Fabrication and Quality Control Of Fuel For Prototype Fast Breeder Reactor (PFBR)

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OUTLINE OF THE PAPER

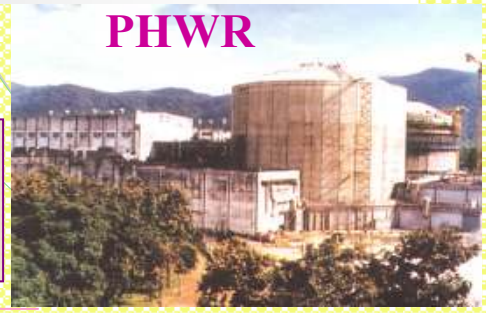
- INTRODUCTION
- MOX FUELS FOR FAST REACTORS
- FABRICATION STEPS FOR PFBR
- QUALITY CONTROL
- CONCLUSION
- ACKNOWLEDGEMENT

Advanced Fuel Fabrication Facility (AFFF), BARC, Tarapur

Pu Bearing MOX Fuel Fabrication for Thermal & Fast Reactors

Scope of work

First stage ⇨ (U~4%Pu) MOX for BWRs (TAPS)
(U~0.4%Pu) MOX for PHWRs (KAPS)



Second stage ⇨ (U-44%Pu) MOX for FBTR
(U-28%Pu) MOX for PFBR

Third stage ⇨ (Th-3%Pu) MOX for AHWR

MOX FUELS FOR FAST EACTORS

MIXED CARBIDE FUEL PINS FOR FBTR

- (0.7 Pu – 0.3 U)C

MOX FUEL PINS FOR FBTR

- (0.44 Pu – 0.56 U)O_2

MOX FUEL PINS FOR PFBR

- (21% PuO_2 & 28% PuO_2)

MOX Fuel for PFBR Technology Developed

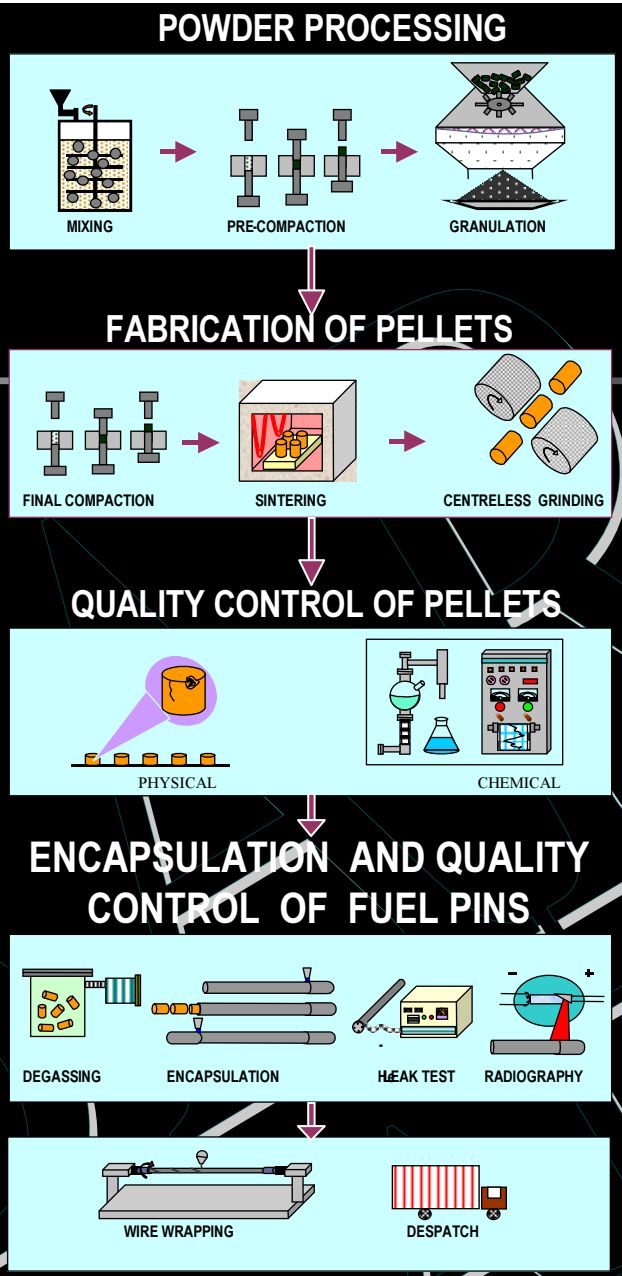
a) Fabrication of annular pellets using rotary press

b) Sinter to size

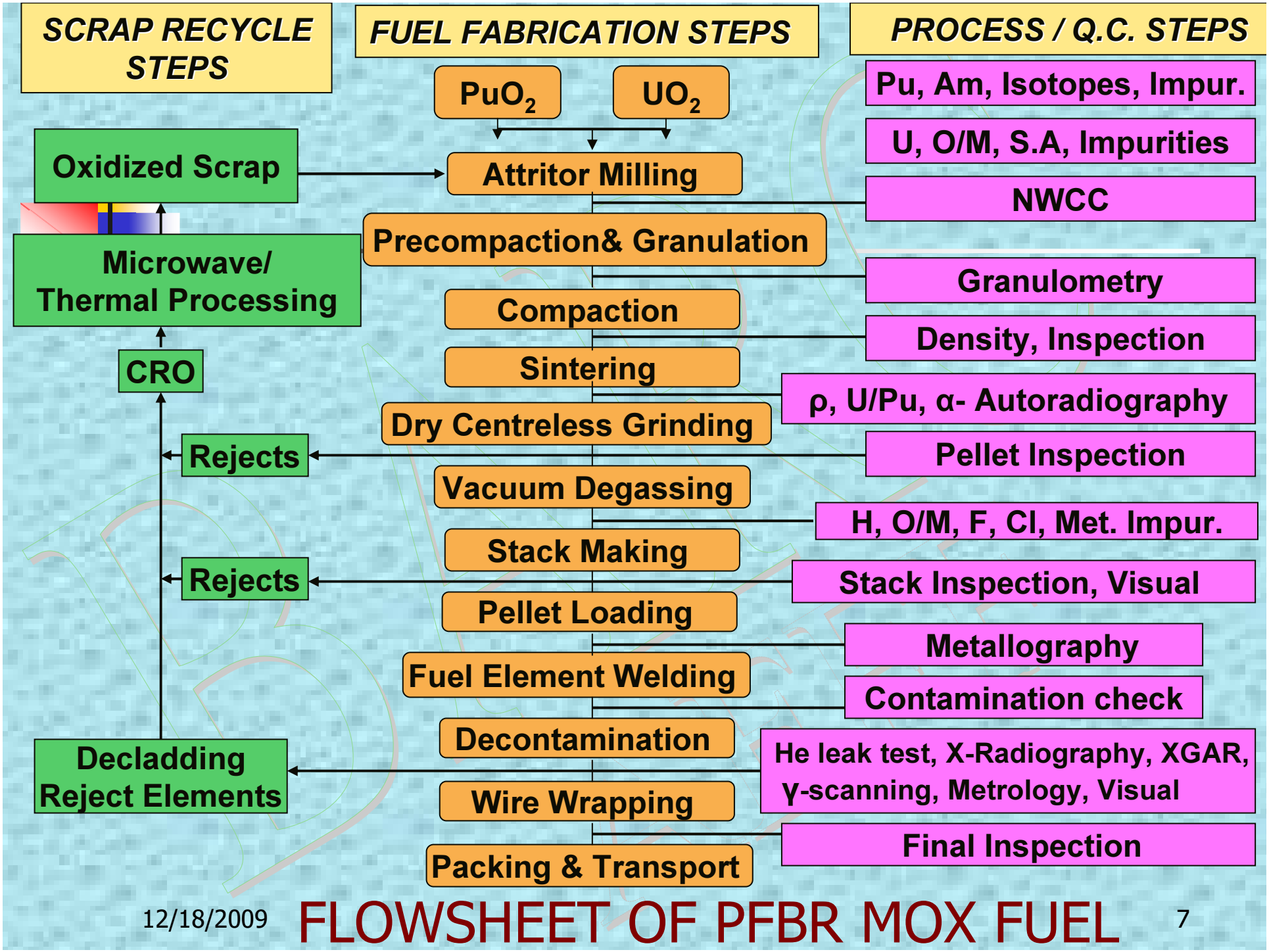
c) Dry Centreless grinding of oversize pellets

