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PREVENTIVE CONSERVATION

Decontaminating an entire museum collection affected by asbestos

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Abstract
The off-site storage of the decorative art collection held by the Historical Museum Thurgau in Frauenfeld, Switzerland, was contaminated by asbestos fallout that had been distributed through the air ducts. This paper describes the asbestos abatement of the collection. After a series of preliminary tests, a decontamination zone was constructed to comply with health and safety laws. Cleaning processes were devised, labeling was developed to facilitate communication, and testing protocols were established. Cleaning involved vacuum cleaning, adjustable compressed air, and brushing. For rough surfaces, only vacuum cleaning was successful. For smooth surfaces, the combination of brushing and compressed air was effective and fast. The average time needed for all steps, including setting up the objects in the new storage area, was 20–25 minutes per object. With 12–20 participants constantly present, cleaning and moving took 10,180 hours over four months. Three different methods of clearance testing confirmed that all objects had been successfully cleaned.

INTRODUCTION

The 35,000-item collection of the Historical Museum Thurgau includes paintings, art on paper, sculpture, military equipment, household tools, ceramics, religious objects, furniture, and upholstery. The collection was contaminated by a small but relevant amount of asbestos fibers generated by spray asbestos applications and entering the museum through air ducts.

Cleaning the entire collection was imperative to allow the objects to be handled and displayed again safely. Disposing of the objects, as recommended by industry standards for asbestos abatement, was not an option. In confronting the problem of asbestos contamination, the following questions had to be addressed: Can the collection be cleaned at all? How? How can asbestos clearance be tested? How much time will this take? And how much space will be needed?

A literature review identified many publications describing efforts to deal with asbestos-containing materials in industrial heritage sites, museum objects, and historic houses. However, few case studies have addressed the cleaning of collections contaminated by asbestos fallout (Kominsky et al. 1993, Deucher et al. 2000), and only a few relevant exchanges in conservation forums have taken place (e.g., ConsDistList 2018), although there are probably many contaminated collections that have been successfully cleaned.

Based on the literature review we were able to discuss the contamination problem at our museum with some of the authors and, through their referral, with colleagues who have dealt with asbestos cleaning but were sworn to confidentiality by the respective institutions. These conversations provided a starting point for cleaning treatments. However, it was uncertain whether the standardized method for clearance testing (air-sampling), also used by the authors of previous papers, would be sufficient. Furthermore, we had no information regarding the time and space needed for cleaning, because previous treatments were conducted in-house and were thus not time tracked.

Since it is likely that many collections have an as-yet-undiscovered asbestos contamination, our experiences may be informative for museum staff confronted with similar threats to their collections. Note that this article does not discuss the health problems caused by asbestos or health and safety protection measures, as these topics are covered elsewhere (e.g., Roach et al. 2002, Müller et al. 2003; for Switzerland: SUVA 2019).

Figure 1. Clearance testing, vacuum-cleaner method: 2 m^2 of surface was sucked onto a glass-fiber filter. The filter number was written on the nozzle

PRELIMINARY TESTS

At the outset, there was a refusal to believe that cleaning would be necessary at all, an issue resolved by several rounds of preliminary testing.

Preliminary tests for the presence of asbestos

Testing for the presence of asbestos fibers in the collection was performed using velvet and adhesive carbon pads (see analytical protocol below). All tests indicated the presence of chrysotile and crocidolite asbestos fibers in small but relevant amounts. Sampling of the ambient air did not show any asbestos fibers suspended in air.

Additional testing was performed on objects in closed cabinets, drawers, boxes, and on stackable containers with open handles where dust might settle. All 100 tests were negative. Thus, asbestos fibers were present on all open surfaces (including the outsides of boxes) but the containers and textile dust covers had protected the objects, reducing the number that had to be cleaned.

Preliminary tests of the effectiveness of possible cleaning treatments

Cleaning protocols were then tested on the four types of surfaces expected to be the most difficult to treat: roughened fabric (representative of coarse textiles), rough-sawn wood, broken brick and stone, and feathers. Sample surfaces were deliberately contaminated by asbestos. A small sample of sprayed asbestos was ground into dust and distributed onto the surfaces by small bursts of compressed air in order to achieve a random contamination. The different surfaces were then cleaned by suction with a HEPA-filtered vacuum cleaner, by brushing, and by blowing with compressed air. After the surfaces had been cleaned, each was tested for contamination using the vacuum-cleaning method outlined below. Contamination and cleaning were performed in a specially constructed workstation under negative pressure, where before its release the air was filtered through a HEPA 14 filter.

