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# FIRE SAFETY REGULATION ON HIGH ENERGY ARCING FAULTS (HEAF)

**Hajime KABASHIMA**

Regulatory Standard and Research Department,
Secretariat of Nuclear Regulation Authority
(S/NRA/R), Tokyo, Japan

# Outline

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1. Introduction
2. S/NRA/R HEAF tests
3. Discussion on ensuing fire
4. HEAF protection measures
5. Regulatory actions
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# 1.1 What is HEAF

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## HEAF : High Energy Arcing Faults

**First phase**
**Explosion** caused by arc discharge

**Second phase**
**Fire** caused by arc discharge

- **First phase**

  **Explosion causes destructive force that results in serious damage to the equipment.**

- **Second phase**

  **Ensuing fire would result in serious damage to cables and other components around the equipment.**

# 1.2 Onagawa HEAF event

- The OECD/NEA FIRE Database (1979-2012) has indicated that 48 HEAF events occurred out of the total 415 fire events.
- At Tohoku EPCO's Onagawa Nuclear Power Station (NPS) Unit 1, HEAF event took place inside the metal-clad switchgears (M/C) during the Great East Japan Earthquake of March 11, 2011.


Figure Damage to metal-clad switchgears caused by the HEAF event at unit 1 of Onagawa nuclear power station (http://warp.da.ndl.go.jp/info:ndljp/pid/10378577/www.nsr.go.jp/data/000160077.pdf)

- Arc thermo-mechanical energies and an ensuing fire subsequently spread to 9 other M/Cs via cable duct.
- Two residual heat removal pumps were stopped for a short period and consequently influenced the safety function of the unit.

# 1.3 Overview of this presentation

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**HEAF events have occurred in the electrical equipment and components at NPSs worldwide.**

**(Cause of HEAF : electrical equipment connections being damaged by earthquakes, aging electrical equipment, human errors in maintenance, etc.)**

**HEAF is one of the safety issues to be urgently resolved.**

**(Current HEAF test projects: S/NRA/R HEAF test project (Japanese regulatory side tests), OECD/NEA HEAF Project, and CRIEPI HEAF test project (Japanese utilities' research institute tests))**

**This presentation summarizes the information on the S/NRA/R test results and regulatory actions taken on HEAF.**

# 2.1 Purpose of S/NRA/R HEAF tests

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**Securing electric power for electrical equipment and components at NPSs is a highly important.**

**That's why S/NRA/R carried out the HEAF tests:**

- **To obtain technical knowledge on phenomena involve in HEAF events**
- **To understand what occurred in the Onagawa NPS due to the HEAF event**
- **To obtain the arc energy level over which a fire is caused by arc discharge**