d) Pellet inspection using digital imaging

e) Welding technology for D-9

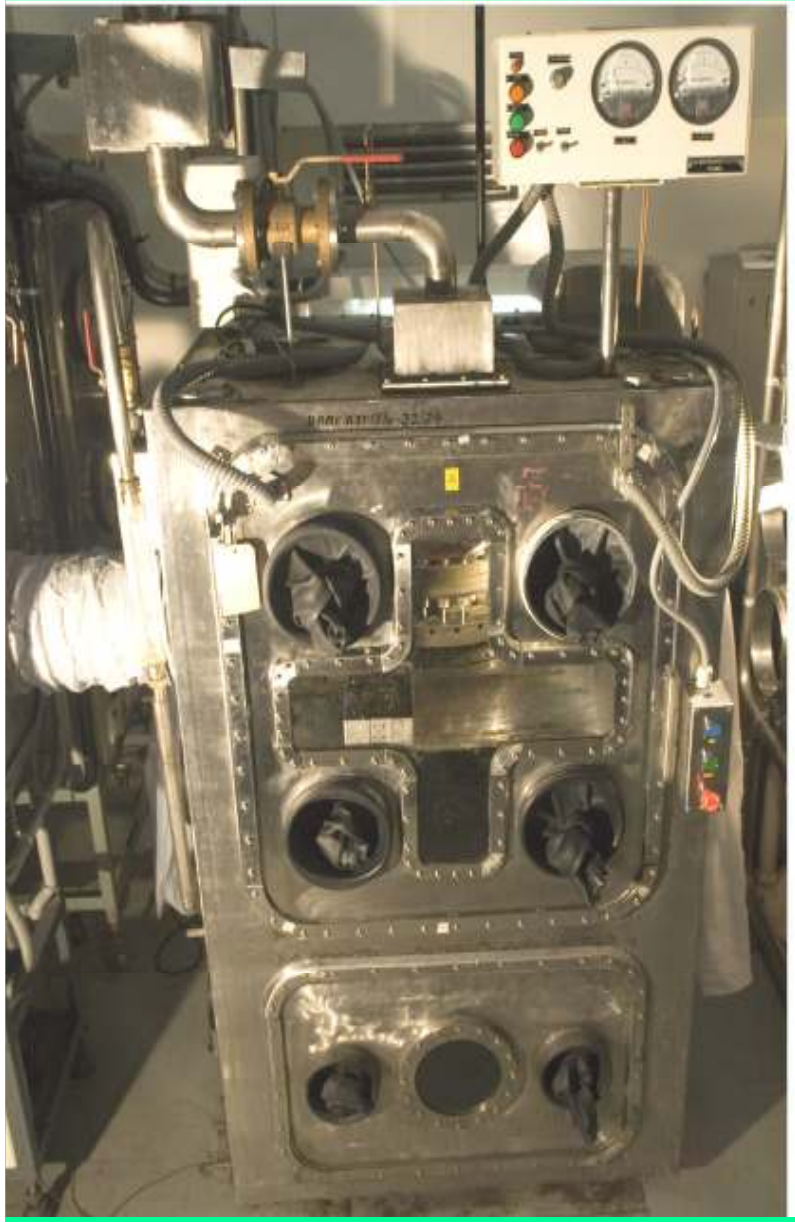


FLOWSHEET OF MOX FUEL FABRICATION



FLOWSHEET OF PFBR MOX FUEL

FABRICATION OF MOX FUEL



COMPACTION PRESS AND COMPACTED PELLETS

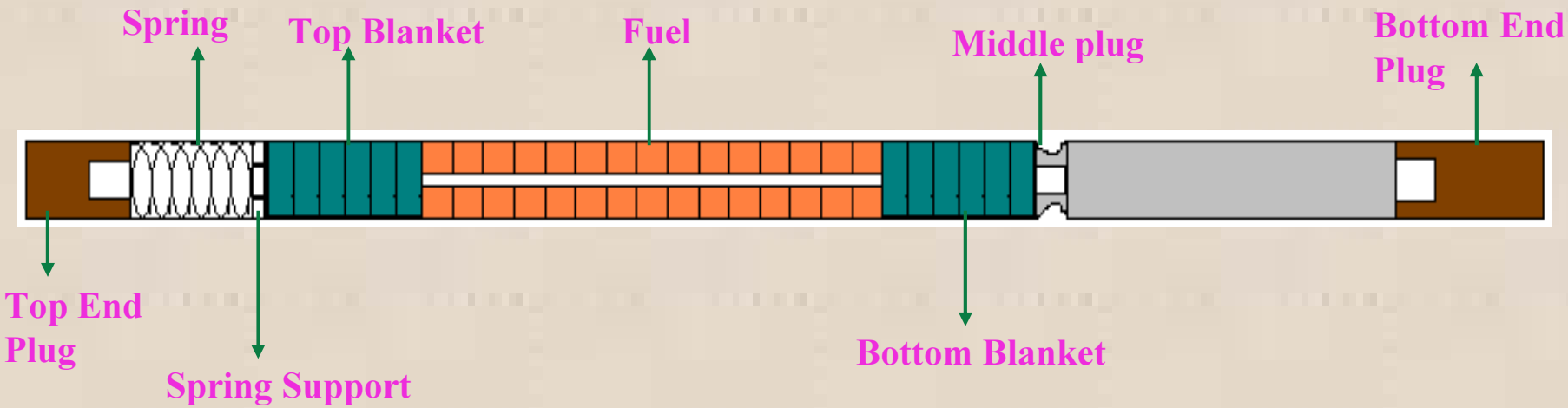
AUTOMATION IN PELLET FABRICATION SYSTEM

AUTOMATION IN FABRICATION SYSTEM

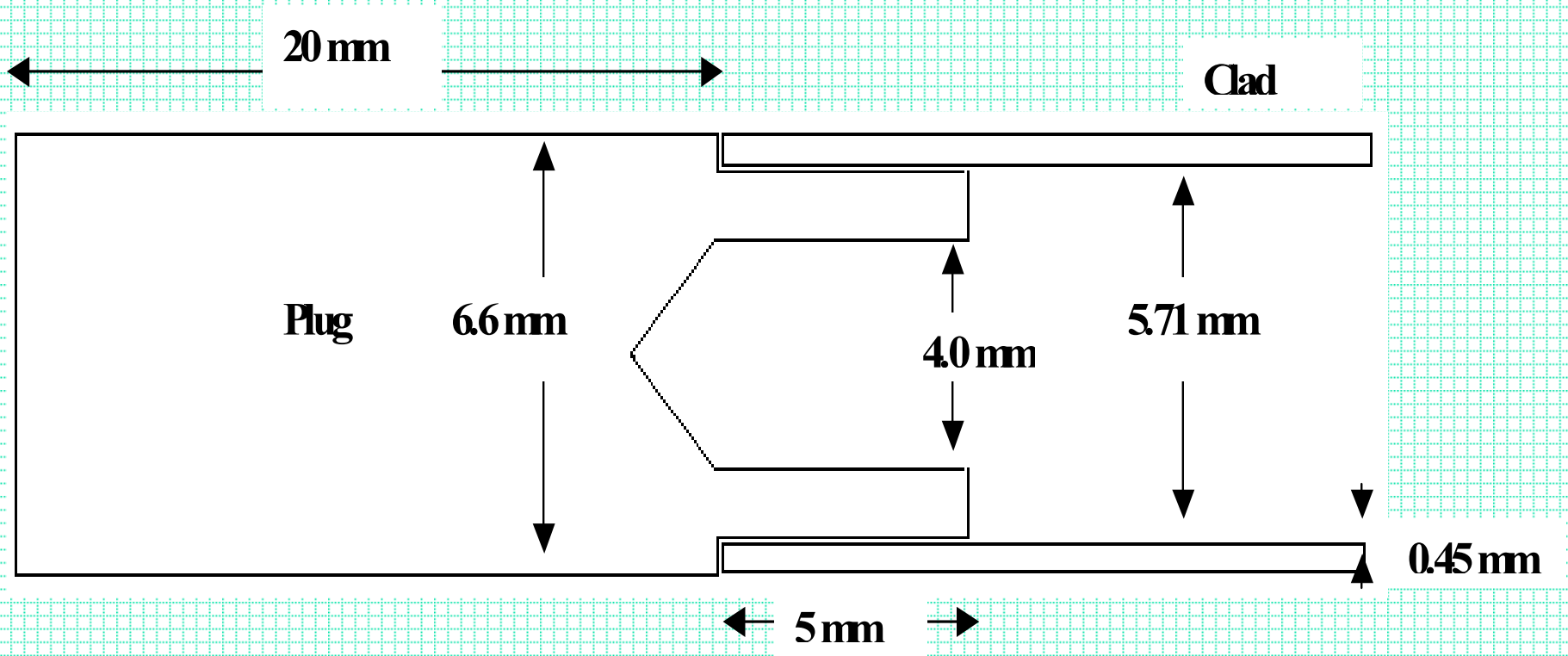
PELLET TRANSFER SYSTEM

PFBR PELLETS

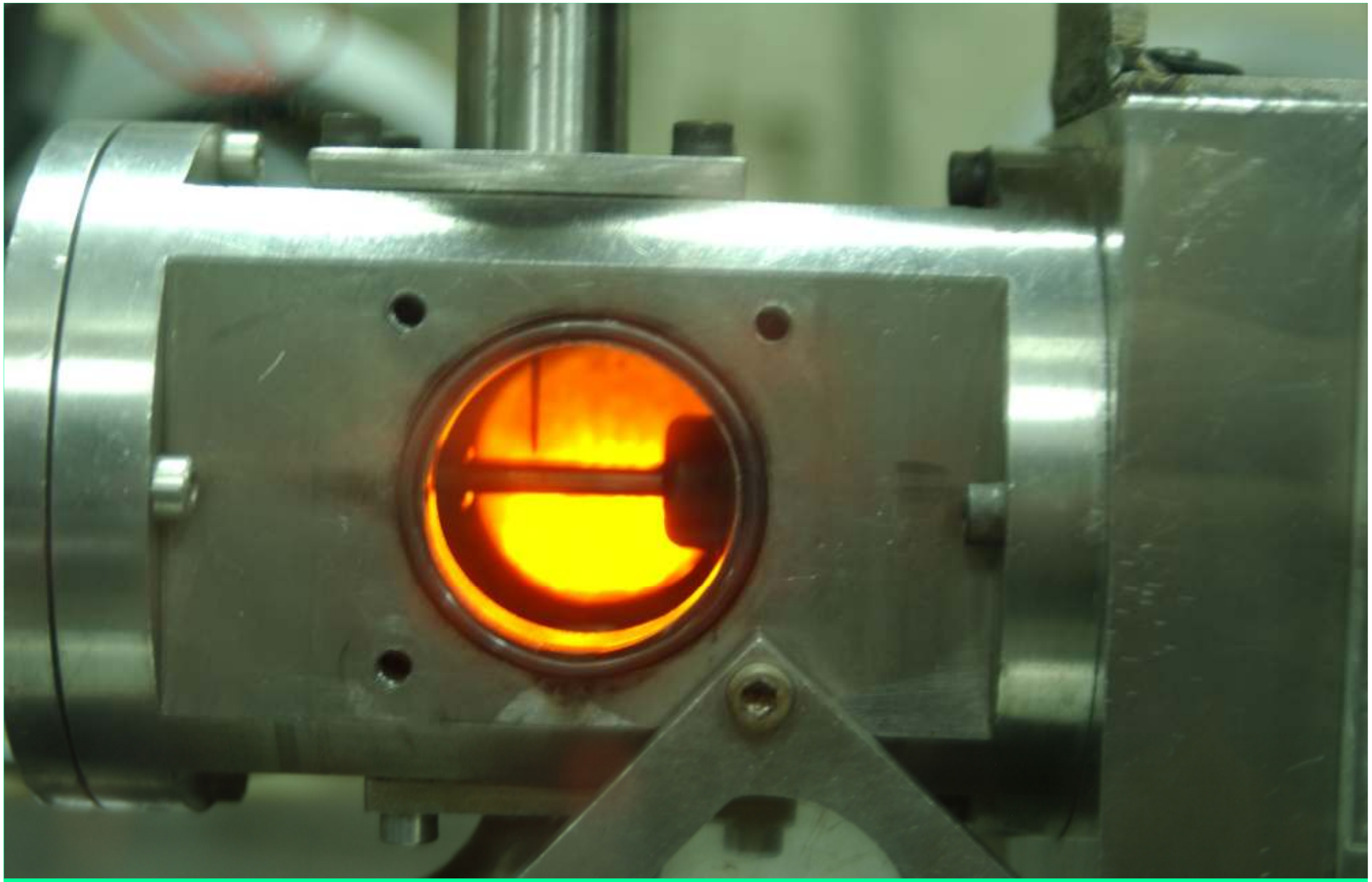
PFBR FUEL PIN



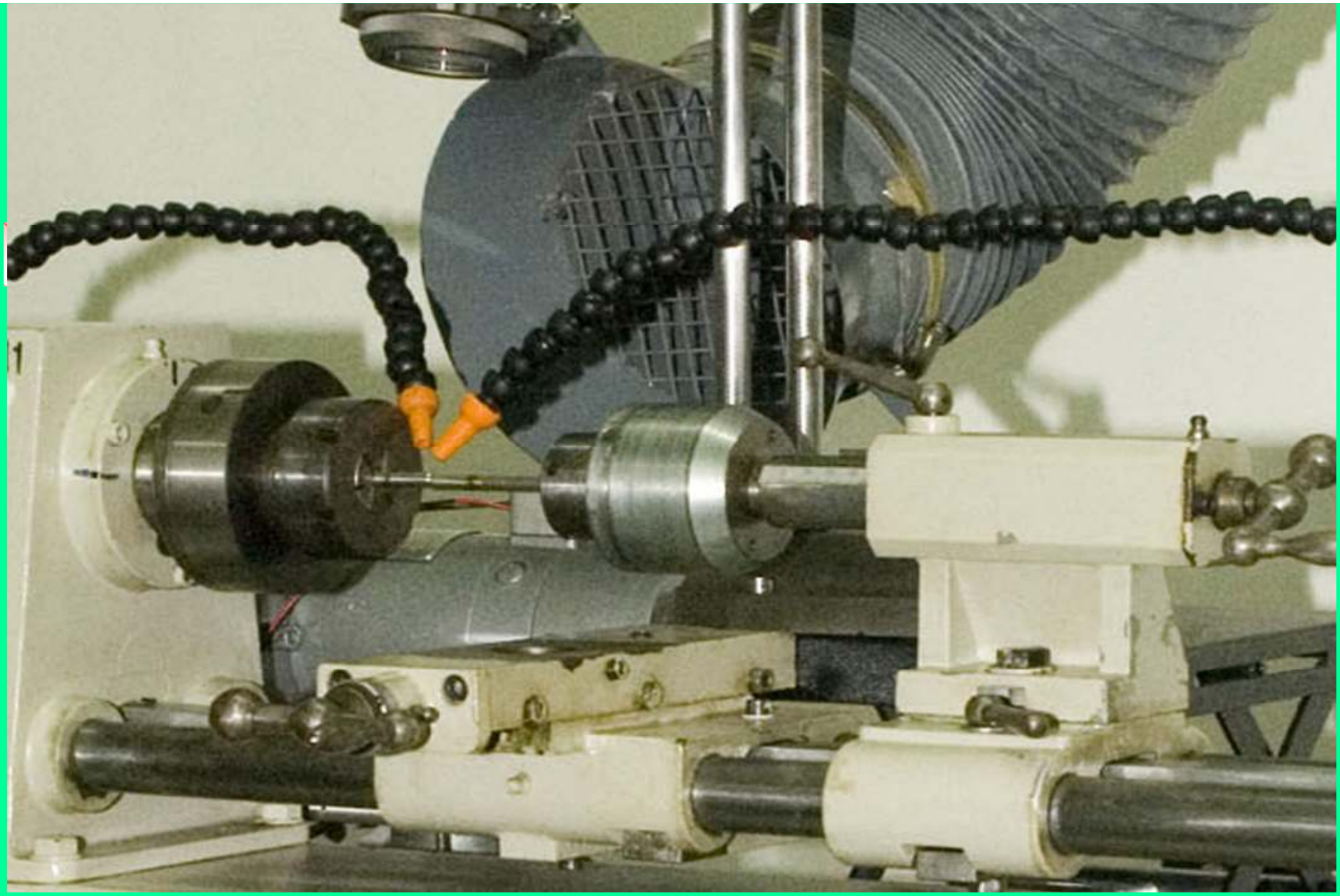
Fit-up Of PFBR Tube With Plug (Before Welding)



WELDING OF FUEL PIN

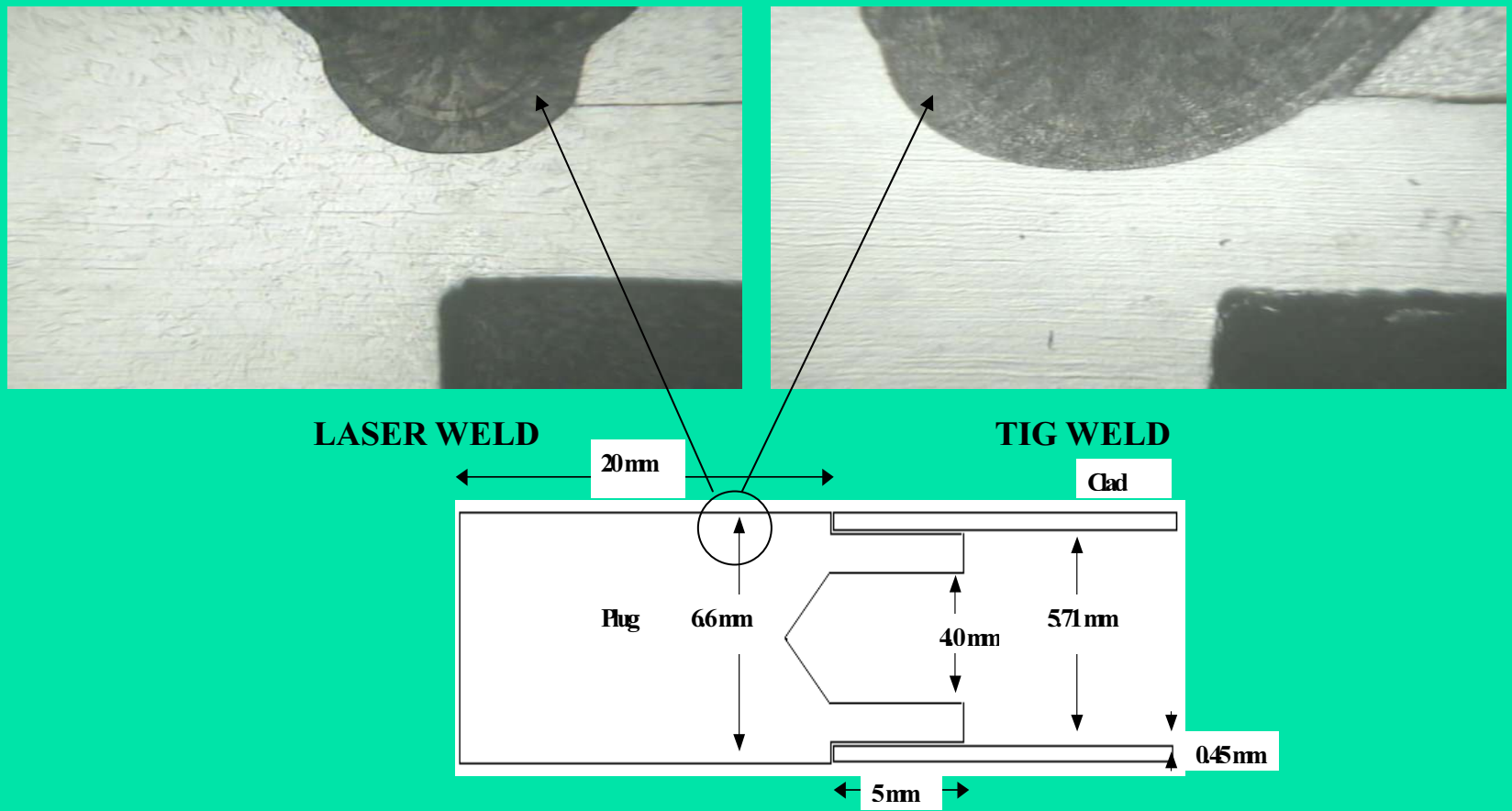


WELDING OF FUEL PIN (CLOSEUP)

