Accident Analysis of the Process of Transferring Cobalt-60 Radioactive Waste of Teletherapy Machine into the Transport Container with Fault Tree Analysis (FTA) Method

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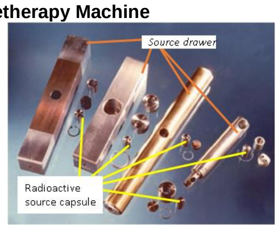
1. Background and Goal

Radioactive waste from teletherapy machines is classified as Spent High Activity Radioactive Sources (SHARS). It must be sent to the Centre for Radioactive Waste Management (PRTLR) of Indonesia for disposal In Indonesia, head teletherapy is used as a transport container for this proses, requiring more space than the available storage space. It costs a lot to buy a new one. Therefore, it is necessary to provide a transport container that follows existing regulations while still paying attention to its economic value and practicality.

To design a transport container, it is necessary to analyze the accidents in transferring ^{60}Co radioactive waste from the teletherapy machine into the transport container. Factors causing this accident need to be known to assist in making a design that can anticipate them. In addition, evaluating the probability of the accident's cause is also essential. The factors causing accidents and their probability evaluation can be determined using the Fault Tree Analysis (FTA) method.

2. Identification of the Radioactive Waste of Teletherapy Machine

- The ^{60}Co source radioactive waste is in the form of capsules in the source drawer.
- The source drawer is cylindrical and made of lead



Types of Source Drawer

3. *Determined the Scenario of Transferring Cobalt-60 Radioactive Waste of Teletherapy Machine into the Transport Container*

- The main scenario is the transfer process with two transportation options, namely a gantry crane and a semi-electric hand stacker.
- The transfer of radioactive waste from the teletherapy machine into a transport container is carried out using a special tool called T-rod.

4. *Determine Failure Event in the Process of Transferring Radioactive Waste*

4.1. *Identification of Undesired Event*

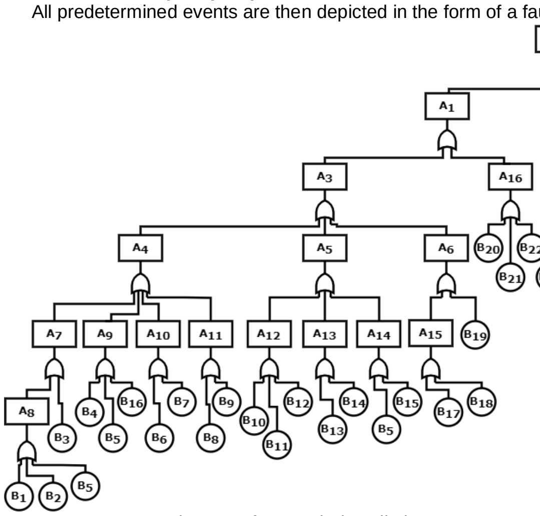
- The most undesired event in this study is an event that can cause radiation exposure that exceeds the limits for both workers and the environment. It can also be unexpected radiation exposure in transferring the radioactive waste.
- The most undesired event (Top event) determined in this study is "Radiation exposure that exceeds the limit".

4.2. *Analyze the cause of Undesired Event*

- Radiation exposure that exceeds the limit can occur when
  - Radioactive waste is not at the targeted transfer location or in its original place.
  - Leaks in the container used as a transportation place also can cause radiation exposure.
- Based on the explanation, it can be determined that the events are "Source Drawer Fell" and "The Container Leaks"
- The causes of these two events are then identified and analyzed on a top-down basis to obtain the basic event.

5. Fault Tree Analysis (FTA)

- All predetermined events are then depicted in the form of a fault tree diagram.



