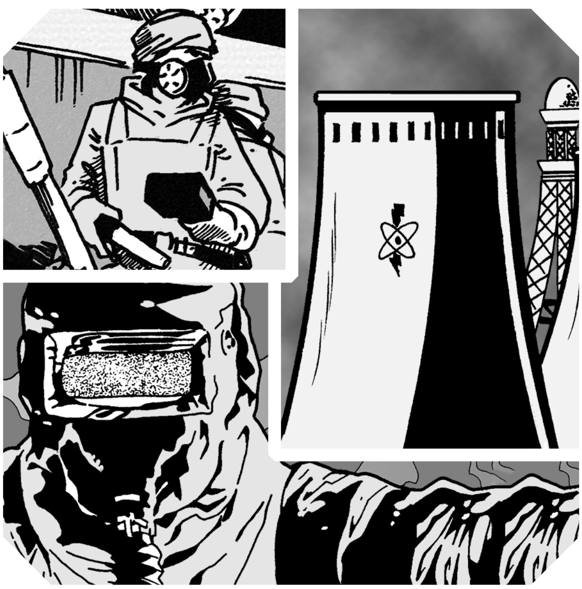
GURPS Fourth Edition

DISASTERS

MELTDOWN AND FALLOUT™



Written by
ROGER BURTON WEST
Edited by NIKOLA VRTIS
Illustrated by JOHN HARTWELL, RAY LUNCEFORD, and DAN SMITH

Additional Material by
S.A. FISHER, MICHAEL HURST, JASON "PK" LEVINE, KENNETH PETERS, DAVID L. PULVER, SEAN PUNCH, and HANS-CHRISTIAN VORTISCH

GURPS System Design ▮ STEVE JACKSON
GURPS Line Editor ▮ SEAN PUNCH
Assistant ***GURPS*** Line Editor ▮ JASON "PK" LEVINE
GURPS Project Manager ▮ STEVEN MARSH
Production Artist and Indexer ▮ NIKOLA VRTIS
GURPS FAQ Maintainer ▮ VICKY "MOLOKH" KOLENKO

Chief Executive Officer ▮ PHILIP REED
Chief Operating Officer ▮ SAMUEL MITSCHKE
Executive Editor ▮ MIRANDA HORNER
Marketing Director ▮ RHEA FRIESEN
Director of Sales ▮ ROSS JEPSON
Page Design ▮ PHIL REED and JUSTIN DE WITT
Art Direction and Prepress Checker ▮ NIKKI VRTIS

Special Thanks: John Dallman, David Damerell, and Phil Masters

Reviewers: Luke Campbell, David Chart, S.A. Fisher, Vicky "Molokh" Kolenko, Timothy Ponce, Christopher R. Rice, William H. Stoddard, and Antoni Ten Monrós

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About *GURPS*

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Errata. Everyone makes mistakes, including us – but we do our best to fix our errors. Up-to-date errata pages for all ***GURPS*** releases, including this book, are available on our website – see above.

Rules and statistics in this book are specifically for the ***GURPS Basic Set,*** *Fourth Edition.* Page references that begin with B refer to that book, not this one.

Introduction

Warning lights flash and sirens sound as temperature gauges go into the red . . . a worried news anchor points at a graphic of a cloud spreading across the country . . . a group of black-clad figures sneaks away, carrying a case marked with warning trefoils . . .

Radiation scares people. You can't see or taste it, but it damages you in a weird and unpleasant way, sometimes years after you thought you were safe. And scary things are good game fodder.

Nuclear accidents make excellent challenges in a modern game. Covert operatives may be sent to sabotage a hostile country's nuclear program, while local engineers and scientists work guard against similar enemy action (as well as genuine accidents). Even people who aren't directly involved with nuclear safety will be affected by the evacuation and panic that follow the mere threat of a major radiation release.

Nuclear reactors offer many different kinds of adventure possibilities for modern campaigns.

In a science-fiction game, reactors will be safer than they are today, but an isolated spaceship crew still has to worry about radiation in addition to hostile aliens. Maybe they can be used against each other!

