Australian Government

Australian Nuclear Science and Technology Organisation

MATERIALS SURVEILLANCE PROGRAM FOR THE OPAL RESEARCH REACTOR

by

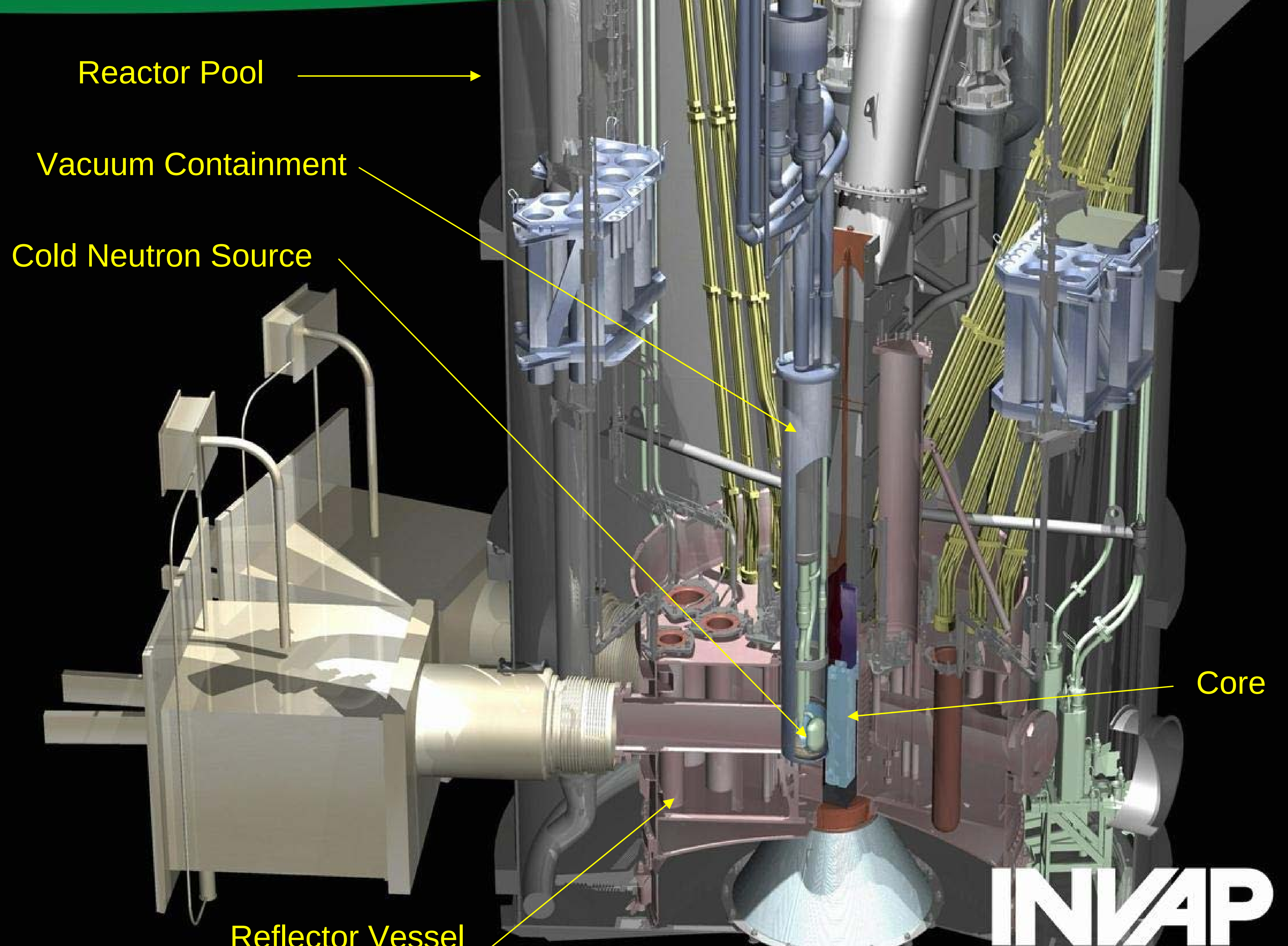
Bob Harrison

Institute of Materials and Engineering Science

RRFM/IGORR Conference, Lyon, 11 – 15 March 2007

Outline

- Need for surveillance program
- Materials and components included
- Basis of program
- Location of samples
- Types of testing to be undertaken
- Acknowledgements