TESTING FOR CLEARANCE: ANALYTICAL PROTOCOLS

At the end of the project, the museum objects had to be certified as free of asbestos fibers. Because all air samples in the preliminary tests were clean, it was suspected that the measuring techniques described by Kominsky et al. (1993) would provide false-negative results.

The standard method for measuring asbestos in fibrous dust on surfaces (see VDI 2011, HSE 1994) uses adhesive pads to test a small proportion of the surface, but this risks missing the area(s) of contamination. Certifying complete removal of asbestos by this method would require a large number of samples and thus incur high laboratory costs. To control costs, save time, assess large surface areas, and ensure that all of the asbestos had been removed, new test methods were developed to detect even small amounts of asbestos fibers in large amounts of dust:

- Vacuum-cleaner method (Figure 1)
  Asbestos contamination was measured using a vacuum cleaner (Ghibli and Wirbel fitted with an H14 filter) and a dust collector (ROM-Elektronik GmbH) mounted on the inlet nozzle. Inside the dust collector (Ø 70 mm)

was a glass-fiber filter (MN 85/70, MACHEREY-NAGEL AG) with a retention capacity of 0.6 µm. Objects tested for asbestos were vacuum cleaned by gently following the whole surface with the dust collector. Each time an area of 2 m² was vacuumed, the glass-fiber filter was removed to avoid an overlay of fibers. The filter was analyzed for asbestos using polarized light microscopy following the MDHS 77 norm (MDHS 77 1994). After each filter had been removed for analysis, the dust collector was cleaned in an ultrasonic bath and then dried.

- Push-pull method (Figures 2 and 3)
  Clean air was pushed by a vacuum pump (Membran-Vakuumpumpe N 816.1.2 KT.18, KNF Neuenberger AG) through a silica tube into the base of an inverted funnel and drawn out the top through a gold-coated capillary-pore polycarbonate membrane filter. The airflow whirled the fibers up from the surface and out the top of the funnel. The use of this method was restricted to individual objects (not multiple objects in a row) and the filters were analyzed by scanning electron microscope–energy dispersive X-ray spectroscopy (SEM–EDX). This method was implemented for especially sensitive objects and as an additional means of quality control, performed randomly among objects that had been tested using the vacuum-cleaner method.
- Carbon-pads method (Figure 4)
  A carbon pad (Plano Leit-Tabs, Plano GmbH) with an adhesive surface (Ø 12 mm) was pressed on multiple areas on an individual object. Dust and fibers that stuck to the pad were analyzed by SEM–EDX. This method was used for quality control and was randomly applied among objects assessed using the vacuum-cleaner method. Since this method requires direct contact with the adhesive surface, it could only be used on sturdier objects.

Figure 2. Push-pull method, used for difficult to clean, porous surfaces. Air is blown into the dome-shaped handpiece (right tube) and pulled out vertically through the black testing tube

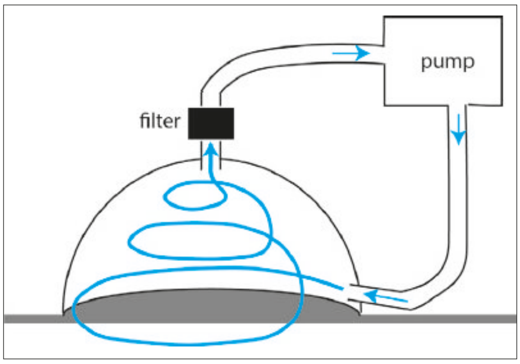

Figure 3. Working principle of the push-pull test method: A pump pushes air into a dome-shaped handpiece, whirling up dust from the surface. The air is pulled back to the pump through the filter at the top of the handpiece

Figure 4. Carbon-pad method used as quality control for clearance testing with the other methods

Discussion

The push-pull method was the most sensitive (and most expensive) method for testing porous, difficult to clean surfaces, followed by the vacuum-cleaner method. Air-sampling was least effective, and the adhesive pad allowed only localized analyses.

