International Atomic Energy Agency

Decommissioning of Nuclear Facilities

Dismantling Technologies

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Lesson Objectives

- Review basic objectives of dismantling techniques and processes
- Review selection criteria and factors for consideration in selecting a dismantling process
- Review some typical dismantling technologies and experiences

Fundamental Goals of Dismantling

- Perform the work safely (radiological and non-radiological)
- Minimize dose uptake as much as possible
- Reduce the costs as much as reasonably possible
- Minimize the generated waste

Safety is surely the main basic objective

- Different aspects have to be looked at:
  - Radiation protection
    (for the workers, population and environment)
  - Industrial safety
- When selecting or developing dismantling techniques, this objective must be the first priority
- Indirect safety aspects should also be considered

Typical Hazards for dismantling

- Chemical exposure hazards: asbestos, solvents, etc ; Oral, dermal and inhalation
- Noise: machinery, close working quarters
- Light exposure: Laser, uv, ir, etc
- Ergonomics: Vibration, heavy equipment, computers, lab, lifting, etc.
- Biological hazards: Agents in ventilation systems and static areas; Vectors, plants, animals, insects
- Electrical: Removal of services; Temporary services; use of electric devices
- Explosives: facility, demolition, construction- nailers
- Operation of heavy equipment and power tools
- Overhead work: falling objects, struck against
- Environmental conditions: Heat, cold, wet, slippery, limited visibility
- Housekeeping: construction debris, dismantlement debris
- Confined spaces

Typical Hazards contd.

- Welding and cutting: Industrial hazard; Fire
- Excavations
- Rigging and hoisting
- Toxic and Hazardous substances: Chemicals; Radioactive materials
- Material handling
- Fall Protection
- Field sanitation
- Illumination
- Non-ionizing radiation
- Explosive gas production (e.g. H_2 when cutting with plasma)

Applicability of a technology

- There is no single technique to address all dismantling needs on a decommissioning project
- The selection of technologies depends is influenced by and depends on:
  - The type of facility (power plant, fuel cycle facility, research facility)
  - The type of isotopes present
  - The activity level of the equipments and parts
  - The physical/chemical properties of the equipments/parts to be dismantled (e.g. concrete vs. metal), and of the radioisotopes and contamination layer.

Secondary Waste Generation

- Generally, dismantling techniques produce "secondary" waste like abrasive particles, liquid effluents, chips and fumes, etc
- A method to capture and control these materials is important since
  - It influences worker safety (e.g. production of aerosols; handling of this waste, etc)
  - It impacts waste management (more waste to be disposed of)

Secondary wastes

- When trapping particles on filters, the volume of produced waste can increase the total waste volume significantly
- Secondary waste handling and treatment can be more expensive than simply using a slightly more expensive process from the start but with less secondary waste generation
- Often waste generation is not a factor drawing much attention from the manufacturing industry

Costs

- The overall costs of a dismantling operation consists of:
  - the investment cost
  - the operating costs (incl. manpower, consumables, auxiliary facilities, utilities,…)
  - the waste costs (handling, characterization, packaging, conditioning, transport, disposal)
  - the auxiliary costs (health physics, project management, etc…)
- The investment cost is often marginal when compared to the total cost

Reliability

- The reliability of a technique is linked to the frequency & ease of maintenance and also has an impact on:
  - Overall operating cost
  - Operators safety and dose uptake
  - Secondary waste production
  - Duration of and planning of the operation
- The use of proven industrial technologies, with good reliability, has been shown to optimize this process

The type of facility to be dismantled has also some influence

- The type of facility (power plant, fuel cycle facility, research facility, …) has a direct influence on:
  - The isotope content (α or β,γ emitters)
  - The industrial safety (presence of acids, toxic or exotic materials like Be, asbestos, Pb, various chemicals, …)
  - The environment of the cutting process (e.g. criticality hazard can imply to exclude the use of water as cooling or dielectric medium)
- which in turn has impact on the process selection

Three typical scenarios

- First case: the contact dose rate of the piece to cut is high (a few mSv/h or more).
- Operator may not "touch" the piece to cut - shielding is required
  - This requires a remotely controlled* cutting technique (shielded workshop, underwater cutting…) – never the less industrially proven techniques are available
  - The conception work is then focused on the remote deployment and maintenance of the technique - but maintenance of the equipment is an important factor

*Note: remote control does NOT mean *robotics*. Simple low # DOF remote controlled tools are often more efficient.

