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Spent Fuel Management: Semi-dry storage

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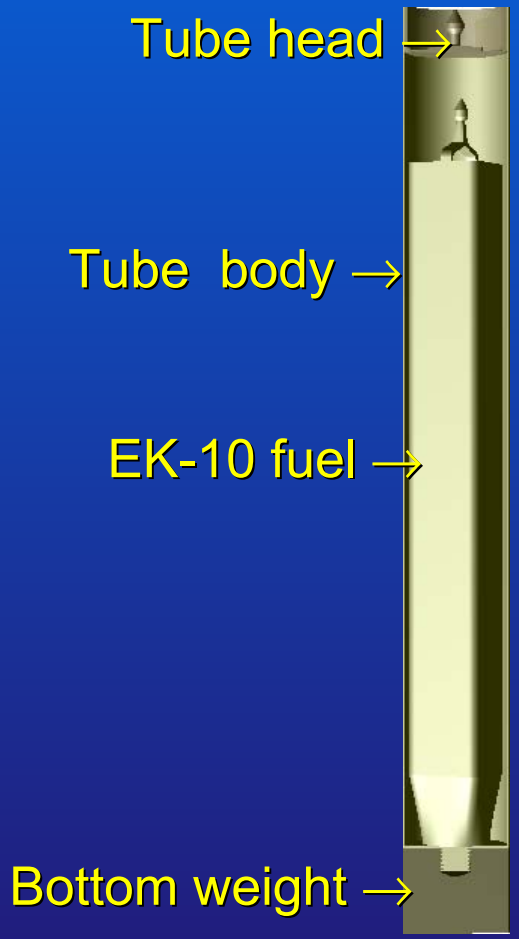
Topics

- NSF's storage practices and problems
- Introduction to the canning technology and equipment
- Canning in practice – movie clips
- Canning results at BRR
- Conclusions

Way to the canning

- **The storage practice**
  - Temporary storage (AR pool→decay+emergency, AFR pool→long time)
  - Wet storage technology (stored under water)
- **The problem → originated from long term wet storage**
  - Wet storage can be intermediate only (oldest for 40 years)
  - Transport: no decision no date (to ship final deposit place)
  - Signs of corrosion appeared
- **What to do? → Decreasing the corrosion process**
  - Change the storage mode *from WET to SEMI-WET*
- **The Solution → Canning**
  - Technology: encapsulation
    - → Placing NSF into a tube, → drying, vacuuming, → filling up with inert gas, → hermetical closing of this package
  - **Requirements:**
    - Ensure +50 years intermediate storage
    - Provide solution for both fuel types
    - Ensure easy monitoring after canning
    - Leave open all ways for final solution

3D-drawings of Canning Tube



Canning

Construction

- Tube construction
- Al-alloy
- Thickness: 3 mm
- Length: 939 mm
- Diameter: ∅ 100 mm

The Canning Equipment

- **Design philosophy:**
  - Easy handling – fuel manipulation before and after canning only → *compact container*
  - Closed technology → *PLC control*
  - Defective canning tube handling → *cropping machine*
  - Leave open all way for final solution → *shipment as package or unpacking*

- **Construction:** compact and mobile construction

1. Canning Unit

- **Canning Cask**
  - Rotating Head
  - Cask Body
  - Transfer Pipe
- **Assembly Trolley**
- **Control Unit**
- **Power Supply**
  - Electrical with UPS
  - Compressed Air
  - Nitrogen Supply System