The vacuum-cleaner method was chosen as the "standard clearance testing" method for this project because it allowed sampling of a very large surface area on multiple objects, while resulting in fewer samples and a lower cost as well as enabling the sampling of fissures, textile structures, and inaccessible surfaces.

LAYOUT OF WORK ZONES ON SITE

Following these preliminary tests, the workspace layout, cleaning procedures, and workflow were chosen.

Once the asbestos abatement specialists had cleaned the ground floor, work zones covering an area of 650 m², with few walls, were established on the ground floor of the contaminated building (Figure 5). The space around the elevator serving the storage areas was considered contaminated. The remaining area was sealed off and over-pressurized to prevent asbestos from the contaminated building from entering the work zones.

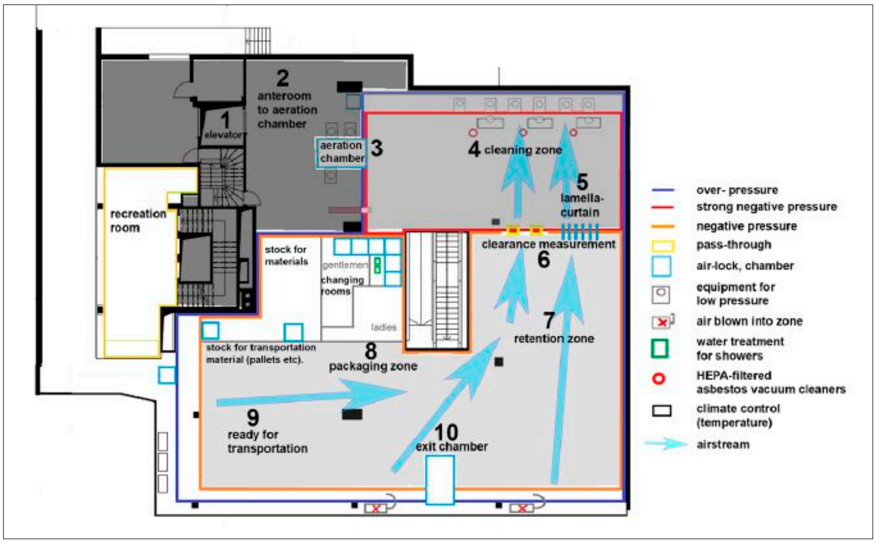

Figure 5. Map of the working zones, with their dimensions and showing the airstream from clean to less clean zones. Numbers indicate the sequence of working posts

The work zones were kept at negative pressure, with the lowest pressure at the cleaning zone and only minimally lowered pressures in the clean packaging and preparation zones. This created a strong airstream from clean towards less clean zones. At the beginning of the project, 1,000 m^3 air/hour were pumped and recycled into the zone. Later in the project, the rate reached 4,000 m^3/hour, due to an increasing number of tiny leaks in the plastic walls. The zones were separated by chambers through which objects were passed.

PROTECTION OF PERSONNEL

Personnel wore overalls with hoods and half masks with powered air-purifying respirators. People working in clean(er) zones passed through a single airlock, leaving their work overalls in the chamber for safe disposal, whereas people working in the contaminated and cleaning zones passed through a triple airlock, taking a shower after leaving their work overalls in the first chamber. Thirty-three air-sampling and on-person samples were taken and analyzed. Asbestos fibers were found in only one sample (144 fibers/m^3) from the ambient air of a storage room.

TREATMENT PROCESS

Objects were moved from one processing area to the next, while people stayed in their working zone.

"Air-shower" in the aeration chamber

In the contaminated storage rooms, all objects were loosely placed on pallets and then brought to the ground floor, where they were subjected to a 100× air exchange in the chamber between the contaminated zone and the cleaning space, called the "aeration chamber." The 100× air exchange took 3–10 minutes, depending on the acceptable strength of the air flow relative to the stability of the object.

Cleaning

All cleaning had to be performed without the prior consolidation of fragile layers. No humidity was used during treatment, only dry methods: vacuum cleaning, brushing, and compressed air. Each workplace for cleaning was located in front of a very large hose with strong suction, with another hose at floor level (Figure 6) to create a strong airflow away from the worker. The air was filtered through HEPA asbestos filtering systems and then recycled in order to stabilize the climate and avoid the intake of large amounts of outside air.

