WATER OPERATION AND MAINTENANCE

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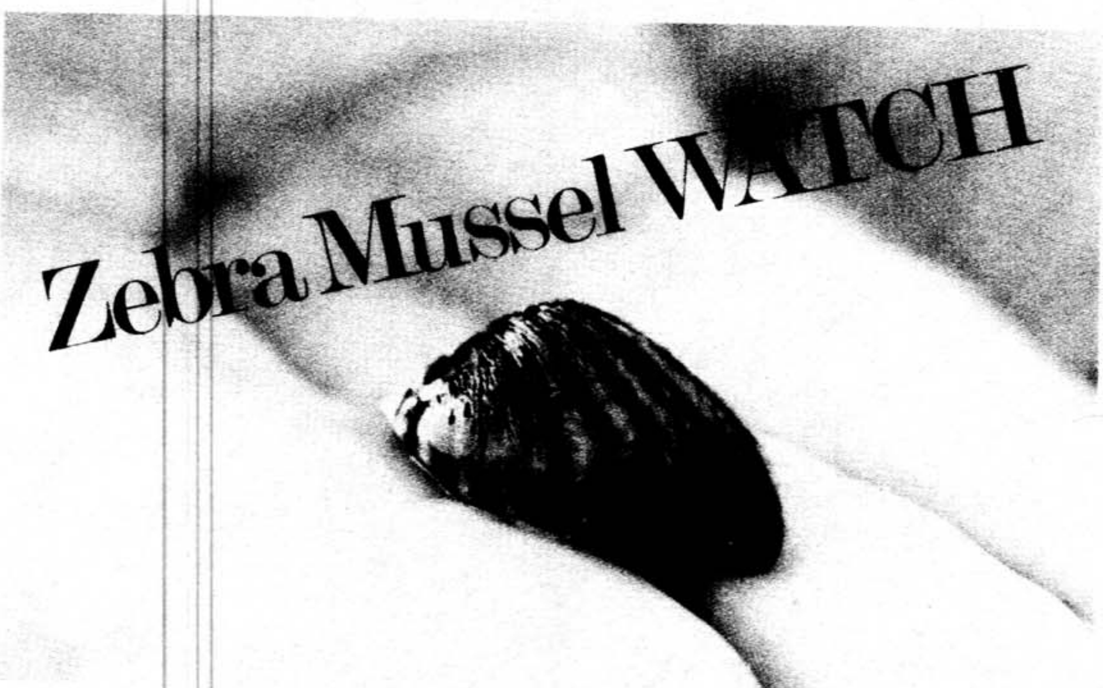

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UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Reclamation

The Water Operation and Maintenance Bulletin is published quarterly for the benefit of those operating water supply systems. Its principal purpose is to serve as a medium of exchanging information for use by Bureau personnel and water user groups for operating and maintaining project facilities.

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Cover photograph:

Zebra Mussel

(photo University of Wisconsin Sea Grant Institute)

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THE ZEBRA MUSSEL MENACE

A Problem Species in the Great Lakes Makes Its Move Toward Prominence in the West

by Cal McNabb[1], Fred Nibling[2], and Charles Liston[3]

A prolific clam-like creature has plugged up the works in multimillion dollar state-of-the-art electric power and water treatment facilities on the Great Lakes. Also, its voracious feeding has stripped suspended particles from the water, including food that supports the billion dollar commercial and recreational fisheries on the Great Lakes. Maintenance costs for infested structures and intakes at individual facilities are currently running at millions of dollars annually. The overhaul of water systems and damage to fisheries are estimated to cost $4–$5 billion in the Great Lakes region during the next decade.

Photo 1.–In addition to impacts on industrial water supplies, zebra mussels have profound effects on native aquatic fauna. For example, this picture shows smaller zebra mussels crowded around the food intake of a larger native clam. In this position, zebra mussels rob native clams of their food, and cause native clam extinctions.

Severe economic losses will occur at several locations in the Mississippi River basin if native clams are destroyed. They are harvested from rivers in the region for their shells, used as raw materials in the button industry.

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Adult zebra mussels (*Dreissena polymorpha*) were first found in North America in 1988 at a location in the Great Lakes near Detroit. The animal had recently arrived from Europe. Adapted to life in fresh or slightly brackish water, it jumped the salt water barrier between Europe and the Great Lakes in the ballast of an inbound commercial freighter. It became established after the ballast was discharged. In the past 3 years, the mussel has shown it is not just another run-of-the-mill pest limited to the Great Lakes region. It is expected to encounter few geographical or environmental barriers to prevent colonization of freshwater habitats throughout temperate North America. Predictions are that it will be common in the West in the next 3-5 years. Both structures and fisheries in Reclamation's highly automated networks of water delivery systems are at serious risk from this pest, if it goes unattended in early stages of invasion.

Pest Characteristics

There are several aspects of zebra mussel ecology that make it a menace of national significance. The animal is adapted to live in the great majority of freshwater habitats in the continental United States. No predators are naturally effective in controlling zebra mussels in either North America or Europe. Parasites and organisms that can cause it disease are also uncommon. The zebra mussel is unique among the clans of freshwater clams; it is the only one that, as an adult, grows firmly attached to solid objects. Adult animals have the tendency to grow attached to one another, forming dense clusters. Because of this tendency, it is not uncommon to find 40,000-100,000 adult mussels per square meter (33,400-83,500 per square yard) in good habitat on intake cribs, concrete channel linings and the like. The zebra mussel's rate of reproduction is tremendously high; each mature female produces 30,000 to 40,000 eggs per year. Young mussels are formed in parental colonies. They are very small in size, and travel about unnoticed. Distances over which they can move away from parental colonies are astounding. They drift about on water currents or attached to barges, boats, boat trailers, anchors, bait buckets, waders, wet swimming suits; and perhaps among the feathers of waterfowl.

Young zebra mussels eventually settle down and attach to solid surfaces. Almost any kind of surface will do. They feed by filtering small algae, bacteria, and bits of decomposing material out of the water. Zebra mussels live for 3-5 years, and older animals reach a length of 2.5-4.0 cm (1.0-1.6 inches). They grow best down in the water, or in and around pipes and structures where they are out of bright light. They favor a moderate current which brings their food to their doorstep. Reclamation's water conveyance systems abound with prime habitat of this kind.

Photo 2.–Small floating larvae of zebra mussels are drawn into water intake pipes where they settle down, grow, and block waterflow to critical components of cooling systems in industrial plants and on ships and pleasure boats. (Photo by Peter Yates)

Natural Restrictions

The zebra mussel is coming west, but it will not grow everywhere. In general, they are adapted to live in relatively clean waters in locations with a temperate zone climate, where the seasons come and go. As with other species, their genetics and physiology will put limits on their ability to infest certain kinds of habitats, some of which may be found in the West. For example, they will generally not develop infestations where:

* Water temperature in summer is 29–30 °C (84–86 °F) for extended periods of time.

* Calcium in the water (required for shell formation and maintenance) averages less than 10 milligrams per liter.

* Dissolved oxygen is low (less than 20–30 percent of atmospheric saturation) or absent.

* Turbidity is high enough to impair gill function.

* Salinity is greater than 4–5 parts per thousand parts of water.

* Velocities of currents are greater than 1–1.5 meters per second (3–5 feet per second).

* Toxic pollutants are abundant.

Where habitats are suitable in regard to these conditions, and free of effective predators and disease organisms, the size of zebra mussel infestations will be largely a function of the abundance of permanently submerged solid substrates for colonization, and the amount of food (small algae, bacteria) available for the young and adults.

Photo 3.–Water at high pressure has been used to blow zebra mussels off walls of invested chambers at electric power stations, municipal waterworks, and pumping stations. Freed mussels must be collected to prevent them from washing downstream into screens, nozzles, and other constrictions when cleanup is over and plant operation resumes.

Early Action: The Key To Control

History has shown that the American Great Lakes, as well as water intake structures on their shorelines, were ideal habitats for zebra mussels to colonize. With few exceptions, the industrial and scientific communities of the Great Lakes region were caught by surprise at the speed at which mussel infestations developed, and the size of infestations. Measures to minimize their effects were not undertaken until clusters of two to three generations of animals, one generation growing on top of the other, had plugged screens and trashracks and smaller diameter pipes, reduced flows in conduits with larger cross sections, blocked control gates, interfered with pumps, disrupted gauging and flow rate instrument networks, piled up in wet wells, fouled fire control systems and accelerated corrosion. In retrospect, regular maintenance inspection of structures and timely mechanical removal could have alleviated a considerable portion of these problems.

Prospects

An alarming aspect of the North American zebra mussel invasion has been the speed at which mussels have spread and colonized new habitats. In the 3 years since they were first noted, zebra mussels have spread into an area with a radius of about 600 miles around the point of origin near Detroit. They have, for example, moved east to the Hudson River, south to the TVA system, and northwest to the upper Mississippi River. There is no evidence to suggest they will not continue to move very rapidly into the West and infest lakes, streams, and reservoirs across the continent.

Early detection and manual maintenance are the first line of offense to minimize zebra mussel impacts on Reclamation facilities. In areas of heavy infestation, manual maintenance may need to be used as part of an integrated approach that incorporates other control procedures. For example, fish predators may be confined in infested canals to reduce breeding populations of mussels and thereby their densities on critical water control structures downstream. Chlorine, hot water, and commercial biocides may have application in closed or semi-closed portions of water systems. Copper and zinc surface coatings, which inhibit mussel attachment and/or development, may be used effectively in key trouble spots along water distribution lines. Sonic waves, ultraviolet rays, and electrical shock are other alternatives for control. The Applied Sciences Branch at the Denver Federal Center is undertaking research related to early detection and control under Project EE025: Control of Exotic Molluscs.

In the long-term, American water works are likely to be adapted to operate with a high level of tolerance for the presence of the zebra mussel. In Europe, the animal was present nearly 100 years before modern urban and industrial development began. As a result, water systems were designed early-on to manage infestations with minimum disruption of service. Similar structural modifications will likely be made to existing facilities in infested drainage basins in the United States, and new designs will appear for facilities yet to come. Looking ahead, zebra mussels are likely to find accommodations in American facilities, including those of Reclamation, much less hospitable than they have been to date.

Reclamation's Regional Offices have been furnished with information for distribution to personnel and others, as well as a VCR tape on these mussels.

Zebra Mussel Watch

The great majority of Western waters meet all the ecological requirements of suitable habitat for zebra mussels. Early detection will be the key to maintaining efficient operation of Reclamation's water delivery structures in areas that become infested by the animal. It will also set the stage for implementation of new management strategies to promote recreational fisheries and endangered fish species in lakes, streams, reservoirs, and tail waters impacted by zebra mussels.

We invite you to participate in Reclamation's ZEBRA MUSSEL WATCH, a program aimed at early detection in western waters. Zebra mussels are easy to capture. They are also easy to identify because adults are the only clam-like animals in inland waters that attach themselves to solid objects. First-time detection at a particular location is most often made by finding animals on objects that are retrieved from a water depth of several feet.

Hang a Rope

A rope tied to a brick anchor makes a great device for detecting zebra mussels. Any kind of rope will do; however, nylon is preferred because small mussels are easier to distinguish on its smooth surface than they are on ropes with rough surfaces. Adult animals produce young mussels in the spring when the water warms up, and they continue to produce young until fall. Young mussels float about in the water and eventually attach themselves to ropes or other objects. They are smaller than the head of a common straight pin and quite transparent when first attached. They grow to 1/4 inch in

2–3 months, and take on the appearance of small, dark-colored clams. They commonly grow to 1/2 inch before their first winter.

Hang a rope in 8 feet or less of well-oxygenated water. Select a spot where wave action will not move the bottom of the rope to any great degree. Zebra mussels like slow currents. They will not attach where the current is moving 4–5 feet per second or faster. Young zebra mussels settle down on surfaces that are coated with algae and other microscopic organisms. Leave your rope in the water for 2–3 weeks to allow these microorganisms to grow. Thereafter, lift the rope at 2–3 week intervals and examine it for young mussels. If adults are around, the young will eventually show up. Remember, it is as important to know that adult mussels are not around as it is to know that they are!

Reclamation's Zebra Mussel Program coordinates information on geographical distribution of zebra mussels with offices of Reclamation and other public agencies. Report your work whether or not you find zebra mussels. If you think you have found zebra mussels, record the place found and lengths of their shells. Have the identification of your specimens confirmed. Preserve them in rubbing alcohol, wrap them in a piece of tissue, and send them to:

Dr. Cal McNabb
Reclamation's Zebra Mussel Program
PO Box 25007, Code D-3742
Denver CO 80225-0007
Telephone: (303) 236-6007

You will receive a reply regarding your specimens and a summary of information gathered by others participating in this program.

GUIDELINES ON SAFETY DURING LEAD PAINT OPERATIONS[1]

Editor's Note: In response to an increase in the incidence of lead poisoning among construction workers, including blasters and painters, the National Institute for Occupational Safety and Health (NIOSH) issued a NIOSH Alert entitled Request for Assistance in Preventing Lead Poisoning in Construction Workers in the Fall of 1991.

The document is a guidance document and as such it does not have the force of law or regulation behind it.

OSHA is in the process of developing a regulation for worker exposure to lead in the construction industry, but until that document is complete, the NIOSH Alert and the OSHA/NIOSH Interim Guidelines, reprinted in the July 1991 JPCL, pp. 44–55, are the most current documents from Federal health and safety agencies on protecting construction workers from overexposure to lead.

Readers are permitted to photo-copy the reprinted Alert without seeking permission from JPCL or NIOSH.

