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Methodology for risk assessment of higher or lower flammability refrigerants

Koji Yamashita

Air-Conditioning & Refrigeration Engineering Laboratory

5-2-43-202, Nishiaoki, Kawaguchi City, Saitama, 332-0035, Japan

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EXTENDED ABSTRACT

Air-Conditioning & Refrigeration Engineering Laboratory is the only organization in Japan that provides guidance on risk assessment for ignition of refrigeration and air conditioning equipment, and is currently providing guidance on risk assessment of A3 refrigerants for the Chiller Risk Assessment Working Group 3.

The methodology of risk assessment for higher or lower flammability refrigerants by the Japan Refrigeration and Air Conditioning Industry Association (JRAIA) is explained. Risk assessment is carried out in the following steps.

1) Select representative model of target equipment and clarify specifications
- Determine the structure, capacity, and refrigerant charge of the target equipment based on survey results. Investigate and determine the number of target equipment in use.
- Clarify the installation environment and determine all life stages.
- Investigate the refrigerant leak probability during usage. The refrigerant leak probability from shipment to installation is the same as conventional units. When repairing or removing, it is set based on human error.
- Set the tolerable value. For safety reasons, all ignition accidents are assumed to be fatal accidents, and the tolerable value for the probability of accident occurrence is set to 10^{-8} cases/unit/year or less from the R-MAP. From this, the ignition accident occurrence level is set to once in 100 years for the number of units in use.

2) Clarification of scenario, quantification of ignition source and flammable volume-time integration
- Clarify the flammability classification (A3, A2L) of the target refrigerants and clarify the ignition sources for the target flammability classification. Ignition sources for A3 and A2L refrigerants are set based on NEDO research results and JRAIA's survey results.
- Quantification of ignition scenario for each ignition source (conduct research as necessary)
- Carry out refrigerant leak analysis. Quantification of average flammable volume and duration of the flammable region, the product of which is the flammable volume-time integration.

3) Creation of FTA, probability value allocation table, and calculation of ignition probability
- FTA (Fault Tree Analysis) is a method to analyze the cause of an accident and evaluate the occurrence probability. Each item of FTA is set based on the scenario. The probability value allocation table is a table for calculating values in FTA. The basis for setting the values for each item is also listed in it.
- Calculation formula for ignition probability P is as follows:

$$P = P_t \times P_s \times P_r, \quad P_s = V_v / V_g$$

Temporal encounter probability:

$$\text{[Usage]}\ P_t = k \cdot \left\{ 1 - \left(1 - \frac{T_i + T_v}{24} \right)^n \right\}, \text{ [Work]}$$

Encountering probabilities between leaked refrigerant and ignition sources are calculated, taking into account work time.

k: ignition source existence coefficient, n: number of ignition source operations per day, P_r: leak probability, P_s: spatial encounter probability, P_t: temporal encounter probability, T_i: existence time of ignition source, T_v: duration of flammable region, V_g: average flammable volume, V_v: volume of space

4) Consideration of safety measures, clarification of operation rules
- Clarification of safety measures against each ignition source (clarification of scenarios in which the ignition probability is reduced by safety measures)
- Quantification of the effectiveness of each safety measure (literature research, case studies, experiments are carried out as necessary). Add safety measures until the ignition probability reach equal the tolerable value or lower.

  [Examples of effectiveness of measures] Education/displays (fire warning signs, no smoking signs) --- 10^{-1}, alarms ---10^{-1}, portable leak detectors --- 10^{-2}, anti-static gloves --- 10^{-2}
- Creation of standards/guidelines based on risk assessment results.
- Public awareness activities of standards/guidelines.

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燃焼性を有する冷媒のリスクアセスメントの方法

山下浩司　　空調冷熱技術研究所
*

埼玉県川口市西青木 5 丁目 2-43-202 号

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EXTENDED ABSTRACT

空調冷熱技術研究所は冷凍空調機器の着火リスクアセスメントの指導を行っている日本で唯一の機関であり, 現在チラーリスクアセスメント WG3 の A3 冷媒のリスクアセスメントの指導を行っている。

日本冷凍空調工業会で行っている燃焼性を有する冷媒のリスクアセスメントの方法を説明する．リスクアセスメントは次の手順で実施する．

1) 対象とする機器の代表機種の選定・仕様の明確化
- 対象機器の構造・容量・充填冷媒量を調査結果に基に決定．対象機器の普及台数を調査し決定
- 設置環境を明確化し全ライフステージを決定
- 使用時漏えい発生確率の調査．出荷から据付の漏えい発生確率は従来と同じ．修理・撤去時はヒューマンエラーを基に設定
- 許容値の設定．安全のため着火事故は全て致命的な事故であると考え，事故発生確率の許容値は R-MAP から 10^{-8} 件/(台・年)以下．普及台数に対し 100 年に 1 回の事故発生レベルとする

2) シナリオの明確化・着火源定量化・可燃空間時空積の定量化
- 対象冷媒の燃焼性区分（A3，A2L）の明確化と対象燃焼性区分での着火源の明確化．NEDO 研究結果および日本冷凍空調工業会での調査結果に基づき A3・A2L 冷媒に対する着火源を設定
- 各着火源の着火シナリオの定量化（必要に応じて調査を実施）
- 冷媒漏えい解析の実施．平均可燃空間体積・可燃域継続時間（可燃空間時空積）の定量化

3) FTA・確率数値割付表の作成・着火確率の計算
- FTA(Fault Tree Analysis)は事故の原因を分析し発生確率を評価する手法. シナリオに基づき FTA の各項目を設定．確率数値割付表は FTA の数値を計算する表．各項目の数値設定根拠も記載
- 着火確率 $P = P_{\mathrm{t}} \times P_{\mathrm{s}} \times P_{\mathrm{r}}$，$P_{\mathrm{s}} = V_{\mathrm{v}} / V_{\mathrm{g}}$

  時間的遭遇確率

  [使用時] $P_{\mathrm{t}} = k \cdot \left\{ 1 - \left(1 - \dfrac{T_{\mathrm{i}} + T_{\mathrm{v}}}{24} \right)^{n} \right\}$, [作業時]　作業時間を考慮した漏えい冷媒と着火源の遭遇確率を計算

  ［k:着火源存在係数, n:1 日の着火源作動回数, P_{r}:漏えい発生確率, P_{s}:空間的遭遇確率, P_{t}:時間的遭遇確率, T_{i}:着火源存在時間, T_{v}:可燃域継続時間, V_{g}:平均可燃空間体積, V_{v}:空間体積］

4) 安全対策の検討，運用ルールの明確化
- 各着火源の安全対策の明確化（安全対策によって着火確率が下がるシナリオを明確化）
- 各安全対策の効果定量化（文献調査，事例調査．必要に応じて実験を行う）。着火確率が許容値以下になるまで安全対策を追加

  【対策効果の例】　教育・表示（火災の警告表示，禁煙表示）・・・ 10^{-1}，警報 ・・・ 10^{-1},
  携帯形漏えい検知器 ・・・ 10^{-2} ，静電気防止手袋 ・・・ 10^{-2}
- リスクアセスメント結果に基づく規格・ガイドラインの作成
- 規格・ガイドラインの周知活動