# 2.2 Selection of Test Devices

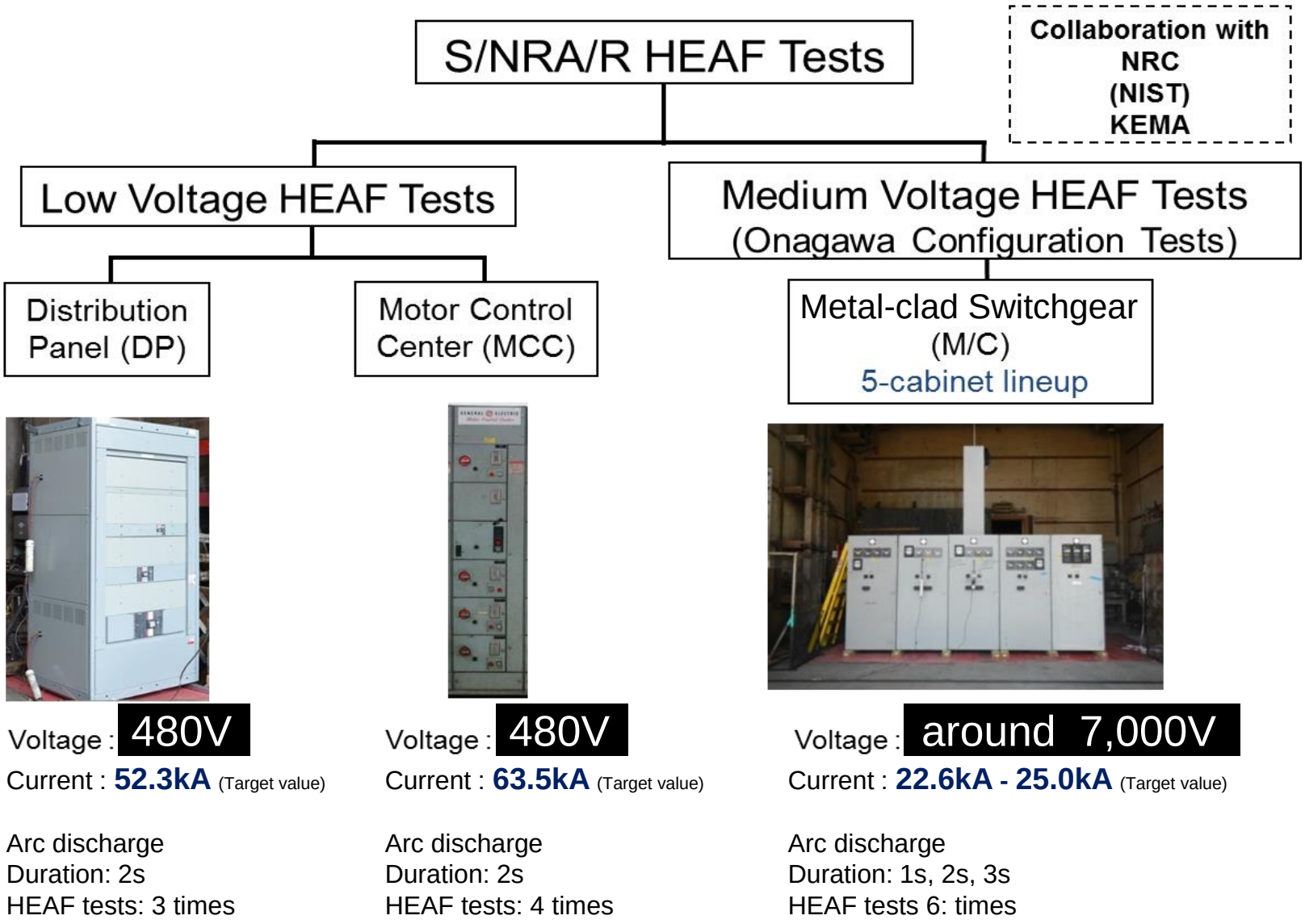



**Figure** Three types of electrical equipment in a typical nuclear power plant

# 2.3 M/C HEAF test results


(1) Before the test

(2) Moment when arc discharge occurred (after approximately 0.2 seconds)

(3) Metallic fumes, etc. were generated (after approximately 2 seconds)

(4) Ensuing fire occurred (after approximately 10 minutes)