NIOSH Alert: Request for Assistance in Preventing Lead Poisoning in Construction Workers

The National Institute for Occupational Safety and Health (NIOSH) requests assistance in preventing the lead poisoning[2] of workers engaged in the maintenance, repainting, or demolition of bridges or other steel structures coated with lead-containing paints. NIOSH recently learned of 42 workers who developed lead poisoning while working on bridges. Operations such as abrasive blasting, sanding, burning, cutting, or welding on steel structures coated with lead-containing paints may produce very high concentrations of lead dust and fumes. Furthermore, the recent introduction of containment structures (enclosures designed to reduce environmental contamination by capturing particles of paint and used blasting material) may result in even higher airborne concentrations of lead. Lead dust at the worksite may also result in contamination of workers' homes and automobiles.

WARNING!

Lead poisoning may occur in workers during abrasive blasting, sanding, cutting, burning, or welding of bridges and other steel structures coated with lead-containing paints.

For the construction industry, NIOSH and the Occupational Safety and Health Administration (OSHA) have recently recommended that exposure to lead dust and fumes be minimized by the use of engineering controls and work practices, and by the use

[1] Reprinted from an article in *JPCL* (Journal of Protective Coatings & Linings), 2100 Wharton Street, Suite 310, Pittsburgh PA 15203; January 1992 issue, pp. 40-54.

[2] For the purposes of this document, NIOSH has defined lead poisoning as a concentration of lead in whole blood (known by OSHA as a blood lead level, or BLL) exceeding 50 micrograms per deciliter ($\mu g/dl$). See table 4 for a list of actions required by the Occupational Safety and Health Administration (OSHA) general industry standard for various BLL's.

of personal protective equipment (PPE)—including respirators—for additional protection [OSHA/NIOSH 1991]. Airborne lead concentrations and blood lead concentrations should be monitored to determine the effectiveness of controls and PPE. All new contracts of Federal, State, and local departments of transportation *should* include specifications for a mandatory program of worker protection from lead poisoning during the maintenance, repainting, or demolition of bridges and other steel structures.

NIOSH requests that the recommendations in this Alert be brought to the attention of workers and employers (including subcontractors) by general construction contractors, State departments of transportation (including worksite inspectors), labor union representatives, labor associations, editors of appropriate trade journals, and safety and health officials. Your assistance in this effort will help to achieve one of the national health objectives specified by *Healthy People 2000* [DHHS 1990], a statement of national goals for health promotion and disease prevention. These goals are the product of a national effort involving State health departments, national organizations, and many individuals. The goal for workers exposed to lead is to eliminate exposures that result in blood lead concentrations greater than 25 μg/dl of whole blood.

BACKGROUND

Workers are potentially exposed to lead during work on bridges or other steel structures such as water and fuel storage tanks. Workers who may be exposed to lead include abrasive blasters, inspectors, iron workers (welders and cutters), painters, and laborers. In 1987, an estimated 44,000 persons worked in bridge, tunnel, and elevated-highway construction (Standard Industrial Classification Code [SIC] 1622), and an estimated 14,000 persons worked in wrecking and demolition (SIC 1795) [Bureau of the Census 1990].

An estimated 90,000 bridges in the United States are coated with lead-containing paints [Katauskas 1990]. According to a survey of State departments of transportation, lead-containing coatings were found on approximately 77 percent of U.S. bridges [*Editor's Note: The revised estimate is 83 percent.*] that were repainted between 1985 and 1989 [Steel Structures Painting Council 1991].

Maintenance of Steel Structures

Before new coating may be applied to bridges and other steel structures, deteriorated paint and corrosion must be removed and the metal surface must be properly prepared [Katauskas 1990]. In addition, all coatings of lead-based paints must be removed before another type of paint can be applied [Katauskas 1990]. This process is most commonly accomplished by using a portable device for abrasive blast cleaning. These devices are designed to deliver a high-velocity stream of abrasive to the metal surface. Compressed air is generally used, but some devices use water to deliver the abrasive. A variety of nonmetallic and metallic abrasives have been used, including silica sand, slag, and steel grit. The worker performing the blasting directs the blasting nozzle at the surface to be cleaned. As the paint is removed, small particles become airborne, and the used abrasives become contaminated with lead-containing paint particles.

Containment structures are used to reduce the release of lead into the environment by capturing paint chips, dust, and used abrasive. Where possible, containment structures are designed so that the used abrasives and debris are directed through chutes or tubes into a barge or hopper. Because the recovery systems in the containment structures are not completely effective, some of the material must be recovered manually by sweeping, shoveling, or vacuuming. Under the Resource Conservation and Recovery Act (RCRA), waste material must be tested, and if the leachable lead concentration is 5 parts per million (p/m) or greater, the material is classified as a hazardous waste [40 CFR[3] 260].

Containment structures are designed to reduce the dispersion of lead into the environment, but they may increase worker exposure to airborne lead. Current techniques for containment are not well defined and vary in their efficiency in preventing lead from being released into the environment. Some containment structures consist of tarpaulins or open mesh fabrics placed over the blasting area; some use rigid materials of wood, metal, or plastic to enclose the blasting area; and some use a combination of flexible and rigid materials. Large air-moving devices may be mounted on trucks and connected to the containment structures to exhaust dust-laden air. The exhausted air is passed through dust separation devices and filters before it is released to the atmosphere. This ventilation technique may also create a negative pressure within the containment structure and help reduce environmental contamination.

Workers may receive additional exposure at some sites when the containment structures (which may contain residual lead dust and debris) are disassembled and moved. Workers should be adequately protected while performing these operations.

Potential for Exposure to Airborne Lead

At sites where workers performed bridge, tunnel, and elevated-highway construction (SIC 1622), OSHA reported airborne lead concentrations exceeding 200 micrograms per cubic meter ($\mu g/m^3$) for 65 percent of the samples collected between April 1984 and April 1988 [OSHA 1988]. Tables 1 and 2 summarize cases of occupational exposures to lead reported during abrasive blasting, sanding, burning, cutting, and welding. Most of the operations described were conducted outside containment structures. These data indicate that persons working at the jobsite outside the containment structure are also at risk of exposure to lead. *Workers who do not shower and change into clean clothing before leaving the worksite may contaminate their homes and automobiles with lead dust.* Other members of the household may then be exposed to harmful amounts of lead [Grandjean and Bach 1986; Kaye et al. 1987; Matte et al. 1989; Baker et al. 1977].

HEALTH EFFECTS OF LEAD EXPOSURE

The frequency and severity of medical symptoms increase with the concentration of lead in the blood. Many adults with blood lead levels (BLL's) of 80 $\mu g/dl$ or greater have symptoms or signs of acute lead poisoning, although in some individuals, symptoms may be so mild that they are overlooked [NIOSH 1978; Rosenstock and Cullen 1986]. Common symptoms of acute lead poisoning are loss of appetite, nausea, vomiting, stomach cramps, constipation, difficulty in sleeping, fatigue, moodiness, headache, joint or muscle aches, anemia, and decreased sexual drive. Severe health effects of acute lead exposure include damage to the nervous system, including wrist or foot drop, tremors, and convulsions or seizures. Acute lead poisoning from uncontrolled occupational exposures has resulted in fatalities [Hayhurst, 1915].

[3] Code of Federal Regulations. See CFR in references.

Table 1 Airborne Lead Concentrations Reported during Operations on Bridges and Other Painted Steel Structures

Operation	Job	Exposure range during task (μg/m³)	Comments
[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
Bridge demolition (no containment structure) [New Jersey Department of Health 1988b]	Torch burner	110-1,200	Workers were cutting beams on bridge
	Burner helper	330	These workers assisted burners who were cutting the bridge
	Power tool use	5-50	
[redacted]	[redacted]	[redacted]	
	[redacted]	[redacted]	
Paint removal from boiler (no containment structure) [Adkison 1989]	Blaster	230-860	Samples were taken inside respirator
		640-1,400	Samples were taken outside respirator
	Power tool operators	80-790	Workers were spot cleaning an existing surface
[redacted]	[redacted]	[redacted]	
Bridge repair (no containment structure) [Rekus 1988]	Welder	2,200-4,200	
	Blaster	10,400	
	Burner	840-4,900	
	Blaster	1,070-1,120	
[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]

Table 2 Airborne Lead Concentrations Reported for Case Studies

Case No.*	Location and description	Job	Range of airborne lead concentration during task ($\mu g/m^3$)	Comments
[redacted]				
3	Louisiana, paint removal from bridge (with containment structures)	Blaster	2-730	Work conducted inside containment structure
[redacted]				
6	Kentucky, paint removal from bridge (with containment structures)	Blaster	3,690-29,400	Work conducted inside containment structure; samples taken outside respirator
		Blaster	9-190	Work conducted inside containment structure; samples taken inside respirator
		Groundsman	5-6,720	Work conducted outside containment structure

*No samples were collected for Cases 2 and 4.

†Area samples.

Chronic lead poisoning may result after lead has accumulated in the body over time, mostly in the bone. Long after exposure has ceased, some physiological event such as illness or pregnancy may release this stored lead from the bone and produce adverse health effects such as impaired hemoglobin synthesis, alteration in the central and peripheral nervous systems, hypertension, effects on male and female reproductive systems, and damage to the developing fetus [Landrigan, 1989]. These health effects may occur at BLL's below 50 μg/dl.

RELEVANT EXPOSURE CRITERIA AND REGULATIONS

In 1978, OSHA promulgated a comprehensive standard regulating occupational exposure to inorganic lead in general industry [29 CFR 1910.1025]. Under this standard, the permissible exposure limit (PEL) for inorganic lead is 50 $\mu g/m^3$ of air as an 8-hour time-weighted average (TWA). However, the construction industry was exempted from this regulation and has a 200-$\mu g/m^3$ PEL for inorganic lead [29 CFR 1926.55]. Unlike the OSHA standard for general industry, the construction standard does not require medical monitoring of workers exposed to lead or removal of workers from the job when they show elevated concentrations of lead in the blood. Specific medical monitoring recommendations for these workers are discussed in the section on conclusions and recommendations.

The NIOSH recommended exposure limit (REL) for lead is less than 100 $\mu g/m^3$ of air as a TWA for up to 10 hours per day during a 40-hour workweek. This air concentration is to be maintained so that the worker's lead concentration remains below 60 $\mu g/100$ grams of whole blood (approximately equivalent to 60 $\mu g/dl$) [NIOSH 1988c; CDC 1990]. NIOSH is presently reviewing the data on the health effects of lead to determine whether our current recommendations need to be updated.

Several States have instituted programs to protect construction workers from the hazards of occupational lead exposure. For example, Maryland enacted in 1984 (and modified in 1988) a comprehensive standard regulating occupational lead exposure in construction work [Maryland Regulations Code 1988]. Under this standard, the permissible exposure limit for lead is 50 $\mu g/m3$ as an 8-hour TWA. This standard must be incorporated in all contracts involving bridge work in Maryland. Connecticut is currently preparing similar requirements for inclusion in contracts [Connecticut Department of Transportation 1991].

CASE REPORTS OF LEAD POISONING

NIOSH recently learned of 42 construction workers at 8 different worksites who developed lead poisoning (BLL's exceeding 50 $\mu g/dl$ of blood) while working on bridges [Mintz 1990; Rae 1990; Johnson 1990; CDC 1989; Marino et al. 1989; NIOSH 1991b]. The BLL's for these workers ranged from 51 to 160 $\mu g/dl$. The mean BLL for the U.S. population is 13.9 $\mu g/dl$, and the upper 95 percentile is 25.0 $\mu g/dl$ [NCHS 1984]. The airborne concentrations of lead ranged from 2 to 29,000 $\mu g/m^3$ (see table 2). At least 26 of the 42 cases of lead poisoning (62 percent) were workers employed at a site using a containment structure. The actual number of cases of occupational lead poisoning nationwide is much larger than 42, but it cannot be accurately determined since employers are not required to routinely measure lead concentration in the blood of exposed construction workers.

Case No. 1

A study now being conducted in Connecticut has identified four workers with lead poisoning at three different bridge sites [Mintz 1990]. Containment structures were used at all three sites. The workers' BLL's ranged from 51 to 66 $\mu g/dl$, but none reported symptoms of lead intoxication. Personal breathing zone samples indicated airborne lead concentrations of 4 to 640 $\mu g/m^3$. All workers wore respiratory protection (abrasive blasting, half-mask, or disposable respirators).

Case No. 2

In 1989, eight workers at a bridge site in Monroe, Louisiana, developed lead poisoning while working in a containment structure [Rae 1990]. The BLL's of these workers ranged from 56 to 146 $\mu g/dl$. Their complaints included malaise, arm numbness, abdominal discomfort, joint and muscle aches, headache, and diarrhea. Airborne concentrations of lead were not reported.

Case No. 3

In May 1990, 12 bridge workers in Baton Rouge, Louisiana, developed lead poisoning while working in a containment structure [Johnson 1990]. The BLL's of affected workers ranged from 52 to 102 $\mu g/dl$. Reported airborne concentrations of lead ranged from 2 to 730 $\mu g/m^3$. The worker with the BLL of 102 $\mu g/dl$ developed joint pains and required hospitalization for intravenous chelation therapy.

Case No. 4

In March 1988, five workers developed lead poisoning during demolition of a bridge in Massachusetts [CDC 1989]. The BLL's of affected workers ranged from 67 to 160 $\mu g/dl$. All five workers reported symptoms consistent with lead poisoning. Four of the five workers were treated with intravenous chelation therapy. Airborne lead concentrations were not reported.

Case No. 5

In 1987, 11 workers who wore positive-pressure, air-supplied respirators developed lead poisoning during demolition of a bridge in New York [Marino et al. 1989]. The BLL's of these workers ranged from 52 to 120 $\mu g/dl$. One worker with a BLL of 120 $\mu g/dl$ reported symptoms of muscle soreness, weakness, lack of appetite, nausea, and vomiting. Another worker with a BLL of 105 $\mu g/dl$ reported symptoms of headache, tiredness, and abdominal discomfort. Both workers required intravenous chelation therapy. Personal breathing zone concentrations of lead ranged from 600 to 4,000 $\mu g/m^3$.