Three typical scenarios (2)

- Second case : "Low" contact dose rate but potential high level of contamination
  - More attention is focused on the cutting environment and on the individual protection equipment of the operator
  - Strategy often focused on "On site withdrawal" followed by "Production" carried out in a size reduction workshop
  - Some distinction must be made between inside/outside contamination
  - The cutting process must take into account the constraints & requests of the following operations (e.g. decontamination)

Three typical scenarios (3)

- Third case : No (i.e. - very, very low) dose rate (a few μSv/h) and almost no contamination
  - Production rate becomes a priority
  - Safety aspects are “only” classical industrial ones
    - Still, attention needs to be given to the low-level effluents and waste generated
  - Techniques used in industry (e.g. oxygen cutting, plasma arc, grinding, industrial automatic band saw or reciprocating machine, etc) can be used to increase the production rate

Metal parts and concrete structures

- The dismantling techniques for concrete are often similar to the decontamination techniques (see thus also previous lesson on decontamination technologies).
- Let us first start with metal parts dismantling

Some typical dismantling technologies

- Most technologies can be classified into four main groups:
  - Mechanical techniques
  - Thermal techniques
  - Electrical techniques
  - Emerging technologies

Mechanical techniques

- Most of the mechanical techniques are adaptation of industrial technologies:
  - Hydraulic shears
  - Power nibblers
  - Mechanical saws (various types)
  - Milling cutters
  - Orbital cutters
  - Abrasive cutting wheels (disks), blades, wires and core drills

Thermal techniques

- Most of the thermal techniques are also industrial used ones:
  - Plasma arc cutting
  - Flame cutting
  - Powder injection flame cutting ("thermite")
  - Thermic lance
- Powerful and fast, but spreads contamination
- Similar to those thermal technique is the (high pressure) abrasive water jet cutting

Electrical techniques

- The industrial processes are quite slow and produces difficult to trap secondary wastes; other methods are under development:
  - Electro discharge machining (sparkling erosion)
  - Metal disintegration machining
  - *Consumable electrode cutting* (in development)
  - *Contact arc metal cutting* (in development)
  - *Arc saw cutting*
- Proven industrial techniques, but are slow

Emerging technologies

- Some of these techniques are already used in the industry, but for other purposes, some others are developed also for decommissioning:
  - Laser cutting (industrial, but not for typical applications in decommissioning)
  - CAMC (mostly developed in the framework of decommissioning)
  - Consumable electrode
  - Arc saw cutting
  - Liquefied gas cutting
  - Explosive cutting

Summary table of the techniques

Mechanical cutting processes

Technique	Materials	Environment	Remote operation feasibility	State of development
Shears	All metals	Air/UW	++	industrial
Power nibblers	MS, SS	Air/UW	+	industrial
Mech. Saws	All metals	Air/UW	++	industrial
Milling cutters	All metals	Air/UW	++	industrial
Orbital cutters	All metals	Air/UW	+	industrial
Abrasive cutting	All metals	Air/UW	+	industrial

Summary table of the techniques

Thermal & similar cutting processes

Technique	Materials	Environment	Remote op feasibility	State of development
Plasma arc	All metals	Air/UW	++	industrial
Flame cutting	MS	Air/UW	+	industrial
Powder injection	All metals	Air	o	industrial
Thermic lance	All metals	Air/UW	-	industrial
Abrasive water jet	All metals	Air/UW	o	almost industrial

Summary table of the techniques

Electrical cutting processes

Technique	Materials	Environment	Remote op feasibility	State of development
EDM	All metals	Air/UW	o	industrial
MDM	All metals	Air/UW	o	Industrial
Consumable electrode	MS	Air/UW	+	in development
CAMC	All metals	Air/UW	+	in development
Arc saw	All metals	(Air)/UW	o	in development

Summary table of the techniques

New and emerging cutting processes

Technique	Materials	Environment	Remote op feasibility	State of development
Laser cutting	All metals	Air/(UW)	o	In development
Liquefied gas	All materials	Air	o	In development
Explosive cutting	All materials	Air/(UW)	o	In development

Some examples of the use of metal cutting in actual decommissioning operations

Comparison of the three cutting techniques during the Thermal Shield dismantling

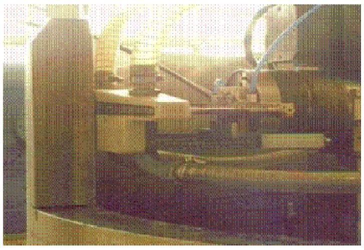
Only relative values

Parameter Cutting Method	Cutting Speed	Operation Duration	Dose Uptake	Secondary Waste Volume
Mechanical	1	1	1	1
Plasma	50	0.63	≈ 1	≈ 5
EDM	1/10	4	≈ 3	≈ 5