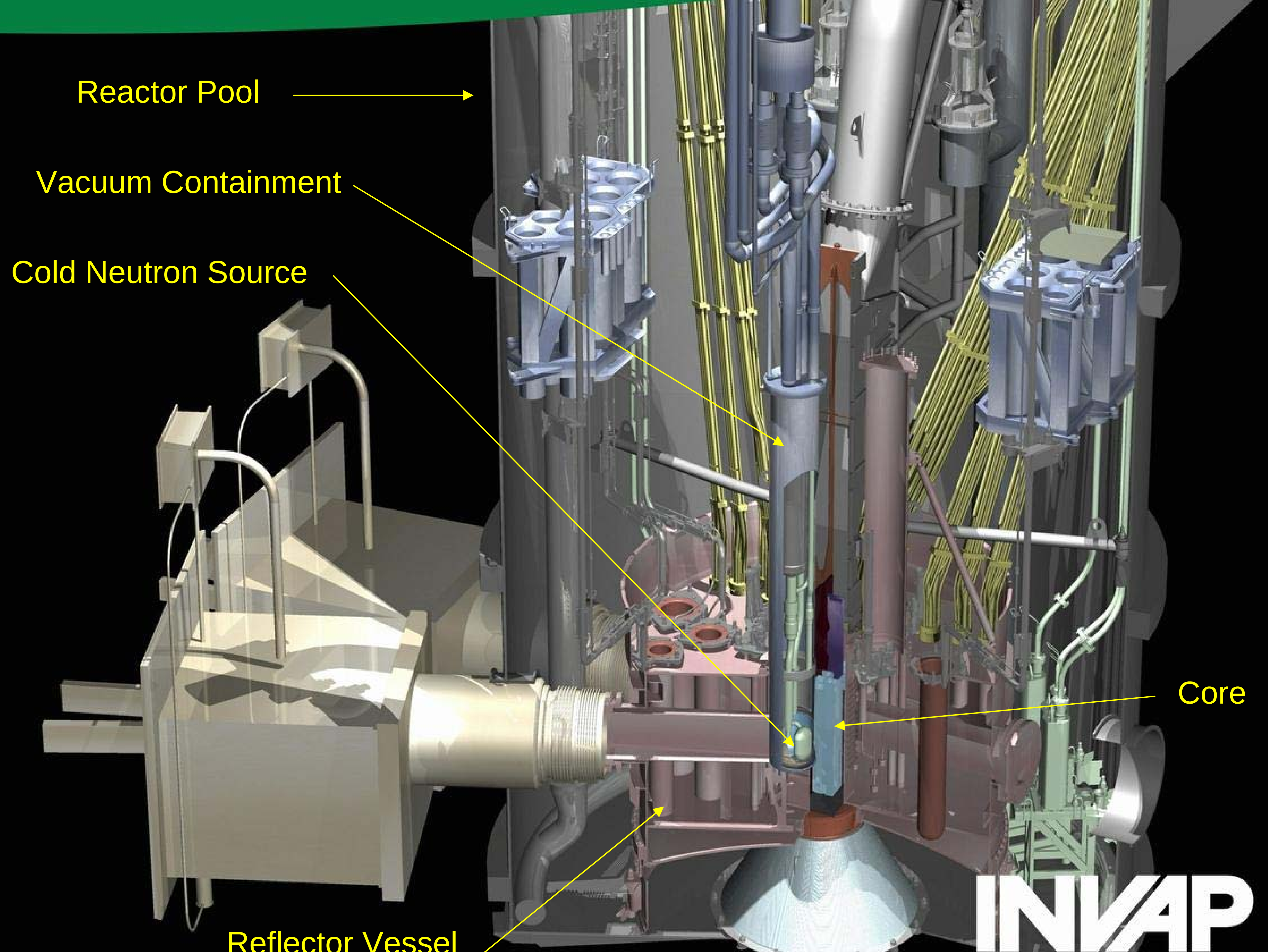

Reactor Pool
Vacuum Containment
Cold Neutron Source
Core
Reflector Vessel
INVAP

Why do we have a surveillance program?

- Need to confirm and determine the effects of radiation on the mechanical properties of the core reactor materials. Effects of interest:
  - Tensile properties – the structural design uses specified minimum values – lower may be unacceptable, higher is probably OK if the ductility does not reduce significantly
  - Fracture toughness – a level is required to prevent propagation of a crack of a certain size
  - Radiation-induced growth – may increase stresses above design allowables
  - Corrosion

Materials included

- Core materials:
  - Zircaloy-4 (reflector vessel)
  - Zr-2.5Nb (CNS vacuum containment)
  - Al6061 (upper grid, irradiation facilities)
  - AlMg5 (CNS moderator vessel)
  - 304L/316L (lower grid, hold-down bolts, fuel clamps and pool liners)