Nuclear steam engines might, with a bit of properly timed inspiration, have been built in the 19th century and have kicked off an era of "atomic-punk." In a fantasy setting, a magical contamination could spread like a radiation cloud rather than like the more conventional plague.

Nuclear power is a relatively recent and extremely high-profile invention; *all meltdowns ever* have been documented by the modern media, so details are easy to find. This supplement concentrates on the game aspects rather than on history.

Nuclear-power producers are unsurprisingly cagey about details of their security precautions. All the real-world information in this supplement was obtained from public sources and off-the-record discussions with experts. Nonetheless, when opinions about potential outcomes or protocols differed, this supplement went with the options with more drama or adventure potential.

Publication History

This is the first edition of ***GURPS Disasters: Meltdown and Fallout.*** It updates equipment statistics from ***GURPS High-Tech*** and includes a number of perks from ***GURPS Zombies.***

About the Author

Roger Burton West is a British computer system administrator and a product of the wave of roleplaying that swept the United Kingdom in the 1980s. While performing research for this supplement, he received a radiation dose of approximately 30 millirads. His gaming website is at **tekeli.li**.

Glossary

GURPS Disasters: Meltdown and Fallout uses the following terms and abbreviations.

corium: A lava-like mixture of nuclear fuel, fission products, control equipment, and structural materials from a containment vessel.

criticality: The state in which an ongoing nuclear reaction is self-sustaining. (A reactor that has "gone critical" is operating normally.)

decay heat: Heat generated from natural decay of radioactive substances, rather than from a chain reaction.

exclusion zone: The area around an accident from which civilians have been forcibly evacuated.

fission: The splitting of an atomic nucleus into two or more smaller pieces, often with a release of energy.

isotope: A different form of an element, with the same number of protons but a different number of neutrons; chemically it is similar, but radiologically it can be very different.

meltdown: The melting of a nuclear reactor core as a result of overheating.

passively safe: A reactor which does not require active cooling to prevent a meltdown.

R-bomb: A conventional bomb jacketed with radioactive material, designed to spread contamination over a wide area. Also one of the many devices known as a "dirty bomb."

SCRAM: The process of shutting a reactor down quickly by inserting control rods or other reaction-inhibiting materials. This is often a separate self-contained mechanism from those used in normal operation. Decay heat continues even after this is done.

shake: An informal measure of time, equal to 10^{-8} seconds (10 nanoseconds).

turnkey reactor: A reactor that can be prefabricated, moved to where it's needed, then turned on, rather than one that needs major construction work on-site.

void coefficient: How a reactor's power output changes when liquid coolant develops "voids," or gaps, such as steam bubbles. A large positive or negative void coefficient can lead to a reactor running out of control when voids form or collapse suddenly.

Economics and Politics

Nuclear power costs more than power from coal, oil, gas, or hydroelectric plants, but much less than power from solar, wind, or wave sources. That's a rough estimate; costs of wind and solar are dropping, and opinions differ. Nuclear plants must have waste disposal included in their costs, and fossil-fuel ones don't, but the byproducts (pollution) from fossil-fuel power are arguably much more damaging than the worst plausible reactor accident would be. France, generating 75-80% of its electricity from nuclear power, has the cheapest electricity in Europe and sells a great deal of it to other countries.

Nuclear power research was spurred in the 1970s after the oil-price shocks, but it has rather languished since, with politicians unwilling to take on anti-nuclear activists for distinctly arguable gains. Following events in Fukushima, Germany decided to eliminate nuclear power, and France is scaling down its commitment. Japan shut down its reactors without making a formal policy decision, though as of 2015, it is starting to put some back in service. The United States is now extracting enough oil and gas within its borders that being held hostage by foreign oil sellers is no longer a major concern.

Nuclear Myths

Even though radiation is still a fairly new idea, there's been plenty of time for mythology to grow up around it.