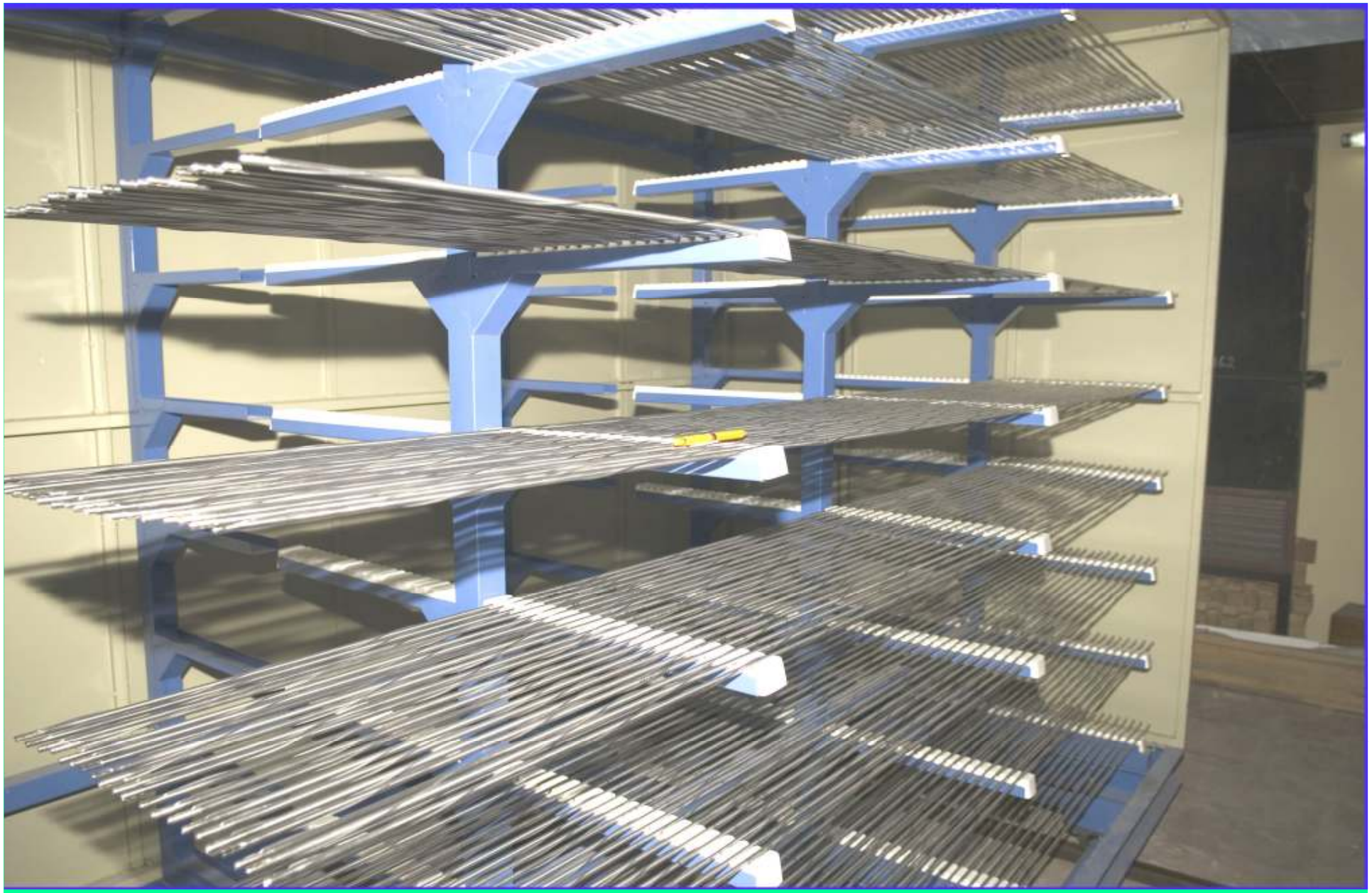


CLOSE VIEW OF LASER WELDING SETUP

PFBR END PLUG WELDS



SPACER WIRE WRAPPING OF PFBR PINS



PFBR FUEL PINS

QUALITY CONTROL CHECKS

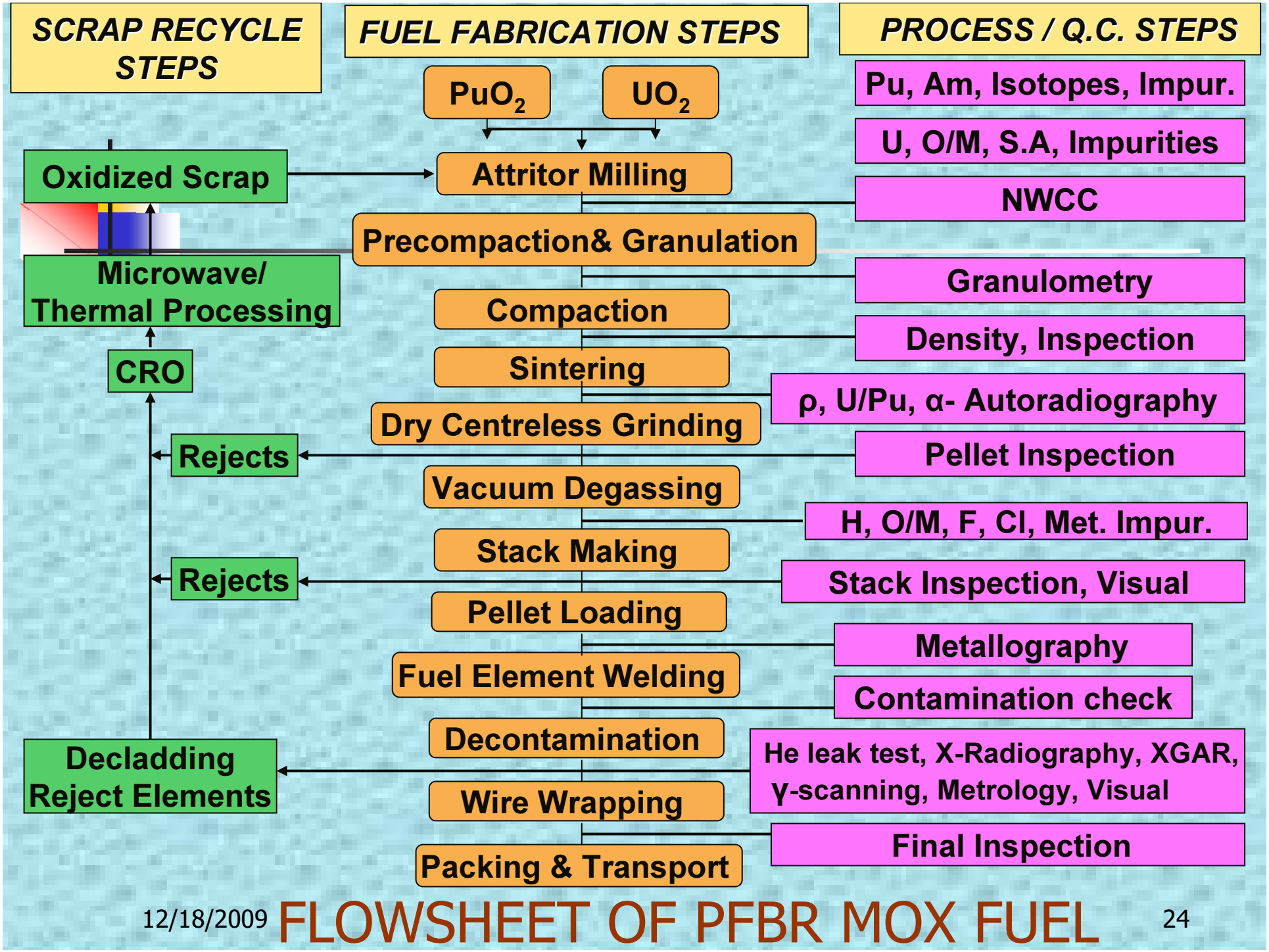
QUALITY CONTROL IN A TYPICAL FUEL FABRICATION PLANT

INITIAL INCOMING MATERIALS

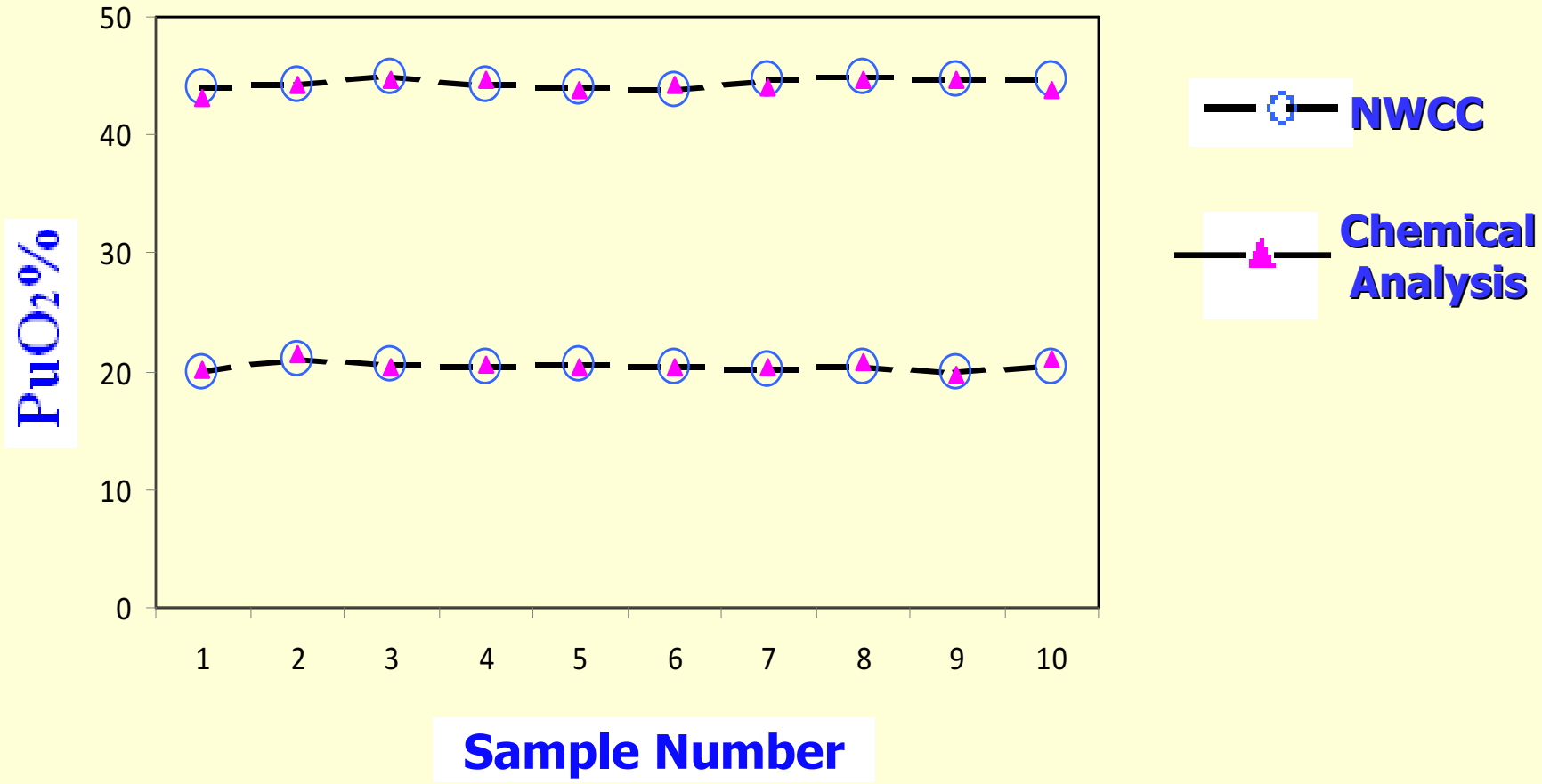
: HARDWARE, FUEL FEED MATERIALS

DURING PRODUCTION

1. **GREEN PELLETS : VISUAL, DENSITY, DIMENSIONS**
2. **SINTERED PELLETS : VISUAL, DENSITY AND OTHER CHARACTERISTICS**
3. **MONITORING VARIOUS PRODUCTION PARAMETERS AND COMPARE WITH MANUFACTURING ENGINEERING INDEX**
4. **FUEL RODS**
5. **FUEL BUNDLES**
6. **DOCUMENTATION**