Reactor Pool
Vacuum Containment
Cold Neutron Source
Core
Reflector Vessel
INVAP

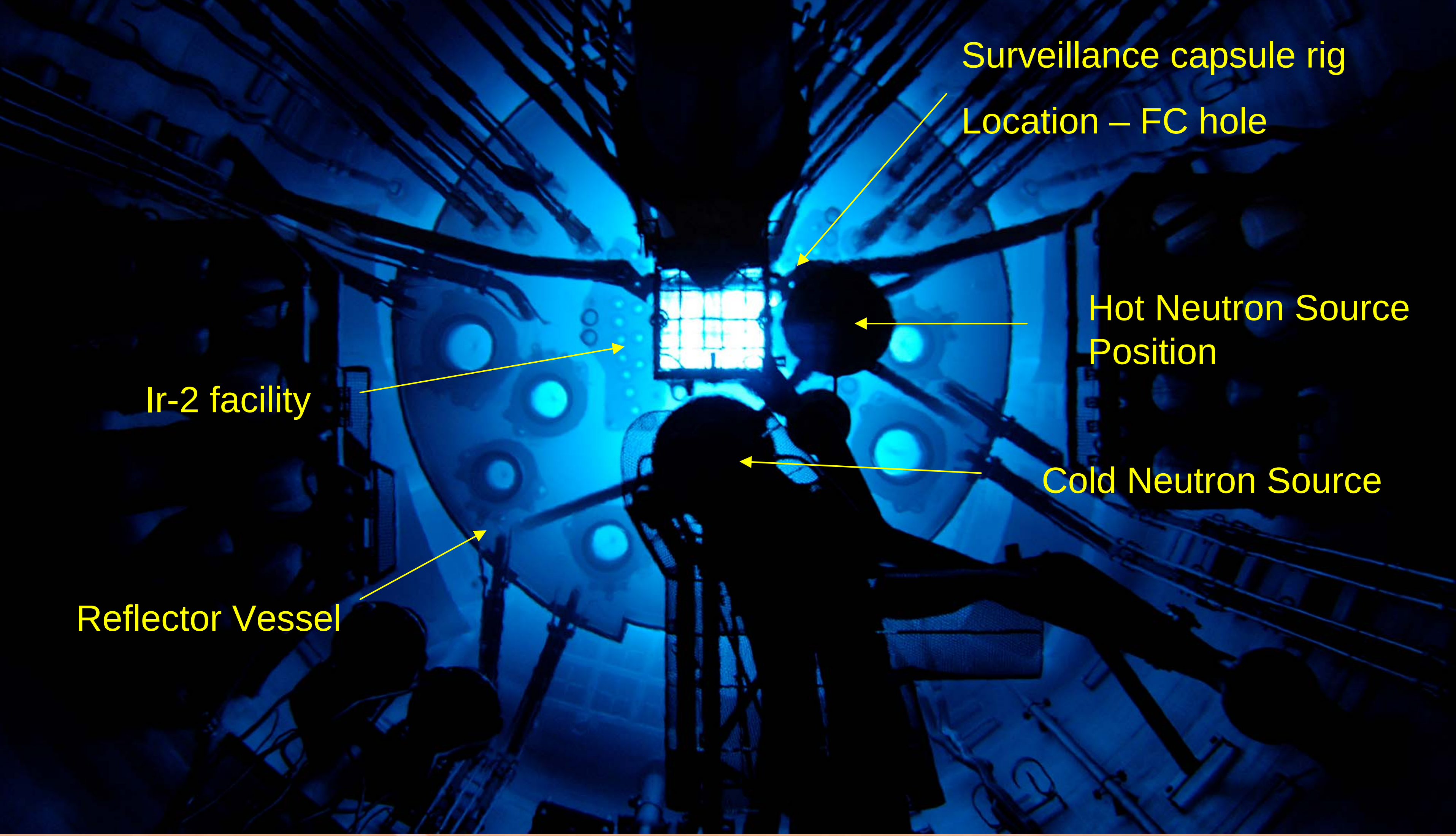
Basis of Program

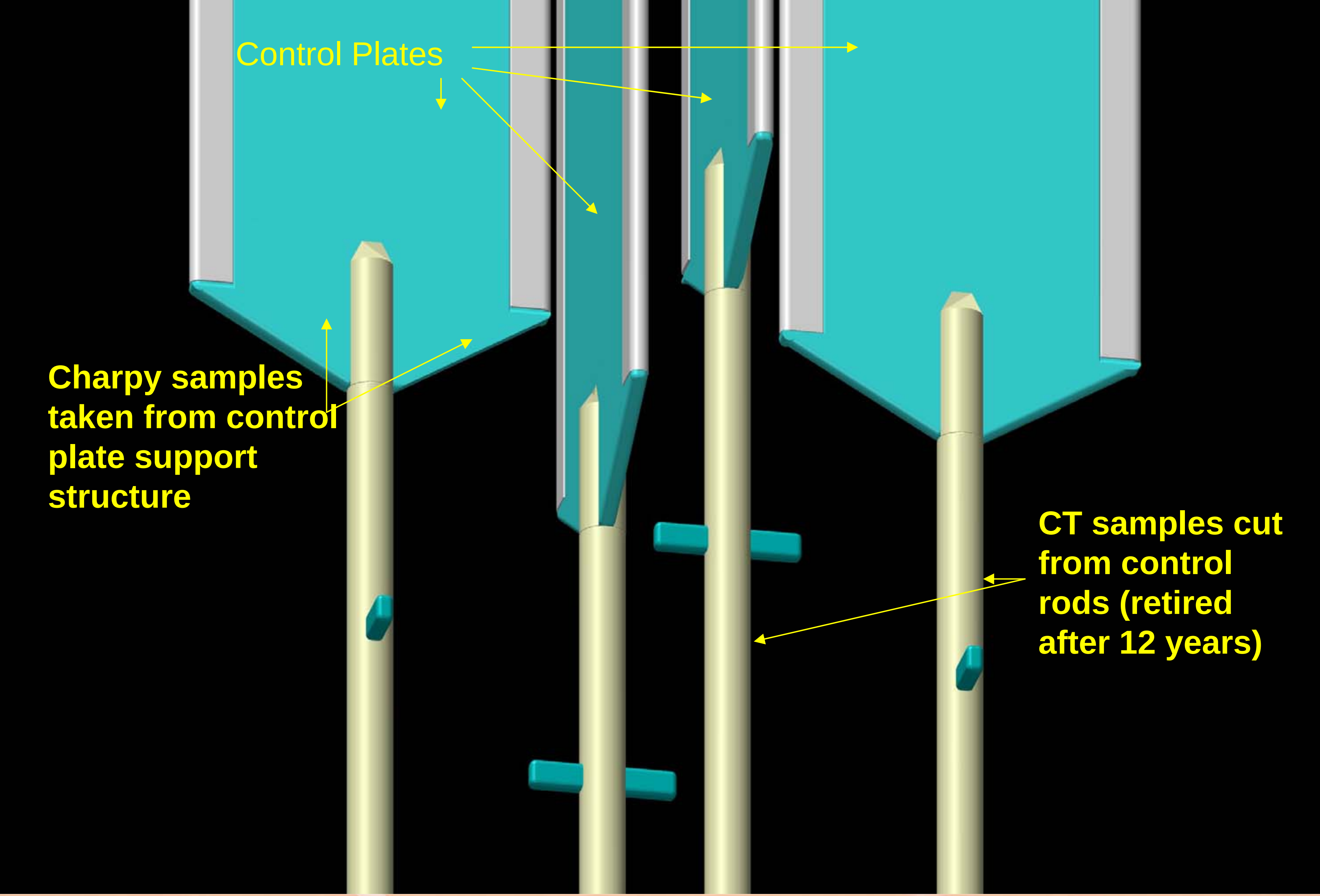
- Methodology based on ASTM E185, which was designed for light water power reactors
- Removable surveillance coupons are placed in various locations in OPAL
- Where possible the coupons are placed in regions where the flux is higher than the component they represent
- The coupons are removed at intervals (5, 10, 20, 30 and 40 years) and their mechanical properties (and dimensions) are compared with the original values and the design limits (this requires the capability of testing active samples!)
- Corrosion coupons placed in various locations within the RPO – removed after 1 year and then at longer intervals

Location of Samples

- Radiation effects - three areas – two containing test samples, one using reactor materials that are later converted to test samples after removal
  - FC location in the reflector vessel (main coupon location)
  - IR-2 facility (bottom position)
  - Control rods and control plate frames
- Corrosion – 7 spools in locations at different heights within the RPO

