Discussion on Fire Risk Assessment for Irradiation Room

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Abstract. In order to study fire hazards, the reason that we chose 60Co round irradiation room of stacking is just because it is very typical. Ignition temperatures of several radiation cargo can be sequentially gotten by experiment. Both numerical simulation and experiment were adopted to research the rule of change in smoke temperature under source blockage. The fire scenario was simulated to discuss temperature field by FDS. The results I have seen show that temperatures of fire smoke in round irradiation room rose rapidly at 0.5h in the early stage of source blockage. Temperature field in irradiation room gradually comes to stability as time goes on, and the temperature is rising very slowly. The temperature will reach the ignition temperature of radiation cargo, 3.56 days after source blockage. Some radiation cargo may be ignited and cause a fire.

1. Introduction
In today's trend for ever more irradiation facilities, irradiation processing is being used more and more widely [1]. At last count, more than two hundred irradiation facilities, many of which are very active, are in use [2]. If there is a radiation accident, the consequences will be unimaginable.

Source blockage in irradiation room refers to that the radioactive source gets stuck in the process of being put back into the storage well and cannot be normally put back into the specific location. In this case, the radiation cargo is irradiated for a long time and the temperature rises, which may cause a fire and lead to a radiation accident. Therefore, under source blockage, the fire risk in the irradiation room is an issue that must be concerned. LIU put forward the necessary conditions for safe operation of irradiation facilities and studied the shielding protection [3]. LI explored the common reasons and main features of radioactivity fire, and summed up the fire prevention and rescue measures [4]. ZHENG summarized the radiation protection and safety evaluation of irradiation room, and outlined radiation protective measures [5].

The researches in related field are only made qualitative analysis, no quantitative conclusion. At the same time, the early work related, pointed out the deficiency existing in the research work, and put forward some problems to be studied further. The DW-02 ignition point detector is used to measure ignition temperatures of radiation cargo. In this paper, we use 60Co round irradiation room of stacking to study the risk of fire. Considering the most disadvantage condition, FDS software is used to simulate the fire temperature field. The method of combining experimental research and numerical simulation is exploited for the fire risk assessment on round irradiation room of stacking under source blockage.
2. Fire Model

2.1. Model of irradiation room

The selected \(^{60}\)Co round irradiation room is 5 meters in diameter and 4.8 meters high. The average thickness of the concrete wall is 2m, as shown in Figure 1. Cylindrical shelves with a diameter of 0.4m are placed in the center of the room. \(^{60}\)Co radioactive sources are placed on the shelves. When working, the shelves are one meter from the bottom and one meter from the top.

![Figure 1. The floor plan of irradiation room.](image)

2.2. Fire scenario

2.2.1. Analysis of fire hazard criterion. According to the analysis, on the one hand, the radiation cargo in the room will be set ablaze, because the items are irradiated for a long time, the temperature keeps rising. On the other hand, the increasing indoor temperature leads to the destruction of the wall and other structural components. According to relevant information, the strength of concrete member does not change significantly at 300°C. When the temperature is between 600 and 700°C, cracks appear on the surface and the strength decreases a lot. When the temperature reaches 800 ~ 900°C, the strength of concrete member is almost zero \([6]\). The ignition temperature of radiation cargo is generally between 150-300°C, far lower than the failure temperature of concrete member. Therefore, the ignition temperature of radiation cargo should be selected as the criterion of fire hazard. According to the authors' previous findings \([7]\), the lowest ignition temperatures of typical radiation cargo is 210°C measured from the experiment.

2.2.2. Numerical model. In order to obtain the fire risk on irradiation room under the most unfavorable conditions, the following assumptions are made in the theoretical calculation and numerical simulation: 1)\(^{60}\)Co radioactive source continuously releases heat, which is equivalent to a source of ignition under source blockage. 2)The cylindrical irradiation room is closed and the ventilation system fails.

In this paper, fire simulation software FDS, which is widely used at home and abroad, is used for numerical simulation. The structure of the irradiation room is simplified cylindrical, and the thermal conductivity of the concrete member is set to 0.72 w/m•k. The fire model is built by FDS as shown in Figure 2. Considering the reliability of numerical simulation results, the simulation time is 6h.
2.2.3. **Fire power.** According to the conversion between fire power and activity of $^{60}$Co radioactive sources, when the activity is 10000 Ci, the fire power is 154 w. 700000 Ci is equivalent to 10.78kw. The relevant data are shown in Table 1.

| activity (Ci) | fire power (kW) | 1# survey point | 2# survey point |
|---------------|-----------------|-----------------|-----------------|
| 700000        | 10.78           | (-0.4,0,2.6)    | (0,0,4.6)       |

According to the numerical simulation results, the temperature data from 1h to 6h can be fitted linearly. So we can predict whether the temperature will reach the ignition temperature of radiation cargo and when it will reach the ignition temperature. Using linear fitting, the fitting result is smaller than the actual value, and the conclusion is conservative.

3. **Analysis of Simulation Results**

Two survey points are set in the model. Considering the reliability of numerical simulation results, the simulation time is 6h. The temperature change curves of the two survey points within six hours are shown in Figure 3.

In the range of 0-0.5h, the temperature of 2# survey point rises rapidly, reaching 58 ℃. The temperature rises slowly over the next 5.5 hours. The indoor temperature field tends to be stable gradually. The temperature at # 2 is the highest, so the fire risk is the greatest. The temperature change curve of 2# was fitted linearly. The formula obtained by linear fitting is $T=1.81566t+55.02266$ as shown in Figure 4. Through the preliminary experiment, the lowest ignition temperature was measured to be 210 ℃. The time required to reach the ignition temperature can be calculated by the formula as 85.36h. That is to say, 3.56 days after source blockage, the radiation cargo may be ignited and cause a fire.
Figure 3. Temperature change curves of the two survey points.

Figure 4. Liner fitting curve and fitting formulas of temperature.

4. Conclusion
Under the most unfavorable fire conditions, the fire risk assessment for irradiation room was studied by combining experimental measurement and numerical simulation, and the corresponding conclusions were obtained by qualitative and quantitative analysis:

Source blockage occurred within 0.5h, the indoor temperature rose rapidly. Over time, the temperature rises more slowly and the indoor temperature field tends to be stable gradually. The temperature at #2 is the highest, so the fire risk is the greatest. The temperature change rule of #2 measuring point can be obtained by linear fitting. 3.56 days after source blockage, the radiation cargo may be ignited and it could cause a radiation accident.

Although the probability of radiation accident is low, we still need to pay attention to it. In case of source blockage, we should remove the combustible as soon as possible. If the ventilation condition is improved and the indoor temperature is reduced rapidly, the radiation accident can be avoided.

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