FLOWSHEET OF PFBR MOX FUEL

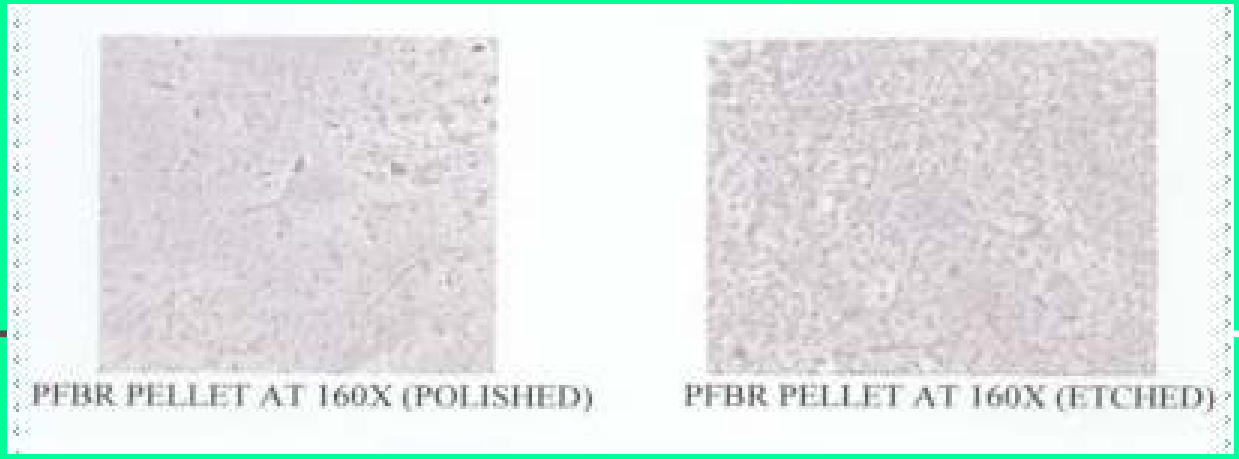


Comparison of NWCC and Chemical Analysis Results of MOX Fuel for Fast Reactors

ALPHA AUTO RADIOGRAPHY

- DISTRIBUTION OF Pu
- PuO2 AGGLOMERATES

- ALPHA PARTICLES FALL ON CELLULOSE NITRATE FILM
- PROCESSED FILM REVEALS TRACKS
- UNIFORMITY AND SIZE
- COLOUR IMAGE

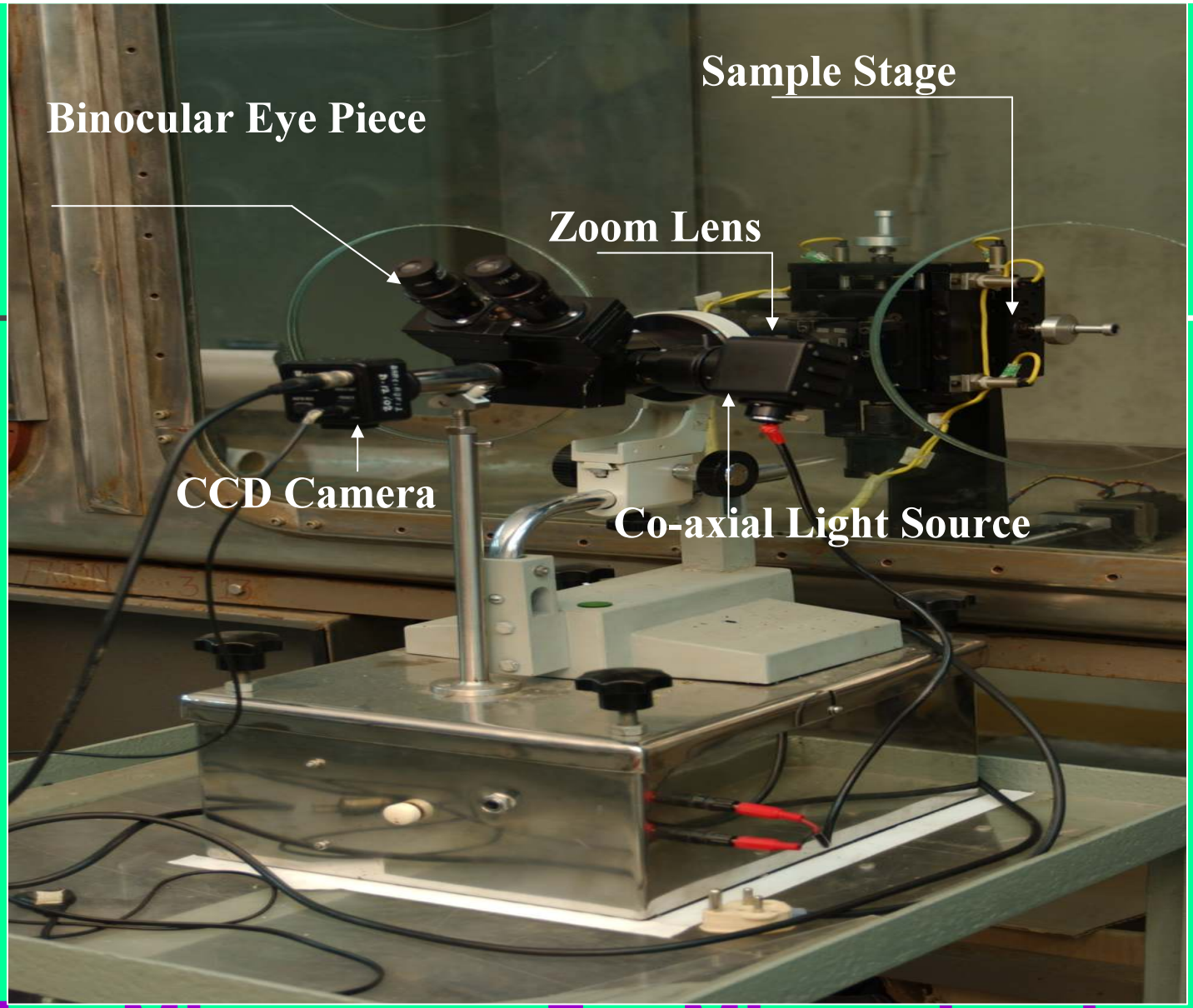


PHOTOMICROGRAPHS OF PFBR PELLET

Longitudinal section

Transverse section

ALPHA AUTORADIOGRAPH OF PFBR PELLET

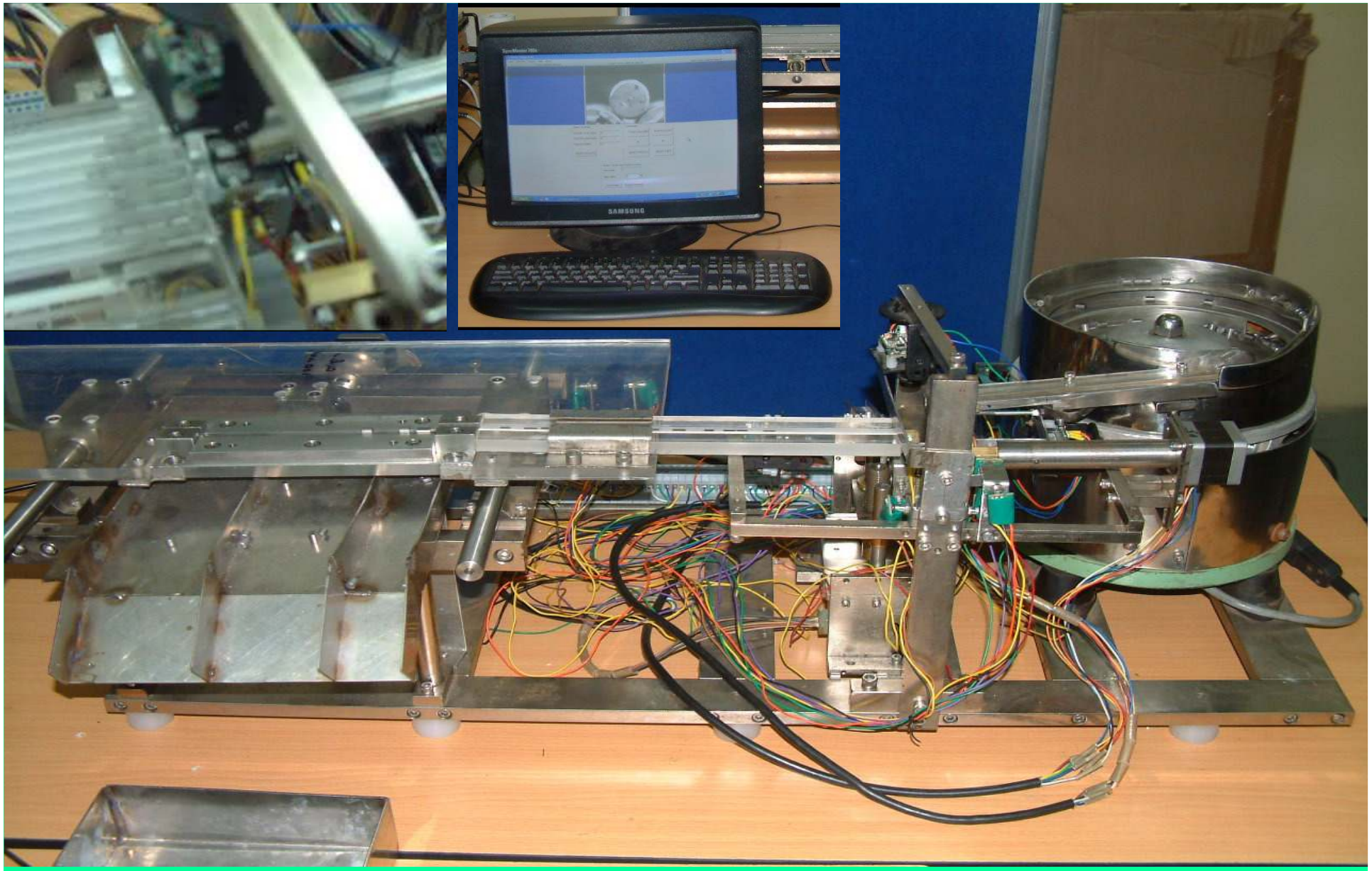


Video Microscope For Micro structural Evaluation Of MOX Pellets

1- Laser Detector, 2- Laser Transmitter, 3- Solenoid, 4- Solenoid

5- Bowl Feeder, 6- Controller for Vibratory Bowl Feeder, 7- Main Control Unit

FR 09 Kyoto, Japan



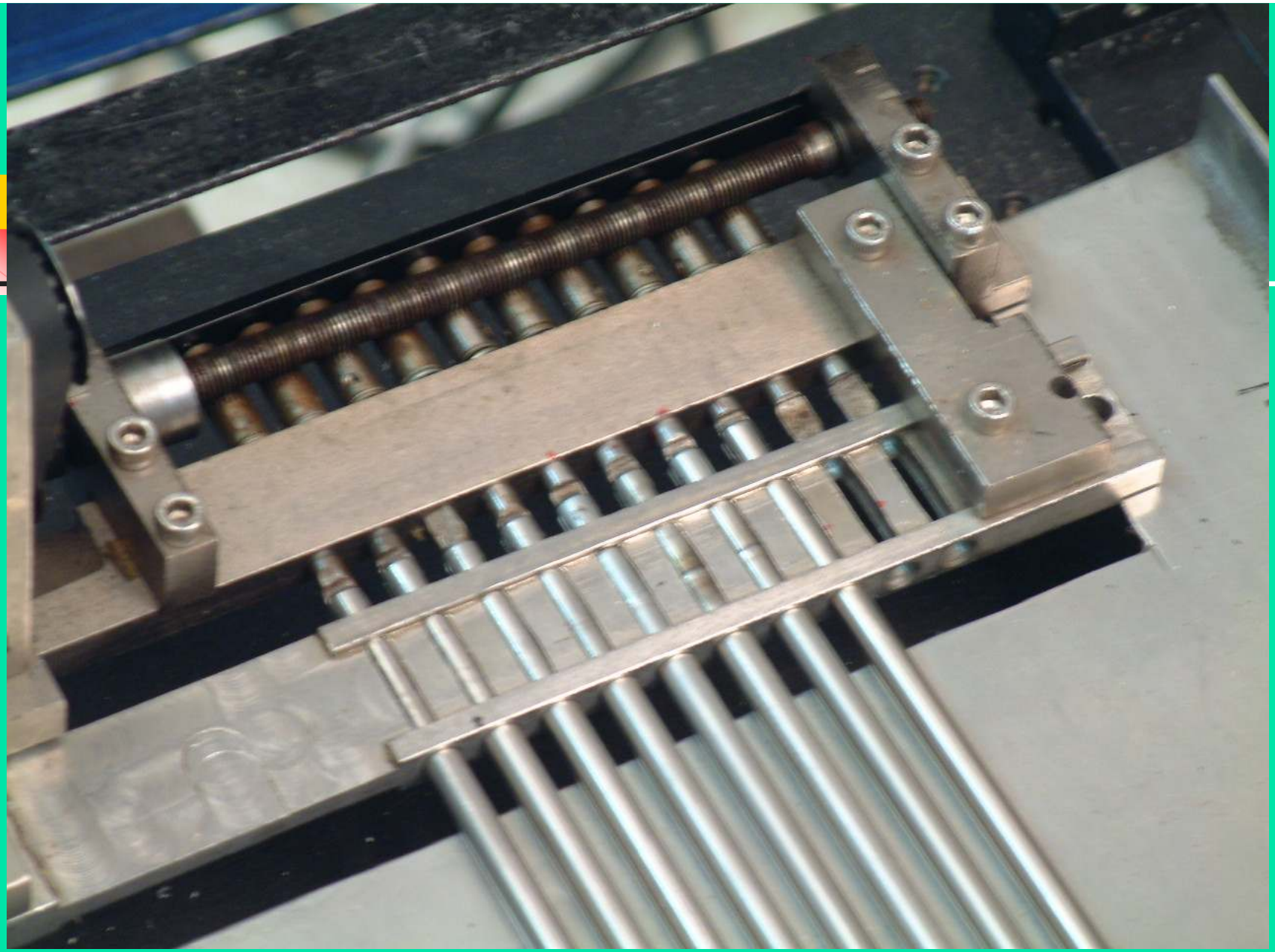
VISUAL INSPECTION & PELLET SORTING SYSTEM

CHEMICAL CHARACTERISATION OF MOX FUELS

1. PuO_2 % ENRICHMENT
2. HEAVY METAL CONTENT
3. DISSOLUTION TEST
4. O/M RATIO
5. NON METALLIC IMPURITIES
6. TRACE METALLIC IMPURITIES
7. COVER GAS ANALYSIS
8. TOTAL GAS ANALYSIS

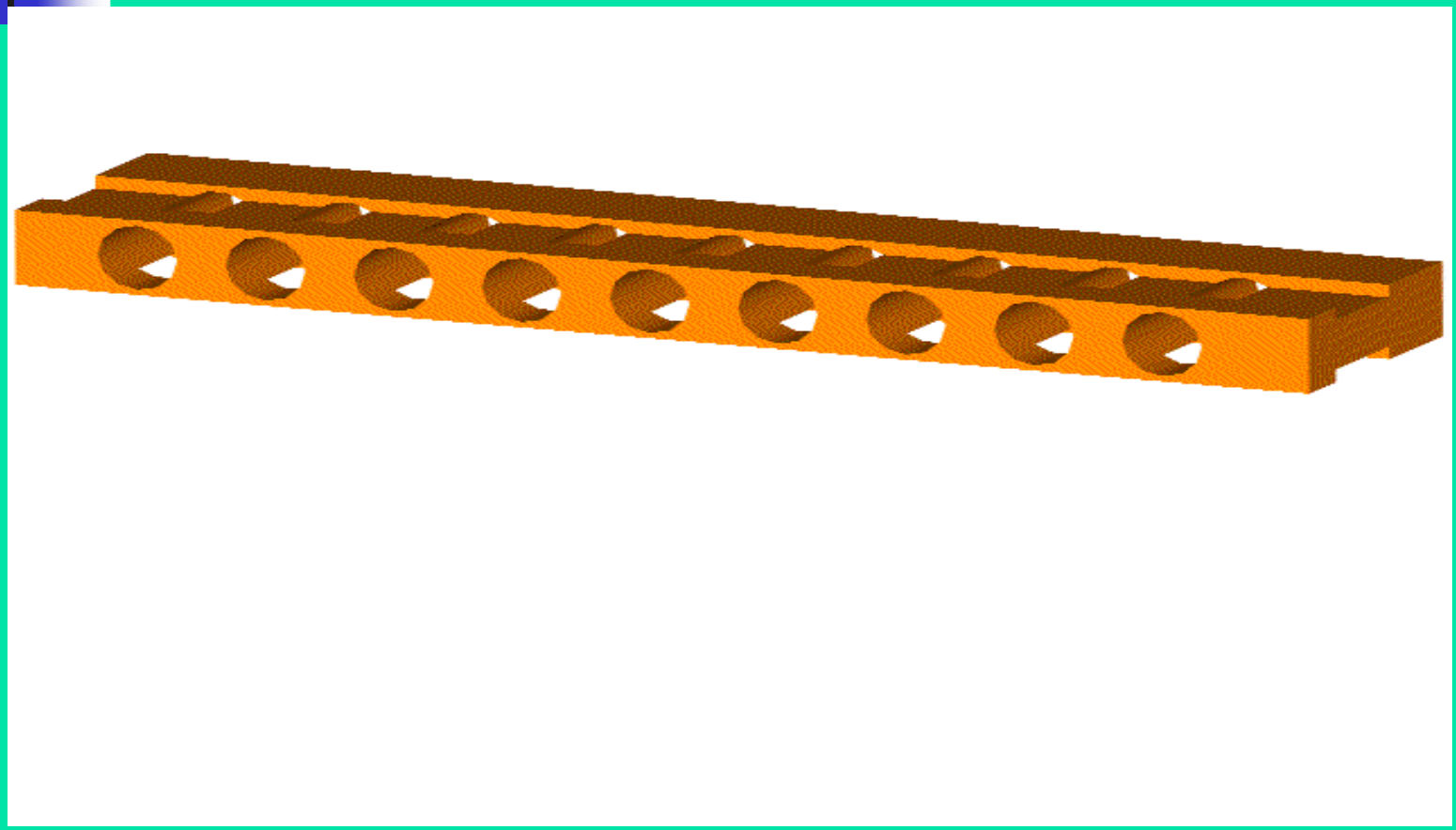
END PLUG WELD

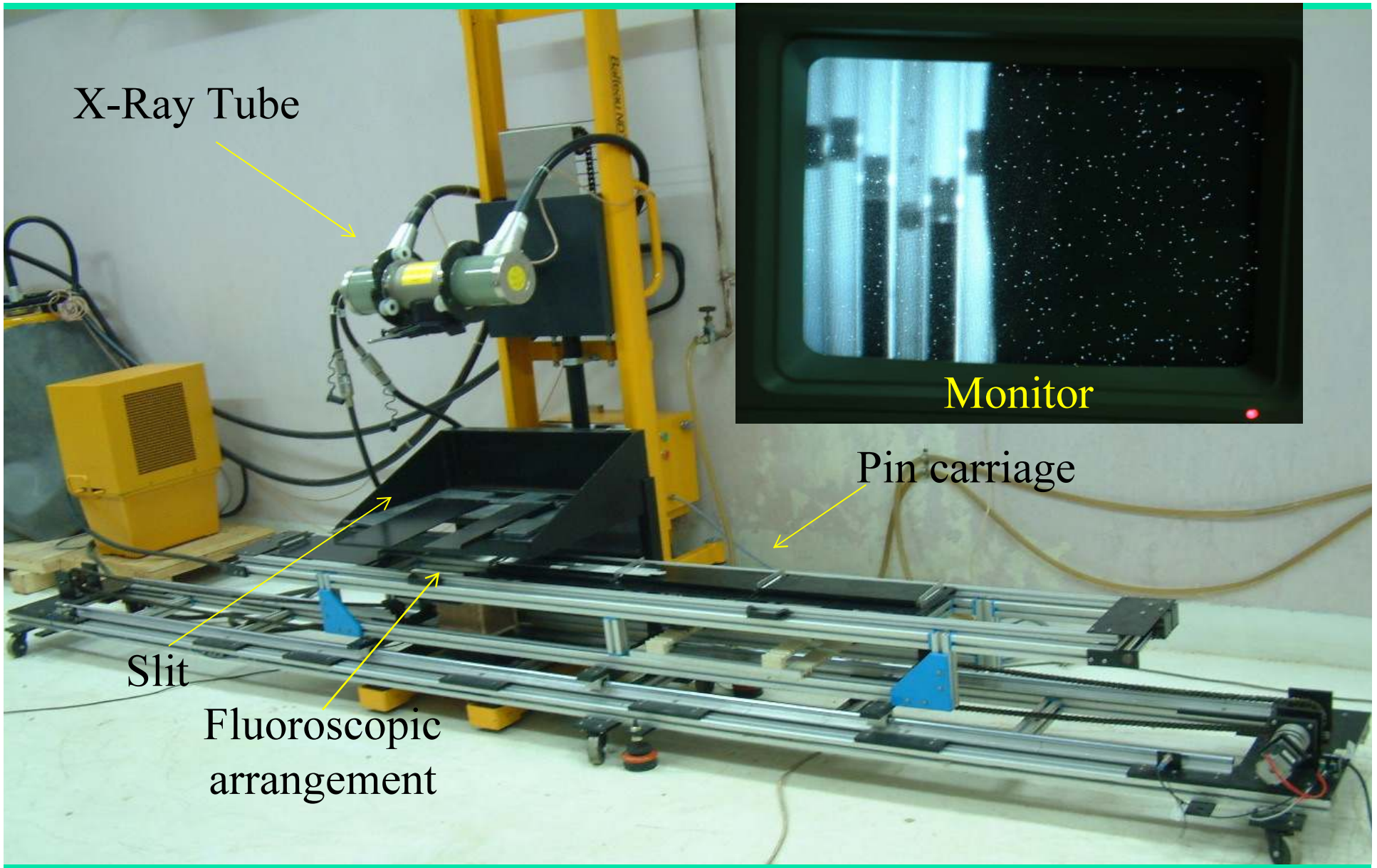
- TIG WELD — X-RADIOGRAPHY
- FREEDOM FROM — LACK OF PENETRATION
  - LACK OF FUSION
  - POROSITY – INCLUSION-OTHER
- MODIFICATIONS — SHAPE CORRECTION BLOCK
  - DEFECT STANDARD
  - MICRODENSITOMETRY
- ADVANCED TECHNIQUES — IMAGE PROCESSING
  - REAL TIME MOTION RADIOGRAPHY
  - LINEAR ARRAY DETECTORS
  - ULTRASONICS



Radiography of End Cap Welds

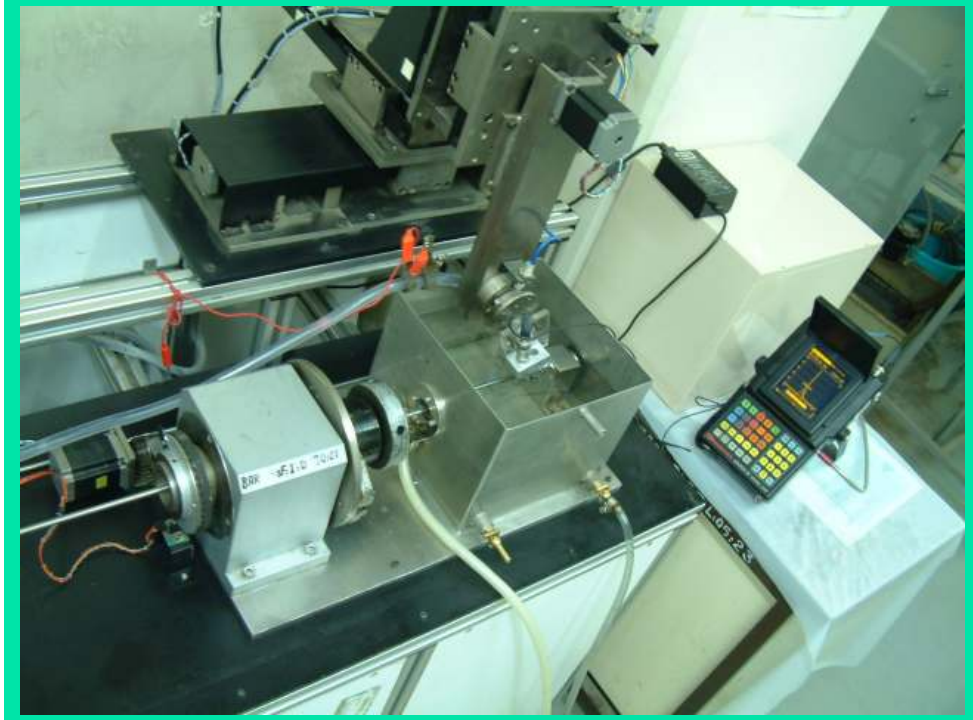
Shape Correction Block For PFBR End Cap Welds