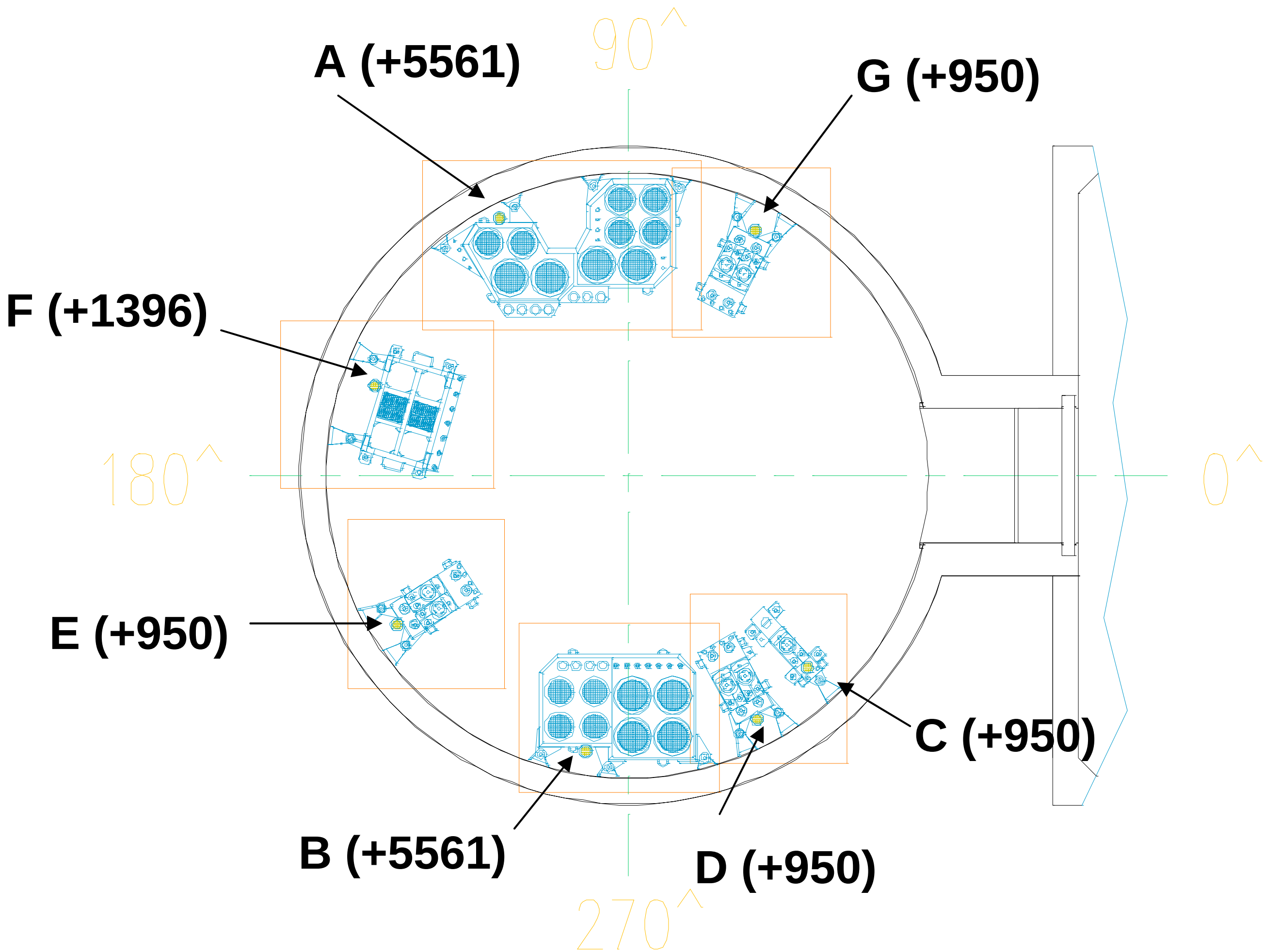
Surveillance program – sample locations





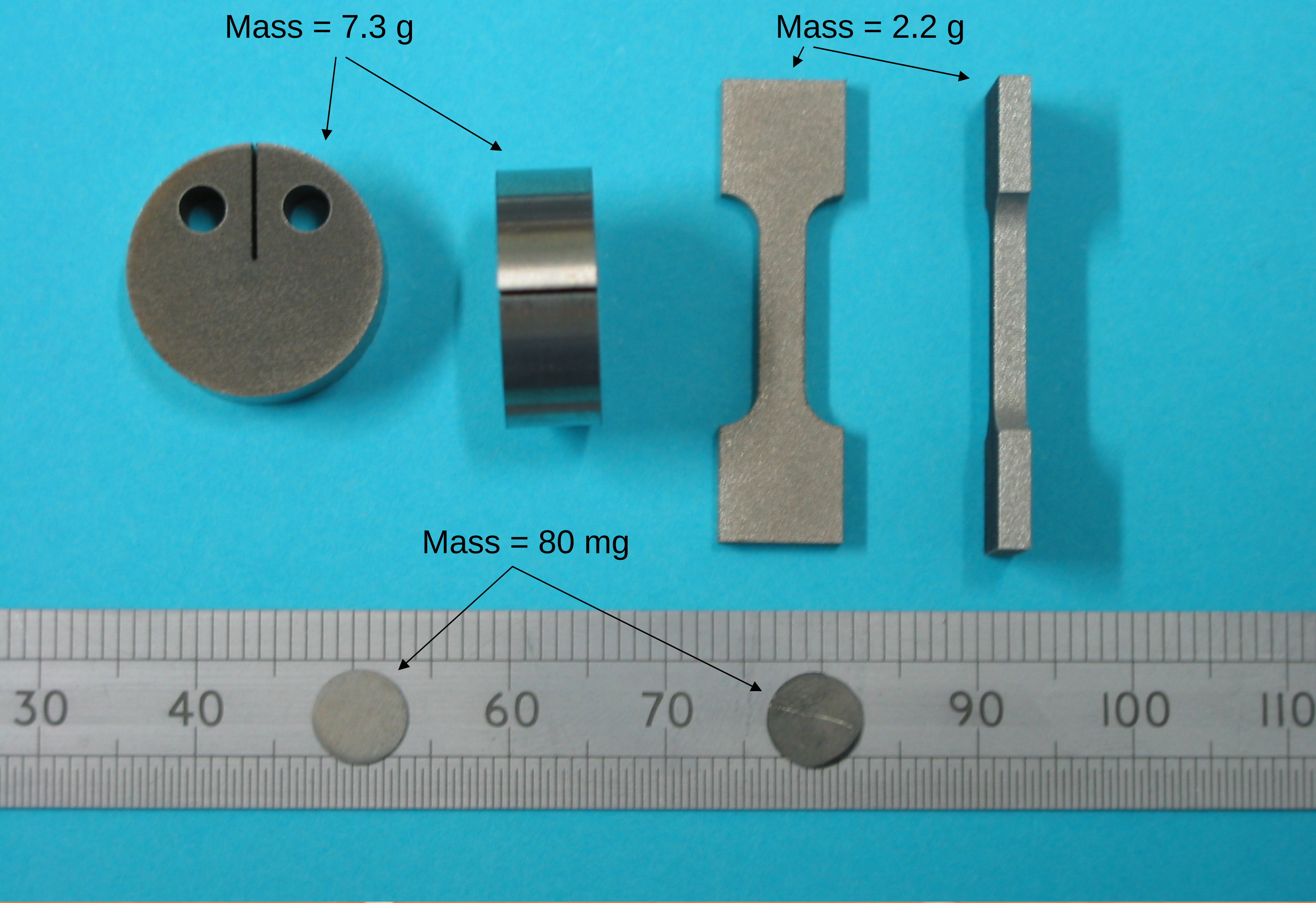
Control Plates
Charpy samples taken from control plate support structure
CT samples cut from control rods (retired after 12 years)