FTA Diagram of Exceeded Radiation Exposure Events

Description of code and event summary

Code	Event	Code	Event	Code	Event
T	Radiation exposure exceeds the limit	A17	Failure of the container body to withstand radiation	B14	The hand stacker wheel is damaged or detached when lifting
A1	Source drawer falling	A18	Failure of the container door to withstand radiation	B15	Crack on the semi-electric hand stacker fork
A2	The transport container has a leak	A19	The container door failed to close properly	B16	The crane chain is corroded or due to age
A3	The transport container detached from the teletherapy head and fell while the source drawer was in the process of being moved	A20	The container door failed to lock properly	B17	Extra lock strap broke
A4	Installation of transport containers using gantry crane is not right	B1	The hook is not stored properly, so the end of the hook cracks and then breaks	B18	Chain for extra lock lose
A5	Improper installation of a transport container using a semi-electric hand stacker	B2	Corrosion hook and age factor	B19	The container and the teletherapy head do not lock together due to the shape that does not match
A6	Transport container detached from the crane hook	B3	The hook without the safety lock is deformed or stretched	B20	The T-rod has reached the stress limit, so it breaks when the T-rod is about to be inserted
A7	Transport container detached from the crane hook	B4	Crane chain lose due to cracked	B21	The T-rod is inserted into the teletherapy head incorrectly, so it is bent
A8	The crane hook that is equipped with safety lock is not working properly	B5	The excess weight of the object lifted	B22	The T-rod thread is loose, so it cannot grip the source drawer
A9	Loose crane chain	B6	Transport container handle cracks due to age or corrosion	B23	There are cracks in the container due to extreme falls
A10	The hook handle on the transport container is broken	B7	The handle of the transport container cracked because the container had fallen in an extreme way	B24	Corrosion on the container body
A11	Broken crane mast	B8	Cracks in the crane post welding	B25	Bent transport container door
A12	Failure of the semi-electric hand stacker drive	B9	Gantry crane mast corrosion or age factor	B26	Broken transport container door hinge
A13	Failure to lock the semi-electric hand stacker position	B10	The semi-electric hand stacker motor turns off when in use	B27	The crust on the door of the transport container
A14	Broken semi-electric hand stacker fork	B11	The semi-electric hand stacker battery is not recharged to sufficient	B28	Transport container bolts and nuts are not tight due to corrosion
A15	Additional locks are not good	B12	Hydraulic of hand stacker semi-electric jam	B29	Broken transport container bolts and nuts
A16	T-rod does not work	B13	The hand stacker wheel lock does not work because it is loose		

5.2. *Qualitative Analysis*

- Calculation of the minimum cut set using a software tool that is based on Boolean Algebra. The minimum cut set is the smallest combination of independent component failures required by top events to occur.

5.3. *Quantitative Analysis*

- To determine the probability value of each basic event and the top event
- The probability value of each basic event is generic data from various sources. Generic data were used due to data limitations.

Generic Data Sources
NUREG-0612
IAEA TECDOC 478
Component Failure-Rate Data with Potential Applicability to A Nuclear Fuel Reprocessing Plant (DP-1633) by Dexter and Perkins
Reliability and Maintainability in Perspective Practical, Contractual, Commercial & Software Aspects, Third Edition
Failure Rate Estimates for Passive Mechanical Components
Nonelectronic Parts Reliability Data 1991 (NPRD-91) by W. Denson, G. Chandler, et al.
Handbook of Reliability Prediction Procedures for Mechanical Equipment by Naval Surface Warfare Center (NSWC-10)

- The basic event probabilities that have been obtained are then inputted into the Fault Tree Analysis Software Tool to obtain the top event probability values.
- Based on the results of calculations that have been carried out, it is known that the probability of radiation exposure events that exceed the limit can occur at 9.76×10^{-3} or 0.976%.

6. Evaluations

- Qualitative Evaluation
  - To determine the order of minimal cut sets and the type of basic events. The calculation generates 29 Minimal cut sets in the same order as order 1. Smaller orders have a high criticality, top events could happen more easily.
- Quantitative Evaluation
  - Quantitative evaluation is done by calculating the cut set importance or frequency of each minimal cut set.
  - The use of a semi-electric hand stacker for transferring the container has a greater probability of failure than using a gantry crane because it has active components that are more dynamic so that they will be damaged more quickly.
  - Related to the transport container, the part that to pay attention to is the door hinge.

7. Conclusions

- Based on the research that has been done, it can be concluded that the failure of 29 basic events could cause the accident in the process of transferring the radioactive waste of ^{60}Co and 29 minimal cut sets.
- Radiation exposure events that exceed the limit have a probability of 9.76×10^{-3} or 0.976%. This value can be categorized as still safe.
- In this study, several things need further analysis, for example using an advanced analysis method and specific data to obtain a more detailed result.

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