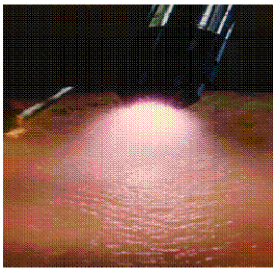
Comparison of Underwater remote EDM cutting, Mechanical Cutting and Plasma arc torch in one project

Milling

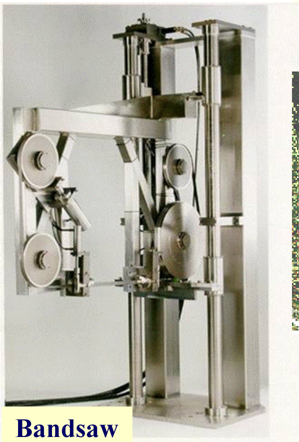
Electric Discharge Machining



Plasma torch

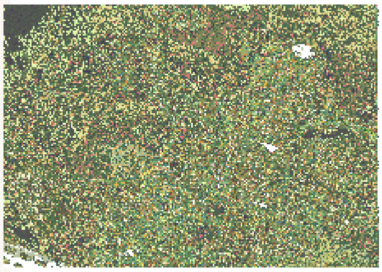


Remote controlled underwater mechanical cutting



Bandsaw

Circular Saw



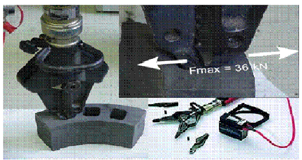
Mechanical cutting is quite easy to remote control; but requires stiffness of the work piece and/or of the tools.

Reciprocating Saw

Mechanical cutting on contaminated parts

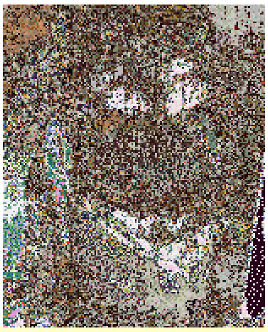
Orbital cutter to dismantle primary piping

Using power nibbler for dismantling a tank



Mechanical breaking of graphite

Various types of band saws



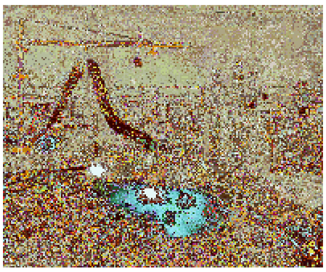
Cutting of steam generator
by band sawing after freezing

Band saw for cutting large equipment

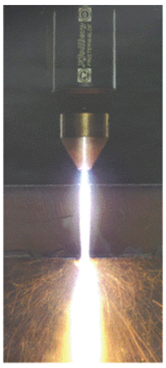
Hand held band saw

Underwater thermal (plasma) cutting

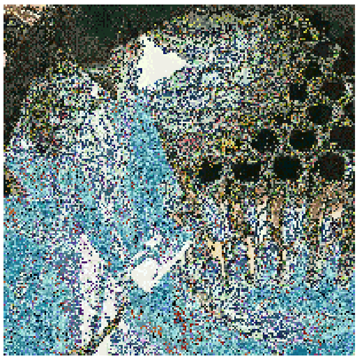
Underwater plasma arc cutting
of highly activated parts



Plasma cutting can be remote
controlled and used under water

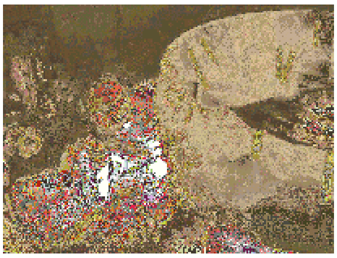


Cutting of stand pipes by automated
plasma arc cutting tool



Plasma cutting in dry conditions (workshop)

Hand held plasma arc torch used on contaminated material



Manipulator with Plasma Arc Cutting Tool

Other thermal cutting tools

Cutting RPV head with thermic lance

Cutting large piping with oxygen torch

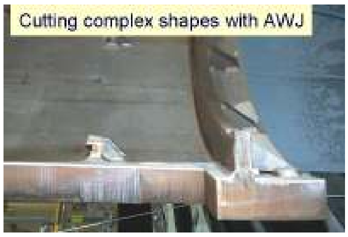
Note the individual protection always wear by the operators

Abrasive water jet (AWJ)

Remote controlled AWJ for cutting RPV and internals

The use of AWJ is presently under development and used in pilot projects

AWJ deployed by tele-robotic arm



Cutting complex shapes with AWJ

Two systems are existing, with each his own advantages and drawbacks:
- the suspension jet (water and abrasives are mixed at the pump)
-the injection jet (abrasives are mixed at the torch level)