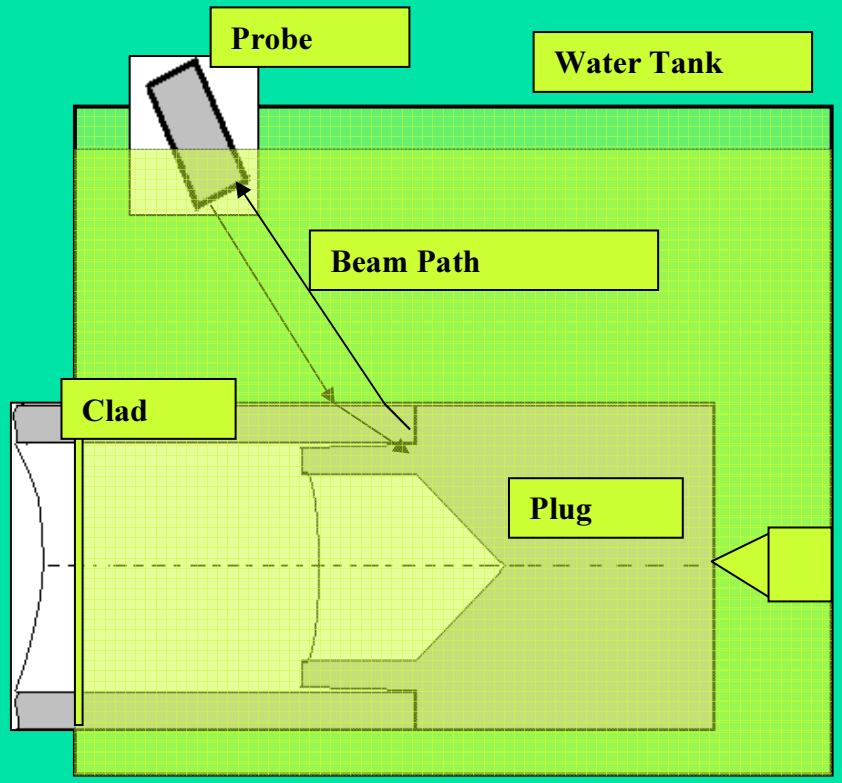


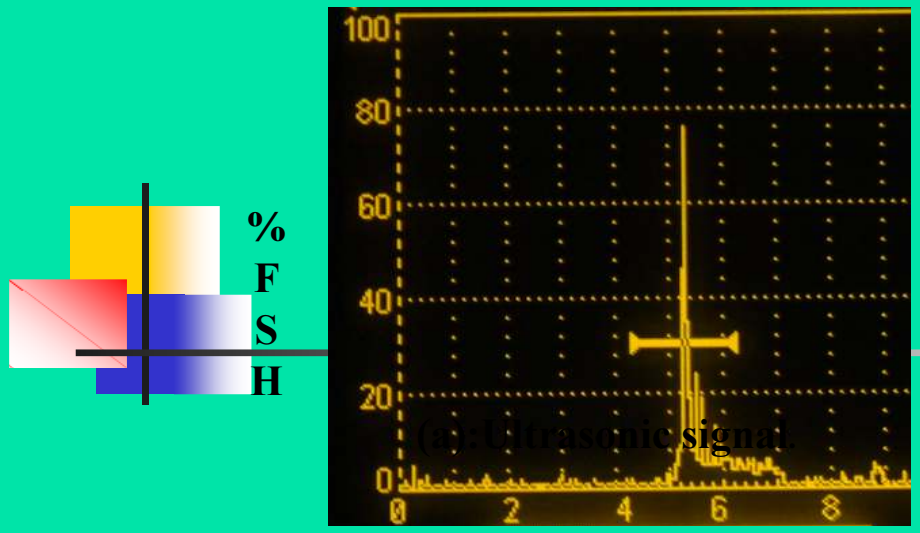


REAL TIME MOTION RADIOGRAPHY

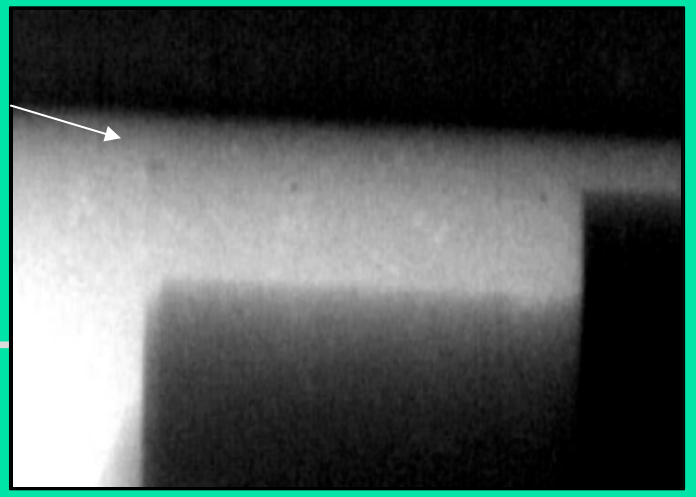
ULTRASONIC END CAP WELD INSPECTION







(a): Ultrasonic signal.



(b): Radiograph

(c): Photomicrograph

Detection of a gross lack of penetration

GAMMA AUTORADIOGRAPHY (GAR)

- PuO_2 AGGLOMERATE AND COMPOSITION BY NDE
- X RAY FILMS IN PVC CASSETTES KEPT IN CONTACT WITH WELDED RODS
- DARKENING OF THE PROCESSED FILM IS PROPORTIONAL TO PuO_2 ENRICHMENT
- DEFECTS :
  - PELLETS OF WRONG ENRICHMENT
  - PuO2 AGGLOMERATES IN THE PERIPHERY
  - COMPOSITIONAL VARIATION

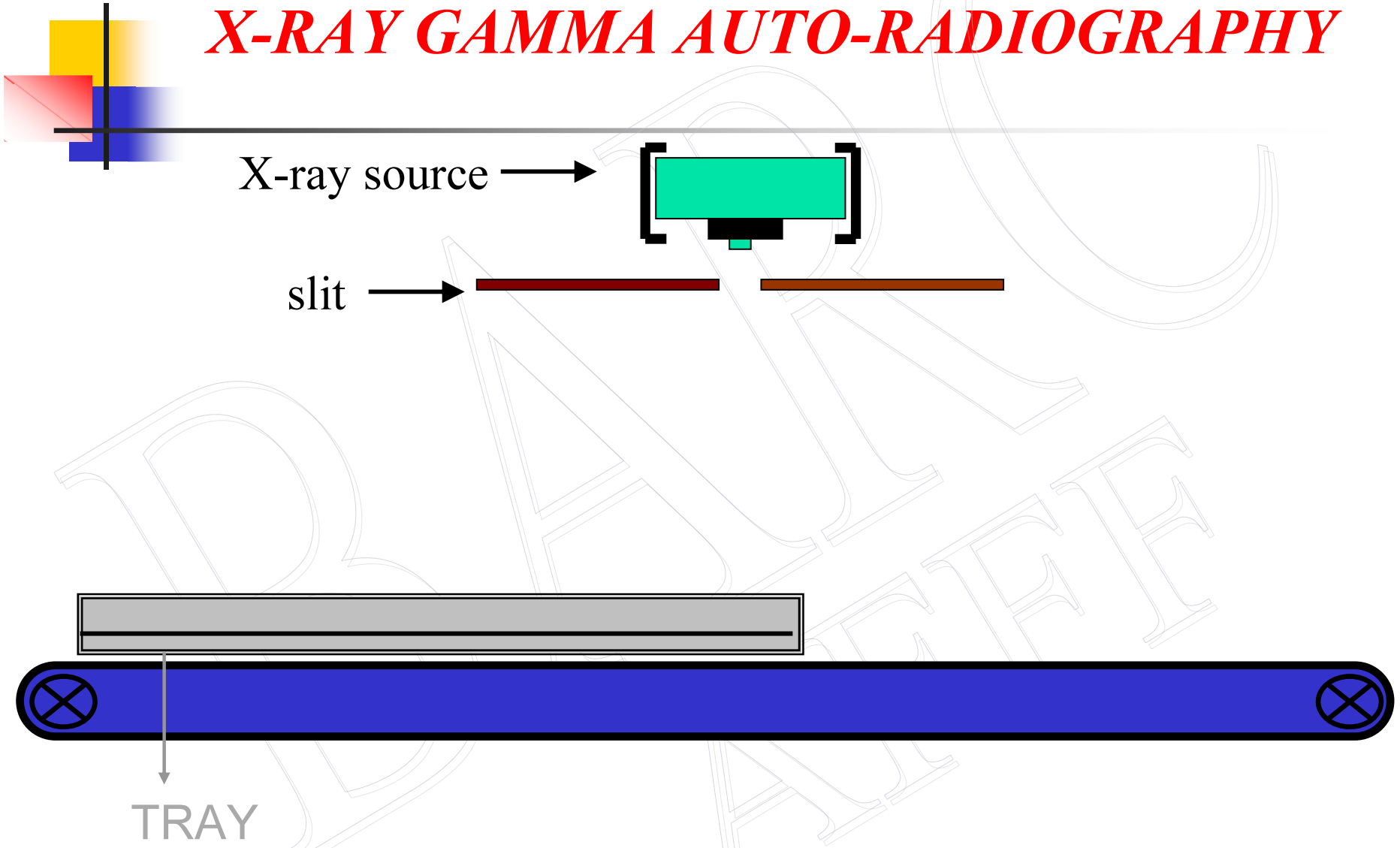
GAMMA AUTORADIOGRAPHY (GAR)

(Cont…)

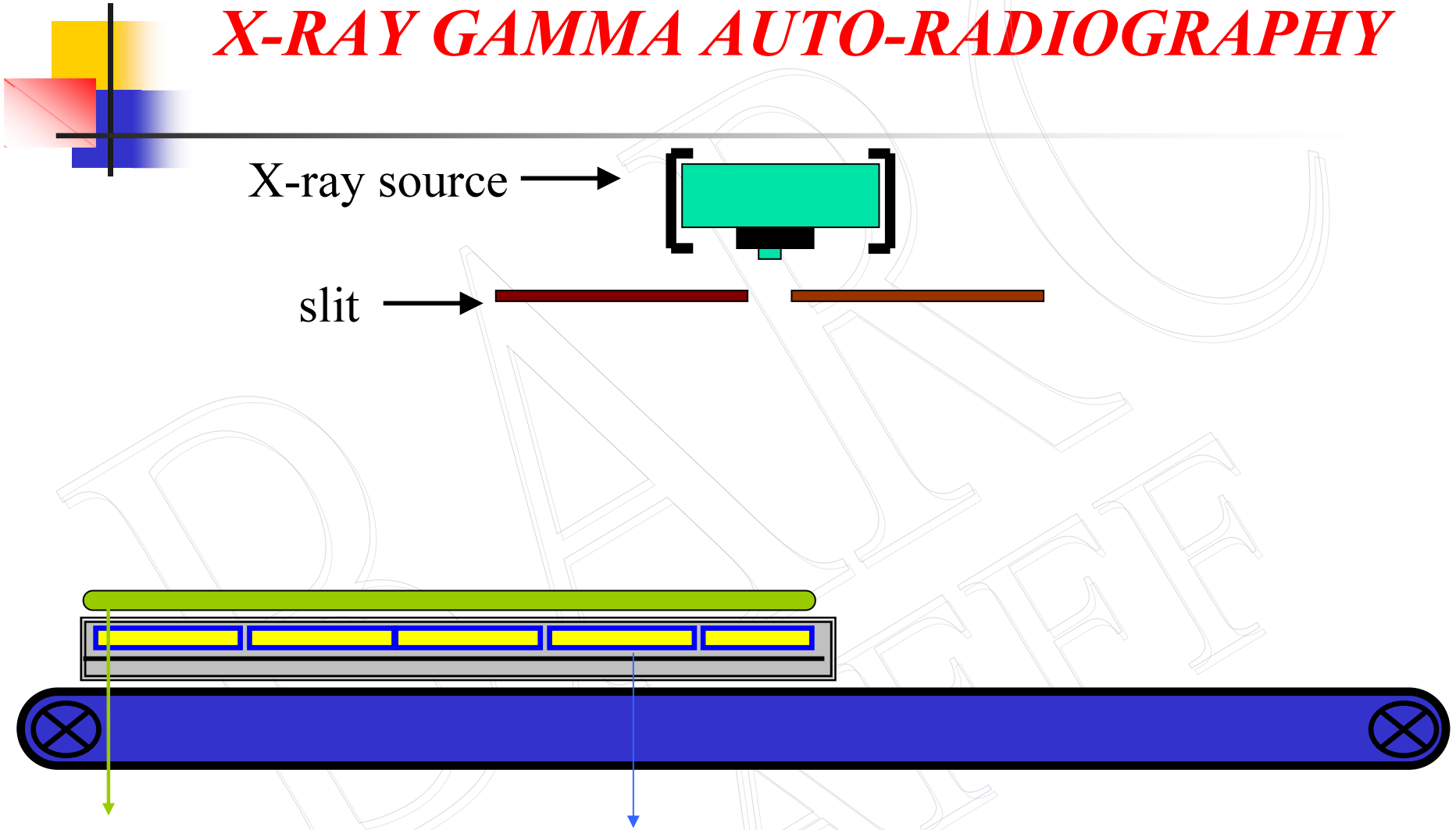
- ANOTHER CHECK FOR PuO_2 ENRICHMENT
- ADDITIONAL QUALITY CONTROL STEP INTRODUCED
- MICRODENSITOMETRY
- COLOUR GAMMA AUTORADIOGRAPHY
- SIMPLE TEST
- **X-GAR : (X-RADIOGRAPHY+GAMMA AUTORADIOGRAPHY)**

  RESULTANT IMAGE GIVES ADDITIONAL INFORMATION ABOUT INTERNAL COMPONENTS LIKE SPRING, SPRING SUPPORT etc.