**Figure** HEAF test of M/Cs

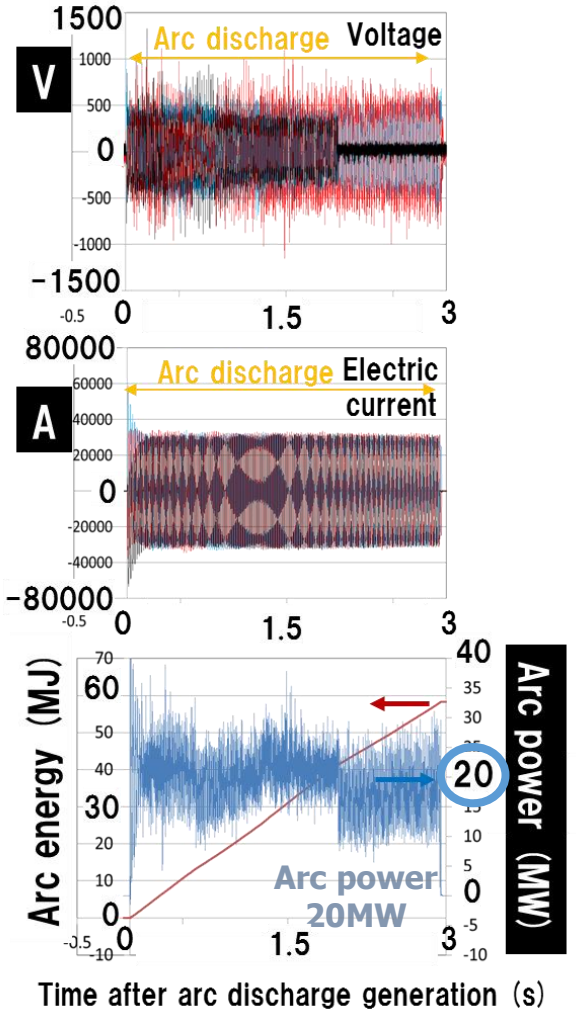
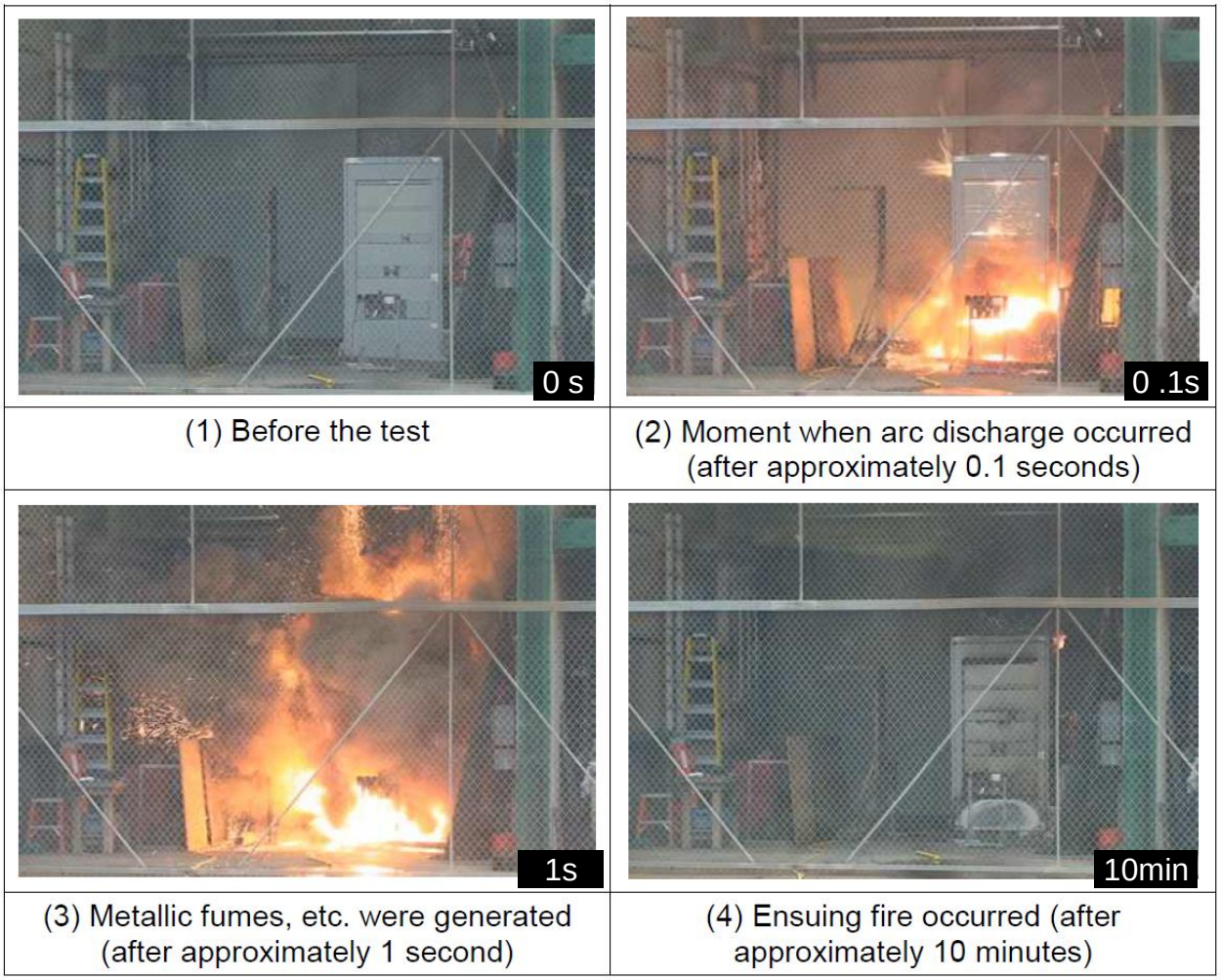