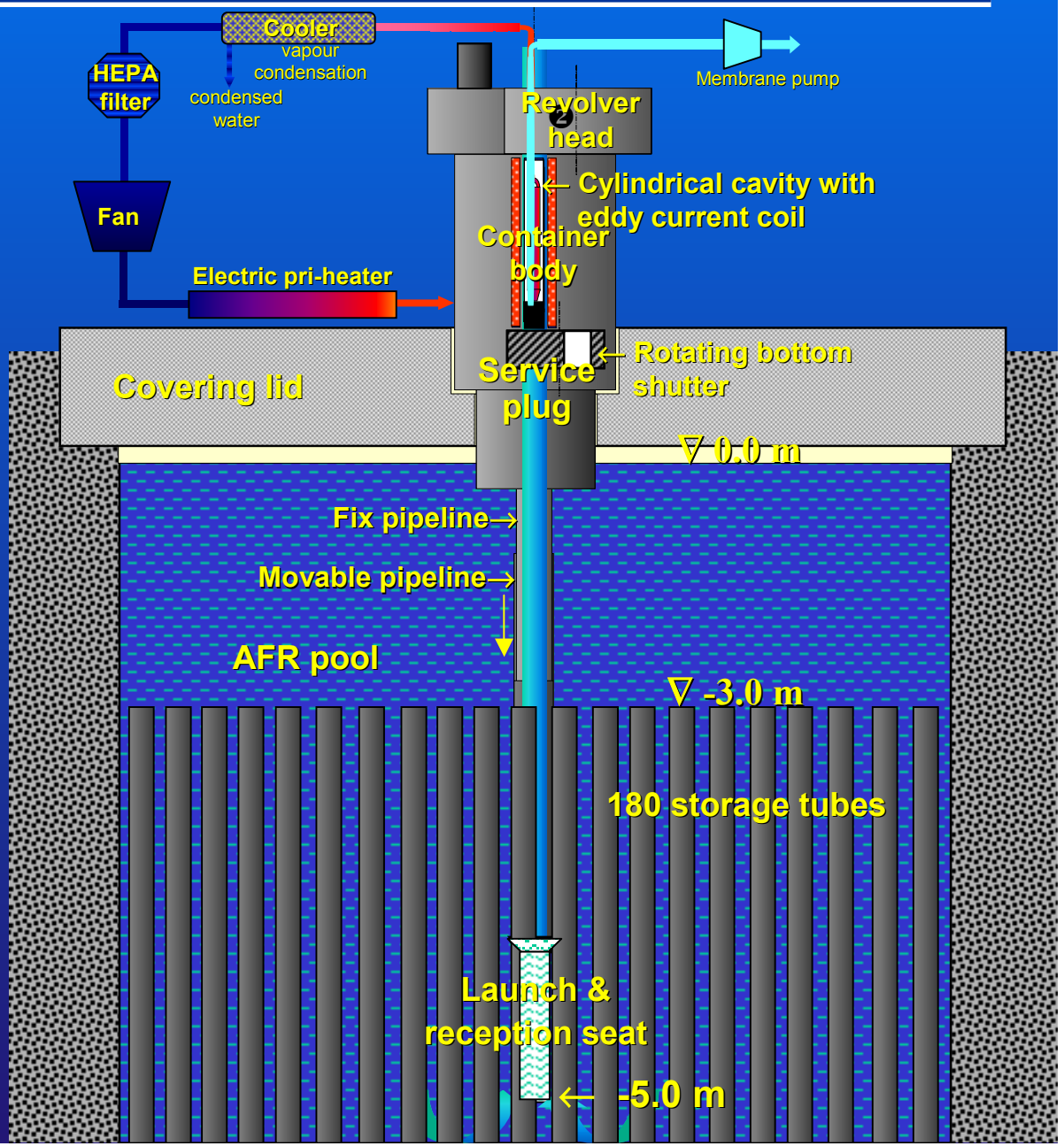
2. Cropping Machine

- **Driving Unit**
- **Cropping Container**
  - Single-fuel nest
  - Triple-fuel nest
  - Tube Body nest

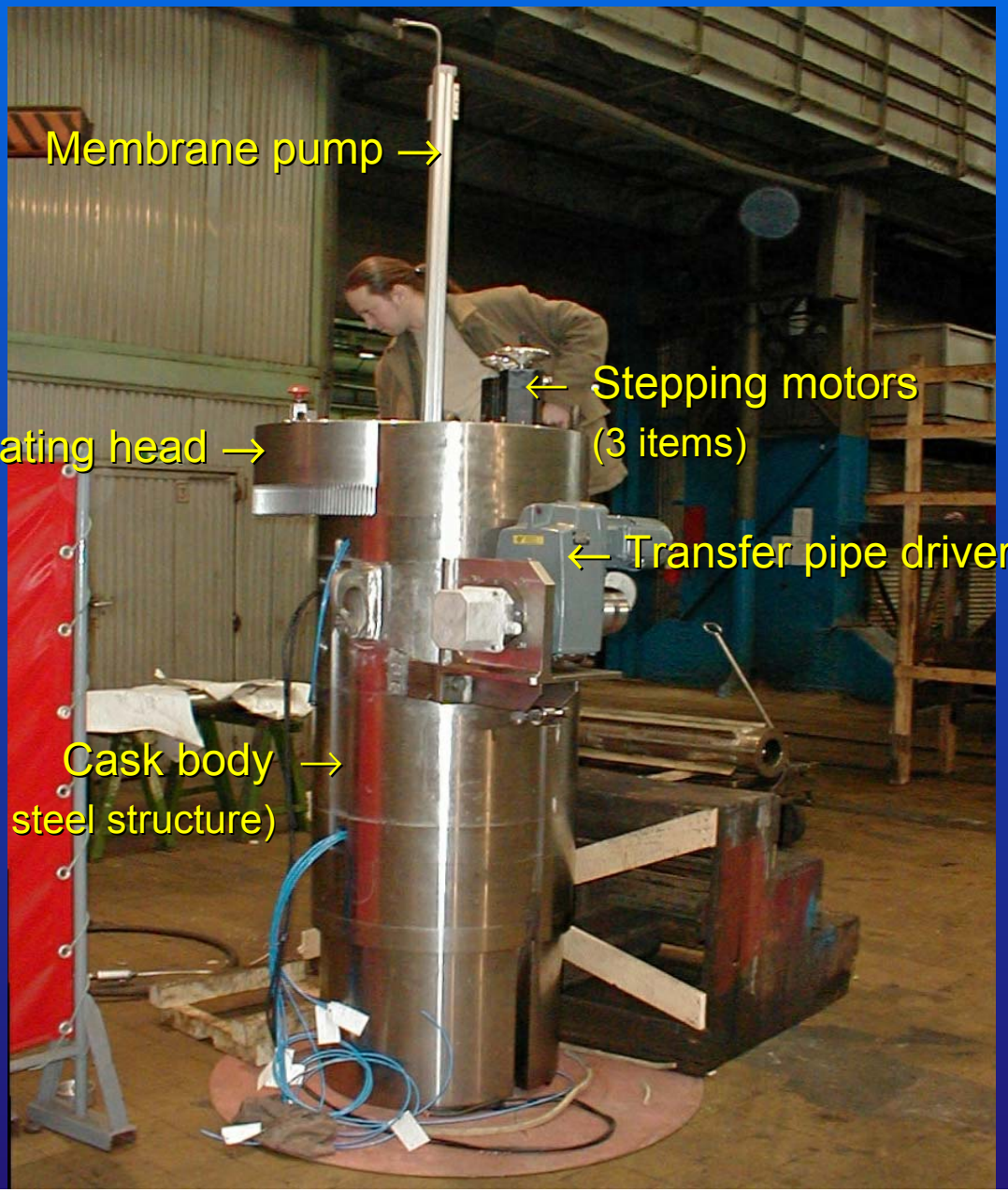
Operation (animated slide)