Because asbestos fibers are very fine and not visible to the naked eye, controlling the cleaning process was challenging. To ensure that the entire surface had been cleaned and that no uncleaned "islands" had been left behind, each object was cleaned using the largest possible brush appropriate to that object.

Figure 6. Cleaning zone with the extraction hose above and at floor level next to the worktables

In general, smooth surfaces were brushed and/or cleaned using compressed air. Rough surfaces could only be vacuum cleaned because brushing or compressed air would have forced the asbestos fibers further into the surface layer. For intermediate surfaces, compressed air and/or vacuum cleaning was chosen (Table 1). Large cupboards were dismantled for transport and cleaning.

Vacuum cleaning with HEPA asbestos filtering

Whenever possible, a soft vacuum-cleaner brush (horse or goat hair) was used directly on or over the surface of the object, with no screen in between. Screens were only used for fragile paintings and textiles with loose fragments.

Brushes

Soft brushes were used. Brushing was always performed away from the person and toward the hose.

Compressed air

Adjustable air pressure was used at a maximum of 1.6 to 2 bar, with the air touching the surface tangentially so as to lift the asbestos fibers away from the surface. For most objects, a round nozzle with several holes arranged in a circle (Mehrlochdüse BlowStar Prematic) was used to provide a wider air stream and to prevent untreated areas on the object. When the interior of pots or vases was cleaned, a long nozzle with one hole (Langdüse Prematic) was used and the open end was placed at the bottom of the vessel before the airflow was activated. This caused the air to move upwards along the wall of the vessel and to carry the asbestos fibers away. Blowing air from the top would have led to air circulation within the vessel, displacing rather than removing the asbestos fibers.

Water

Aqueous cleaning was performed only on metal storage racks and shelving. When possible, the dismantled metal shelving was cleaned with pressurized water in order to clean the interior of the hollow structure of the sides. Smooth flat metal pieces could also be wiped with damp towels (water or water + surfactant). Drying was done with compressed air.

Washing dust covers

A washing protocol was developed to clean the reusable dust covers. Dust covers were stored and transported in water-soluble washing-bags designed to dissolve during washing. The dust covers went through three cycles at 40°C, twice with washing detergent and once without. The dust covers were then dried, and every fourth cover was tested for contamination using the vacuum-cleaner method (see Analytical protocols). If contamination

Table 1. Cleaning and clearance testing methods used in asbestos removal, listed by object group

Object/surface type	Specific objects	Decontamination method	Clearance method
All objects:	All objects	Aeration chamber 100× air exchange	Vacuum cleaner Carbon pad
Followed by:			
Metals	Farm equipment, industrial equipment, electrical equipment, photographic cameras, medical equipment, arms and weapons, bicycles, wrought iron, canon balls, billboards, musical instruments (metal), chalices, tinware	Compressed air or compressed air + soft brushes	Vacuum cleaner Carbon pad
Glass and ceramics	Dishes, porcelain, vases, lamps, stained glass, mirrors, glass doors in furniture	Compressed air or compressed air + soft brushes	Vacuum cleaner Carbon pad
Sculpture unpainted	Plaster, stone, metal	Compressed air or compressed air + soft brushes	Vacuum cleaner Carbon pad
Plastics, rubber, etc.	Kitchenware and household equipment, boxes and containers, medical equipment, industrial equipment	Compressed air or compressed air + soft brushes	Vacuum cleaner Carbon pad
Paper / cardboard	Books, archives, drawings, prints, wallcoverings (rolled), cardboard boxes (with boxed objects)	Soft brushes, followed by compressed air	Push-pull
Painted surfaces stable	Paintings and sculpture with smooth, intact surface/varnished	Soft brushes, followed by compressed air	Vacuum cleaner Carbon pad
Painted surfaces less stable	Paintings and sculpture unvarnished, with cracked or slightly powdery surface	Vacuum cleaning through screen with fine mesh, if possible, followed by compressed air at low pressure	Vacuum cleaner Carbon pad
Textiles	Uniforms, costumes, Flags, hats and military headgear	Vacuum cleaning	Vacuum cleaner Push-pull
Feathers, 3D embroideries	On helmets, 3D objetcs „Klosterarbeit“	compressed air only	Vacuum cleaner Push-pull
Leather	Suitcases, shoes, belts	Compressed air or compressed air + soft brushes	Vacuum cleaner Push-pull
Upholstery	Upholstered furniture, sledges, baby carriages, mattresses, pillows	Vacuum cleaning. For upholstery with losses and open padding: vacuum cleaning through wide-mesh screen directly on the surface (no dust brush).	Vacuum cleaner Push-pull
Basketry	Baskets, household equipment	Vacuum cleaning followed by compressed air	Vacuum cleaner Carbon pad
Wood (sealed or smooth)	Furniture, clocks, kitchen and household equipment (bowls, cutting boards, cutlery, spinning wheels, etc.), musical instruments (wood)	Vacuum cleaning with brush attachment and/or compressed air. For cracks and slits between boards in cabinets and clocks: compressed air from within with simultaneous vacuum cleaning from the outside	Vacuum cleaner Carbon pad
Wood unsealed	Pallets, decking, farm machinery	Vacuum cleaning	Vacuum cleaner Carbon pad
Mixed-media objects	Carnival decoration, religious and secular objects, doll houses, models of bridges and houses	Vacuum cleaning followed by compressed air	Vacuum cleaner Push-pull
Metal shelves (storage racks)	Frames, tablets, screws, etc. (no rolling racks, fixed shelving only)	Liquid water (pressure wash) followed by drying or humid towels (water + detergent)	Vacuum cleaner Carbon pad