Case No. 6

In March 1991, NIOSH investigators began a study of lead exposures in 12 workers engaged in abrasive blasting and repainting of a bridge in Kentucky [NIOSH 1991b]. BLL's were measured during the first week of work and ranged from 5 to 48 $\mu g/dl$. The BLL's were measured again after 1 month of exposure and ranged from 9 to 61 $\mu g/dl$. Two workers had BLL's exceeding 50 $\mu g/dl$. The airborne concentration of inorganic lead ranged from 5 to 29,400 $\mu g/m^3$. Blasters wore continuous flow abrasive blasting respirators. Other workers used half-mask, air-purifying respirators with high-efficiency particulate air (HEPA) filters. However, there was no complete respiratory protection program consistent with OSHA requirements [29 CFR 1910.134] and NIOSH recommendations [NIOSH 1987a; NIOSH 1987b]. Running water, coveralls, and clean change-rooms were not available at the site.

CONCLUSIONS AND RECOMMENDATIONS

Lead poisoning may occur when workers inhale or ingest lead dust and fumes during abrasive blasting, sanding, cutting, burning, or welding of bridges and other steel structures coated with lead-containing paints. Data presented in this document reveal lead poisoning among workers who were wearing respirators. Therefore, a prudent policy is to minimize the risk of adverse health effects by keeping lead concentrations as low as possible and by using all available controls—including engineering controls, work practices, and respiratory protection. To help achieve the *Healthy People 2000* [DHHS

1990] objective of limiting worker blood lead concentrations to 25 $\mu g/dl$, NIOSH recommends the following measures for reducing lead exposure and preventing lead poisoning among workers involved in demolishing or maintaining bridges and other steel structures.

Air Monitoring

An industrial hygienist or other qualified professional should perform an initial hazard assessment of the worksite to determine the composition of the paint. Environmental monitoring should also be performed to (1) measure worker exposure to airborne lead and other hazardous agents (e.g., silica and solvents), and (2) select the engineering controls and PPE required. Environmental monitoring should be performed as needed to measure the effectiveness of controls and to determine whether the proper respiratory protection is being worn. Air samples should be collected and analyzed according to NIOSH methods [NIOSH 1984] or their equivalent.

Engineering Controls

Engineering controls should be used to minimize exposures to lead at the worksite. At a minimum, airborne lead exposures should not exceed the current OSHA PEL for general industry (50 $\mu g/m^3$). Whenever possible, engineering controls should include material substitution (i.e., repainting of structures with less toxic material), process and equipment modification, isolation or automation, and local and general exhaust ventilation. The appropriate types of controls vary with the operation.

Welding, Cutting, or Burning

Before welding, cutting, or burning any metal coated with lead-containing materials, remove the coating to a point at least 4 inches from the area where heat will be applied [29 CFR 1926.354]. When removal of lead-containing paint is not feasible, use engineering controls (e.g., local exhaust ventilation) to protect workers who are welding, cutting, or burning lead-bearing materials. Such controls should be used to remove fumes and smoke at the source and to keep the concentration of lead in the breathing zone below the OSHA PEL. Contaminated air should be filtered before it is discharged into the environment well away from the source of intake air and other workers. Replace contaminated air with clean air [29 CFR 1926.353].

Surface Preparation

When performing abrasive blasting, scaling, chipping, grinding, or other operations to remove lead-containing paint, use work practices that minimize the amount of dust generated. Less dusty blasting techniques include centrifugal blasting (using rotating blades to propel the abrasive, which is recovered and recycled), wet blasting (using high-pressure water with or without an abrasive, or surrounding the blast nozzle with a ring of water), and vacuum blasting (shrouding the nozzle with local exhaust ventilation) [Rex 1990]. Other methods that reduce dust include scraping, heating and scraping, use of needle guns, and chemical removal.

Materials containing crystalline silica should not be used as abrasives for any blasting operation, including paint removal [NIOSH 1988b]. Crystalline silica is associated with silicosis and is classified by NIOSH as a potential occupational carcinogen [NIOSH 1988d].

Lead-containing dust and abrasive materials should be removed daily by using vacuums equipped with HEPA filters or by using wet methods to prevent lead-containing particles from becoming airborne [Steel Structures Painting Council 1991].

Work Inside Containment Structures

Containment structures are often used to reduce environmental contamination by capturing particles of paint and used blasting materials. Although such structures reduce environmental contamination, they may also increase lead exposures for workers. Ventilation should be provided to reduce the airborne concentration of lead and increase visibility. Containment structures should be designed to optimize the flow of ventilation air past the worker(s). Insofar as possible, workers should be upstream from the blasting operation to reduce exposure to lead dust entrained in the ventilation air and to improve visibility. Designs for the containment structure and ventilation systems should be specific to each task because of varied conditions at the worksite (i.e., the type of steel structure being blasted, the type of blasting methods, and the type of materials used for construction).

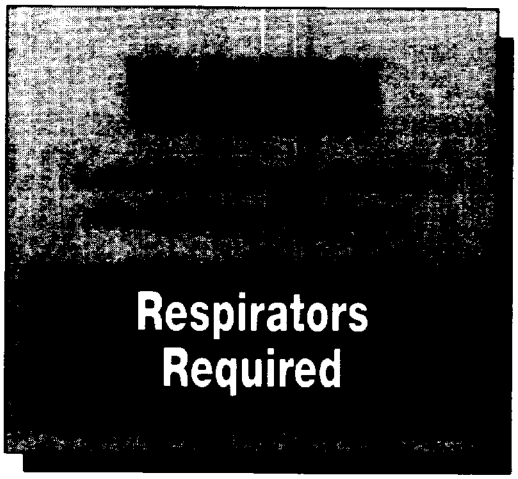

Figure 1.–Sample of warning sign for lead work area requiring respirators.

Contract Specifications

All new contracts of Federal, State, and local departments of transportation should include specifications for a mandatory program of worker protection from lead poisoning during the maintenance, repainting, or demolition of bridges and other steel structures.

Personal Hygiene Practices

Personal hygiene is an important element of any program for protecting workers from exposure to lead dust [Ulenbelt et al. 1990]. OSHA requires employers to provide adequate washing facilities at the worksite so that workers can remove lead particles that accumulate on the skin and hair [29 CFR 1926.51]. Showers should also be available [OSHA/NIOSH 1991].

All workers exposed to lead should wash their hands and faces before eating, drinking, or smoking, and they should not eat, drink, or use tobacco products in the work area. Tobacco products (cigarettes, cigars, chewing tobacco, etc.) and food items should not be permitted in the work area. Contaminated work clothes should be removed before eating.

Workers should change into work clothes at the worksite. Work clothes include disposable or washable coveralls. Street clothes should be stored separately from work clothes

LEAD POISONING IN CONSTRUCTION WORKERS

WARNING!

Workers are at risk of lead poisoning during the maintenance, repainting, or demolition of bridges or other steel structures coated with lead-containing paint.

Take the following steps to protect yourself and your family from lead exposure:

- Be aware of the health effects of lead exposure (see p. [44] of the NIOSH Alert, Request for Assistance in Preventing Lead Poisoning in Construction Workers) and discuss with your doctor any symptoms or concerns that may be related to lead poisoning.
- Participate in any blood lead or air monitoring program offered by your employer.
- Use engineering controls such as source containment and local exhaust ventilation to minimize exposures to lead.
- Be aware that the highest lead concentrations may occur inside containment structures.
- Use respirators when blasting, sweeping, vacuuming, or performing other high-risk jobs (as determined by an industrial hygienist or other qualified professional).
- Change into disposable or washable coveralls at the worksite.
- Do not eat, drink, or use tobacco products in the work area.
- Wash your hands and face before eating, drinking, or smoking outside the work area.
- Shower and change into clean clothing before leaving the worksite to prevent contaminating homes and automobiles.

in a clean area provided by the employer. Separate lockers or storage facilities should be provided so that clean clothing is not contaminated by work clothing and shoes. Workers should change back into their street clothes after washing or showering before leaving the worksite to prevent the accumulation of lead dust in the workers' cars and homes and thereby protect family members from exposure to lead. Cars should be parked where they will not be contaminated with lead.

Employers should arrange for the laundering of protective clothing; or, if disposable protective clothing is used, the employer should maintain an adequate supply at the worksite and arrange for its safe disposal according to applicable Federal [40 CFR 260] and State regulations.

Warning Signs

Warning signs should be posted to mark the boundaries of lead-contaminated work areas. These signs should follow the example presented in the OSHA general industry standard [29 CFR 1910.1025], which warns about the lead hazard and prohibits eating and drinking in the area. Such signs should also specify any PPE required (for example, respirators). The sample sign in figure 1 contains all the information needed for a lead-contaminated work area where respirators are required.

Personal Protective Equipment (PPE)

Engineering controls and good work practices should be used to minimize worker exposure to lead. Because of the variable exposure concentrations in the construction industry and the difficulty of monitoring a mobile workforce, PPE should be used whenever workers are potentially exposed to lead [OSHA/NIOSH 1991]. The use of PPE should supplement the continued use of engineering controls and good work practices.

Protective Clothing

Protective clothing not only shields workers from the hazards of welding and abrasive blasting, but it also minimizes the accumulation of lead on the worker's skin and hair. Workers should change into washable coveralls or disposable clothing before entering the contaminated work area. Because wearing PPE (especially protective clothing) can contribute to the development of heat stress [NIOSH/OSHA/USCG/EPA 1985], a potentially serious illness, regular monitoring and other preventive measures are vital [NIOSH 1986].

To minimize the amount of lead that may accumulate in the worker's car and home and to protect the members of the worker's household, lead-contaminated clothing (including work shoes) should be left at the worksite for cleaning or disposal. Workers who are welding, cutting, or burning should wear nonflamable clothing [NIOSH 1988a].

Respiratory Protection

Effective source control measures (such as containment or local exhausting ventilation) should be implemented to minimize worker exposure to lead. NIOSH prefers such measures as the primary means of protecting workers; but source control at construction sites is often ineffective, and airborne lead concentrations may be high or may vary unpredictably. Therefore, respiratory protection is also necessary for certain operations such as blasting, sweeping, and vacuuming, and for other jobs as determined at the worksite by an industrial hygienist or other qualified professional. However, respirators are the least preferred method of controlling lead exposure, and they should not be used as the only means of preventing or minimizing exposures. The use of respirators should supplement the continued use of engineering controls and good work practices [OSHA/NIOSH 1991].

When respirators are used, the employer must establish a comprehensive respiratory protection program as outlined in the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a], and as required in the OSHA respiratory protection standard [29 CFR 1910.134]. Important elements of the OSHA respiratory protection standard are (1) an evaluation of the worker's ability to perform the work while wearing a respirator, (2) regular training of personnel, (3) periodic environmental monitoring, and (4) respirator fit testing, maintenance, inspection, cleaning, and storage. The program should be evaluated regularly by the employer. Without a complete respiratory protection program, workers will not receive the protection anticipated.

Respirators should be selected by the person who is in charge of the program and knowledgeable about the workplace and the limitations associated with each type of respirator. Because exposures to lead during construction may vary substantially throughout a workshift and between days, the highest anticipated exposure should be used to determine the appropriate respirator for each job.

Respirator selection should be made according to the guidelines in table 3. Employers must use respirators that are certified by NIOSH and the Mine Safety and Health Administration (MSHA) [NIOSH 1991a].

NIOSH-type CE respirators are required for use by abrasive blasting operators [29 CFR 1910.94]. Currently, only continuous-flow respirators are certified by NIOSH for abrasive blasting [29 CFR 1910.94], but positive-pressure, supplied-air respirators would provide greater protection [NIOSH 1987b; 30 CFR 11]. The continuous-flow respirators are recommended by NIOSH only for airborne concentrations less than or equal to 25 times the OSHA PEL for general industry—50 $\mu g/m^3$ [NIOSH 1987b]. Furthermore, manufacturer's instructions regarding quality of air, air pressure, and inside diameter and length of hoses must be strictly followed. Use of longer hoses, hoses having a smaller inside diameter, or hoses with kinks and bends may restrict the flow of air to the respirator.

In all cases, respiratory protection should be donned before entering the contaminated work area, and it should be removed only after the worker has left that area.

Medical Surveillance—Medical Monitoring

BLL's are currently the best indicator of personal lead exposure. Workers potentially exposed to lead should therefore be monitored for the presence of lead in blood and the effects of lead on the blood-forming system. This assessment is necessary to ensure that engineering controls, personal hygiene practices, and PPE are preventing lead exposure.

The OSHA general industry standard contains provisions for the medical monitoring of workers exposed to lead [29 CFR 1910.25]. NIOSH supports the use of these provisions for construction workers but acknowledges that these workers may require more frequent blood lead monitoring (for example, monthly) than specified in the OSHA standard because of their highly variable, unpredictable exposures to lead. Similar provisions for more frequent monitoring have also been specified by the Connecticut Department of Transportation to be included in bid specifications for construction work involving lead exposure [Connecticut Department of Transportation 1991].

Lead concentration in the blood should be measured for any exposed worker who experiences symptoms or signs of lead poisoning. Analyses of blood should be performed only by OSHA-listed laboratories (a listing is available from the OSHA Analytical Laboratory in Salt Lake City, Utah; telephone (801) 524-4270).

The results of all laboratory analyses, a description of the worker's job, and any available data on possible exposures should be evaluated by a physician with experience and training in occupational health. To detect the health effects of excess lead exposure and to provide a baseline for comparison with future results, an occupational health interview and a physical examination should be performed before job placement, before returning to work after being removed from the job because of elevated blood lead concentrations, and annually for all workers exposed to lead.