New ideas

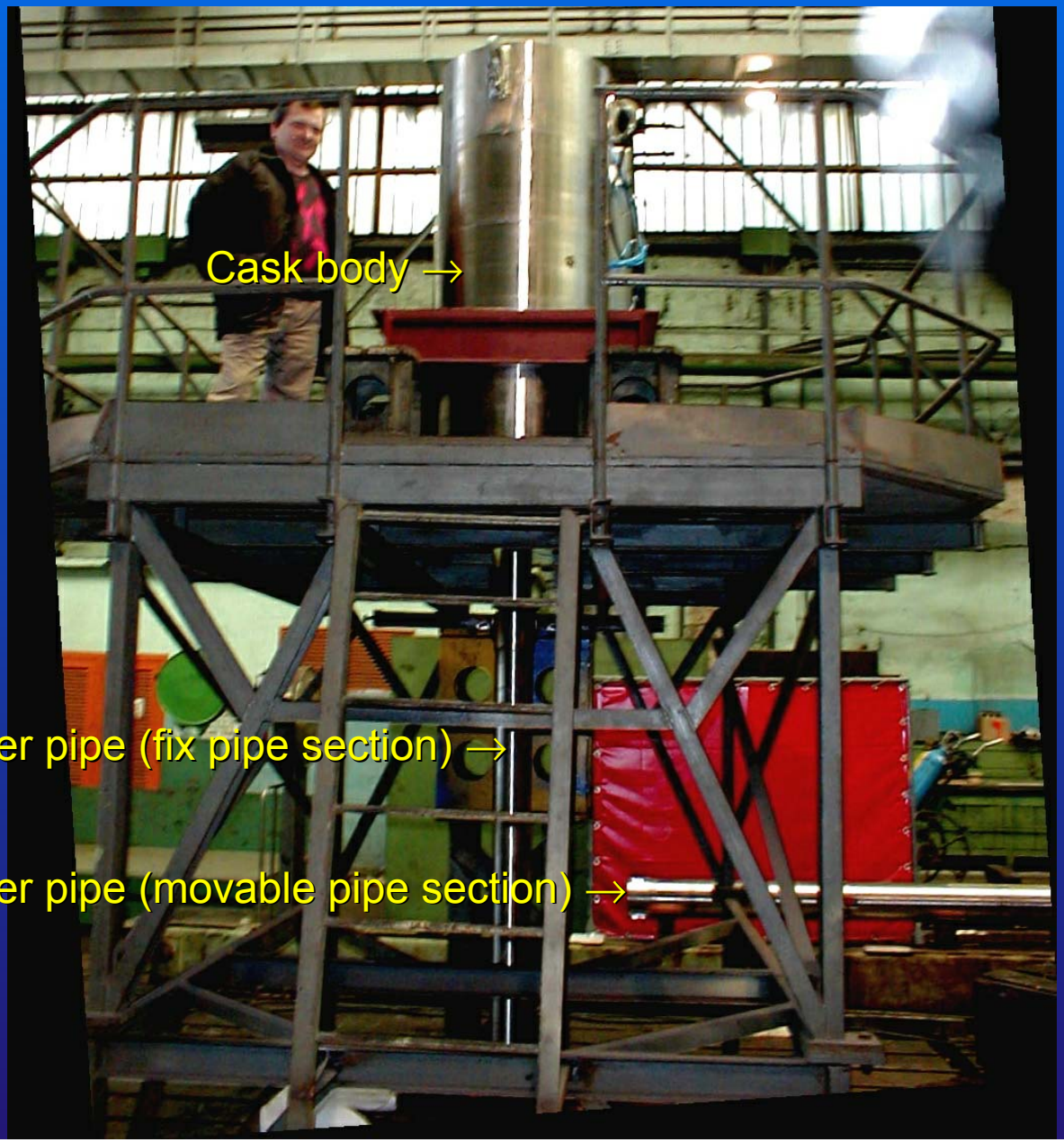
1. Sucking up
2. Heating
3. Rotating head (compact container)
4. Welding under pressurized air (vacuum-tight sealing in the operation chamber of the container)



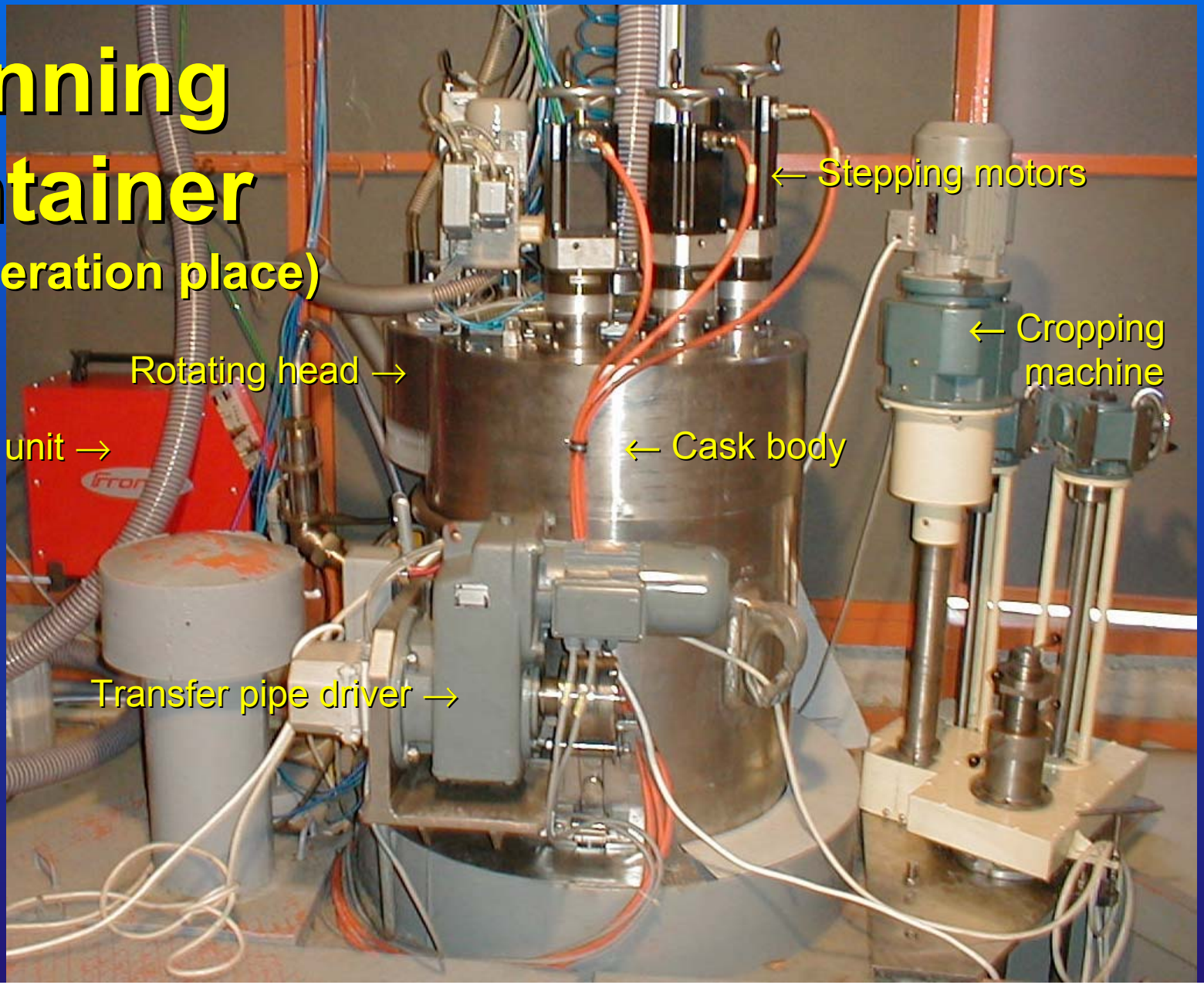
Canning cask
(assembling phase)