When radioactivity was newly discovered (from 1896), this powerful force was used in much the same way that electricity had been a few years earlier, by quack physicians (and even some genuine-but-misguided ones) as a healing tool – radium pendants to cure rheumatism, natural radon water to increase vigor, uranium blankets to treat arthritis and so on. Many of these were fakes, of course, but the ones which did provide a genuine radioactive dose (such as the radium-thorium tonic Radithor) were often fatal to heavy users. "Doramad" radioactive toothpaste was produced in Germany during the Second World War, but radiation cures gradually fell out of favor in the United States during the 1930s. A few such products are even still on the market today, largely in Japan, though consumer-protection laws prevent them from having actual harmful content. It's rumored that some people have even tried to gain superpowers by irradiating themselves, with predictably dismal results (but see *Superhero Origin Stories*, pp. 13-14).

"Red mercury" appeared in the 1980s, generally presented as a Soviet secret available at a very low price (for cash only). Depending on the seller, it could make uranium enrichment much faster; be a powerful "ballotechnic" substance (similar to an explosive, but producing vast amounts of heat rather than pressure) which could trigger a pure fusion bomb "the size of a softball" without the need for a bulky fission first stage; or be the superconducting secret of radar-invisible "stealth" vehicles or missile guidance systems. Actual samples recovered from supposed sellers have been a variety of inert red-colored powders. Of course, that may just be what *they* want you to think. For more on this, see "Eidetic Memory: Red Science" in *Pyramid #3/46: Weird Science.*

Causes and Evolutions of Problems

The primary cause of reactor accidents is optimism. Pipes become corroded; maintenance is underspecified or not carried out correctly; warning signs are ignored because commercial pressure requires full operation at all times. But external factors also can cause problems: a plane can crash into the reactor (though containment buildings are already specified to withstand that); an earthquake, tornado, or tsunami can hit the site; or terrorists could target it.

Any nuclear facility is likely to have large tanks of chemicals for various technical purposes; for example, chlorine, propane, sulfuric acid, and ammonia have all been used at British AGRs. Those tanks need to be refilled periodically, and chemical spills are a concern.

A secondary coolant leak is probably more dangerous from the steam and hot water than because of the radiation. Primary coolant is even hotter, but also highly radioactive. If enough of it gets out, the reactor core is more likely to overheat and melt. Should the core itself become damaged, raw fuel and decay products would get out; these are sufficiently hot to melt the structural materials of the core and start burning their way down through the concrete foundations.

If any radiation leaks are combined with structural damage (perhaps from steam or hydrogen mixing with oxygen and causing explosions, from chemical leaks corroding or exploding protective barriers, or from energetic weather effects), even solid contamination can be scattered well beyond the boundaries of the power plant. The "R-bomb," a type of dirty bomb which wraps a conventional explosive core in a jacket of highly radioactive material, works in a similar manner. Fires in fuel or bomb-assembly plants can spread a great deal of contamination; a single fire at the Rocky Flats nuclear weapons plant in 1957 released around one TBq of plutonium.

Other Radiation Effects

As a guideline, many people can survive a dose up to about 500 rads in the short term even without medical care, or up to 800 or so if care is provided; anything more than that is certainly fatal. Those numbers drop by around half in a population that's already unhealthy. In the longer term, even doses well below the level needed to cause noticeable acute radiation sickness seem to lead to increased levels of cancer (especially leukemia) and birth defects in offspring.

Even purely psychological effects on those who think they *may* have been exposed to dangerous radiation doses can apparently shorten their lives by around five years. At the very least, a credible threat of radiation exposure should call for Fright Checks (see *Radioactive Terror,* p. 24) – and people without relevant skills will find almost any threat credible.

Cinematic PCs are debilitated in the same way as others, but usually won't die of radiation exposure even when they miss their HT rolls; their FP and HP won't go to zero just from radiation. Instead, they can stagger around at -5 to all rolls until they get treatment. Alternatively, use Radiation Threshold Points (p. 16).

Some settings have a hazard which acts a bit like radiation, but doesn't have the normal ill effects. Instead, someone who picks up enough of this special radiation changes in some way, perhaps becoming a zombie (see ***GURPS Zombies,*** particularly *Radiation Ghoul,* p. 91) or developing "mutant powers" (see *Superhero Origin Stories,* pp. 13-14). Use the *Radiation Effects Table* (p. B436) to determine the modifier to the resistance roll based on cumulative dose; a failed HT (or perhaps Will) roll means that the effect takes place.