Table 3 NIOSH-Recommended Respiratory Protection for Workers Exposed to Inorganic Lead

Condition	Minimum respiratory protection*
[illegible]	[illegible]
≤1.25 mg/m^3 (25 x PEL)	Any powered, air-purifying respirator with a high-efficiency particulate filter, or Any supplied-air respirator equipped with a hood or helmet and operated in a continuous-flow mode (for example, type CE abrasive blasting respirators)
[illegible]	[illegible]
≤50 mg/m^3 (1,000 x PEL)	Any supplied-air respirator equipped with a half-mask and operated in a pressure-demand or other positive-pressure mode
[illegible]	[illegible]
Planned or emergency entry into environments containing unknown concentrations or concentrations above 100 mg/m^3 (2,000 x PEL)	Any self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode, or Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive-pressure mode
[illegible]	[illegible]
Escape only	Any air-purifying, full-facepiece respirator with a high-efficiency particulate filter, or Any appropriate escape-type, self-contained breathing apparatus

**Only NIOSH/MSHA-approved equipment should be used.*
†Less than or equal to 0.5 mg/m^3.
††Multiple of the OSHA PEL for general industry.

Medical Protection

The OSHA lead standard for general industry [29 CFR 1910.1025] requires that certain actions be taken at given concentrations of lead in the blood (see table 4). These actions are designed to prevent many of the adverse health effects of lead exposure.

Table 4 **Actions Required by the OSHA General Industry Standard for Various Lead Concentrations in Blood (BLLs)**

Number of tests	BLL* (µg/dl)	Action required
1	≥40†	Notification of worker in writing; medical examination of worker and consultation
3 (average)	≥50	Removal of worker from job with potential lead exposure
1	≥60	Removal of worker from job with potential lead exposure
2	<40§	Reinstatement of worker in job with potential lead exposure

**In the OSHA general industry standard for lead, BLLs are reported in micrograms per 100 grams (µg/100g) of whole blood, which is approximately equal to µg/dl.*

†Greater than or equal to 40.

§Less than 40.

Mandatory Reporting

Presently, 15 states require laboratories and health care providers to report cases of elevated blood lead concentrations to the State health department [Freund et al. 1989]. Table 5 provides a list of the States that require such reporting and the concentration that requires reporting for each State. To monitor progress in achieving the *HealthyPeople 2000* objective for lead concentrations in blood [DHHS 1990], cases of elevated BLL's should be reported to all State health departments.

Training

Workers should receive training [29 CFR 1926.21] that includes the following:

- Information about the potential adverse health effects of lead exposure
- Information about the early recognition of lead intoxication
- Information in material safety data sheets for new paints or coatings that contain lead or other hazardous materials [29 CFR 1926.59]
- Instruction about heeding signs that mark the boundaries of lead-contaminated work areas

Table 5 State Agencies that Require the Reporting of Individuals with Elevated Lead Concentrations in Blood (BLLs)* [as of August 1991]

State and contact person	Concentration that requires (μg/dl) reporting	State and contact person	Concentration that requires (μg/dl) reporting
Alabama Charles Woernle, M.D., M.P.H. State Epidemiologist Department of Public Health 434 Monroe Street Montgomery, AL 36130; 205-242-5131	15	Michigan [illegible] [illegible] [illegible] [illegible] [illegible] Lansing, [illegible]	[illegible]
California Neil Maizlish, Ph.D. Occupational Health Program California Department of Health Services 2151 Berkeley Way, Room 504 Berkeley, CA 94704; 415-540-2115	25	New Jersey Barbara Gerwel, M.D. Occupational Disease Prevention Program New Jersey Department of Health C N 360, John Fitch Plaza Trenton, NJ 08625; 609-984-1863	25
Colorado Jane McCammon Colorado Department of Health Epidemiology Division 4210 E. 11th Avenue Denver, CO 80220; 303-331-8330	25	New York [illegible] New York State Department of Health [illegible] Albany, NY [illegible]	[illegible]
Connecticut Narda Tolentino, M.P.H. Connecticut Department of Health Services Environmental Epidemiology and Occupational Health (EEOH) 150 Washington Street Hartford, CT 06106; 203-566-8167	25	Oregon Jane Gordon, Ph.D. Deputy State Epidemiologist Oregon Health Division 1400 SW 5th Avenue Portland, OR 97201; 503-229-5821	25
Illinois Jane Keller Occupational Disease Registry Illinois Department of Public Health Division of Epidemiologic Studies 605 W. Jefferson Springfield, IL 62761; 217-785-1873	25	Texas [illegible] Texas Department of Health [illegible] Austin, TX [illegible]	[illegible]
Iowa Joann Muldoon Environmental Epidemiology Section Iowa Department of Public Health Lucas State Office Building Des Moines, IA 50319; 515-281-5643	25	Utah David J. Thurman, M.D., M.P.H. Bureau of Epidemiology Utah Department of Health P.O. Box 16660 Salt Lake City, UT 84116-0660 801-538-6191	30 (≥18 years of age) 20 (≥18 years of age)
Maryland Ellen Coe, R.N., M.P.H. Health Registries Division Maryland Department of the Environment 2500 Broening Highway Baltimore, MD 21224; 301-631-3851 fax: 301-631-3198	25	Wisconsin [illegible] Wisconsin Department of Health and Social Services [illegible] Box [illegible] Madison, WI [illegible]	25
Massachusetts Richard Rabin Massachusetts Department of Labor and Industries Division of Occupational Hygiene 1001 Watertown Street Newton, MA 02165; 617-969-7177	15		

Questions regarding these reporting requirements should be directed to the contact person in each State.

- Discussion of the importance of personal hygiene practices in reducing lead exposure

- Instruction about the use and care of appropriate protective equipment (including protective clothing and respiratory protection)

- Information about specific work practices for working safely with lead-containing paints

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For engineering information, please contact Phillip Froehlich; William Heitbrink, Ph.D., C.I.H.; or Leroy Mickelsen, M.S.; telephone (513) 841-4221; Division of Physical Sciences and Engineering (DPSE); or J. Donald Millar, M.D., D.T.P.H. (Lond.), Assistant Surgeon General Director, National Institute for Occupational Safety and Health, Centers for Disease Control.

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29 CFR 1926.55. *Code of Federal Regulations*; Washington, D.C.; U.S. Government Printing Office, Office of the *Federal Register*.
29 CFR 1926.59. *Code of Federal Regulations*; Washington, D.C.; U.S. Government Printing Office, Office of the *Federal Register*.
29 CFR 1926.353. *Code of Federal Regulations*; Washington, D.C.; U.S. Government Printing Office, Office of the *Federal Register*.
29 CFR 1926.354. *Code of Federal Regulations*; Washington, D.C.; U.S. Government Printing Office, Office of the *Federal Register*.
30 CFR 11. *Code of Federal Regulations*; Washington, D.C.; U.S. GovernmentPrinting Office, Office of the *Federal Register*.
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FINDING EQUIPMENT FOR PROTECTING WORKERS

by the *JPCL* Staff

JPCL has compiled a list of manufacturers that include safety and hygiene equipment for lead paint removal in their product lines. The list is based on information available to JPCL at press time. Companies not listed are invited to submit information for an update to The Editor, *JPCL*, 2100 Wharton Street, Suite 310, Pittsburgh PA 15203.

- Abatement Technologies (Lawrenceville, GA); Portable showers, air and water filtration products, and HEPA vacuums; 1-800-634-9091
- Aerospace America, Inc. (Bay City, MI); Portable showers; (517) 684-2121
- Anderson Instruments (Atlanta, GA), Environmental air monitoring equipment; (404) 691-1910
- BGI Inc. (Waltham, MA); Personal air sampling pumps; (617) 891-9380
- E. D. Bullard (Cynthiana, KY); Respiratory protection equipment; (800) 827-0423
- Cabot Safety Corp. (Southbridge, MA); Respiratory protection equipment; (508) 764-5500
- Eagle Industries (New Orleans, LA); Decontamination trailers and portable showers; (504) 733-3510
- Environmental Express (Mt. Pleasant, SC); Personal air monitoring cassettes; (803) 881-6560
- Gilian Instrument Corp. (West Caldwell, NJ); Personal air monitoring equipment (201) 808-3355
- 3M Company OHSP (St. Paul, MN); Respiratory protection equipment; 1-800-666-6477
- Mine Safety Appliances (Pittsburgh, PA); Protective clothing and respiratory equipment; (412) 967-3000
- Neoterik Health Technologies Inc. (Woodsboro, MD); Respiratory protection equipment; (301) 845-2777
- North (Siebe North) Inc. (Cranston, RI); Respirator protection equipment; (401) 943-4400
- Northstar Manufacturing (Spring, TX); Respiratory protection equipment; (713) 353-3753
- Nuclepore (Cambridge, MA); Personal air monitoring cassettes; (617) 868-6200
- Racal Health & Safety Inc. (Frederick, MD); Respiratory protection equipment; (301) 695-8200
- Regency International Group Inc. (West Chester, PA); Portable showers and decontamination units; (215) 344-0637
- Sensidyne (Clearwater, FL); Particulate air detection and monitoring equipment; (813) 530-3602
- Spectrex (Redwood City, CA); Personal air sampling pumps and calibrators; 1-800-842-3940
- Survivair (Santa Ana, CA); Respiratory protection equipment; (714) 545-0410.

MYTHS AND REALITIES OF SURFACE-TOLERANT COATINGS FOR BRIDGES[1]

by Karen A. Kapsanis and Bernard R. Appleman[2]

Like any component of technology, "surface-tolerant" coatings can be misused if their purposes and limits are not adequately understood. They can be mistakenly expected to do everything from eliminating the need for surface preparation to improving the adhesion of an existing coating.

This first Point-Counterpoint article reports on a panel discussion, "Myths and Realities of Surface-Tolerant Coatings," held in Pittsburgh, Pennsylvania, last June in conjunction with the International Bridge Conference and co-sponsored by SSPC (Steel Structures Painting Council) and the Engineers Society of Western Pennsylvania. The panel included Richard Hanlon, West Virginia Department of Transportation (WVDOT); Simon Boocock, SSPC; Dan Griffin, Porter International; John Montle, Carboline Co.; Stavros Semanderes, Odyssey Contracting; and Richard Winick, Witco. Steve Pinney of S. G. Pinney and Associates was moderator. Members of the audience also shared their expertise.

The panel was assembled to illuminate misunderstandings or myths about surface-tolerant coatings and to examine the realities of the materials—experiences and realistic expectations about use and performance.

This article is not a comprehensive account of the panel or of the use of surface-tolerant coatings. Rather, it organizes several issues raised at the discussion, explains their significance, and summarizes insights from the panel. The explanation of the significance of each question, including the potential for misunderstanding the technology, constitutes the "Point" in the point-counterpoint framework. The summary of panelists' insights constitutes the "Counterpoint"—nuanced answers from experts to clarify and qualify the purposes and uses of the technology.

What Are Surface-Tolerant Coatings?

An earlier name for these materials, "rust-tolerant" coatings, indicated that the coatings did not require removal of all rust (as well as millscale and paint) as specified in SSPC-SP 6 and higher degrees of surface preparation. Eventually, this term came to include surfaces containing small amounts of moisture, grease, and oil. A starting definition for surface-tolerant coatings, therefore, is coatings that are intended to be applied over a lesser degree of surface preparation than that defined in SSPC-SP 6. These coatings are thus distinguished from high-technology synthetic polymer coatings such as vinyls, conventional urethanes and epoxies, and zinc silicates, which are intended to be applied over a commercial grade (SSPC-SP 6) or better.

As Pinney pointed out, new products tend to be used initially in too many places. He thus opened the panel with an attempt to further define surface-tolerant coatings. He

[1] Reprinted with permission from the Editor, JPCL (*Journal of Protective Coatings & Linings*), 2100 Wharton Street, Suite 310, Pittsburgh PA 15203; pages 56-60; January 1992 issue.
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started the discussion with the following slightly different definition of surface-tolerant coatings: coatings that are designed to wet out over a surface that has not been completely cleaned. He included coal tars and oil-based coatings, which have been used for years, and newer coatings such as moisture-cured urethanes, various epoxy mastics, and calcium-sulfonate-based coatings.

Other distinctions were added. For instance, Boocock pointed out that "surface tolerance" may need to be further qualified in terms of the types of surfaces over which the coating can be applied, such as over an aged alkyd, or an oily surface, and in terms of what makes the coatings surface-tolerant.

The Hulton Bridge near Pittsburgh PA before recent removal of lead-based alkyd (commercial blast) and recoating with an epoxy mastic primer and urethane topcoat. (Picture courtesy of Pennsylvania Department of Transportation, Pittsburgh, Pennsylvania.)

Griffin suggested also identifying the amount of chlorides and the amount and types of rust (e.g., loose or stratified) that can be tolerated by specific products.

Semanderes suggested that an SSPC-SP 7, Brush-Off Blast, with tightly adherent millscale, rust, and paint on the surface, is suitable for a surface-tolerant coating. Winick agreed and suggested that SSPC-SP 2 (hand tool cleaning) and SSPC-SP 3 (power tool cleaning) be included in the definition, since like SP 7, both allow adherent millscale, rust, and paint to remain.

From the audience, William Brinton of Wasser and consultant Mal Hendry elaborated on other types of surface-tolerant coatings. Hendry described the use of moisture-tolerant coatings in the wet, salt-laden atmospheres of the North Sea area. Brinton described the use of moisture-cured urethanes in the wet, subfreezing conditions of Alaska.

Are There General Guidelines on Where and How To Apply Surface-Tolerant Coatings?