**Figure** Waveforms obtained from M/C HEAF tests (voltage, electric current and arc power)

In the M/C HEAF tests, **ensuing fire** occurred in four out of six tests.
Arc power was approximately 20MW for four tests and larger than 20MW for two tests.

# 2.4 DP HEAF test results




(1) Before the test

(2) Moment when arc discharge occurred (after approximately 0.1 seconds)

(3) Metallic fumes, etc. were generated (after approximately 1 second)

(4) Ensuing fire occurred (after approximately 10 minutes)

**Figure** HEAF test of DP

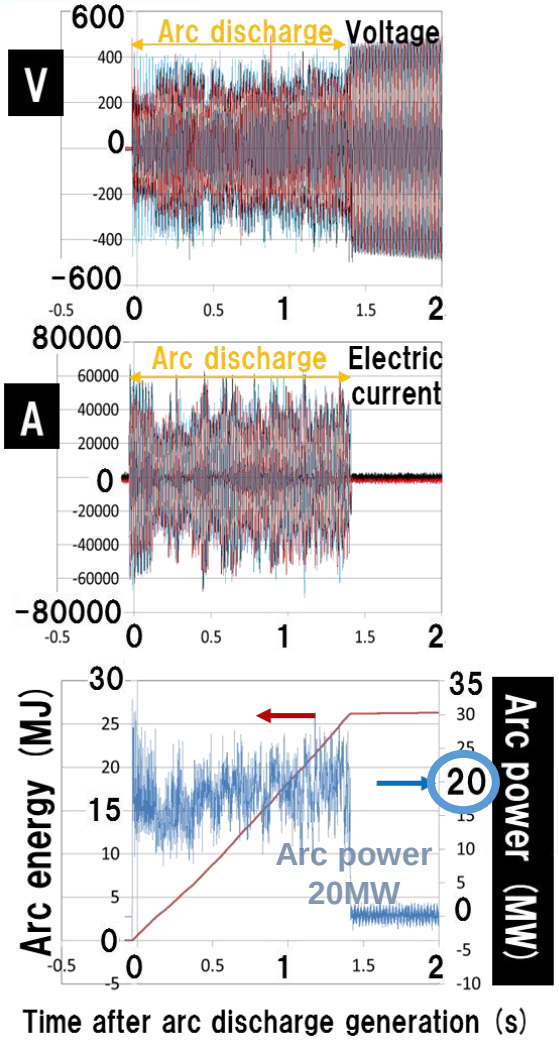



**Figure** Waveforms obtained from DP HEAF tests (voltage, electric current and arc power)

In the DP HEAF tests, **ensuing fire** occurred in two out of three tests.
Arc power was approximately 20MW for all the tests.