If the effect is a positive one, reverse the modifier, and the change takes place following a *success* on the roll.

> *In the map of nearly every country of the world three or four more red circles, a score of miles in diameter, mark the position of the dying atomic bombs, and the death areas that men have been forced to abandon around them.*
>
> *– H.G. Wells,* ***The World Set Free***

Chaos

Once radioactive material has got out, it spreads. ***GURPS High-Tech,*** pp. 195-196, gives a model for use with nuclear weapons: The primary contaminated zone is 800 yards long by 200 yards wide for a 0.1kt device used in a ground burst, each dimension doubled for each tenfold increase in yield. Within this area, assess 100 rads/hour if passing through a few hours after detonation, 10 rads/hour two days later, and one rad/hour two weeks later. This shape is the result of wind carrying contaminants away from the blast site; if there is no wind at all, it will be a circle 200 yards wide, with four times the dose rate. An air burst disperses the fallout much more widely, and doesn't produce a high-radiation zone.

The fallout released from a reactor is very different in composition from what's dispersed by a ground-burst nuclear weapon (which consists of the pulverized remains of the fissile material and the target area). For simplicity, three main classes of substances can come from nuclear meltdowns, radiation leaks, and other nonbomb sources: *slow particulates* such as cesium-137 and strontium-90, which are relatively inactive but persist for a long time; *fast particulates* such as iodine-131, which is highly active and becomes concentrated in particular organs of the body; and *fast gases* such as xenon-133. (There are also *ultra-slow particulates,* such as uranium-235 itself, but these do not generally form a significant proportion of a radioactive release; even if they get loose, they stay in the immediate area of the core.) The GM will need to select the amount of each component in the release, using historical examples (pp. 18-19) or the demands of the plot as a guideline.

For each class, divide the leak's size in PBq by 500 to approximate the dose rate in rads/hour. This spreads at about 15 mph into the immediate footprint, which is very roughly an ellipse 20 miles long and five miles wide. Scale the dose rate up or down with the size of the release, but the area stays about the same. This footprint is subject to distortion by wind (which can increase the spread rate to as much as 40 mph) and weather (rain will make it smaller but more intense) and may be an irregular shape, or even circular in the rare case of no wind at all. In extreme weather conditions such as a hurricane or tornado, the main footprint may not form at all – all the contaminants are carried away and dispersed across a much wider area, at a concentration too low to be dangerous.

The *rate* at which the types of contaminant decay varies substantially:

- *Slow particulate* contamination takes many forms. Some of it will be dust that is inhaled or sticks to skin, some of it will dissolve in water, and some of it will simply lie around emitting gamma rays. Halve the dose rate each 30 years. (*Ultra-slow particulates* continue at the same dose rate indefinitely, getting into timescales of thousands or millions of years.)
- *Fast particulates* behave roughly like the slow ones, but the mammalian body concentrates them into particular areas (in the case of iodine-131, the thyroid and milk glands). Halve the dose rate each eight days.
- *Fast gases* are heavier than air and spread quickly at ground level before mixing with air and dispersing if there's any more wind than a dead calm. Fast gases are inhaled by unprotected victims, doing significant damage, but are largely harmless to those with their own air supplies. Halve the dose rate each five days; if there's significant wind, the dose disappears completely after the first day.

Fast and slow particulates become lodged in the bodies of those who spend at least an hour inhaling the particulates. The victims take half the dose rate on an ongoing basis for 30 days or until they receive chelating drugs.

Moving up, the next stage of human evolution could be kicked off early, perhaps manifesting as supernaturally intelligent or psionic children. See *Superhero Origin Stories* (pp. 13-14) for some additional ideas.

Any sort of Fortean phenomenon other than the blatantly occult could also be blamed on a radiation release: strange weather, outbreaks of mental illness around a particular time or place, odd lights in the sky, and so on.