Surface-tolerant coatings represent a tradeoff between cost and performance. Steel covered with rust, millscale, moisture, oil, and grease is not an ideal substrate on which to apply coatings. A surface-tolerant coating partially overcomes these deficiencies by providing a combination of good wetting, barrier protection, and, in some cases, other means of suppressing the natural tendency of oxides to absorb moisture and expand. Thus, a surface-tolerant coating will have a greater chance of success in those situations where forces promoting corrosion are least severe. Circumstances to avoid include:

- Highly aggressive exposure environments (e.g., heavy chemical fumes, high temperature, frequent immersion); and
- Highly contaminated substrates (e.g., containing chlorides, sulfates, or high quantities of grease or other contaminants).

Millscale, poor adhesion of an existing coating, or incompatibilities between it and a surface-tolerant coating could also contribute to early failure of a surface-tolerant coating.

Winick noted that his company's tests on calcium-sulfonate-based and other surface-tolerant coatings indicated that chloride contamination has been a more important limiting factor in their use than the adhesion of the existing coatings.

Montle added that in his company's field tests, a limitation of conventional surface-tolerant epoxy mastics is rust with salt, unless high-pressure water blasting is used to remove much of the salt contamination.

Semanderes described good results with several products, including moisture-cured urethanes and aluminum epoxies, but he cautioned that some of them must be sprayed; they are too thick to be brushed or rolled.

Is a Surface-Tolerant Coating Better Over a Blast-Cleaned Surface or a Hand or Power Tool-Cleaned Surface?

It is an axiom of protective coatings technology that the better the surface preparation, the longer the coating lifetime. It has been reported that some surface-tolerant coatings perform better over hand or power tool-cleaned surfaces than over blast-cleaned steel. It is vital to carefully examine the evidence of these claims and to identify the specific circumstances and limits of these occurrences.

Montle qualified the claim by describing several test programs with varying results. In one program, an epoxy mastic over blast-cleaned steel gave in quickly to pinpoint rust in salt fog, while the same coating over a wire brush-cleaned surface did not show pinpoint rusting. The substrate did not have millscale or contaminants such as oil or salts, only rust from weathering. Another study indicated that one coat of an epoxy mastic over rusted steel would perform about the same as the one-coat mastic over abrasive-blasted steel, 15 years over rusted steel and 13 over blast-cleaned steel. In 13,000 hours of salt fog cabinet testing, blast-cleaned panels failed, showing four medium-dense blisters and traces of rust while the hand-cleaned steel panel performed satisfactorily. But on millscale, the surface-tolerant coatings performed poorly if the steel was hand cleaned, not blast cleaned.

Winick cited results from a study with which he was involved (*JPCL*, January 1989). Nine commercial epoxy mastics were evaluated in salt spray over surfaces ranging from an SP 2, Hand Tool Cleaning, to an SP 5, White Metal. According to Winick, most epoxy mastics delaminated at the scribe on an SP 2 surface but generally adhered well to blast-cleaned steel. On unscribed hand tool-cleaned steel, the coatings did not delaminate but adhesion strength diminished compared to the coatings over blast-cleaned steel.

Boocock cited SSPC research in which a variety of surface-tolerant coatings, including a number of epoxy mastics, have been tested over SP 2, hand tool-cleaned surfaces, and SP 10, near white surfaces. Generally, he said, deterioration is occurring earlier on SP 2 surfaces than on the SP 10. But not all formulations have been tested, he said, emphasizing that performance is critically related to formulation characteristics.

When a steel surface is intended, the specifier has a much wider selection of materials. Whether to use a surface-tolerant coating depends on the overall merits of this system and of the alternatives (e.g., application characteristics, expected performance, ease of maintenance, and costs). A surface-tolerant coating over blast-cleaned steel could provide some insurance when the specified degree of cleaning is not achieved.

Hanlon offered one user's perspective: specify surface-tolerant coatings for bridges that are very difficult to blast, not for bridges that can be blasted efficiently. Griffin suggested that epoxy mastics are suitable for use over different degrees of cleaning. He cautioned users to specify dry film thicknesses of at least 5 mils (125 microns) for surfaces with either a high blast profile or a great deal of pitting.

Are There Differences Among Surface-Tolerant Coatings?

"Surface-tolerant coating" is a very loose, non-generic description. Among the types of materials touted as having surface tolerance are one- and two-component epoxies, moisture-cured urethanes, oils and alkyds, petroleum wax, petrolatum, coal tars, and others. Thus, it is first necessary to identify the generic class. Two commonly used types are high-solids, high-build, two-component epoxy ("epoxy mastic") with good wetting ability, and one-component moisture-curing urethanes.

Even within these generic classes, variations in chemical types can be substantial. "Epoxy mastic" can use a variety of curing agents, solvents, wetting agents, and other additives. As a result, the chemical and physical properties, durability, and performance properties under different exposure conditions can vary enormously among products.

To the unsophisticated, coatings that are generically similar are expected to perform similarly. There is also a long-standing pattern in the industry of specifying coatings by generic type rather than by performance. But real world experience, as evidenced in the panel discussion, is often quite contrary to the expectations for generically similar surface-tolerant coatings.

Performance can vary widely among generically similar coatings.

Reporting again on his study, Winick noted significant differences among nine epoxy mastics in chemical and solvent resistance as well as salt spray performance.

Montle concurred, adding that there are also differences in performance within coatings from the same manufacturer because a company may market materials with different components of performance, depending on the intended use and surface preparation.

Hanlon explained why WVDOT adopted a specification for epoxy mastics that includes an approved products list. Before the specification was used, there was little control over selection of surface-tolerant coatings and no monitoring of performance. Thus, if a coating failed, no one was sure of the cause: specification, surface preparation, application, or formulation. The current specification, adapted from Virginia DOT, guides bridge engineers when selecting surface-tolerant coatings and provides a basis for monitoring performance. For the six or seven epoxy mastics on the approved list, at least as many other epoxy mastics have been turned down. (Monitoring of field performance is in the early stages, he said.)

To Encapsulate Lead-Based Paint?

The danger of assuming surface-tolerant coatings withstand any substrate condition extends to the issue of lead paint removal in bridge maintenance. Covering a deteriorating lead paint with a surface-tolerant coating may appear to be a cost-effective alternative to removal, treatment, and disposal of lead paint.

But it is important to keep in mind the types of surfaces for which surface-tolerant coatings were designed and the types of surfaces often found on bridges. Virtually every reputable coatings manufacturer requires that the surface-tolerant coating be applied to tight rust, tight millscale, and tight intact paint. Unfortunately, these conditions do not usually describe the condition of most bridges that are scheduled for repainting; thus, they require surface preparation by hand or power tool cleaning, water jetting, or other means. The generation of potentially hazardous dust and debris must be considered when examining the repaint options. Also, typically, the most badly corroded areas are those subject to salt dripping and splash. Many of the most common surface-tolerant coatings are least effective in protecting these chloride-contaminated joints and flange areas.

There is no magic number for adhesion testing before specifying encapsulation.

Moreover, as audience member Tom Calzone of Carboline Co. explained, encapsulation has often been specified without first assessing the surface and existing coating for their compatibility with the surface-tolerant coating. Incompatibilities can lead to premature failure of the encapsulant. He therefore urged prequalification of a bridge before specification and inspection during application if encapsulation is to be specified appropriately. The issue of coating compatibility was then discussed in terms of practical field tests, as described below.

How Can One Determine Compatibility of a Surface-Tolerant Coating and the Existing Coating?

As noted, surface-tolerant coatings are typically designed to be applied over a variety of surfaces, including existing intact paint. The physical condition (e.g., brittleness, thickness) and chemical type (e.g., linseed oil, alkyd, or phenolic resin and various pigment types) of old paint can vary significantly. The compatibility of the new and old paint cannot be assumed. Consequently, testing for compatibility or adhesion may be required.

Pinney cited a case illustrating the danger of applying a surface-tolerant coating that is not compatible with the existing lead-based paint. In one case, an epoxy mastic, specified as an encapsulant over a lead-based coating, became, in effect, "a red lead remover," Pinney said, because the whole system beneath the mastic delaminated. Griffin said that to prevent such catastrophic failures, test patches of the surface-tolerant system should be applied to make sure that it will in fact tolerate the existing coating (or surface).

Montle described another source of trouble when surface-tolerant coatings are specified as encapsulants on bridges that were not blasted originally. Often, the adhesion of the underlying coating is substandard.

Panelists agreed that adhesion testing was needed to determine whether the existing coating was strong enough to be encapsulated, but there is not a single criterion for adhesion testing before specifying encapsulation. Brinton and Winick added that a more flexible surface-tolerant coating may put less stress on existing coatings than a "harder" one.

From the audience, Lou Vincent of S. G. Pinney pointed to cases in which surface-tolerant coatings lifted off coatings with high adhesion rates as well as coatings with low adhesion rates. In the former case, he said, a surface-tolerant coating had been applied well above the specified dry film thickness. According to Vincent, the epoxy mastic looked intact for about 3 months, until the temperature dropped 62 °F (34 °C) and the mastic pulled the original coating off.

He suggested using several test patches over different configurations on the steel to determine whether the surface-tolerant coating will pull off the existing coating. It is important to do multiple test patches through the cycle of weather to which the bridge is subject, he added, because weather will affect various configurations of the steel differently.

Hanlon agreed with comments on the need for testing but reminded panelists that most highway departments lack funds and staff for testing. Thus, he said, the DOTS want surface-tolerant coatings that are easy to use.

Conclusions

From the panel discussion, several conclusions can be drawn.

- Surface-tolerant coatings are diverse materials designed to be applied over surfaces that receive less than a commercial blast cleaning.

- Surface-tolerant coatings have achieved a strong position in the industrial maintenance painting market. They have demonstrated a significant value in certain applications but also have severe limitations.

- There are many types of surface-tolerant coatings and major differences within a given class such as "epoxy mastic." Each product must be investigated to verify that it has the properties sought.

- Epoxy mastics are most successful over hand-cleaned rusted steel free of salt contamination. They are much less effective over millscale or chloride-contaminated surfaces. Other surface-tolerant coatings are suitable for moist and damp surfaces. Surface-tolerant coatings are generally less effective in severe exposures.

- Most protective coatings, including surface-tolerant coatings, perform better over uncontaminated blast-cleaned substrates. The value of a surface-tolerant coating is that it can often provide only slightly reduced performance at a significant cost savings. In some instances, a significant loss of performance may occur, but when blast cleaning is restricted, this may be the best alternative.

- Because of possible incompatibilities, patch tests are strongly recommended when applying a surface-tolerant coating over an existing coating. Tests should cover representative areas of the structure and should last long enough to observe several temperature fluctuations. Field adhesion tests (i.e., cross-cut tape test) may be used but are less reliable.

- Performance of surface-tolerant coatings depends on proper specification and application as well as formulation.

DEWATERING USING A FLOATING BULKHEAD PROVES FLEXIBLE, REUSABLE, AND COST EFFECTIVE[1]

by Frederick Lux III[2] and Eric P. Regner[3]

Introduction

Going beyond a traditional bulkhead dropped in place with a barge crane or crane hoist, a floating bulkhead was conceived to dewater powerplant intakes, gated spillway bays or outlet works. It is especially suited where the structure has no provision for dewatering, cranes are not available to install stoplogs or the dewatering structures are no longer serviceable. For aging hydroelectric plants, it is an effective means to dewater entire intakes or bays so that gates or the structure itself can be maintained or repaired. With the Federal Energy Regulatory Commission (FERC) requiring each spillway gate to be operated through its full range once every 5 years, a bulkhead allows gate operation without making a release or lowering the reservoir.

The floating bulkhead consists of a number of individual floating caissons that can be used separately like stoplogs, or pinned together and installed as a unit. A caisson consists of a floatation compartment and another compartment to sink or float it (see figure 1). Each caisson is lowered into the reservoir from a suitable location and towed into position by a boat. Individual caissons can be placed one at a time or pinned together, depending upon the opening or intake structure configuration. If installed as a unit, the caissons are pinned together at hinges. The bulkhead unit resembles a giant garage door as it floats on the water. A caisson is slowly submerged by filling a specific compartment in a controlled manner. If assembled as a unit, the submerged caisson pulls the remainder of the bulkhead behind it (figure 2). When the bulkhead needs to be removed, it is raised by draining water from the caisson chambers, floated to the next intake to be dewatered and reinstalled. Installation of the floating bulkhead has taken less than 2 hours. Removal has been performed in about 30 minutes.

Besides using a conventional bulkhead, other dewatering schemes include lowering the reservoir, constructing a temporary cofferdam upstream of the intakes or performing the repairs underwater. Lowering the reservoir involves a loss of generation revenue and regulatory agencies may not permit such an action. A temporary cofferdam may represent a significant portion of the cost to repair or maintain intake features, particularly for high dams or where work must be done on a frequent basis. While it may be economical to repair portions of a structure using divers, maintenance of operating components, such as painting of gates, needs to be performed under dry conditions. Thus, a bulkhead provides the most economical and practical approach for most dewatering applications.