# 2.5 MCC HEAF test results


(1) Before the test

(2) Moment when arc discharge occurred (after approximately 0.2 seconds)

(3) Metallic fumes, etc. blew out (after approximately 0.5 seconds)

(4) Metallic dust, etc. were generated (after approximately 2 seconds)

**Figure** HEAF test of DP

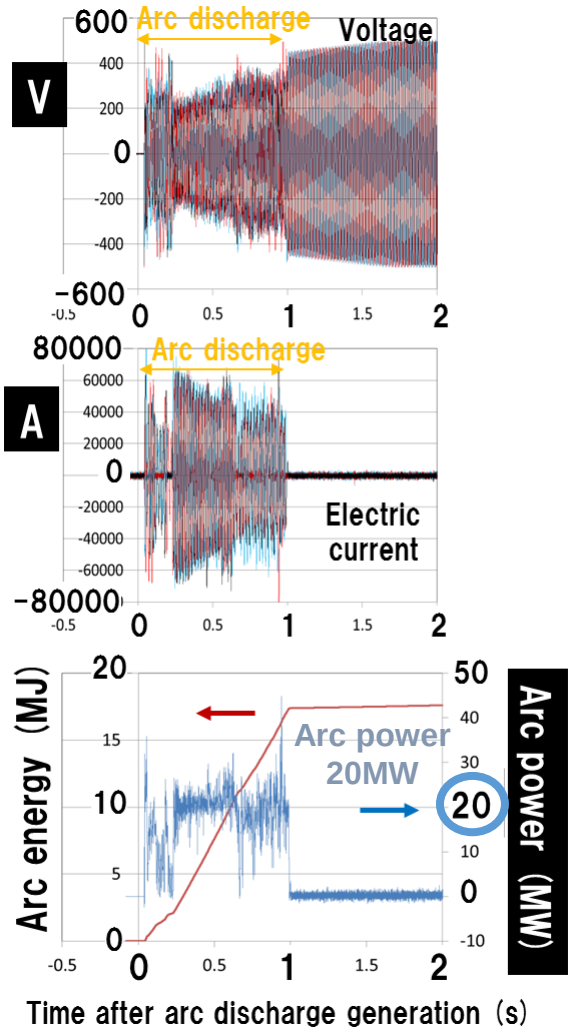
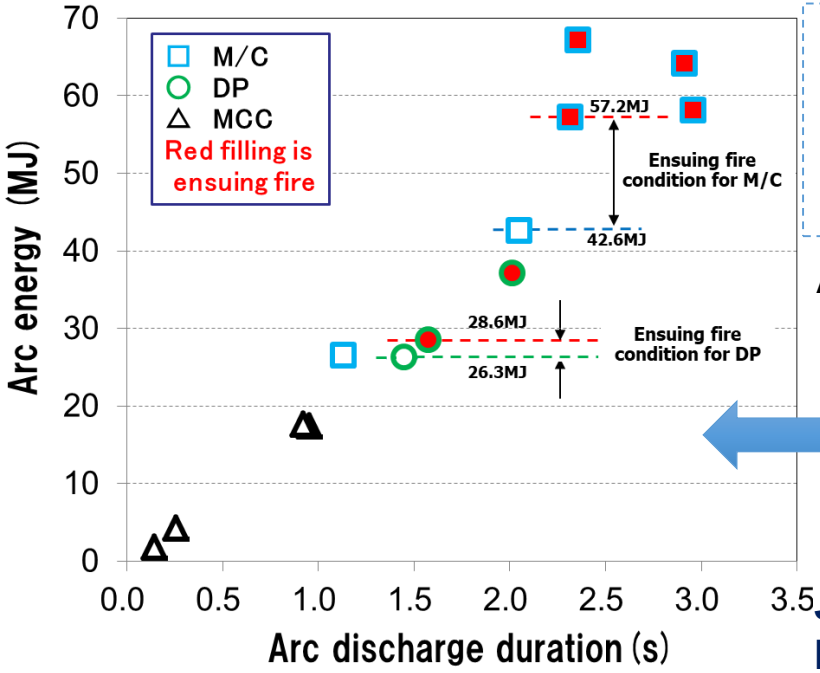



**Figure** Waveforms obtained from MCC HEAF tests (voltage, electric current and arc power)

In the MCC HEAF tests, **ensuing fire** did not occur for all four tests.
Arc power was approximately 20MW for all tests.