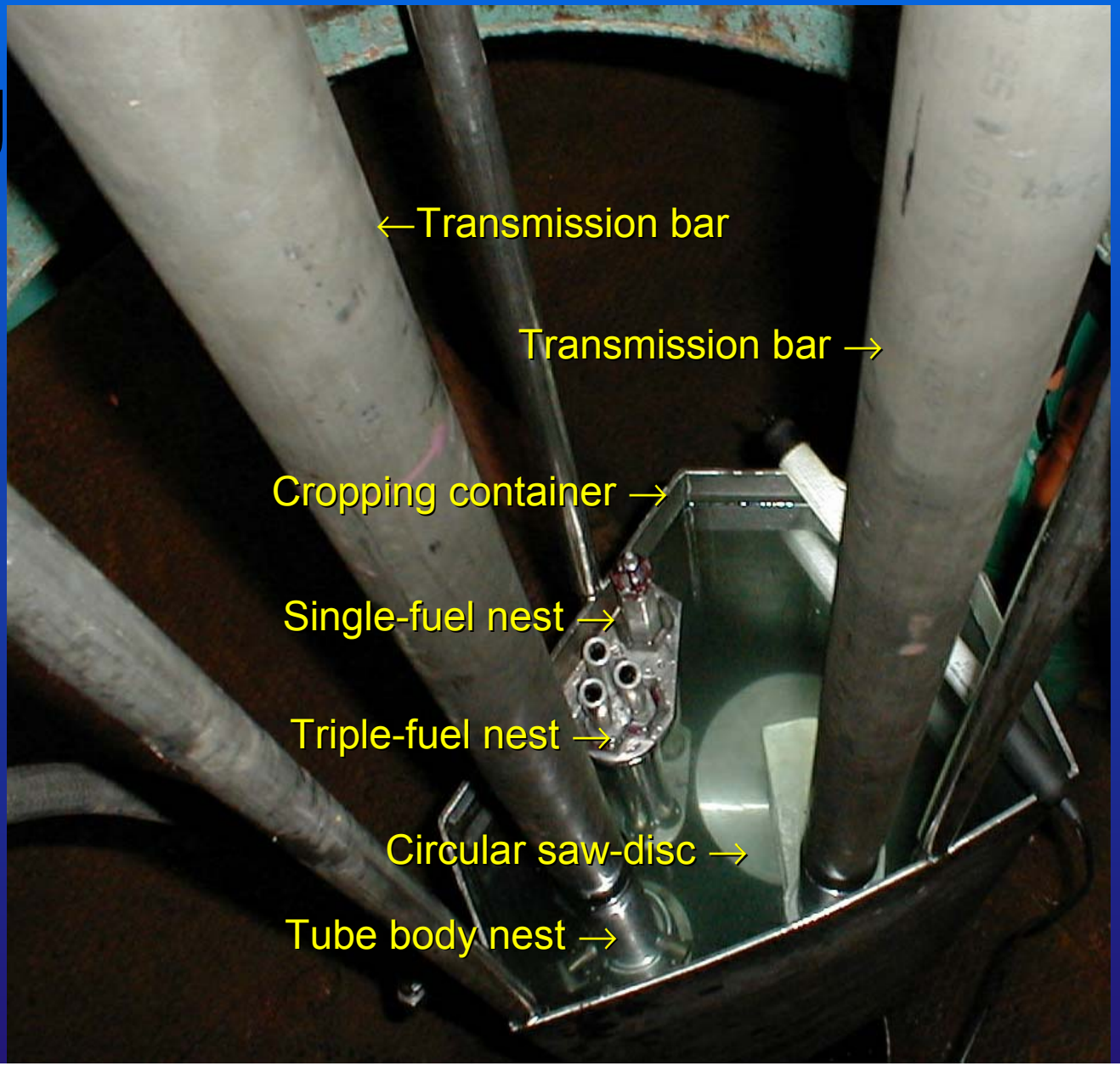
Canning cask
(assembling phase)



Canning container
(on its operation place)



Cropping machine



Canning procedure

Work phases	Activity	Time	Op.M.
Prep. phase	NSF's leg-cutting, capsule & NSF are placed in the reception seat	≈ 20 min.	Manual op.
1st op. phase	float up the capsule with intensive water flow	≈ 3 min.	AUT op. Closed tech-nology chain
2nd op. phase	removing the water from the capsule	≈ 5 min.	
3rd op. phase	drying and maintaining a given heat	≈ 70 min.	
4th op. phase	vacuuming, filling up with nitrogen, and pressing in the capsule head	≈ 8 min.	
5th op. phase	capsule head is secured by welding	≈ 4 min.	
Control phase	welded seam inspected by CCTV, underwater observation (bubble test)	≈ 5 min.	Manual op.
Closing phase	✓ placing to its designated position X opening by cropping machine	≈ 5 min.	
	TOTAL CICLE TIME	≈ 120 min.	