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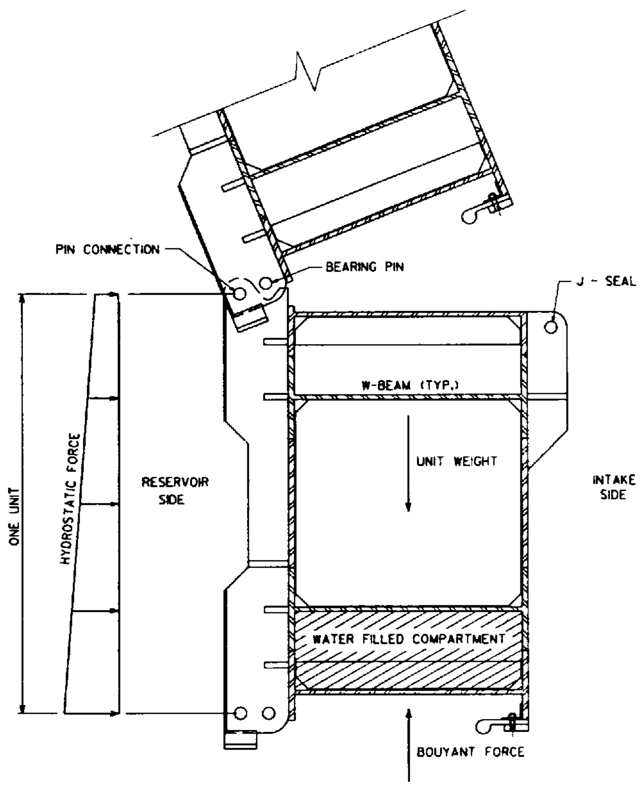

Figure 1.–Section through bulkhead caisson.

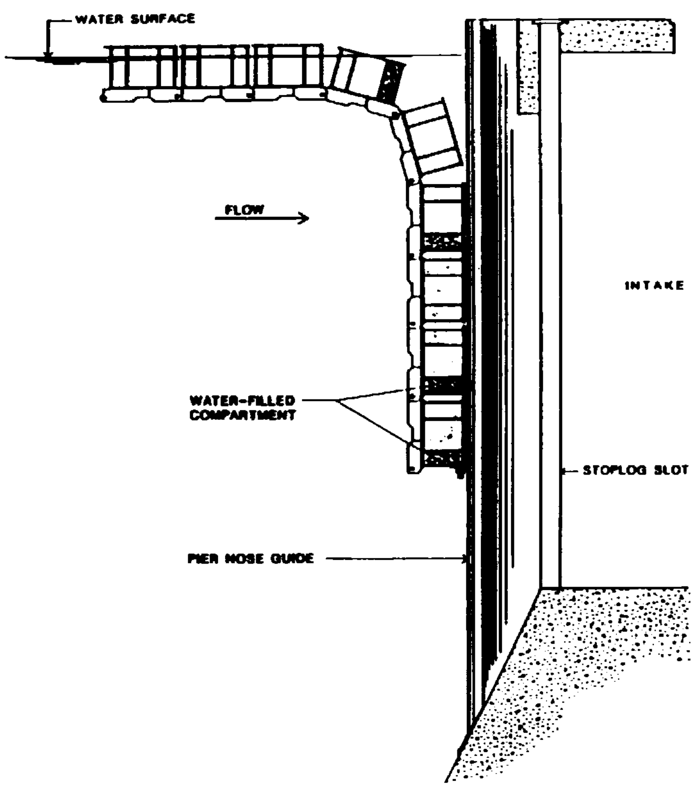

Figure 2.–Section through intake during bulkhead installation.

Advantages of the articulated floating bulkhead over conventional bulkheads or stoplogs include:

- One bulkhead can be adapted to fit various intake configurations.
- One bulkhead can be used at a number of dams rather than being a site-specific design.
- A large capacity crane is not needed at the dam to carry and position the caissons.
- Bulkhead slots are not needed since it seals against the upstream face of the structure. However, it can be used where existing bulkhead slots are present.
- The floating bulkhead may be used as a barge or work platform in the water, when it is not required for use as a bulkhead.

Design

Four general requirements were established for design of the floating bulkhead. First, each caisson must float or sink, depending on the amount of water it contains. Second, the bulkhead must be able to resist the hydrostatic pressures of the dewatering process. Third, upon removing the bulkhead, each caisson must ascend slowly to reduce the potential danger of heavy caissons ascending quickly, rising above the water, and damaging the dam and bulkhead or injuring workmen. Fourth, the bulkhead caissons must be small enough to hoist out of the water and transport to other dams by truck.

The height and number of bulkhead caissons selected for each design were based on the range of reservoir fluctuations expected, intake characteristics, site access, and transportation requirements. Structural design of each caisson was based on strength, deflections, and buoyancy. The bottom caisson is the critical unit for design. It is under the greatest water pressure, yet needs to span the entire intake bay like the caissons above it. The section, as shown in figure 1, has about 15 percent additional bending capacity than required to limit deflection. The deflection was kept low to keep the bottom seal from moving in the event of a significant change in the reservoir water level.

The steel sections used for the bulkhead are comprised of W-shapes in combinations with steel plates (figure 1). The use of steel plates throughout was not considered due to the additional cutting and difficult welding needed. The W-beams have a very low weight to area (depth x flange width) ratio to achieve the required buoyancy. The selected material was readily available to many fabricators. Lighter sections were considered for the upper caissons since less strength is required under a lower hydrostatic head. However, little cost savings would be realized in fabricating lighter upper caissons. Also, the bulkhead would be less versatile and more complex with various size and weight caissons.

The introduction of hinges between each caisson was initially intended for ease of placement when the bulkhead is installed as a unit. Other benefits were realized and some are listed below.

- By allowing only selected compartments in alternate caissons to be filled, the bulkhead remains almost weightless in the water during placement and after the bulkhead is fully installed (see figure 2). This provides easy maneuverability and requires hoists as small as 2-ton (18-kN) capacity on each side of the bulkhead. The weight of the two bulkheads described later are approximately 68 tons (605 kN) and 89 tons (794 kN) dry weight.

- Bulkhead placement and removal can occur fairly quickly. Should the bulkhead need to be installed or removed because of high runoff or emergency use in another location, only a few hours of preparation time is required. Also, diver time in the water is kept to a minimum providing additional cost savings.
- The placement process is safer, since little equipment is used and less work must actually be performed under water than with conventional bulkheads.

The hinges were designed to allow 180 degrees of movement, and the pins are stressed only when the bulkhead is being installed or removed. When the bulkhead is either totally horizontal or vertical, the caissons are in direct contact with one another, leaving the pins free to be removed or installed without shear forces on them.

Where individual caissons are to be installed, such as in a bulkhead slot, each caisson is individually set in place. For this type of installation, the caisson ends are tapered to allow one end to be placed into the slot and the other end to be rotated into alignment with the other bulkhead slot. The individual caisson is then lowered into position by filling a compartment with water. Hoists are used to control the descent and ascent of each caisson.

The design of the bulkhead buoyancy was based on a lower and upper limit. When "full" of water and descending, the bulkhead must be relatively light to allow a small hoist to set it in place. When "empty" and in the vertical position, the wall must be kept heavy to facilitate a slow ascent. This balancing act resulted in a limited amount of water to be used as the "sinking" force.

Three key locations required a seal: between caissons, at the pier nose or bulkhead slot, and at the base of the bulkhead. Wood was placed against concrete because of its ability to conform to irregular, rough surfaces and its slow cost of replacement. Rubber seals were used at steel surfaces. Small leaks through and around the bulkheads were expected; however, construction crews installing the bulkhead have sealed leaks with cinders, rubber hose, etc.

The final major design concern was the durability of the newly fabricated structure. Special attention was given to the welds to assure that faying surfaces would not come in contact with water and corrode. All of the interior surfaces were sprayed with linseed oil. The compartments that are filled with water receive applications of linseed oil at regular intervals. The exterior surfaces were painted with coal-tar epoxy.

In addition to designing the bulkhead itself, assemblies of timber, steel, and rubber were designed as a guide and seal for each pier nose. They consisted of wood, steel sections, and rubber seals, all preassembled and anchored to the concrete piers with expansion anchors. The guides were necessary to ensure that the bottom caisson was in correct location. In addition, steel pieces were placed at the bottom of the guides to pull the bulkhead tight to the pier nose and provide a stop for the bottom caisson when it reached its final position.

Fabrication

The long, longitudinal welds required special care to prevent warping the long bulkhead caissons. Many of the individual steel components had to be heat straightened prior to welding to meet specified tolerance limits. Welding was performed by certified welders, and weld testing was provided by an independent testing laboratory as the caissons were completed. Pressure testing was accomplished prior to painting to ensure that the caissons were watertight. Each caisson was numbered and the caissons above and below the unit fitted in the dry to meet specified tolerances and so caissons could be pinned together in the water. The two sets of bulkheads were fabricated within 90 days.

Wissota Hydro Project — The Hinged Concept

The Wissota Hydro project is located on the Chippewa River about 3 miles upstream from the city of Chippewa Falls, Wisconsin. The Wissota reservoir, which is known as Lake Wissota, extends upstream about 14 miles (22.5 km) and has a surface area of about 6,300 acres (2,550 ha) with a normal full reservoir volume of 56,000 acre-feet (7.9×107 m^3). The maximum height of the dam is 68 feet (20.7 m) above the streambed. The powerhouse contains six 6,000 kW, identical vertical shaft generating units with each unit having an intake bay 26 feet wide (7.9 m) by 24.5 feet high (7.5 m).

Faced with major repairs of the head gates, stoplog slots and trash racks for the Lake Wissota hydroplant's six intakes, Northern States Power Company (NSP) needed a means to seal the entire forebay of each unit or lower the reservoir to perform repairs. The existing stoplog support trusses of this 70-year structure were badly deteriorated and had questionable load-carrying capability. Any work in the headgate area necessitated a minimum 15-foot drawdown of the lake to lower pressure on the stoplogs and ensure the safety of the repair crews.

Rather than rent a barge and crane, an articulated floating bulkhead was designed and fabricated in the fall of 1986. It was installed in Lake Wissota hydroplant's intakes for the first time in 1987 (see Reference at end of article). The bulkhead is 36 feet (11.0 m) square and 27 inches (0.69 m) thick when fully assembled. The bulkhead was designed to span 30.9 feet (9.4 m) under a water head of 35 feet (10.7 m). Each of the nine caissons contains three compartments. Each caisson is comprised of four W27 × 84 steel beams and 5/8-inch-thick (16-mm) steelplate.

Aligned by using vertical guides of steel and timber installed on the pier noses, the bulkhead resembles a giant garage door as it floats in the water before installation. Selectively filling the caisson compartments creates the correct buoyancy for descent. Subsequent caisson compartments fill on their own as they settle (photo 1). The buoyancy of the 136,000-pound (12.5-kN) structure ensures that only about 2,800 pounds (12.5 kN) rests upon the concrete below the headgate. Water pressure from the lake seals the bulkhead (photo 2). When repairs were completed, the water-filled compartments are opened and drained through the headrace. Once emptied, the headrace is filled through gates installed in the bottom caisson. The bulkhead rises along the vertical guides mounted on the pier noses, ready for use on the next bay. The bulkhead has been installed in as little as 2 hours and removed within 30 minutes.

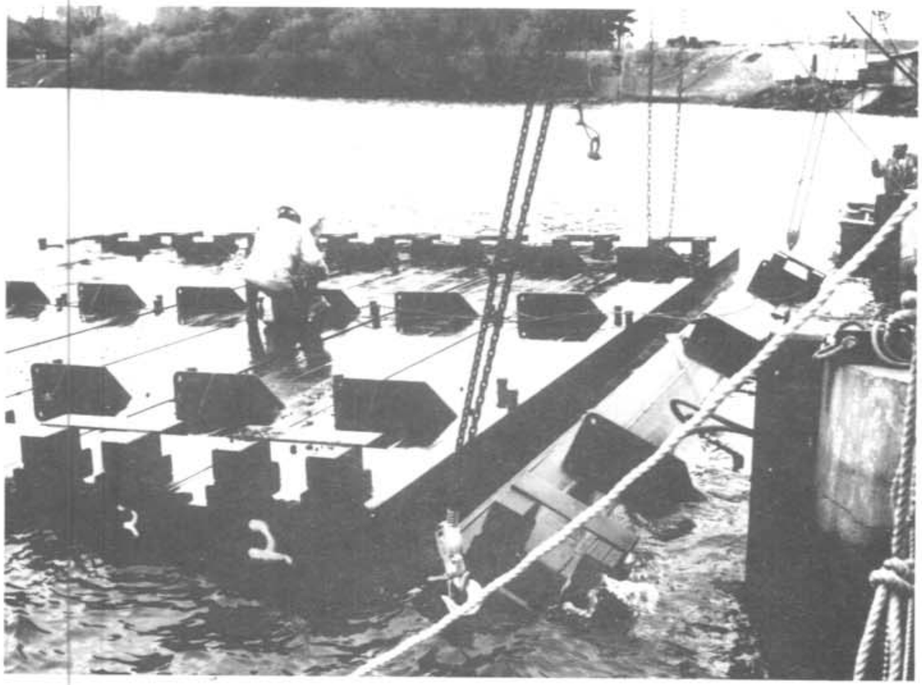

Photo 1.–Filling of caissons for sinking the bulkhead–Wissota hydroplant intake, 1987.

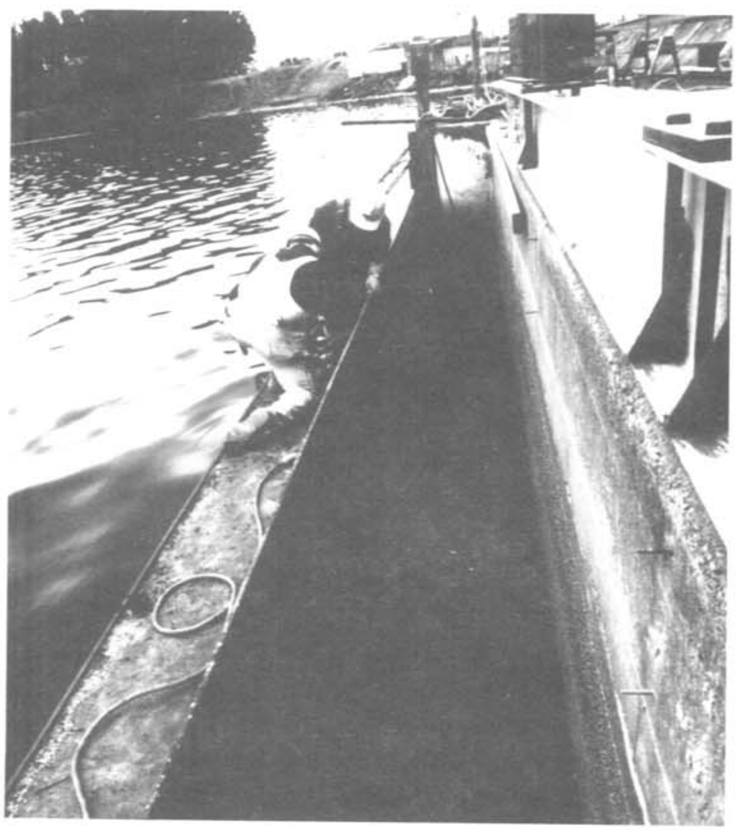

Photo 2.–Bulkhead installed and headrace dewatered–Wissota hydroplant intake, 1987.

