Safety Analysis on the Process of Cobalt-60 Teletherapy Sources Displacement from the Transport Container to the Storage Container using Fault Tree Analysis Method

Wahyu Amalia Nurbaiti, Susetyo Hario Putero, Kusnanto

Department of Nuclear Engineering and Engineering Physics, Universitas Gadjah Mada
Jl. Grafika 2, Yogyakarta 55281, Indonesia
wahyuamalia2017@mail.ugm.ac.id

1. Background and Goal of the Present Work

In this study, a safety analysis was carried out on transferring ^{60}Co teletherapy sources from the transport container to the storage container. This study aims to analyze the causal factors and probability values of accidents that occur in the process of transferring ^{60}Co teletherapy sources. Thus, the results of this study can be considered from the safety aspect in the design of storage containers to facilitate the storage of ^{60}Co teletherapy source waste.

2. Radioactive Source Waste Displacement Scenario

- The waste from the transferred teletherapy machine was a radioactive source of ^{60}Co, classified as category one waste with an A/D ratio ≥1000.
- ^{60}Co source radioactive remains in the source drawer during the transfer from the transport container to the storage container to reduce unwanted radiation exposure.
- The equipment used in the ^{60}Co source transfer process is a forklift, transport container, T-rod tool, and storage container.

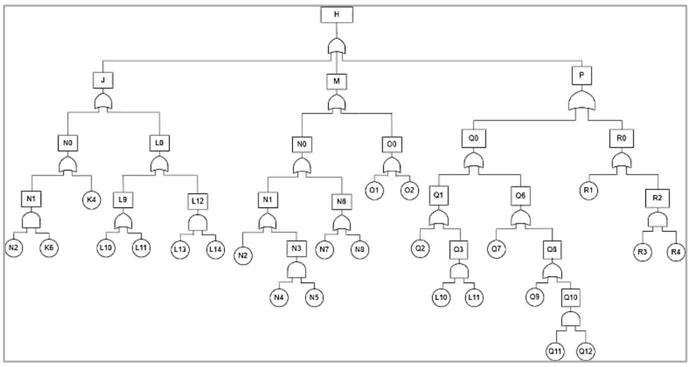
a b c

Picture 2 (a) ^{60}Co source with source drawer (b) T-rod tool (c) Forklift

- The top event in this scenario is the escape of radiation exposure to workers. This event was caused by three main intermediate events: transport container crash, transport container leak, and source drawer crash.

3. Fault Tree Analysis (FTA) Graphic Model Development

1. The fault tree is divided into three main intermediate events as follows:



Picture 3 Fault Tree Analysis Graphic Model

Code	Event Description	Code	Event Description	Code	Event Description
H	radiation exposure to workers	N0	door malfunction	Q2	meaurement failure
J	transport container crasehd	N1	damage to the door joint	Q3	chain break
K0	forklift overturned	N2	broken door hinge	Q6	crane hook loose
K3	damaged control component	N3	bolts not installed properly	Q7	error in hook installation
K4	a collison with a hard object	N4	loose bolt	Q8	improper hook installation
K5	worn out forklift tires	N5	broken bolt	Q9	hook strap on loose container
K6	loose forklift brake	N6	container isn't closed properly	Q10	hook damage
L0	load lifting failure	N7	crooked door	Q11	corrosion hook
L9	forklift lift chain malfunction	N8	rusty door	Q12	cracked hook
L10	chain wear	O0	container door malfunction	R0	canal factor

Code	Event Description	Code	Event Description	Code	Event Description
L11	rusty chain	O1	defect in container body	R1	lock failure
L12	fork damage	O2	corrosion in container body	R2	canal damage
L13	bent fork	P	source drawer crashed	R3	rusty canal
L14	cracked fork	Q0	crane factor	R4	cracked canal
M	container leak	Q1	crane chain broken		

4. Qualitative and Quantitative Analysis using the FTA Method

- To establish the minimum cut set, or the basic event that generates the top event, a qualitative analysis was performed using Boolean algebra.
- A minimal cut set of Boolean algebra calculations is shown below.

Code	Event Description	Code	Event Description
K4	a collison with a hard object	N8	rusty door
K5.K6	worn out forklift tires and loose forklift brake	O1	defect in container body
		O2	corrosion in container body
L10	chain wear	Q2	meaurement failure
L11	rusty chain	Q7	error in hook installation
L13.L14	bent and cracked fork	Q9	hook strap on loose container
N2	broken door hinge	Q11.Q12	corrosion and cracked hook
N4.N5	loose and broken bolt	R1	container isn't closed properly
N7	crooked door	R3.R4	rusty and cracked canal

- A quantitative analysis was conducted using the failure rate data for each basic event. It was performed by applying ALD Group's Fault Tree Analysis v1.0 software.
  - The probability of the transport container crashed is $3{,}99 \times 10^{-5}$.
  - The probability of the container leak is $7{,}92 \times 10^{-4}$.
  - The probability of the source drawer crashed is $1{,}56 \times 10^{-4}$.
  - The probability value of top event is calculated by adding the probabilities of all intermediate events. As a result, the top event has a probability of $9{,}88 \times 10^{-4}$.

5. Safety Evaluation of Radioactive Waste Source Displacement Process

- The qualitative analysis results are compared to the minimal cut set (MCS) results by:
  - View the total number of events that compose the MCS (orde).
  - Review the underlying type of event, including human factor failure, active device failure, or passive device failure.
  - Observing the number of occurrences of basic events in the entire MCS.
- The qualitative analysis results show that the criticality level of failure in this event scenario is quite low. This is due to the fact that order 1 MCSs outnumber order 2 MCSs. Furthermore, passive device failure is a common type of failure.
- The quantitative analysis results are evaluated by calculating the cut set importance for each MCS, allowing the basic events with the greatest influence on the top events to be identified.

$$\textit{Cut set importance} = \left[\frac{\textit{Minimal cut set probability}}{\textit{Top event probability}}\right] \times 100\%$$

- Based on the results of these calculations, the minimal cut sets N7 and N8 have the highest importance of 29.15% with the event description is the damage to the container door.

6. Conclusion

- There are some factors that cause failure on the process ^{60}Co teletherapy sources displacement from transport containers to storage containers.
  - Qualitative Analysis: the top event was caused by 17 minimal cut set (MCS) of basic event.
  - Quantitative Analysis: Damage to the container door, with a failure probability $2{,}88 \times 10^{-4}$, is the basic event that has the biggest influence on the top event.
- The failure probability on the top event is $9{,}88 \times 10^{-4}$ with the basic event contributing the most to this scenario is the damage to the container door.

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