was detected, the covers were washed and tested until no contamination could be measured. The wastewater was processed to remove asbestos.

Clearance

Every fourth object that had been exposed was tested. Within storage boxes, every 14th object was tested. Tested and non-tested objects were all treated as a batch and labeled with the corresponding filter number, written on a slip of colored paper. With each delivery to the analytical lab, the color was changed, making retrieval of the batches easier when lab results arrived. The testing techniques are described in Table 1.

Retention zone

After the objects had been tested for clearance, they were held until the laboratory results were available, normally 1–2 days. To prevent cross-contamination, each batch of objects was tightly wrapped in thin plastic. However, this meant that the objects could not be stacked efficiently, and a considerable amount of space was needed for their temporary storage.

Packaging

Once the objects had been cleared, they were moved to the packaging zone and packed as efficiently as possible for a 10-minute journey by truck. Pallets were moved to a zone where the outline of the truck's area was marked on the floor, to assist in estimating the capacity.

Transportation

For transportation, the pallets were moved into the exit chamber for the driver to collect. The transportation and subsequent receival of the objects at the new storage facility were conventional, as the objects were no longer contaminated.

RESULTS

Effectiveness of cleaning

Although some objects did not initially pass the quality control and had to be cleaned two to five more times, all objects finally passed. Thus, even very rough, porous, difficult surfaces were successfully cleaned, an unexpected and positive outcome.

Number of people needed

As the zones were separated from each other, the minimum number of people needed for the process described was 12–13: 10–11 in the working zones plus 1 person each for coordination of the zones and security (a person licensed in asbestos abatement), and for coordination of the work, materials, transportation, and supplies (conservator). This number reflects the fact that in many cases two people were needed to safely handle the boxes and objects.

Work efficiency was higher if people could concentrate on their work and stay at their workplace while other people moved the objects between workplaces.

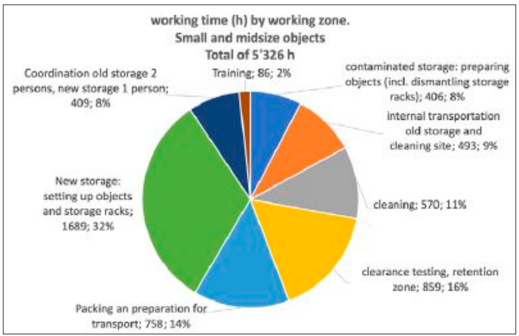

Figure 7. Diagram of the amount of time worked in working zones for midsized and small objects