X-RAY GAMMA AUTO-RADIOGRAPHY



X-RAY GAMMA AUTO-RADIOGRAPHY



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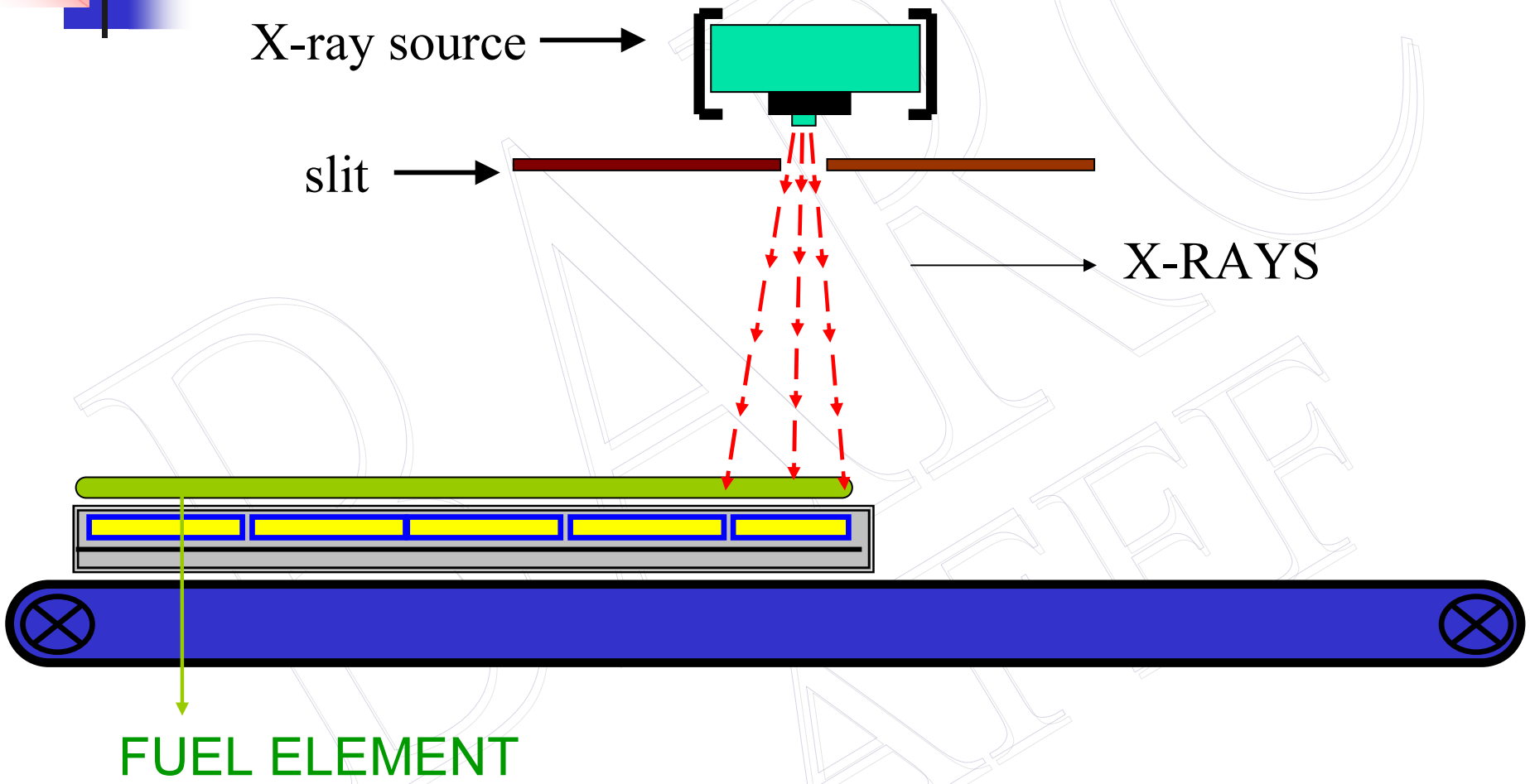

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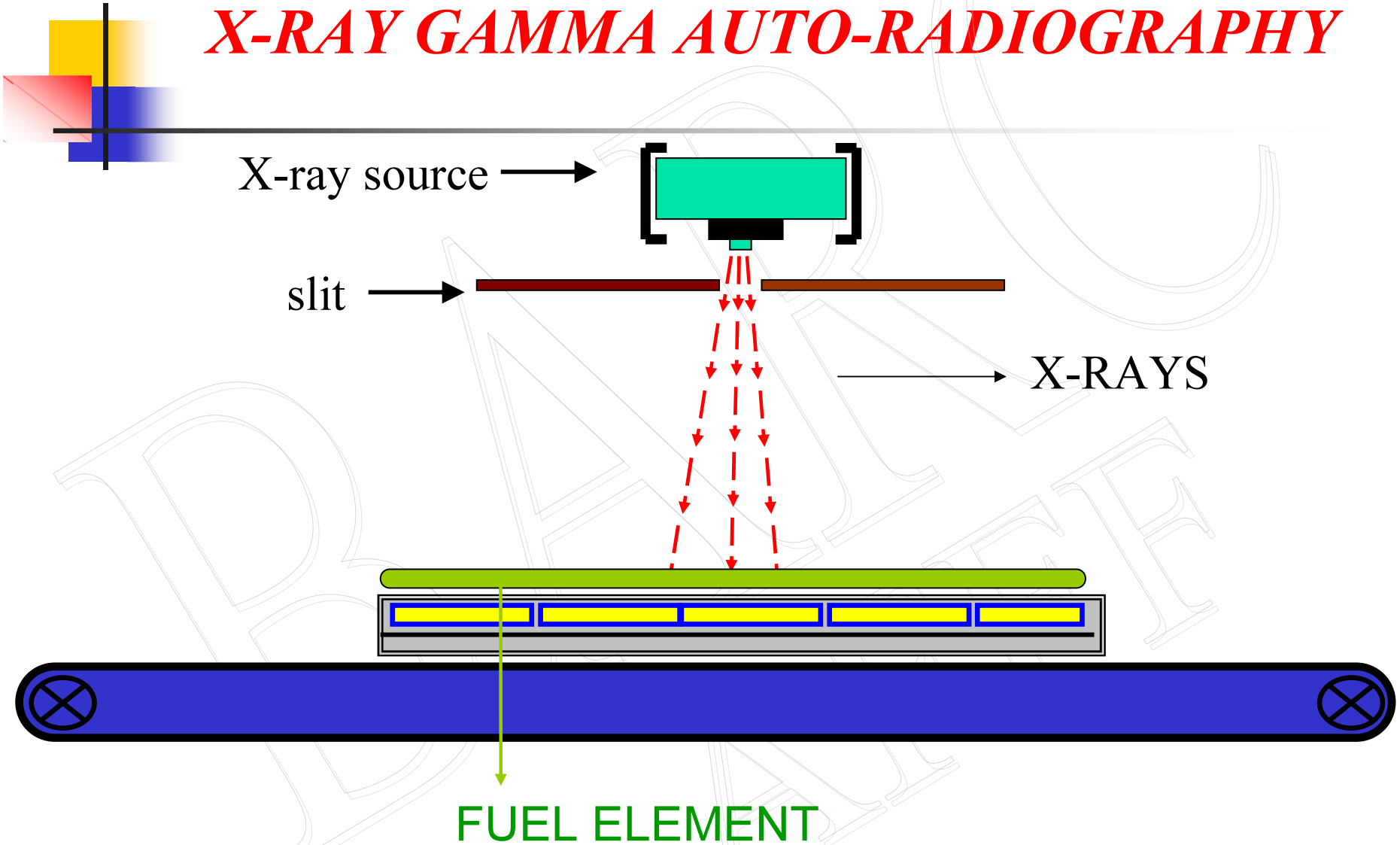
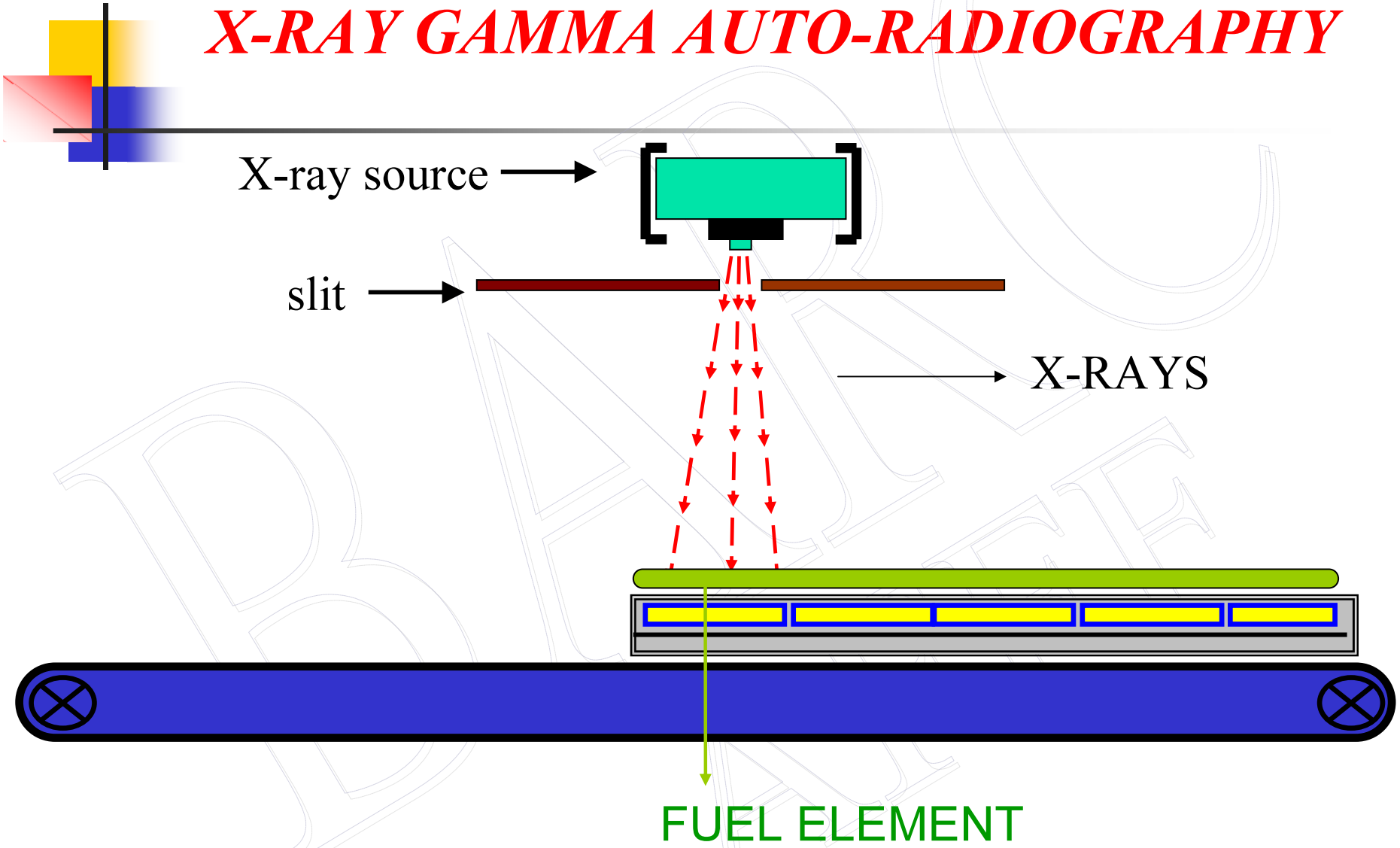


X-RAY GAMMA AUTO-RADIOGRAPHY



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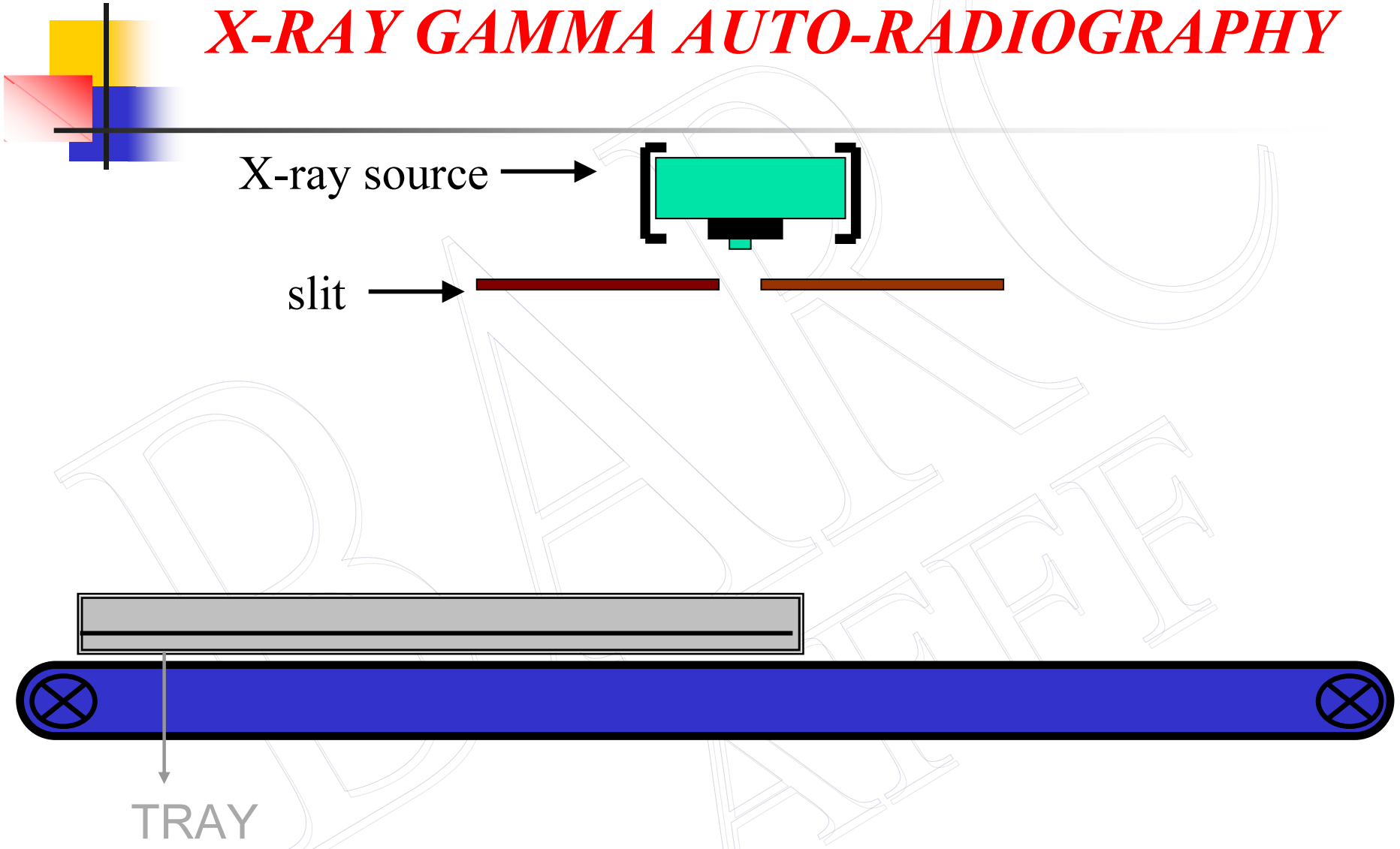

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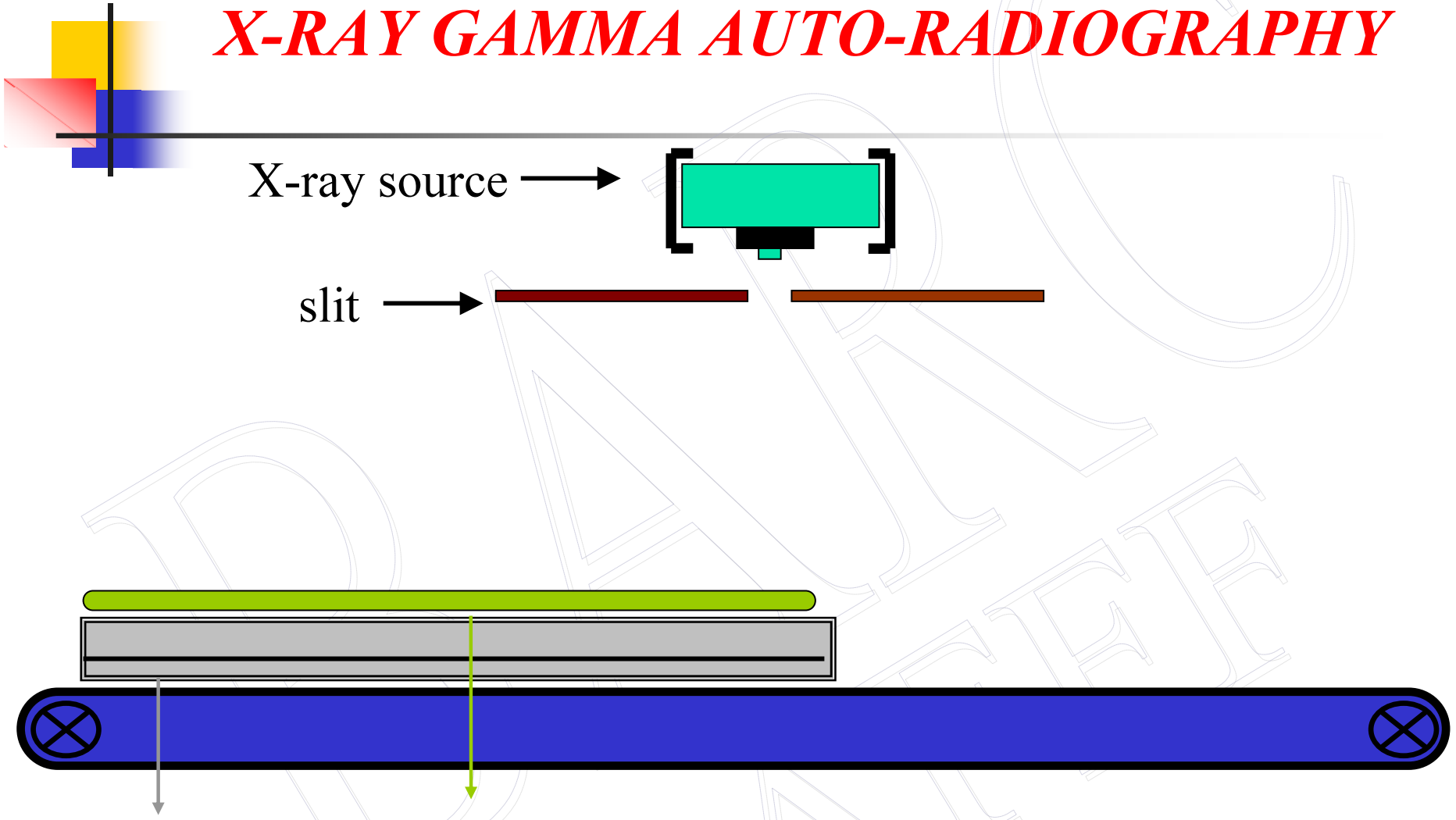