Canning mosaics

➢ Movie clips

From preparation phases

1. *NSF assembly preparation – leg-cutting process (1:17)*
2. *Capsule preparation (1:04)*

From operation phases

3. *1st phase: Float-up phase (0:18)*
4. *2nd phase: Removing the water from the capsule (0:40)*
5. *5th: Welding and control phase (0:58)*
6. *Float back of the package (0:27)*

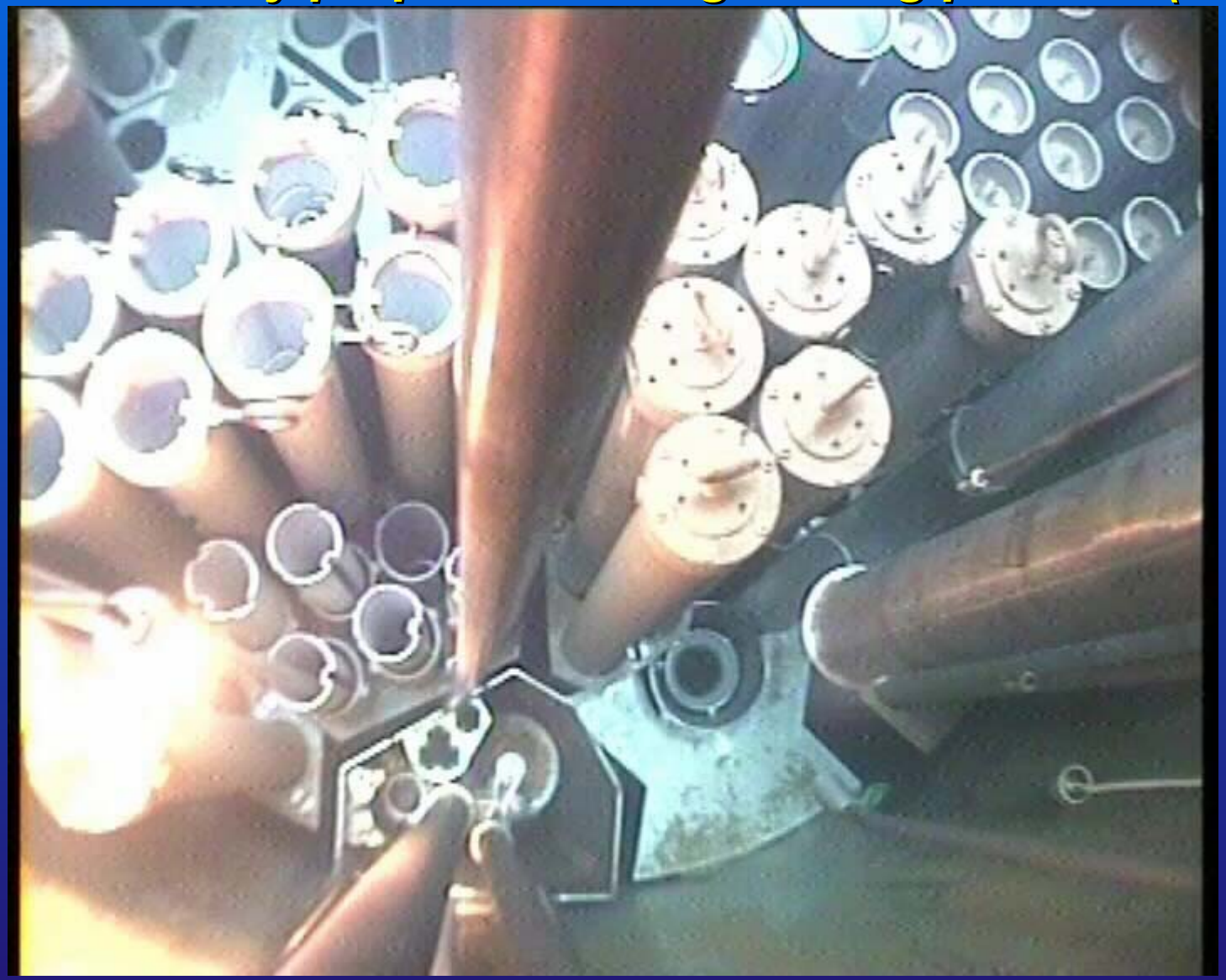
From closing phase

7. *Deposition of the flawless package – 0:56)*

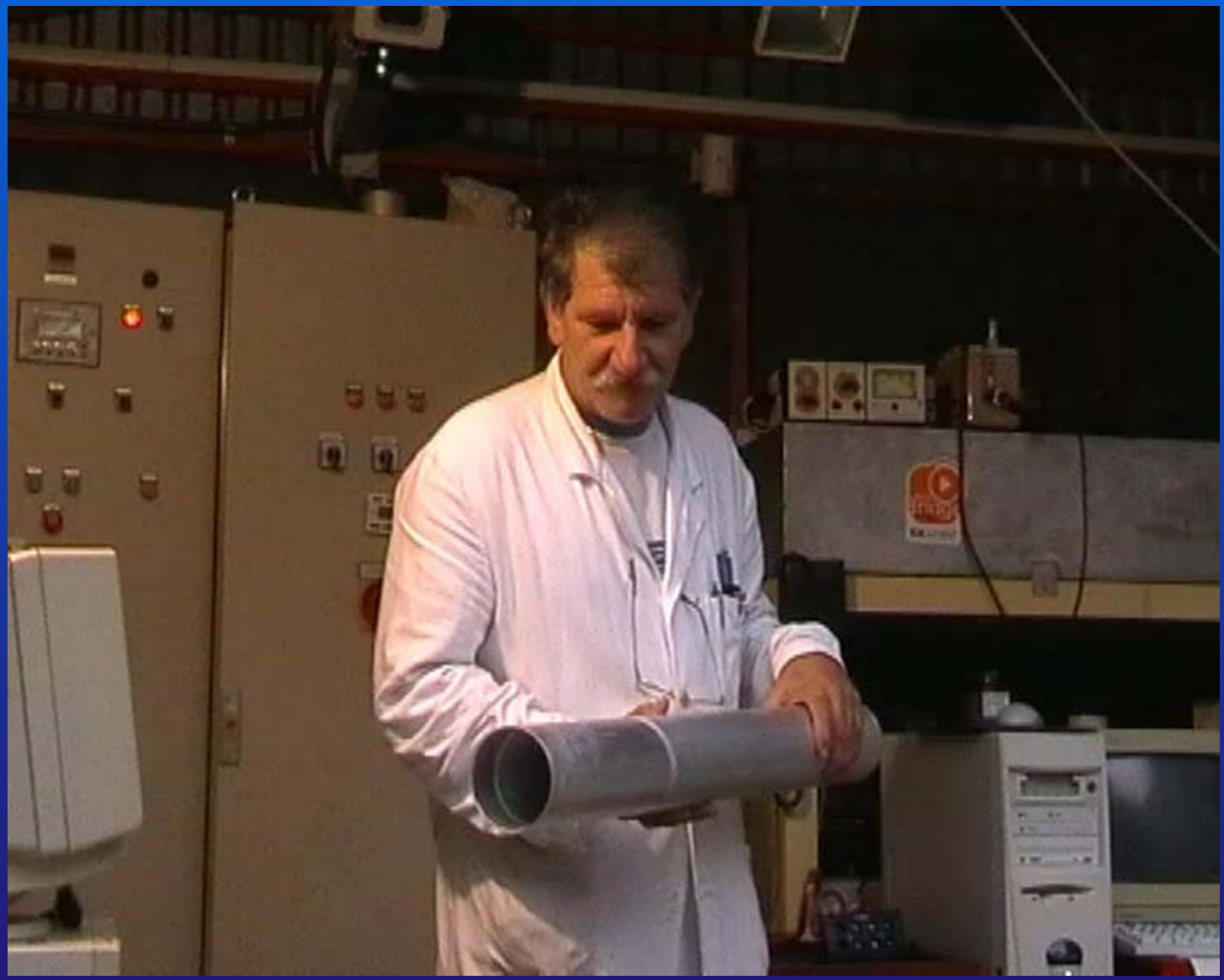
Handling the defective closed capsule

8. *Bubble test and cutting off (2:23)*

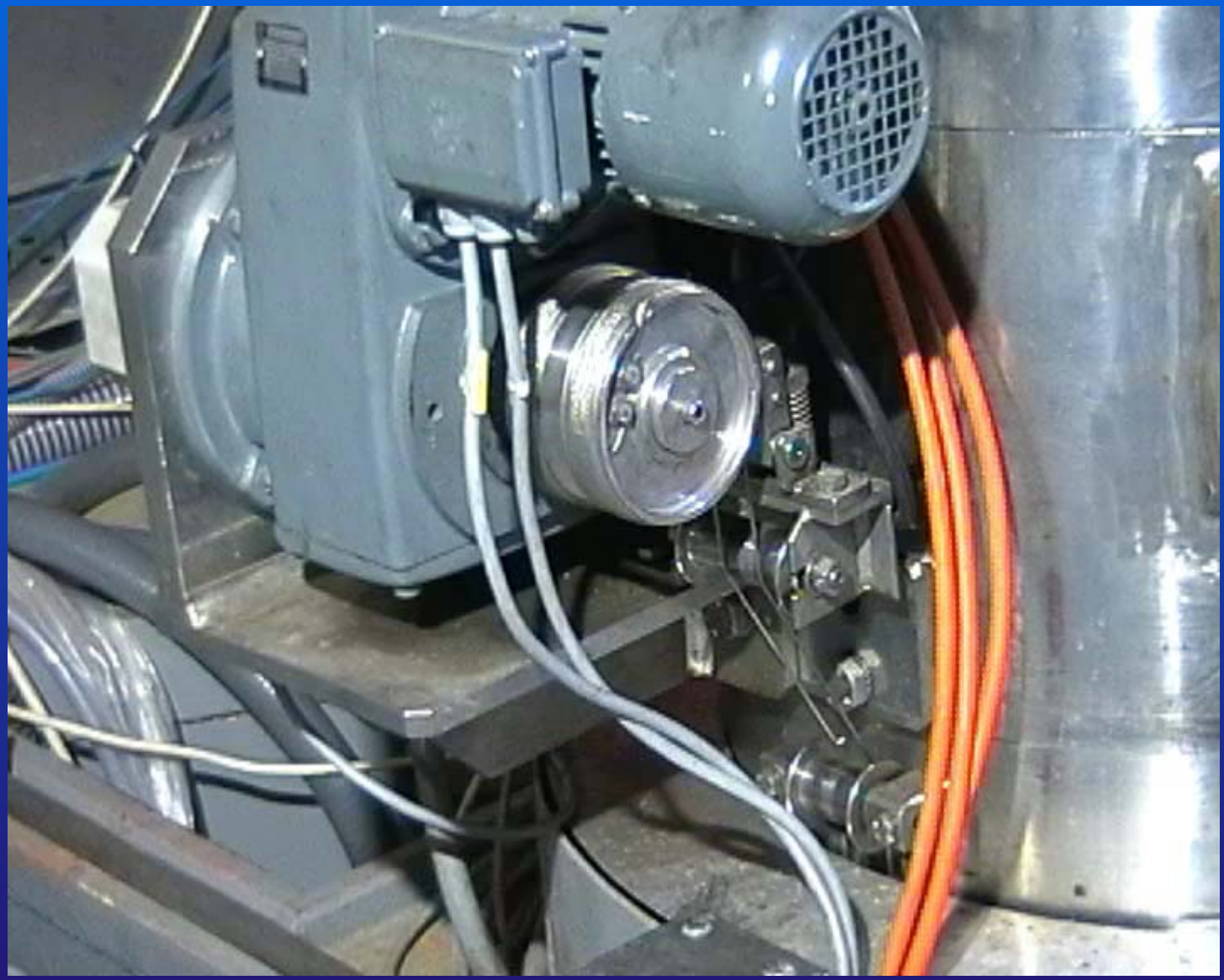
NSF assembly preparation - leg-cutting process (1:17)