Adventures

Two basic forms of adventure can center on a potential radiation leak: the sort that regards a major release as a bad ending, and the sort that starts with the leak happening and goes on from there. Very few stories span the transition from one to the other, particularly since completely different teams of people generally focus on the prevention of accidents and the cleanup after them. Adventures based directly on real events are probably either anticlimactic or career-ending. Nuclear safety culture regards *any* release of radiation above an agreed-upon low baseline as a major failure.

For quick resolutions, search for leaks using Hazardous Materials (Radioactive) or Electronics Operation (Scientific); don protective gear with NBC Suit; and make a leak safe with Hazardous Materials (Radioactive) and an appropriate Mechanic skill. Where cleanup is possible at all, it will take further Hazardous Materials rolls.

Normally, an NBC suit is built to be discarded when it is removed; cleaning it of all contamination is prohibitively difficult. Even vehicles that have taken a heavy radiation dose are normally abandoned rather than decontaminated; neutron bombardment means they will be slightly radioactive for years to come.

Escape

When the heroes find out about a leak, they will probably want to leave the area. Unfortunately, everyone else will feel the same way. Expect jammed roads and ugly crowds around any aircraft or helicopters on the ground. The police will try to keep order, but they'll be worried about themselves and their families, too. If the PCs know about the problem and the public doesn't, they'll have to decide whether to reveal the truth, when to say something, and maybe whether to stay and help manage the chaos.

Survive

Anyone staying in the hot zone needs a reason. Maybe they're rescue workers or someone else with a key job to do. Maybe they have some other reason, important enough to risk death.

Someone who must move around in a hot zone needs protective clothing (pp. 20-21), preferably with its own air supply, or a sealed vehicle. For staying still, a sealed shelter will do; simply staying inside a solidly constructed building, without too many people coming in and out, will protect from the worst of the particulates. Hazardous Materials (Radioactive) is the primary skill for keeping contamination out of a shelter or vehicle. When moving around on foot, Survival (Radioactive Wasteland) helps travelers stay clear of hot spots.

Power and water supplies are likely to be cut off or untrustworthy. Those who have time to plan will stock up on the usual resources for surviving off the grid: air filters, water storage, batteries, chemical toilets, nonperishable rations, and so on.

Adventure Seed: Puncture Test

A terrorist group is trying to steal nuclear material to build an R-bomb. They attempt to hijack a waste shipment in transit. During the ensuing firefight, someone uses an anti-tank rocket or too much dynamite, and a cask is ruptured. Now the emergency team has to deal with the contamination before things get any worse, and the battle may still be going on. Even individual terrorists trying to get away may be spreading hazardous radiation without knowing it.

Rescue

When rescuing victims, the first priority is to avoid becoming a victim. It only makes more work for colleagues. Buddy-check protective gear, and watch the dosimeter.

The reactor site itself is now the scene of an industrial accident. Even away from the core, the site contains a multitude of hazards:

- *Fire* (see pp. B433-B434) up to around 6d per second.
- *Steam* (up to 6d burning jet that doesn't ignite anything).
- *Toxic chemicals* (see pp. B437-439, generally contact or respiratory inflicting 1d toxic damage per cycle for up to 12 hourly cycles but potentially including concentrated acids as on p. B428).
- *Electricity* (see pp. B432-B433) doing from 6d to 6d×3.
- *Structural unsoundness* (see p. B484).
- *Radiation;* see *Core Breach!* (p. 15) and *Effects of Radiation* (pp. 16-17) for long and short-term effects.

Minimizing radiation exposure is the most important consideration. Administer only the most basic first aid to keep people alive, and then get them to safety, preferably to a casualty clearing station.

Generally, that station is on the edge of the contaminated zone. Some workers will go into the site and look for people who couldn't make it out on their own. Others will deal with the victims as they arrive, either on their own feet or brought out by others.

At the clearing station, victims are stripped, and their outer clothes treated as hazardous waste, all supervised by people using Hazardous Materials (Radioactive), which may take penalties for time spent, p. B346, if processing lots of people in a hurry. Victims are then showered and scrubbed thoroughly, using the same skill.

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He had never seen a "Fallout," and he hoped he'd never see one. A consistent description of the monster had not survived, but Francis had heard the legends.

– Walter M. Miller,
A Canticle for Leibowitz

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