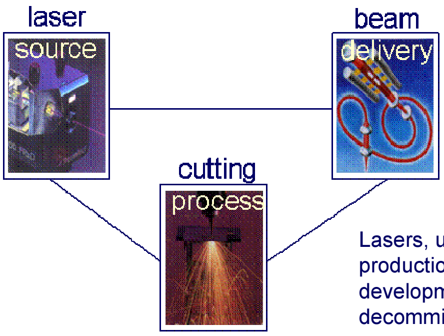
Electrical cutting techniques

EDM head used for dismantling internals of a PWR

CAMC is supposed to cut much faster than EDM and is presently developed in different application (cutting, grinding, drilling)

Contact Arc Metal Cutting in development
view of a cut on a test piece

Emerging techniques are under development for use in dismantling nuclear installations



Lasers, used in the industry for production machining, needs still developments to be used in decommissioning

Arc saw cutting requires very important power source ! (*about 1 MW electric power in the above example*)

Lessons Learned

- **Plasma arc cutting and thermal cutting systems tend to spread contamination. Process cutting speed should be replaced by overall cutting time (incl. preparation and post operation)**
- **Underwater cutting is very efficient and dose uptake does not depend on specific activity of work piece**
- **Investment costs are marginal compared to other costs**
- **Maintenance, tool replacement and ease of decontamination are important factor for selecting a process**
- **The amount of planning required for power supplies, support & deployment systems should not be underestimated**

Lessons Learned (cont'd)

- Few projects require tele-manipulators or sophisticated tools. Simple tools with only a few DOF are often sufficient
- Manipulators need a sufficient payload capacity and must be robust. Allow for contingencies arising from reaction forces and other factors
- Umbilical and cable management is always a problem, and should not be underestimated
- The use of robotics should be considered only after a thorough analysis of other options. Keep dismantling simple.
- The use of mock-ups and computer models is essential for operator training, dose reduction, safety, feasibility & maintenance

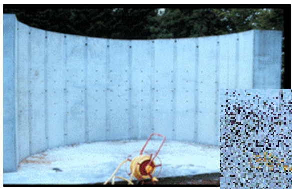
Some examples of the use of concrete cutting in actual decommissioning operations

Remote controlled jackhammer

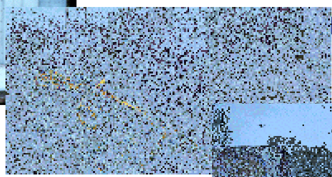
- Simple tool easy to use
- Can be remotely controlled (deployment)
- Very efficient
- Relatively easy to collect the produced debris

Remote controlled jackhammer

Explosive blasting of concrete



Mock up of the bioshield



Positioning of loads

Blasting

Result

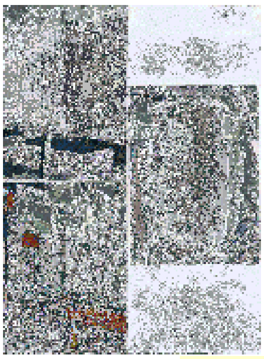
- Difficult to prepare (drill holes)
- Safety issues (unexploded loads)
- Labour intensive post operation
- Filtration issues (shock wave)
- Airborne contamination
- Not always efficient (rebars)

Drilling, and spalling (chemical or mechanical)

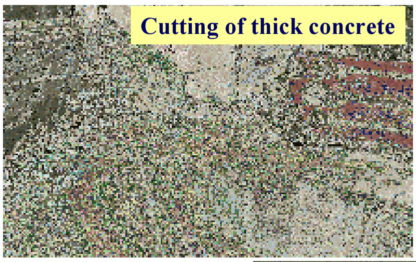
- Drilling (diamond core drills)
  - Easy method, easy to set up
  - Not very efficient
  - Same kind of generated waste as for cutting (sludge, dust, water)
  - Multiply by factor π the length of cut
- Spalling
  - Mentioned in various handbooks
  - Not very commonly used in nuclear decommissioning

Concrete “crushing” using hydraulic shears

Diamond wire cutting



Cutting of thick concrete



Removal of a contaminated layer

Cuts through concrete and re-bar

Example of hand cutting

Not very commonly used in nuclear decommissioning

Summary

- Workers safety, radioprotection optimization, waste minimization and cost reduction are key drivers in the selection of dismantling tools and processes
- The investment cost of a cutting technology is often marginal vs. other costs.
- Do not look only at the instantaneous cutting speed; other factors are very important (total operation duration, waste generation, maintenance and reliability, easiness to use,…)
- Like in all areas of decommissioning, the keyword is: **keep it simple** ! (and reliable, easy to use and to maintain)

References

- IAEA TRS #348
- IAEA TRS #373
- IAEA TRS #395
- IAEA TRS #439
- IAEA TRS #440