# 3. Discussion on ensuing fire

- S/NRA/R HEAF tests showed that the arc energy triggered for initiating **ensuing fire** differed between DP and M/C.
  - The values of arc energy which can trigger **ensuing fire** were between 26.3 and 28.6 MJ for the DPs and between 42.6 and 57.2 MJ for the M/Cs.
  - This triggering energy is considered to be dependent on the characteristics of individual electrical cabinet such as the **cubicle size (interior volume)** and **ventilation opening area (air tightness)**.




| M/C | DP |
|---|---|
| Cubicle size: **Large** | Cubicle size: **Middle** |
| Ventilation opening area: **Large** (Length: 2.1m, Depth: 0.9m, Height: 2.3m) | Ventilation opening area: **Middle** (Length: 0.9m, Depth: 1.2m, Height: 2.3m) |

**A fire may break out due to the accumulation of heat.**

If arc discharge duration could be reduced, arc energy would be decreased and consequently **ensuing fire** could be prevented.

**Japanese utilities' research institute also conducted HEAF tests and obtained similar results.**

**Figure** Arc energy triggered for causing ensuing fire

# 4. HEAF protection measures

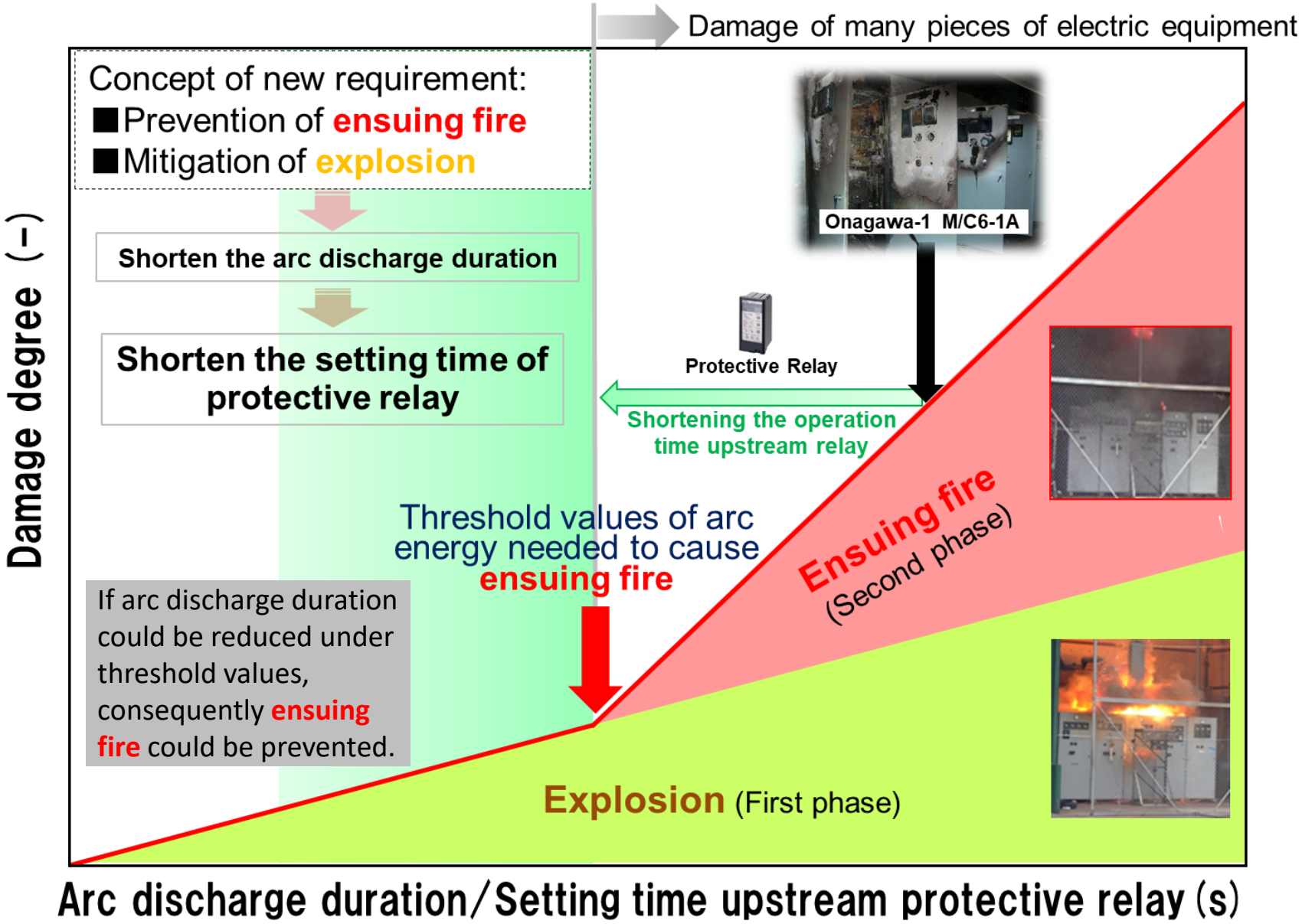



**Figure** Image of the electrical cabinets damage by HEAF

# 5.1 Regulatory actions (1/2)

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## S/NRA/R HEAF Test Results Publication

- U.S.NRC RIC2016 TH-32, March 2016
- NRA Technical Report NTEC-2016-1002, March 2016
- NUREG/IA-0470, August 2016

## Discussion in NRA

- Technical Information Committee (from July 2016)
- Reactor Safety Examination Committee (from August 2016)

***HEAF regulatory requirements***

◆ **Objectives**

- ✓ To prevent **fire** and to mitigate the consequences of **explosions** due to a high energy arcing of concerned electrical cabinets.