This bulkhead was designed to be utilized at other hydroplants besides the Lake Wissota facility. NSP officials estimate a $1.4-million savings through use of the floating bulkhead including avoided loss of generation revenue because a drawdown was not needed. Fabrication cost of the bulkhead was about $130,000.

Snake River Dams — Flexibility and Multiple Use

Idaho Power Company is planning to replace the spillway radial gate seals and paint the spillway gates of the Upper Salmon, Lower Salmon, and Bliss Dams on the Snake River, Idaho. These dams do not have stoplogs or bulkheads to seal the spillway bays, which enables work to be performed on the gates in a dry environment. Except for Bliss Dam, no stoplog or bulkhead slots are provided in the spillway piers. Presently, there is no vehicular access on any of the three dams' spillways; and the spillway hoist bridges cannot carry heavy loads such as a crane or stoplogs. Idaho Power was further limited in its approach to dewatering the spillway bays. The reservoirs could not be lowered without a loss in generating revenue and possible environmental consequences.

A floating bulkhead was designed for use at all three dams to assist in facility repairs and maintenance. Table 1 contains information pertaining to the three dams used in designing the bulkhead. The bulkhead consists of eight caissons each 40 feet wide (12.2 m) and 53 inches high (1.35 m). Total height when all caissons are assembled is 36 feet. The bulkhead was designed to span 38.0 feet (11.6 m) under a water head of 36 feet (11.0 m) at Lower Salmon Dam, the most critical structure. Each of the eight caissons contains three compartments. Each caisson is comprised of four W30 × 108 beams and 3/4-inch- (16-m) thick steel plate. Fabrication cost of the 180,000-pound (800-kN) bulkhead was about $190,000. Idaho Power estimates that use of the floating bulkhead saved them more than $3 million compared to other dewatering means.

Table 1.–Pertinent Data of Idaho Power Spillways

Item	Bliss (feet)	Lower Salmon (feet)	Upper Salmon (feet)
Maximum normal pool elevation	2,654.0	2,798.6	2,880.4
Pool fluctuations	1.5	2.0	0.0
Spillway Crest elevation	2,624.0	2,783.5	2,865.4
U/S apron or sill elevation	2,623.2	2,762.0	2,861.8
Maximum design head	30.8	36.6	18.6
Spillway span at gate	39.0	30.0	30.0
Spillway span at pier	49.0	38.0	38.0
Bulkhead slots	Present	None	None

The same hinged, floating bulkhead design used for Lake Wissota Dam was used at Upper Salmon and Lower Salmon Dams. Minor changes in the side and bottom seals were made to accommodate differing site conditions. At both Upper Salmon and Lower Salmon Dams, the spillway pier noses and an upstream concrete apron will be used as the bearing surfaces for the bulkhead seals (figure 3). The bulkhead will be installed in the same manner as the bulkhead for Lake Wissota Dam.

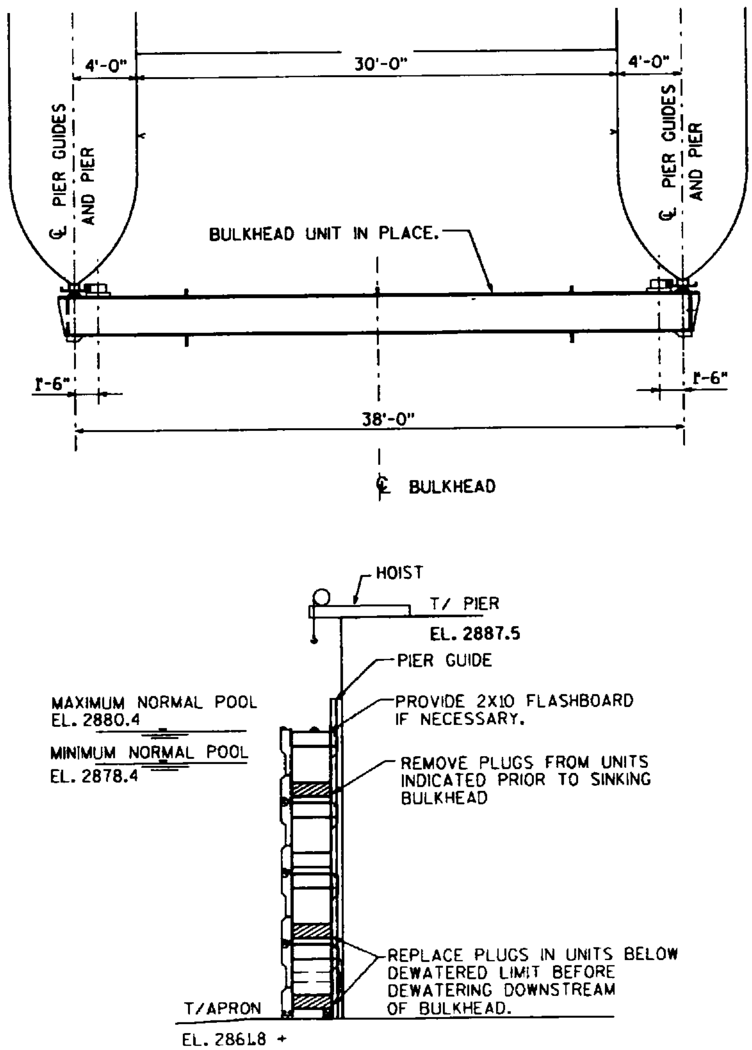

Figure 3.–Upper Salmon Dam–Typical spillway bay, plan, and section.

At Bliss Dam, the existing 13-inch- (0.33-m) wide bulkhead slots will be utilized as the sealing surfaces for the floating bulkhead. At this location, each caisson will be installed and removed individually. Each end of the caisson has a tapered end to allow the bulkhead to be fitted into the bulkhead slots (figure 4).

Summary

Two articulated floating bulkheads have been designed and fabricated for use at several dams. A 36-foot- (11.0-m) square hinged floating bulkhead was used at Wissota Hydro Plant to dewater the powerplant intakes so repairs to the intake, trash racks, and stoplog guides could be performed. Power company officials estimate a $1.4-million savings through the use of this bulkhead including avoided loss of generation revenue. A 40-foot- (12.2-m) wide by 36-foot- (11.0-m) deep bulkhead was designed for use at Bliss, Lower Salmon, and Upper Salmon dams to dewater the spillway bays for gate maintenance. This bulkhead was designed to be installed for both a spillway having bulkhead slots and two spillways with no provision for dewatering. These examples

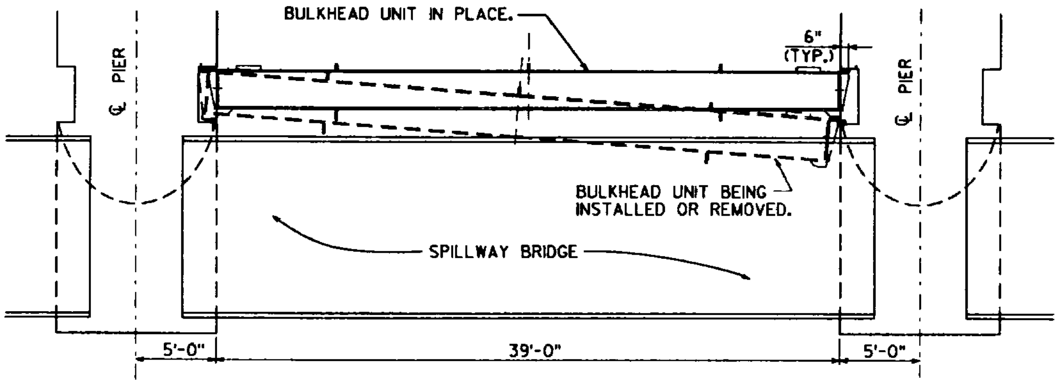

Figure 4.-Bliss Dam-Typical spillway bay plan.

demonstrate the flexibility, reuse potential, and cost effectiveness of the floating bulkhead over conventional dewatering systems.

Reference

Bakken, Jr. R. and J. S. Vonasek, "Floating Bulkhead Installed for Hydro Intake Repair," Small Hydro '88, Ministry of Energy, Toronto, Ontario, Canada, July 1988.

ICE MELTERS AND CONCRETE DAMAGE: ARE THEY RELATED?[1]

by Lawrence E. Balkin and Richard C. Schend, P.E.[2]

Once days get shorter and temperatures get cooler, people across the U.S. snowbelt begin the daily task of maneuvering themselves through ice and snow. As public works officials know, these weather hazards present immediate concerns to the public welfare, but as fewer stop to consider, the secondary concerns can prove just as ominous.

With ice and snow removal comes the use and abuse of public walkways and roadways. The use of heavy equipment and ice melters are a necessary precaution to winter weather, but they can also be directly related to concrete damage.

R. C. Schend & Associates, a consulting engineering company, was commissioned to evaluate concrete damage related to ice melter use. In the base of its findings, the firm has found that concrete damage did not usually occur when ice melter was applied as directed and used on good quality, air-entrained concrete designed for cold weather climates. Instead, concrete damage was most often traced to low-quality concrete lacking in air-entrainment or some other critical ingredient. The freeze/thaw damage that occurs is generally a result of the quality of the concrete laid—not necessarily the type of ice melter applied.

Concrete damage due to freeze/thaw cycles occurs for various reasons and in several different forms, including: scaling, the flaking or peeling away of surface mortar; dusting, the formation of a fine powder that can be rubbed off the surface easily; and popouts, the breaking away of small concrete fragments.

Scaling is the most common form of winter concrete damage. Usually caused by a buildup of excess pressures produced when water in concrete freezes and expands, the expansion forces flakes of mortar loose from the surface. As the cycle repeats, damage accelerates.

Dusting occurs when a small, thin, weak layer called "laitance" appears. It is composed of water, cement, and fine particles. When the surface freezes and thaws, this thin layer becomes dust.

Popouts are formed when a piece of porous rock absorbs more water than its surrounding areas. As the offending aggregate absorbs moisture or freezes, internal pressures are created. Consequently, the concrete ruptures, expelling the rock and leaving a shallow depression.

According to books and articles on the subject of freeze/thaw effects on concrete published by the American Concrete Institute (ACI) and the Portland Cement Association (PCA), the two leading U.S. authorities, concrete quality is measured according to its air-entrainment, strength, water/cement ratio, cement content, and concrete slump.

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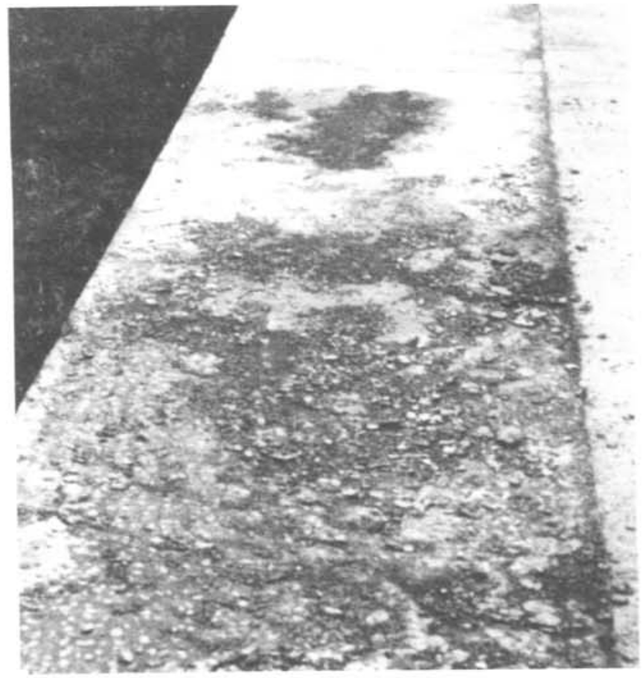
[1] Reprinted with permission from the Associate Editor, Public Works, 200 South Broad Street, Ridgewood NJ 07451; April 1992 issue.

[2] Mr. Balkin is Vice President, Operations/Finance, Koos, Inc., Kenosha, Wisconsin; Mr. Schend is President, R.C. Schend and Associates, Kenosha, Wisconsin.



Flaking and peeling of surface mortar is usually caused by internal pressure created when water freezes within the concrete, not by corrosive chemical action.

To avoid concrete damage completely where freezing and thawing occur, the concrete must be air-entrained. Properly air-entrained concrete provides significantly improved surface durability that resists freezing and thawing in most conditions, even when ice melters are used.

Formulated by either using an air-entrained cement or adding an air-entrained agent, this type of concrete forms microscopic air bubbles throughout the concrete during the mixing process. These air bubbles relieve the pressures that result when absorbed water freezes and expands. In areas with severe freeze/thaw exposure, concrete should contain at least 6 percent air-entrainment.