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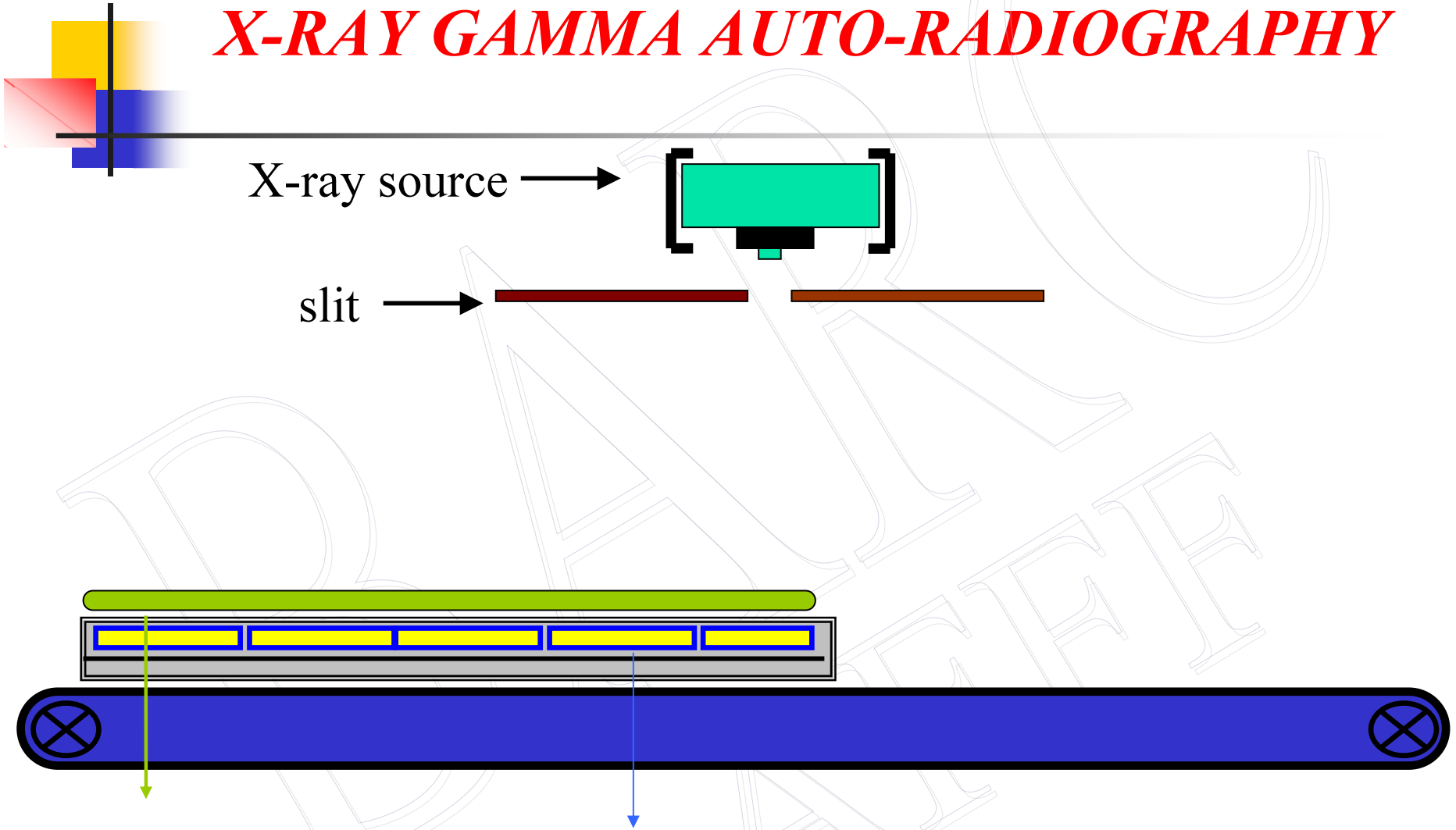

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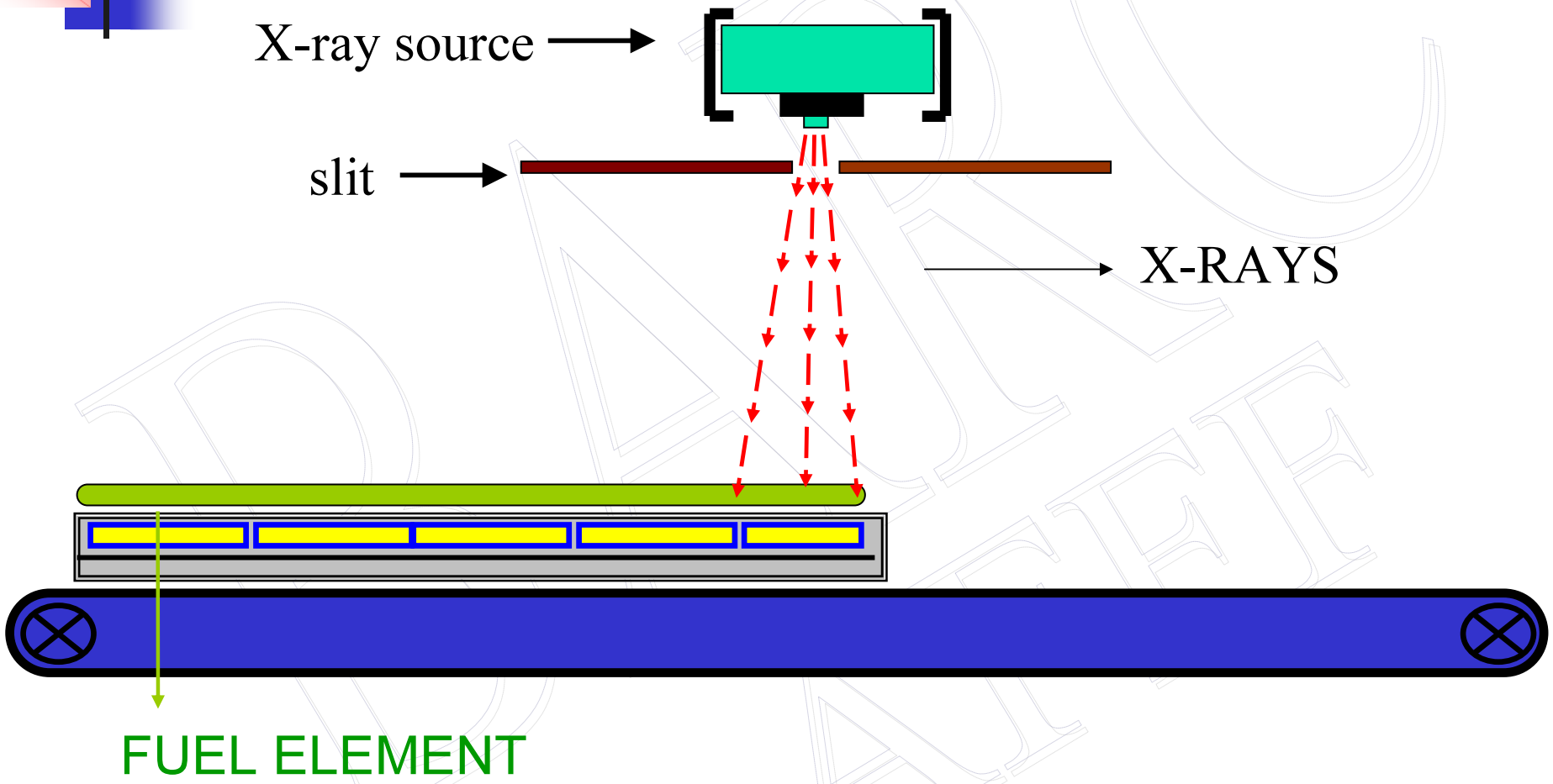

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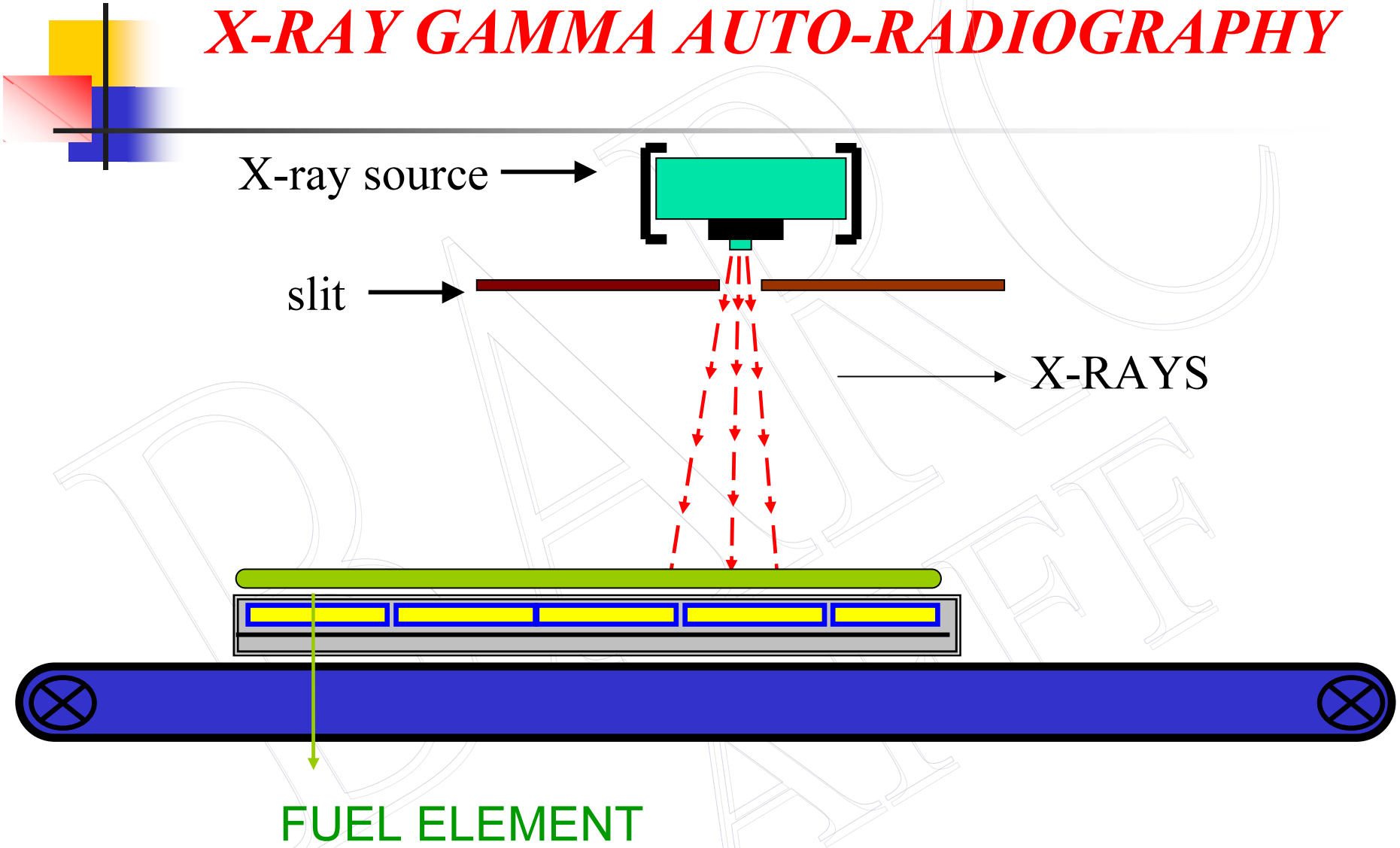

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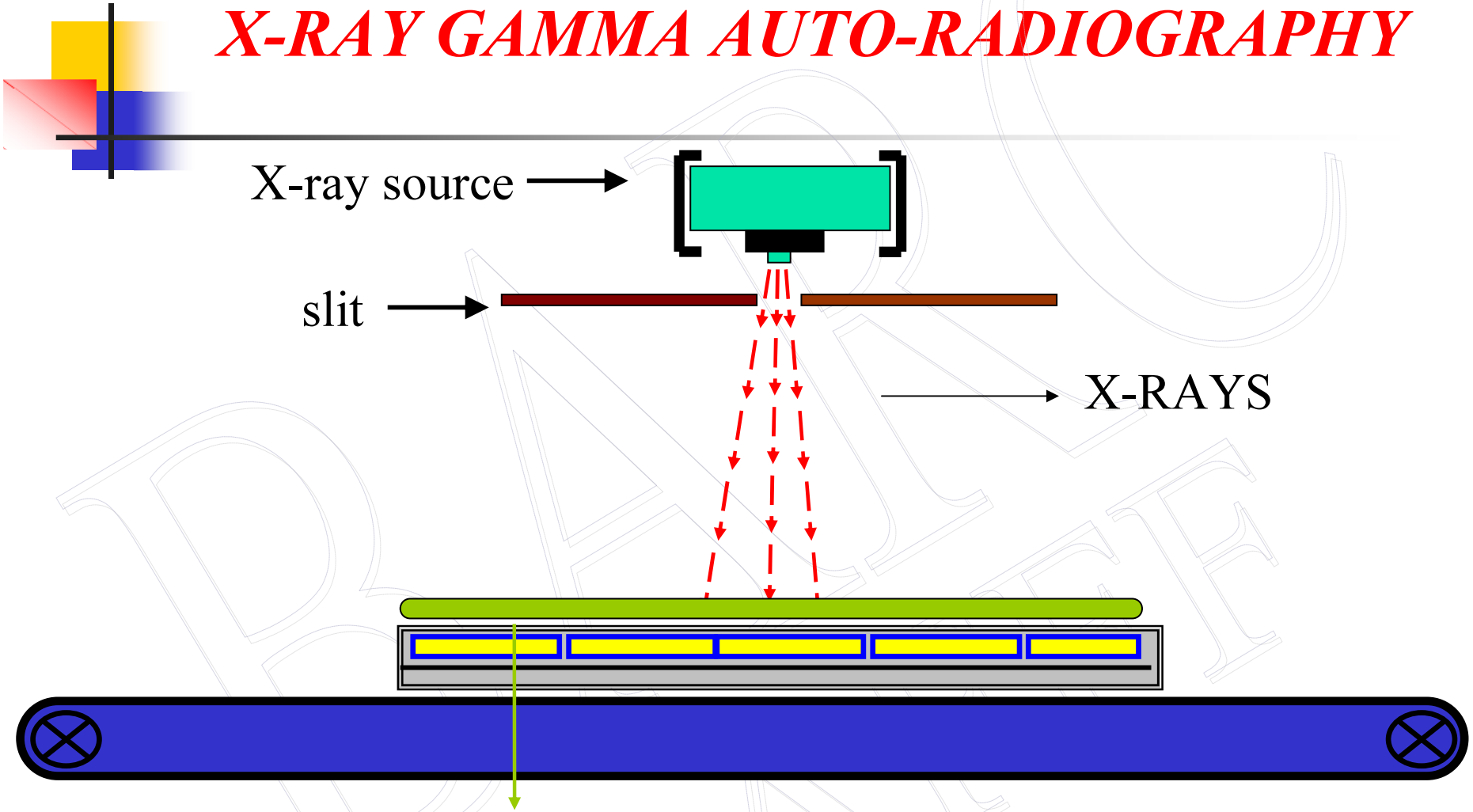