Corrosion coupons - location

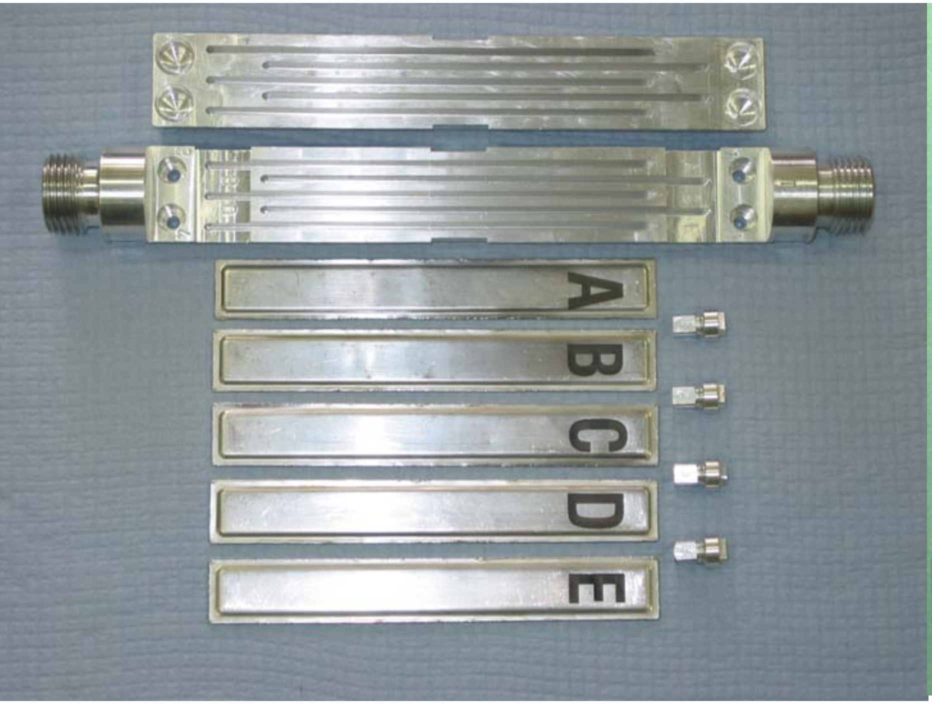


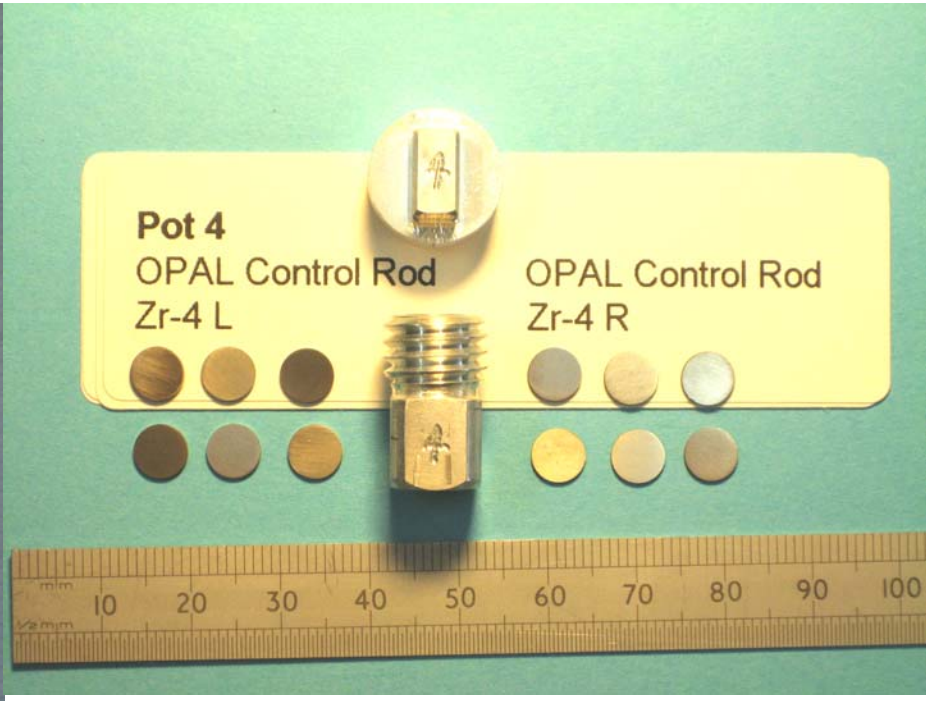
Coupon types

- Radiation effects
  - Miniature “dog-bone” samples (30 x 8 x 2mm) - both parent and weld metal
  - Small punch (SP) discs (6 mm diameter, 0.5 mm thick) - parent metal only (material from KAERI included)
  - Compact tension (CT) discs (16.2 diameter – same as control rods – and 4.6 mm thick) - parent metal only
  - Quarter size Charpy – from control plate frame – parent and weld metal
- Corrosion
  - Disc samples with Zr-4/Al6061 and 304L/Al6061 couples and Al6061