But an adequate amount of entrained air is not the only guarantee of freeze/thaw durability. Several other conditions should be met. The ACI and PCA recommend that concrete be composed of the following when subjected to freeze/thaw conditions:

- Durable materials
- Low water-cement ratio of 45 percent or less
- Slump of 4 inches or less
- Cement content of 564 lb/yd^3 or more
- Adequate drainage with a slope of 1/8 in/lin ft or more
- Minimum compressive strength of 4,000 lb/in^2 at 28 days
- Minimum 30-day drying period after moist curing of the concrete

Also, avoid using ice melters for at least the first winter season after laying the concrete. And, it is equally important to select a reliable and respectable cement contractor.

Selecting an Ice Melter

Ice melters have many effects on concrete and the immediate environment. To decrease the possibility of damage and increase the life of public roadways, the type of ice melter used should be a careful consideration. Sodium chloride, calcium chloride, potassium chloride, potassium-chloride based with added compounds, and urea are the most frequently used ice melter products. Ammonium nitrate and ammonium sulfate are also sometimes used.

In the absence of freezing conditions, sodium chloride has little to no chemical effect on concrete, but will damage surrounding vegetation and corrode metal. Calcium chloride in weak solutions generally has little effect on concrete and vegetation, but does corrode metal. However, in concentrated solutions, it can chemically attach concrete and harm vegetation. Also, when tracked inside, calcium chloride will leave an oily residue on floors, and, when stored, will clump if exposed to moisture. Ammonium nitrate and ammonium sulfate compounds attack and disintegrate concrete, and should be strictly avoided. Urea will not chemically damage concrete, vegetation, or metal.

Potassium chloride-based ice melters, and potassium chloride-based ice melters with additives, can liquefy ice effectively, without harming plants or other vegetation when used as directed.

Another area to consider when choosing an ice melter is how the manufacturer backs the product. All ice melter manufacturers stress that customers must apply deicer products according to directions and maintain good sidewalk maintenance practices. Alter repeated applications, excess water and slush formed by ice melter products should always be removed.

However, many ice melter companies take a "buyer beware" approach, not offering any type of satisfaction guarantee or customer assistance. Several deicer packages include the following disclaimer: "Manufacturer or seller makes no warranty expressed or implied concerning the use of this product other than the purposes indicated on the label. Buyer assumes all risk in storing, handling and the use of this product." Not all companies make this disclaimer and it is always wise to find those that take the responsibility upon themselves, and offer a satisfaction guarantee.

Also as important is the reliability of the supplier. Look for a customer relations or customer service department that is regularly on hand to support your needs.

If damage occurs during the first frost season, or if the concrete is poor quality, a breathable surface treatment should be applied to the dry concrete to help protect against further damage. ACI and PCA recommend adding a penetrating sealer made with boiled linseed oil, silane, siloxane, and/or breathable methacrylate. Non-breathable formulations should be avoided as they may accelerate scaling conditions.

Roadways, walkways, and parking areas need not be replaced on a frequent basis. Careful development of the concrete at the outset as well as a prudent choice of a winter ice melter can go a long way to extending the life of your area concrete—and, in the long run, your overall maintenance budget.

MAINTENANCE WORKSHOP

(Sponsored by Pacific Northwest Region)

by Mike Pearson[1]

In December 1991, the Irrigation Operation and Maintenance Branch held a workshop for personnel responsible for the day-to-day maintenance of Reclamation facilities.

The highly successful workshop was the first of this type presented by Reclamation. In addition to PN Region personnel, other participants came from the Denver Office; Upper Colorado, Mid-Pacific, and Great Plains Regions; State of Oregon; and one irrigation district.

Onsite demonstrations were the highlight of the workshop such as welding repairs for cast iron and epoxy repairs of metal. A unique part of the workshop included a view of a mobile workshop–a special designed vehicle that can be driven directly to a site where maintenance needs are performed. Demonstrations were also made on how to determine equipment failure modes using an infrared gun and vibration testing meter. Other items of maintenance addressed were:

- Electrical and mechanical maintenance: General procedures described along with demonstrations of infrared and vibration testing
- Galvanic corrosion: Lessons learned
- Cavitation: How to recognize, repair, and prevent cavitation damage
- Favorite supplies: Supplies and where to order them
- Lubrication: How to lubricate systems such as control systems, gear boxes, wire ropes, etc.
- Hydraulic control systems: Reclamation design of control systems–how they operate and how to maintain the system
- Gates: Reclamation gate design and common problems
- Welding repairs of cast iron
- Epoxy repairs: Handout of test results done by the Corps of Engineers on tion damage
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- Gates: Reclamation gate design and common problems
- Welding repairs of cast iron
- Epoxy repairs: Handout of test results done by the Corps of Engineers on epoxy and different types of weld metal used to repair cavitation
- Concrete repairs: When and how to repair
- Sealant repairs—Correct procedures and a listing of sealants tested by Reclamation; included are manufacturers' names and telephone numbers
- Nuts, bolts, washers, and torquing procedures

[1] Mike Pearson is a mechanical engineer, Bureau of Reclamation, Pacific Northwest Regional Office, Irrigation Operation and Maintenance Branch, Boise, Idaho.

The workshop is designed to exchange knowledge and provide a forum to discuss techniques and suppliers. Each participant received a reference notebook covering all the information presented.

The PN Region is planning to have two workshops this winter, one for Reclamation employees and one for irrigation district employees within the PN Region. The workshops are listed below:

Workshop for Reclamation Employees.–This workshop is only for Reclamation employees. The workshop will be held at Grand Coulee Dam on December 8–11, 1992. On Friday morning, December 11, participants will be given a tour of the dam and maintenance facilities.

Workshop for Irrigation District Employees.–This workshop is only for irrigation district employees within the PN Region. The workshop will be held in Boise, Idaho, on January 12–14, 1993.

The PN Region would like to have personnel from all Regions participate in the workshop and share maintenance problems and practices. They have reserved a limited number of seats for those desiring to attend.

If you have any questions pertaining to these workshops or wish to attend, please contact Mike Pearson, (208) 334-1169.

This mobile workshop plays a vital part in ensuring that maintenance work can be performed quickly at various project locations.

SILICA FUME CONCRETE REPAIRS ON THE SAN JUAN-CHAMA PROJECT

by Bill Bouley, P.E. and Charles Fisher[2]

The diversion and collection system was constructed between 1964 and 1970. The system conveys San Juan River water through the Continental Divide into the Rio Chama, a tributary of the Rio Grande. Annual diversions average about 110,000 acre-feet. The system consists of three diversion dams, two siphons, and three tunnels. The names of the tunnels, starting with the uppermost, are Blanco which is 8.6 miles long; Oso which is 5 miles long; and Azotea which is 12.8 miles long. All three tunnels are concrete-lined, with inside diameters of 8-foot 7-inches for Blanco and Oso Tunnels, and 10-foot 11-inches for Azotea Tunnel. The 28-day concrete compressive strength used in the design of the system was 3,000 lb/in^2.

The system was designed with sluiceways at each diversion dam to pass the gravelly sediment load carried by the mountain streams. Personnel in the Southwest Regional Office (which office has since been abolished) ordered a halt to the sluicing operations in the late 1970's due to complaints from the Colorado Department of Water Resources and downstream irrigators as those operations were creating a maintenance burden to irrigators and affecting fisheries downstream of the diversion dams. Over several years of operation, the gravelly sediment caused severe wear to the inverts of the tunnels.

Project personnel tried various repair materials to slow the wearing of the invert. Epoxy mortars and polymer concretes were used with little success. The toxic fumes made use of these materials difficult in the closed tunnel environment. Conveyor belt material was attached to the concrete near the portals of some of the tunnels with no success in reducing the damage. It appeared that repairs with conventional concrete mixes to be the best material.

With the gravelly sediments passing through the tunnels, repair materials should be able to withstand the constant abrasion. Silica fume concrete was proposed as a repair material by personnel in the Division of Research in Denver because of its high resistance to abrasion. The 28-day compressive strength for the silica fume concrete is over 11,000 lb/in^2.

In March 1986, Dennis Arney, Division of Research, assisted in providing test sections of silica fume concrete to evaluate its effectiveness in the eroded invert of Blanco Tunnel. The test sections were partially funded through the Open and Closed Conduit Systems research program. Various methods of surface preparation were employed: sawcutting the edges, chipping out tights, and bushhammering the remainder; to sawcutting the edges, chipping out tights, and sandblasting the remainder; to merely washing down the areas and using stiff brooms to clean it out. Other sections of the invert have been repaired with standard concrete mixes using 1-1/2- and 3/4-inch aggregate.

Cores were obtained from all the different sections; i.e., which silica fume concrete mix, which standard concrete mix, or what kind of surface preparation for each concrete

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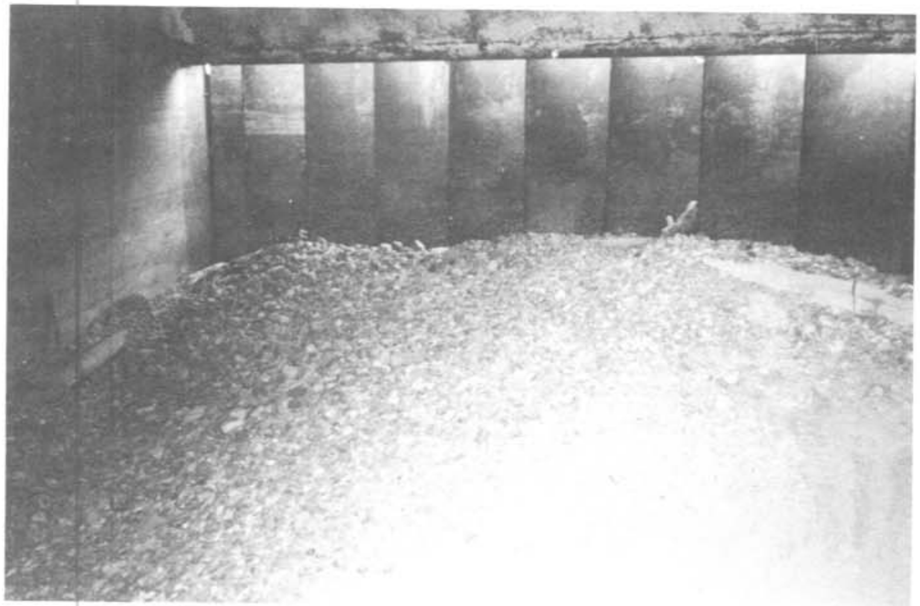
[2] Bill Bouley is a Civil Engineer, Denver Office, Bureau of Reclamation; Charles Fisher is Chief, Chama Field Division, Bureau of Reclamation, Chama, New Mexico.

mix. The cores were then sent to the Denver Office for tensile tests, which indicated there was no apparent advantage in adhesion between any of the new mixes to the existing concrete, or in any of the surface preparations. Based on these results and the lesser material costs, the Chama Field Division has been using a standard concrete mix with a surface preparation consisting of washing and sweeping out the area prior to placing the repair mix.

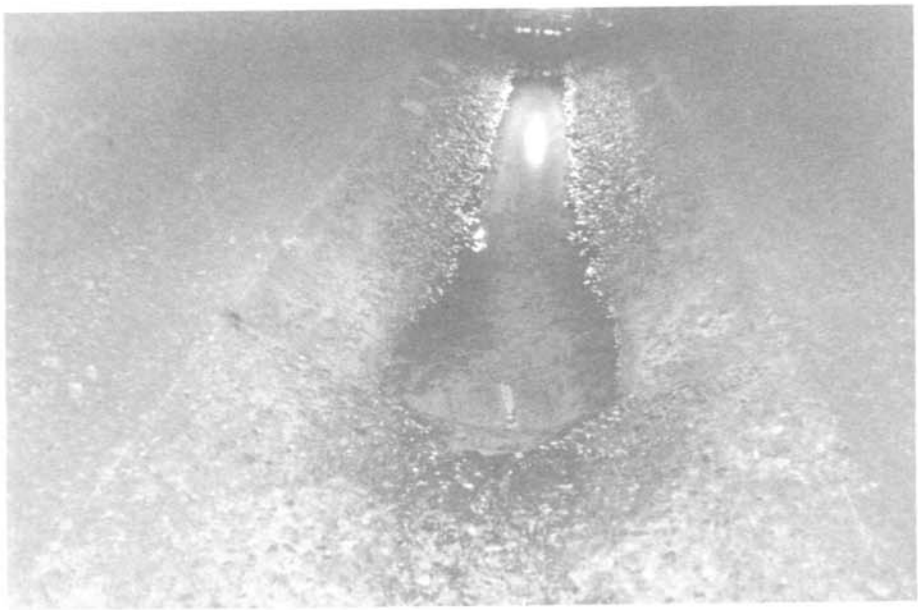
Project personnel continue to inspect the repaired areas annually to monitor the condition of the test sections and past repair work to other tunnel inverts in the system. Since



Typical sediment load–Blanco. 10/22/91

1.10-foot-deep hole in Azotea Tunnel invert. 10/22/91 silica fume mixes are more expensive, Project personnel will use such mixes at the portal areas where exposure to the high altitude weather would be more detrimental. Inside the majority of the tunnel, the air temperature remains near 50 °F, so standard concrete mixes with 1-1/2-inch aggregate should endure against the sediment load.

Personnel in the Chama Field Division plan to use a silica fume concrete mix to repair the sluiceway and a 4-foot-wide Parshall flume at Blanco Diversion Dam in the fall 1992.



0.7-foot-deep hole in Azotea Tunnel invert. 10/22/91

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Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

The purpose of this Bulletin is to serve as a medium of exchanging operation and maintenance information. Its success depends upon your help in obtaining and submitting new and useful O&M ideas.

Advertise your district's or project's resourcefulness by having an article published in the bulletin! So let us hear from you soon.

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