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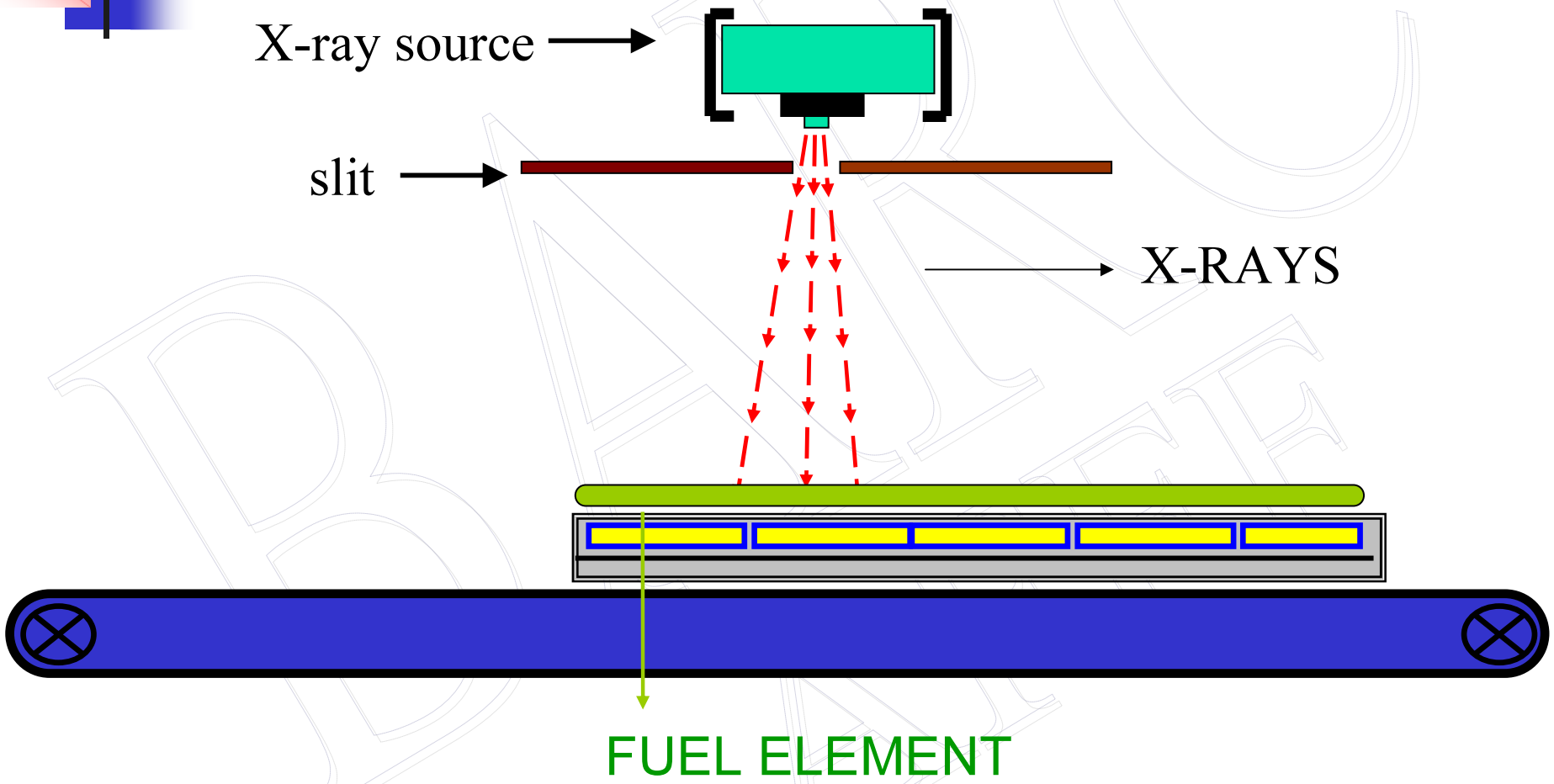

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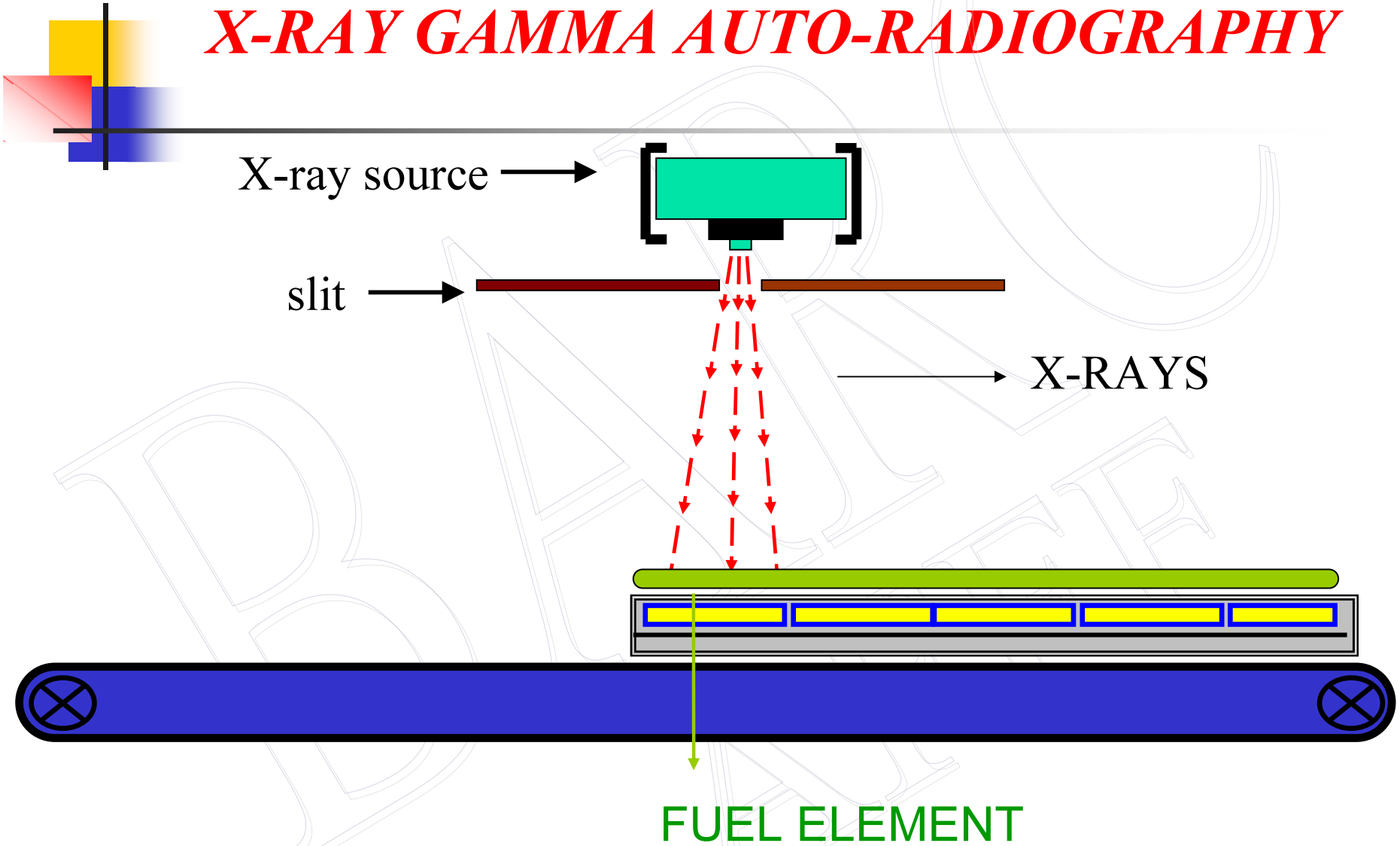
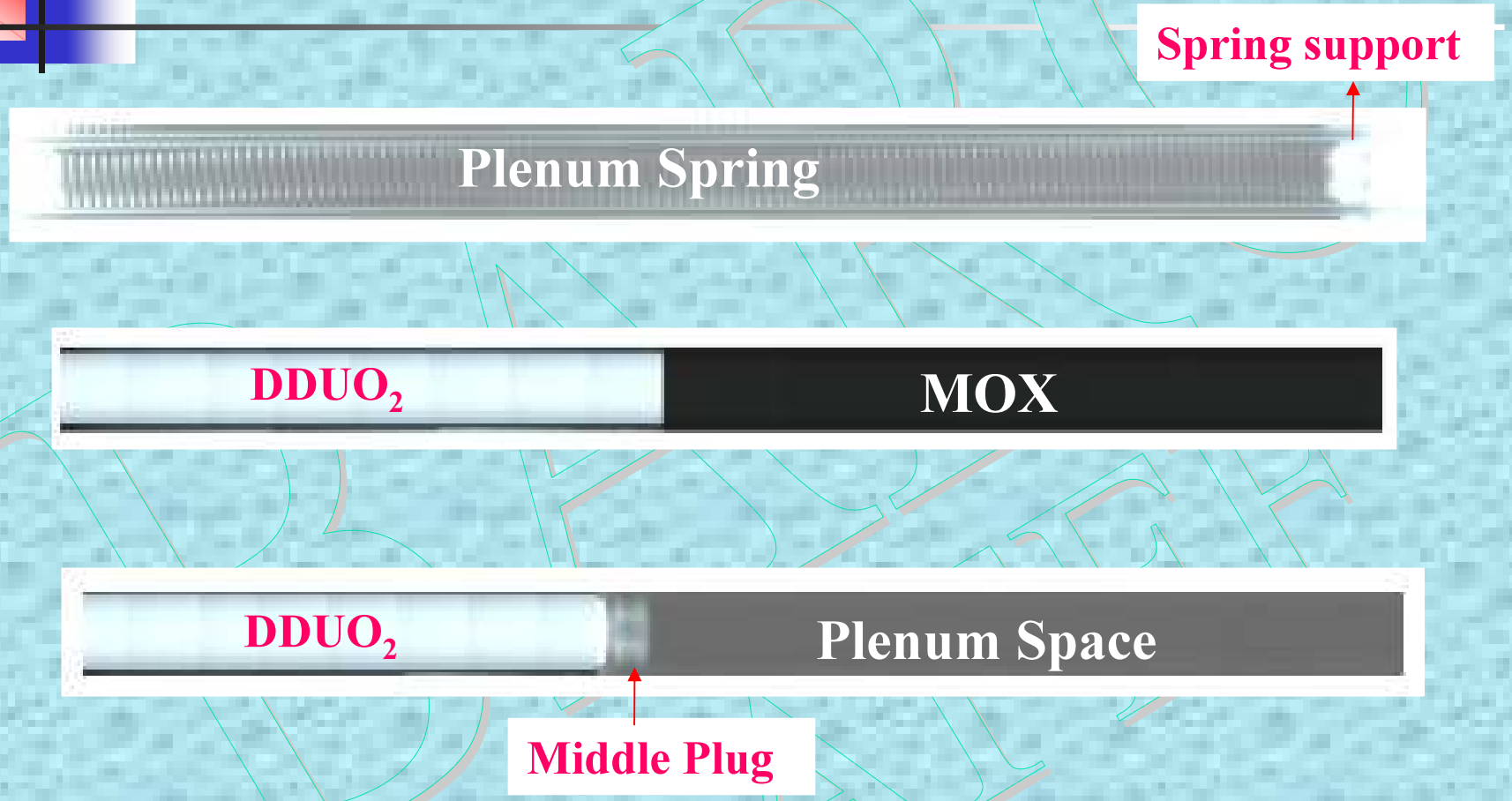
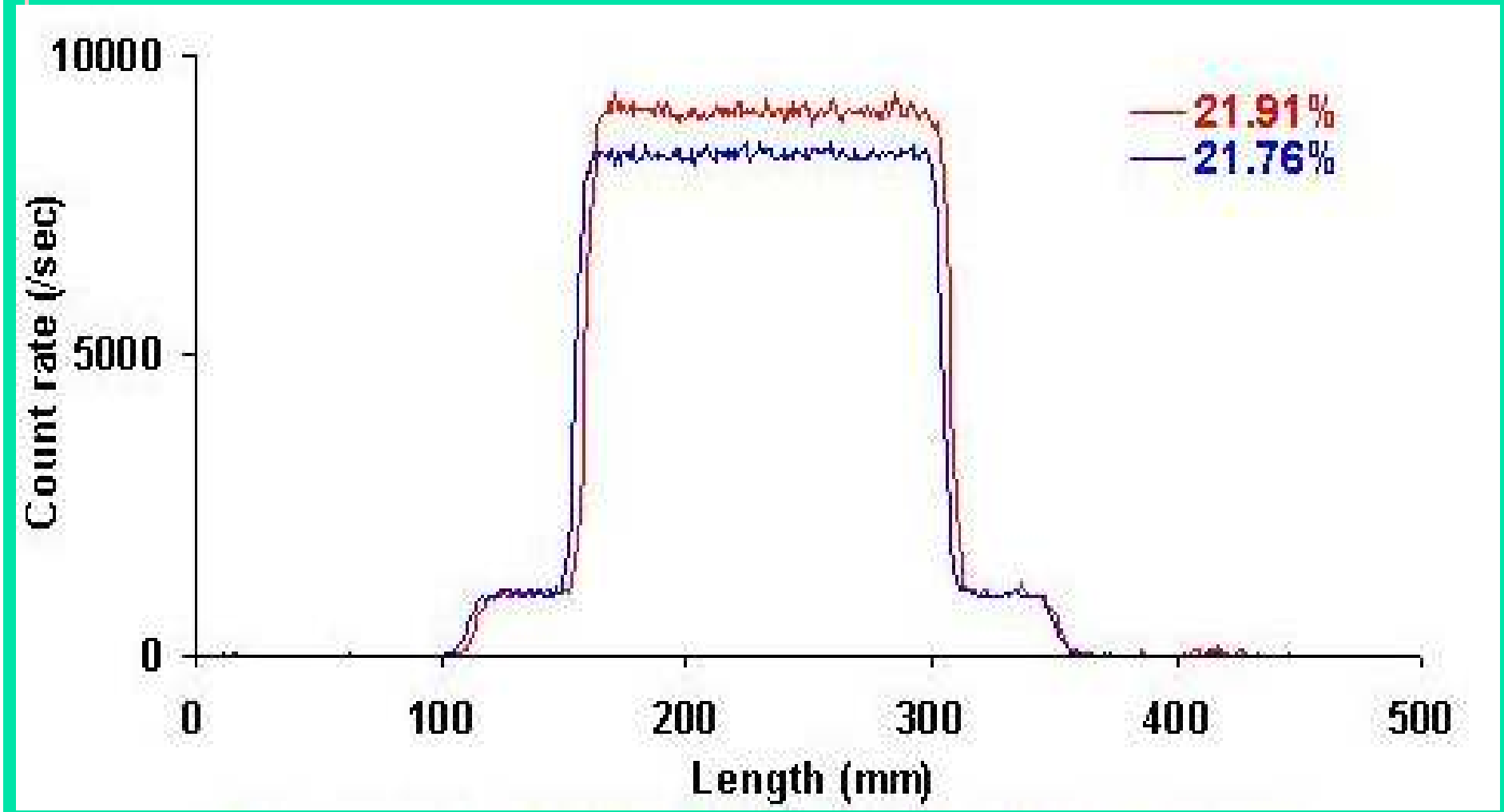


X-GAR OF PFBR FUEL PIN



Gamma Scanning of Fuel Elements

Gamma scan of PFBR MOX fuel pins with varying composition



SURFACE EXAMINATION AND METROLOGY

- ✓ COLOUR, SPARKING, DENTS,
- ✓ SCRATCHES
- ✓ PHYSICAL DAMAGE
- ✓ MANUAL : CCD-TV
- ✓ METROLOGY : MECHANICAL
  LVDT
  NONCONTACT
  (LASER)

TOTAL QUALITY CONTROL

- MORE NDE AND PROCESS CONTROL CHECKS INCREASE RELIABILITY AND CONFIDENCE AND HENCE REDUCE DESTRUCTIVE TESTS
  - e.g. PuO2 ENRICHMENT MONITORED AT DIFFERENT STAGES BY NWCC, PGS, GAR.
- REDUCTION OF DESTRUCTIVE CHEMICAL ANALYSIS
- CHEMICAL ANALYSIS NEEDED FOR SAMPLES NEAR THE LIMITS
- COMBINATION OF PROCESS AND QUALITY CONTROL CHECKS IMPROVE THE QUALITY OF THE FUEL
- INTELLIGENT PROCESSING TECHNIQUES-FOR TQM

CONCLUSION

- PROCESS PARAMETERS FOR FABRICATION OF MOX FUEL FOR PFBR FINALISED.
- ADVANCED TECHNIQUES FOR FABRICATION AND QUALITY CONTROL DEVELOPED.
- AUTOMATION TO REDUCE MANREM

ACKNOWLEDGEMENT

- THE AUTHORS WISH TO THANK OUR COLLEAGUES OF ADVANCED FUEL FABRICATION FACILITY, BARC FOR THEIR CO-OPERATION AND HELP.

- THE FINANCIAL SUPPORT RECEIVED FROM INTERNATIONAL ATOMIC ENERGY AGENCY IS GRATEFULLY ACKNOWLEDGED.


THANK
YOU