Capsule preparation (1:04)



1st phase: Float-up phase (0:18)



2nd phase: Removing the water from the capsule (0:40)

3rd and 4th phases

- **Sorry, no movie clips** ☹

Canning steps are carried out in the operation chamber (no observable)

3rd operation phase:

Drying and maintaining on a given heat

Eddy current heating (48 VAC, 4,5 kVA)

- warming up and min. 40 minutes maintaining on heat (130 °C)
- Total phase time: ≈ 70 minutes

4th operation phase:

Vacuuming, filling up with N_2 and pressing in the capsule head

- Vacuuming < 50 mbar
- Nitrogen: dry nitrogen (N_2 > 99.9999 %; H_2O < 5 ppm), overpressure: 2.5 bar

Steps: vacuuming (3 min.) → filling up with N_2 (1 min.)→ vacuuming (3 min.) → filling up with N_2 (1 min.) → pressing in the capsule head (50 ms) → equal-warming (3 s, shrink fitting)

- Total phase time: ≈ 8 minutes

5th Welding and control phase (0:58)

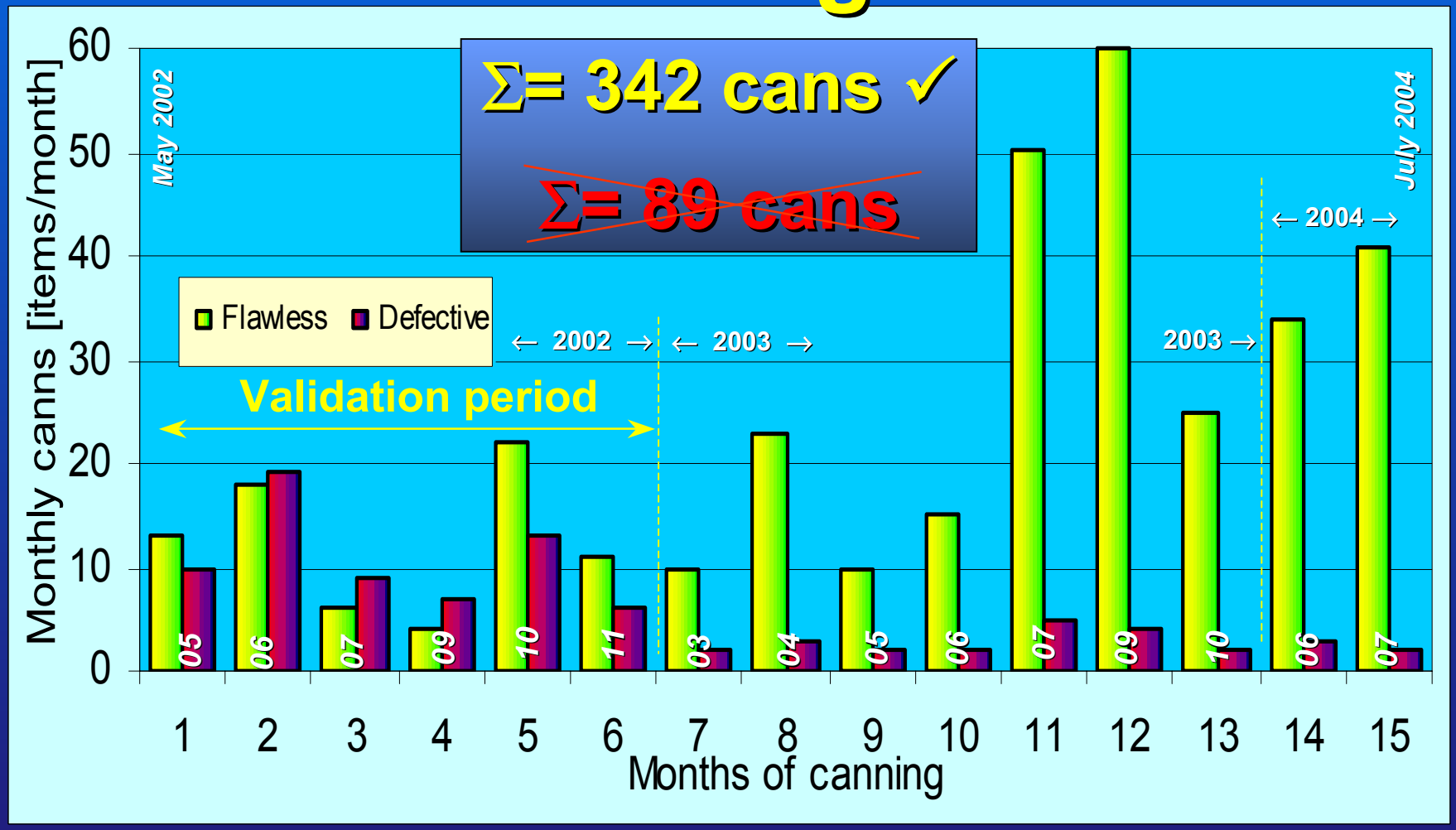
Float back of the package (0:27)