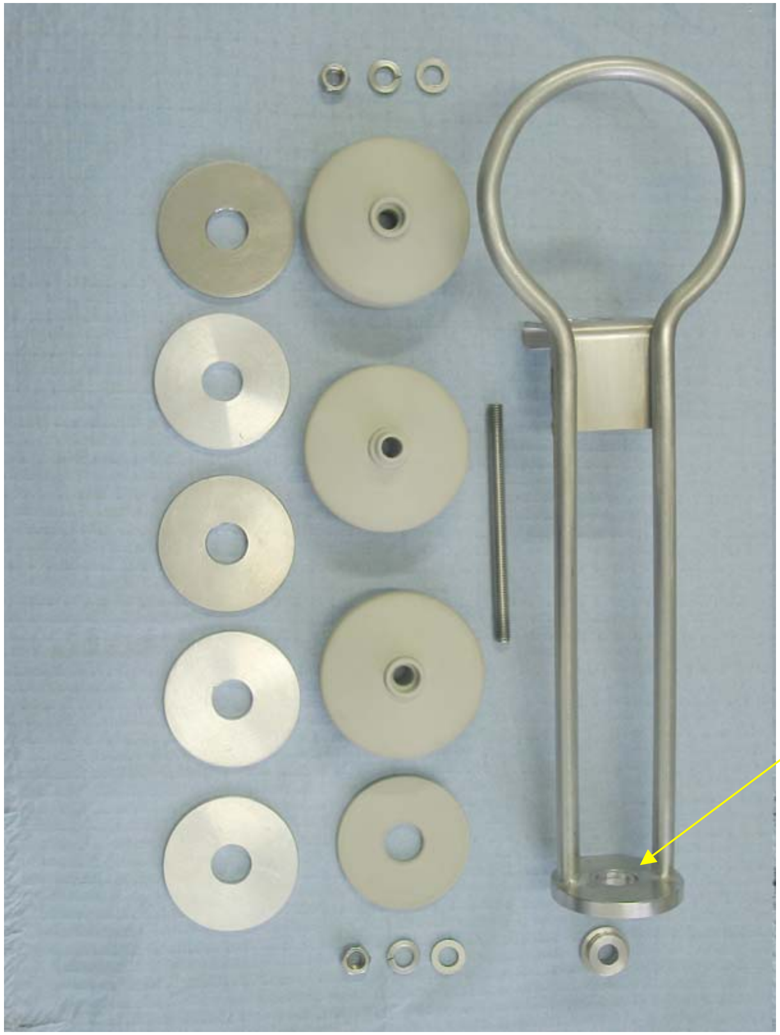

Mass = 7.3 g
Mass = 2.2 g
Mass = 80 mg

Surveillance Sample Capsules and contents of Dosimeter pots





Corrosion coupons



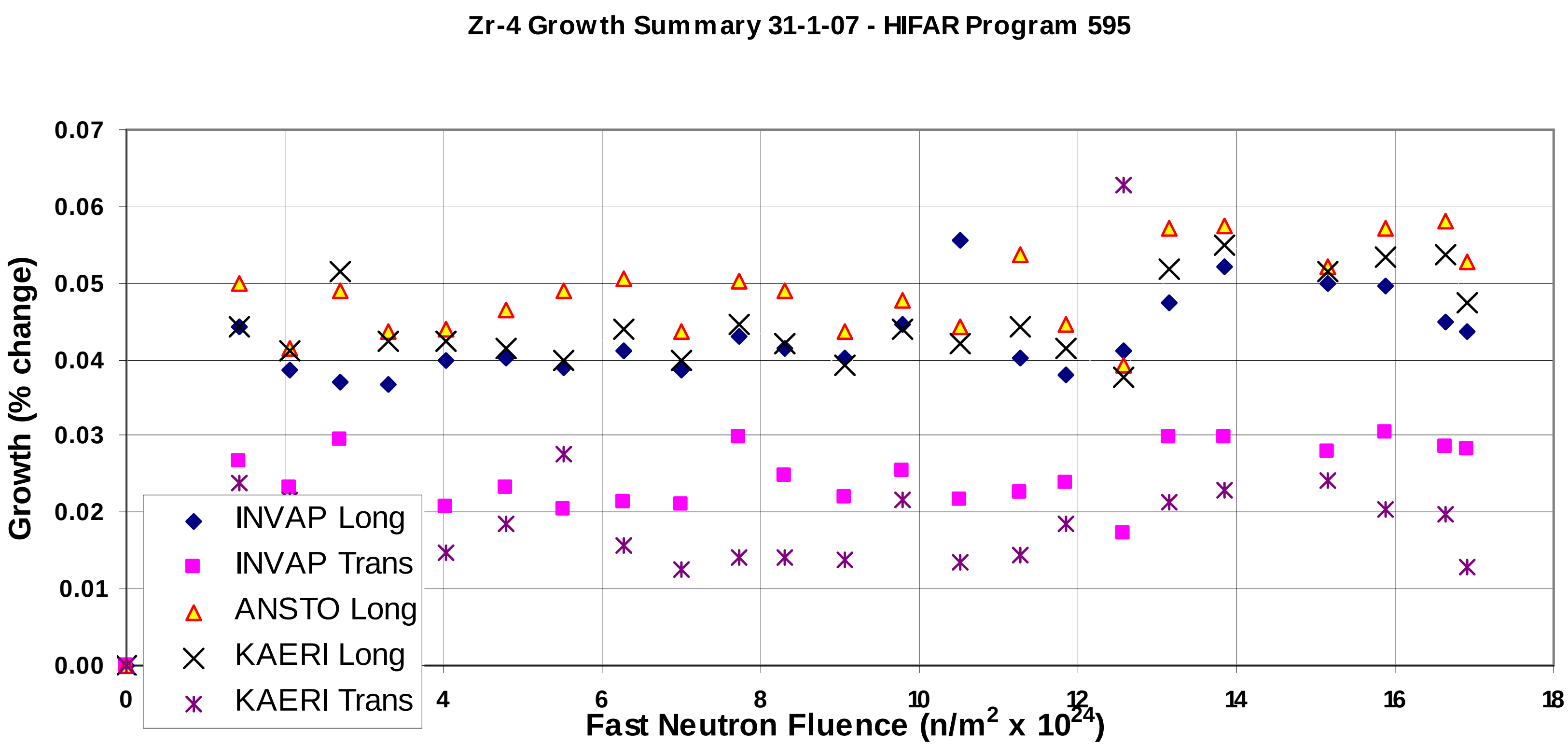
Weld repair from RPO

Zr/Al and SS/Al couples

Radiation-induced growth in Zircaloy-4

- Occurs in certain hcp materials if they have a texture (ie the grain orientation is not random)
- Samples were inserted into HIFAR in October 2004 – their length has been measured at the end of each 5 -week program
- HIFAR now shut – total fluence on samples 1.69×10^{21} n/cm^2 (E > 1MeV)
- Growth is fairly stable at about 0.05% (longitudinal) and 0.025% (transverse)
- It is not worth transferring samples to OPAL as fast flux in irradiation positions is less than in HIFAR – 2.8×10^{13} n/cm^2/s as opposed to ~1.4×10^{13} n/cm^2/s in the Ir-2 position (both E>1MeV) of OPAL

Radiation-induced growth of Zr-4



Manufacture of test samples

- All Small Punch (SP) samples have been made
- CT samples have been manufactured and will be fatigue pre-cracked before being inserted
- All tensile samples have been made
- All corrosion spool racks have been in place since April 2006
- In-cell EDM facilities will be required for the control rods

Types of testing

- Corrosion coupons
  - visual, mass change – may be some contamination but not significant activation