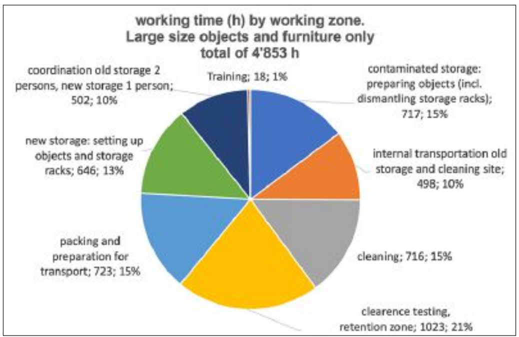

Figure 8. Diagram of the amount of time worked in working zones for large objects and furniture

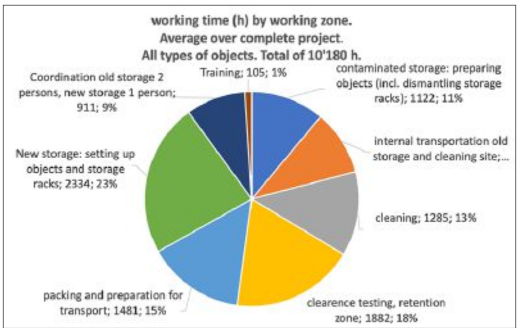

Figure 9. Diagram of the amount of time worked in the different working zones over the whole project, 10% large and 90% small and midsize objects

Time needed per zone/object

All participants logged into a RFID time clock that registered their work zone. This allowed for an evaluation of the time needed in each part of the process (see Figures 7–9). Cleaning was expected to take the most time, but clearance testing and wrapping the objects to be put on hold were the most time-consuming. In future projects, these working-zone-based evaluations will enable predictions of time per process. Time stamping also allowed calculation of the average time needed for an object to pass through the whole process, which was 24 minutes, including dismantling and cleaning all of the storage racks and setting up the objects in the new storage facility. As the collection included a range of object sizes, the average time was calculated for each of these groups: 14 minutes for various midsize to small objects and up to 2 h 12 minutes for large cupboards and objects that required disassembly and reassembly. These numbers are based on the number of items cleaned and then documented by the clearance protocol (see Table 2 and Figures 7–9)

Table 2. Estimation of the treatment time needed per object. Average for all object types, including dismantling and cleaning existing storage racks, and setting up racks and all objects in a new storage facility. As boxes were only cleaned from the outside and treated as one unit with their content, the estimated number of objects stated by the museum (35,000) differed from the number of units counted during clearance

	Number of units	Total working time (h)	Time/ object (h)	Time/object (min)
Mid-size to small objects	23,000	5,325.80	0.23	14
Large objects and furniture (including disassembling and reassembling large furniture)	2,200	4,853.25	2.21	132
Entire project	25,200	10,179.03	0.40	24

Lessons learned and problems encountered

The "air-shower" proved very effective, and the development of a dome-shaped tool for use in the push-pull method allowed for very sensitive albeit more expensive clearance testing.

Equipment that ran 24 hours per day increased the temperature of the workspace enormously. Cooled air had to be brought directly into the cleaning zone where the temperature was highest. The noise level was high, but still at an acceptable level. If the rooms had been located in a basement, ear protection would have become necessary.

The amount of asbestos contamination in the air was none to minimal even during cleaning. This was probably due to the strong airflow installed. If the contamination in the air had exceeded acceptable limits, working with compressed air brought directly into the respiratory mask would have become necessary and the hoses would have reduced the working perimeter drastically. This would have increased the time and money needed to complete the project.

Because this type of cleaning work can become tedious, maintaining quality standards and speed under the working conditions was a constant challenge that required a deliberate effort from each and every person involved. Nonetheless, the team remained motivated and in good spirits. Rotations among working stations helped to break up the routine.

CONCLUSION

The results presented in this paper can serve as a guide for time and space estimates in future projects in which sensitive and effective clearance testing is needed.

Our experience shows that the decontamination of complete collections from asbestos fallout is possible and feasible. Passing the objects first through an "air shower" (100× air exchange) increased the effectiveness of the subsequent cleaning by vacuum cleaning, brushing, and pressurized air. Flushing the working zones with a well-designed airflow and working in front of a "suction wall" minimized asbestos contamination of the air. Organizing the work such that each person performed a single task accelerated the workflow and made the work less stressful, allowing a higher level of concentration. Assigning one person to supervise and organize safety and equipment and another to organize the materials and work also improved the process. Conveying information with the objects in the form of checklists and labels as they moved from one zone to another was essential, as were strict protocols on photographing the objects and reporting damage.

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