◆ **Concerned facilities and equipment**

- ✓ Electrical cabinets of commercial nuclear power reactor facilities, research reactor facilities, and reprocessing facilities.

◆ **Requirements**

- ✓ Regarding the concerned electrical cabinets, it is required to mitigate the consequences of an **explosion.**

# 5.2 Regulatory actions (2/2)

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## Hearing of Licensees' opinions

- Technical interview (from July 2016)

◆ **HEAF protection**

- ✓ One of the possible countermeasures proposed by licensees is replacement of analog-type over-current relays (OCR) to digital-type OCR. The response of the digital-type OCR is much faster than that of analog-type.

## Collecting public comments

- Public comments on the proposal to introduce the HEAF requirements (from February 23 to March 24 in 2017)

**Amendment of the regulatory requirements were issued on August 8, 2017 and enforced on the same day.**

# 6. Summary

- The knowledge about ensuing fire occurrence in the second phase of HEAF has been accumulated, and it is becoming clear that if arcing time can be shortened, it is possible to prevent fire and to mitigate the consequences of explosions.
- In the amended regulatory requirements, prevention of ensuing fire and mitigation of explosion are required.
- Research on the scale of the HEAF impact and other factors at the first phase is to be continued, and when new knowledge is obtained, the results will be reflected in the regulatory requirements further, as necessary.

  - The role of TSO is to make use of research results to actual nuclear safety regulations.
  - S/NRA/R's HEAF research is a good example of research results that was useful for actual nuclear safety regulations.

# Thank you for your attention!