Deposition of the flawless package (0:56)

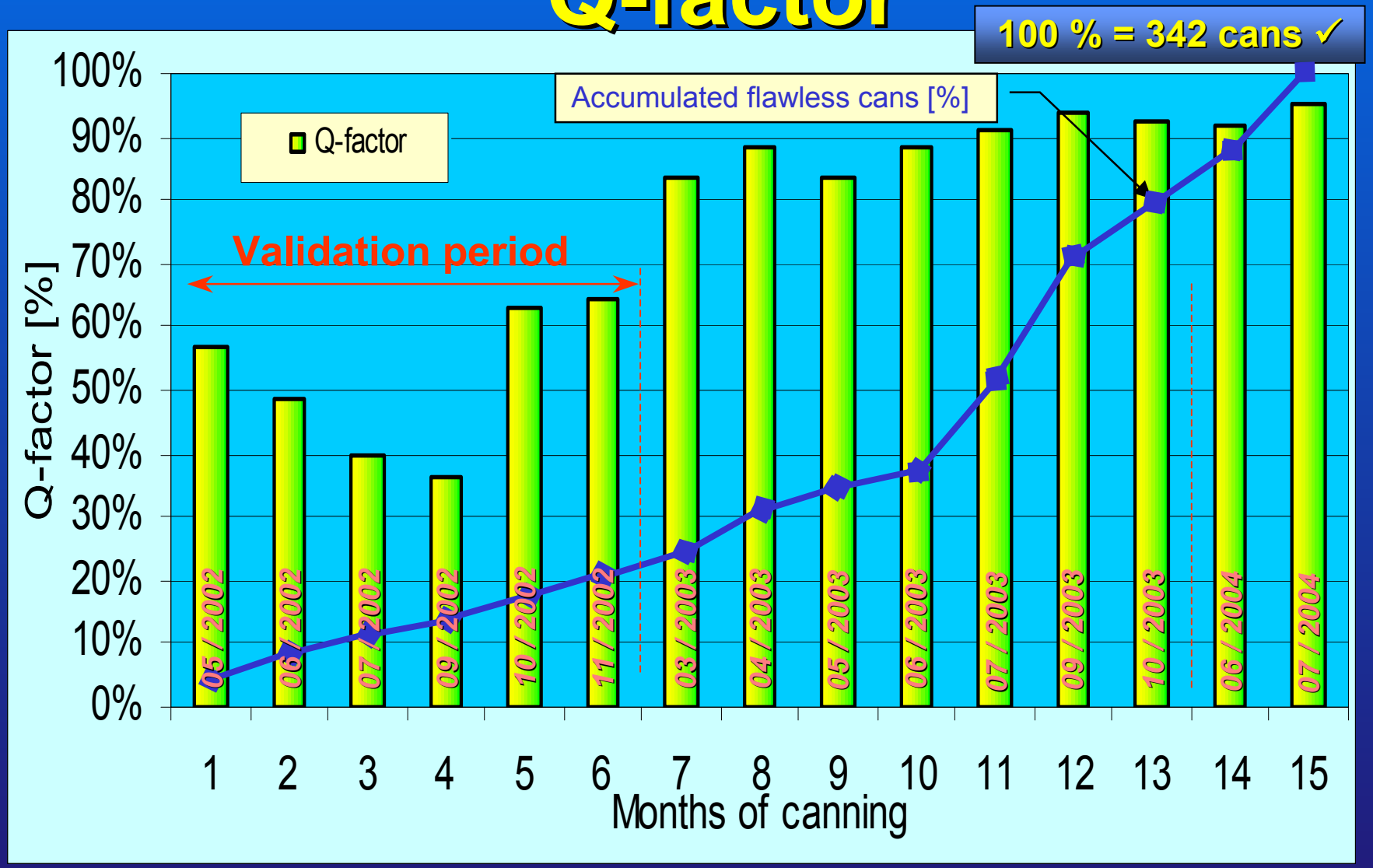
Handling the defective closed NSF

Bubble test and cutting off (2:23)

Canning record



Q-factor


100 % = 342 cans ✓
Accumulated flawless cans [%]
Q-factor
Validation period
Q-factor [%]
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
05 / 2002
06 / 2002
07 / 2002
09 / 2002
10 / 2002
11 / 2002
03 / 2003
04 / 2003
05 / 2003
06 / 2003
07 / 2003
09 / 2003
10 / 2003
06 / 2004
07 / 2004
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Months of canning

Performance indicator

NSF assembly	Quantity to be canned	Required encapsulation	Completed	Defective closed
EK-10	82	82	82✓	66
VVR single	228	76	76✓	9
VVR triple	184	184	184✓	14
TOTAL		342	342✓	89

How further?

Status: Phase 1 has completed. ✓

(encapsulate all NSF irradiated before 1986)

1. Closing activities:
   - Conservation maintenance → *Put it in stand by;*
   - Summary of the experiences → *Closing report.*
2. No decision to start Phase 2

   It will be a periodic canning by 3-5 years → depends on final solution.
3. It is offered to fulfill any canning demand.

Improvement and upgrading (?):

- No decision;
- Depends on outer demands and/or requirements.

Conclusions

- Technology and canning equipment are validated.
- Compact and closed technology that ensures safe reliable and effective encapsulation (demonstrated by 342 encapsulations).
- Cropping machine makes the technology complete (handling the defective canned packages).
- The canned storage technology leaves open all ways for a final solution.
- Human factor (3 operators form an optimum team).
- The experience demonstrates that the equipment provides a proper solution to the spent fuel storage problems of other research and training reactors (transportability, no contamination).

Thanks for your attention!