- Tensile properties
  - "Dog bone" samples will be active – testing will need to be performed in a hot-cell
- Fracture toughness
  - CT – samples will be active – testing in hot cell required
  - Small Punch (SP) – will be active but may be able to be done out of hot cell but in shielded area
  - Charpy samples (from control rods) – will be active – testing in hot cell required

Timeline

- Corrosion coupon examination
  - first in early/mid 2006 – then every 5 years
- Tensile, SP and CT
  - after 5 years of full power operation (2011/12), then after 10, 20, 30 and 40 years (does not require MSD)
  - after 10 - 12 years – control rods are removed and sectioned (requires MSD)
- In-cell testing facilities will be required by 2009/10 to prepare for first samples in 20011.
- In-cell sample preparation facilities will be required by 2017/18 to prepare samples from control rods

Acknowledgements

- **INVAP** Leonardo Boccanera et al
- **ANSTO** **IMES**: Maurice Ripley, Paul Stathers, David Carr, Tao Wei, Sam Humphries, Kevin Thorogood, Richard Blevins, Tim Nichols, Warwick Payten, Phil Bendeich and Maurie Bloom,
  Engineering: Pablo Marzano, Workshops
  NucTech: George Braoudakis, Geoff Durance,
  ARI: Nigel Wood,
  HIFAR: Active handling crew
  OPAL: Paul Phelan and others