock explicitly quoted
include explicitly **main equipment and specific points**

- Surge tanks
- Valve
- Manhole, watertight doors
- Discharge branch or pipe
- Gates
- Pillars
- Piping connections
- Automatism
- Power supply
- Turbine/pump housing

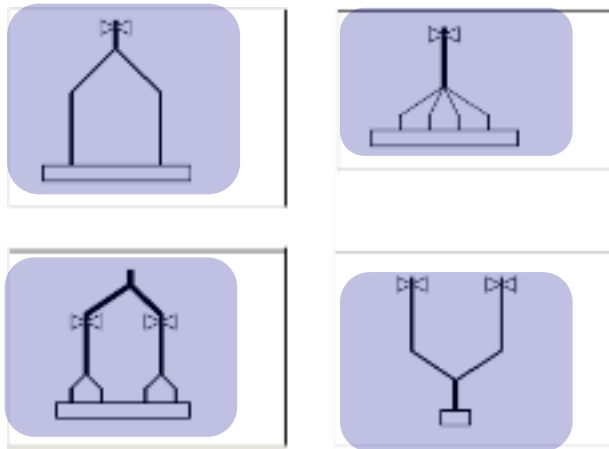
French regulatory definition of penstock

Arbitrations of law 2021-1902

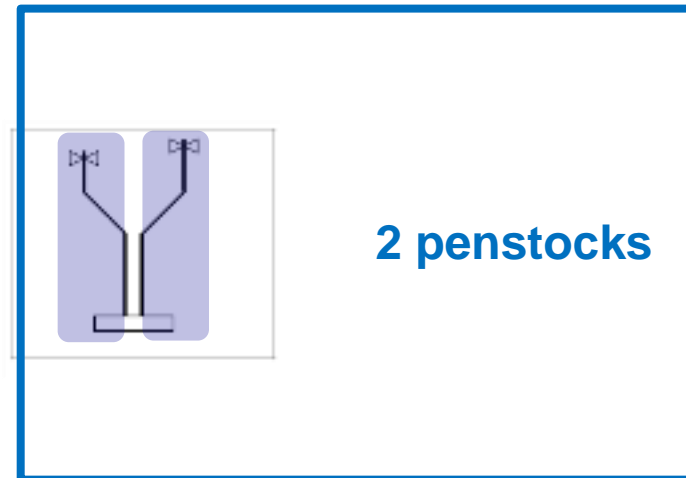
Code de l'environnement R214-112-1
+ Arrêté 29/12/2021

- Hydropower pipes... or other authorized water collection
- 1 pressure network (branched gallery + branched penstocks) = 1 penstock

1 penstock



2 penstocks



French regulatory definition of penstock

Arbitrations of law 2021-1902

*Code de l'environnement R214-112-1
+ Arrêté 29/12/2021*

- **Hydropower pipes... or other authorized water collection**
- **1 pressure network (branched gallery + branched penstocks) = 1 penstock**
 - Starting point(s) : as soon as gallery or pipe no more open channel flow
 - Final point(s) : as soon as free flow conditions
(spear and nozzle (for Pelton) and turbine housing)
 - Include every equipment between starting and final points

French regulatory definition of penstock

Arbitrations of law 2021-1902

*Code de l'environnement R214-112-1
+ Arrêté 29/12/2021*

- Hydropower pipes... or other authorized water collection
- 1 pressure network = 1 penstock
- 4 classes of penstock : **A, B, C, D**

Geometrical parameter : Maximum{H x De} above the network

- H : Head (m)
- De : Equivalent Diameter (m)
- Minimum Head : $H > 30\text{m}$

French regulatory classification of penstock

Arbitrations of law 2021-1902

Code de l'environnement R214-112-1
+ Arrêté 29/12/2021

Maximum{H x De} along the network Thresholds

Typology	Classe A	Classe B	Classe C	Classe D
Purely Steel lined pressure shafts	1400	1000	500	350
Other conception and none branched penstocks or individual branch for branched penstock	1400	700	350	250
Other conception and branched penstocks	1400	900	450	350

Proportionate SaRRA

Arbitrations of law 2021-1902

*Code de l'environnement R214-115+116
+ Arrêté 21/01/2022*

- **Mandatory (or not ?) Safety Review Risk Assessment**
 - Mandatory for class A, B and C penstocks
 - Case by case for class D penstocks
(neighbor penstocks which may be as risky as class C or B penstocks)
- **2 Levels of SaRRA**
 - Simplified SaRRA for class C&D penstocks, if less than 25 persons at risk
some technical requirements
 - (“Normal” or “Detailed”) SaRRA for class A& B and other class C&D penstocks

Schedule for SaRRA

Arbitrations of Law 2021-1902

Code de l'environnement R214-117

- **1st SaRRA of existing penstocks**
 - 31/12/2025 Class A next every 10 years
 - 31/12/2030 Class B next every 10 years
 - 31/12/2032 Class C or D next every 20 years
- **1st surveillance report of existing penstocks**
 - 31/12/2023 Class A&B
 - 31/12/2025 Class C&D

Last details and exceptions

Arbitrations of Arrêtés 29/12/2021 + 21/01/2022

- **Some technical details and exceptions to measure HxDe**
 - Head = Static head
 - Bottom branches should not artificially upgrade the class
 - Limit distance for De : 20m distance between branches
 - **Some administrative exceptions to drive couple analysis**
 - HPP in dams : coupling Dam SaRRA and Penstock SaRRA
 - Neighbour penstocks : possibility to establish only one SaRRA for 2 or more regulatory penstocks
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Bibliography

Décret n° 2021-1902 du 29 décembre 2021 relatif à la sécurité des ouvrages hydrauliques autorisés, déclarés ou concédés en application du code de l'environnement ou du code de l'énergie

<https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000044637932>

Arrêté du 29 décembre 2021 précisant les classes des conduites forcées visées à l'article R. 214-112-1 du code de l'environnement

<https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000044638687>

Arrêté du 21 janvier 2022 précisant le contenu des études de dangers des conduites forcées et des barrages

<https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000045113469>

Thank you

May I answer questions ?
