CNGS Horns

- Introduction
- Design
- «Remote»
- Timing tests

Horn exchange
- Striplines
- Procedure
- Exchange Exercise
Introduction

Electrical Pulse Timing

Beam Extraction
2.4x10^{13} p.p.p.

Flat top
0.01ms

150 kA
180 kA
Introduction

- Weight ~1.2t (Reflector: 1.8t)
- 7 meters long, inner & outer conductor
- Upper frame (exchange) & lower frame (align)
- Electric (manual) & water connections (automatic) at downstream end
Inner conductor

- Thickness 1.8 mm
- Aluminum grade 6082
- 9 machined sections
- Electron beam welds

Support Points (3)
3x3 grooves in inner conductor
S. Steel cables
Insulator
Outer conductor

Heat load horn:
15 kW (Joule)
+ 6 kW (beam)

Cooling through top sprayers, 1.2 bar

Magnetic field:
Max. 1.5 Tesla
Designed for remote handling

Pre-guiding elements, cameras, remotely steered crane, cameras, plug-in water connection...

Pre-guiding upper frame vs. lower frame

Crane with coordinates

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Plug-in Water Connection

To sprayers

Fixed to horn

Leak

Seal

Fixed to lower frame

From side gallery

From water collector

To side gallery

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Grafoil seals

Grafoil seal
- 98% pure graphite
  → Resists high radiation
- Needs only ~5MPa contact pressure

Other applications:
- Two way-valve with spherical graphite seal (switching between water feed circuits)
- Seal between insulating glass disk and plates of electrical connection ("glass disk assembly")

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Decoupled Frames

Seal contact force (from spring) = 2000N

To absorb force

- Need for rigid frames
- Fix collector tube to rigid upper frame

In case of horn exchange

Goes away with horn
Stays in place

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Installation

Fast Coupling Connection (horn exchange)

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Timing: Vibration tests
(courtesy of R. Wilfinger CERN/TU Vienna)

Natural frequency horn: 149Hz (reflector: 73Hz)

- Data collected for future study of effect of
  - Cooling water temperature
  - Glass disk assembly
Vibration tests
(courtesy of R. Wilfinger CERN/TU Vienna)

→ Optimum of 50ms gap for horn
(less fragile reflector: optimum @48ms, +20%@50ms)

During electrical tests:

Electrical Pulse Timing

Vary from 46ms to 52ms,
Measure response

Æ Optimum of 50ms gap for horn
(less fragile reflector: optimum @48ms, +20%@50ms)
Timings: pulse start

During commissioning:

**Electrical Pulse Timing**

Vary from -2ms to 2ms w.r.t. nominal, Measure muons

**Conclusion of successful commissioning (400000 pulses):**

CNGS Horn design validated

(glass disk, water circuit, inner conductor, …)
Horn exchange

Fatigue → Life time of horn (95% confidence):
20 million pulses = 5 years

Highly radioactive zone:
→ Maximize remote & automatic
   → Minimize dose

→ Define detailed procedure (interaction with RP(*) experts)
→ Do complete exercise (realistic conditions)
→ Documentation (photo, film) is extremely important!

(*) Radio Protection
Define procedure

Design phase: Optimization with respect to dose
Experience → First draft of procedure
Input to HAZOP study (*)
  → main remaining risks identified
New version written with input from study & experts
  (radioprotection, handling, transport, …)
Tools designed, produced & tested
Steps were tested & timed → optimisation
100% remote handling (shielding):
  Tested → coordinates noted down in worksheets

→ Updated procedure = script for exercise

(*) Hazard & Operability study
Striplines

- 16m long aluminum plates
- 8 plates of 12mm each
- 8mm isolating rings between plates
- Cu/Ag for flexible link sections

Electrical connections:
- Fast coupling connection
- Stripline link section

500V/150kA
Horn exchange procedure

- Disconnect Fast Coupling
- Take out Stripline Link
- Move stripline (open)
- horn disconnected
- Open shielding
  (roof & side wall)
- Exchange horn remotely
- Close shielding
- Move stripline (close)
- horn reconnected
- Put Stripline Link back
- Connect Fast Coupling
Disconnect Fast Coupling

Fast Coupling

Stripline Link
(rigid plates)
(with shielding in place)

before

after

Move stripline down
(open)

→ Fast Coupling is disconnected
Open shielding

before

after

100% Remote

Overhead crane with coordinates

« mushrooms » as guide

Cameras

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Remove old horn & Install new

100% Remote (radioactive)

from: target chamber
to: radioactive storage

50% Remote (clean)

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Close shielding

before

100% Remote

after

Storage blocks

Crane coordinates recorded during exercise

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Connect Fast Coupling

Move stripline up

→ Fast Coupling is closed

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Horn exchange exercise

Final test = complete exchange

- Realistic conditions:
  - Suits, gloves, masks
  - Lighting, location

- Locations photographed (storage, intervention)

- Every step filmed (except if 100% remote)

- Every step timed and observed by RP experts

- With last inputs → final documents

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Conclusion of successful horn exchange:

CNGS Horn exchange procedure validated

Through documentation, tools, mock-up → knowledge remains
“For both ceramics that we have replaced, the ceramic that leaks is mostly hidden behind a shroud, and we have not yet done an autopsy to look directly at what failed.

For what it is worth, we are guessing that the braze joint is corroding or otherwise failing, and are thinking of switching to shrink-fit connection to the ceramics.

The ceramics that we can see directly (the one between horn inner and outer conductors, the ones mounting the stripline, the ones holding the shrouds) look fine other than color changes.

The ceramics were both on water cooling circuits. There is a flex-hose between the ceramic and the water header mounted directly on the horn, so the ceramic is somewhat insulated from the horn vibration, although vibration can still travel through the horn mounting to the hanger bracket and back to the ceramic.”
Short movies

Preview:

Move the Stripline Link (upstream) (2’40’’)

Starring Victor De Jésus
Horn Design

- Isolated Link
- Cradles
- Water Collector
- Upper / Lower frame
- Alignment & Feet
- Coaxial Plug-in
- Water Connection (*)
- Water in / out

(*) remark review 2004

Outlet cooling water
Hazard & Operability study for horn exchange

1) write specification  
   (incl. Horn exchange procedure)
2) make call for tender (at least 5 companies)  
3) choose company, agree on dates

-> agree on sequences in horn exchange procedure  
-> agree on keywords

-> HAZOP meeting (2.5 days)  15-17 June 2005  
-> approve minutes  
-> follow-up on “actions”  
-> review actions (phone conference)  
-> presentation of HAZOP report  2 Sept. 2005
Horn Exchange: Stripline

Fast Coupling: 5 nuts (manual, through shielding)

Stripline Link: 8x10x2 screws (pneumatic in trench)

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