United States Environmental Protection Agency
Office of Research and Development Washington, DC 20460
Office of International Activities Washington, DC 20460
Office of Solid Waste and Emergency Response Washington, DC 20460
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EPA

Mining Waste Management

EPA Technical Information Packages

This brochure is part of a series of information packages prepared by the United States Environmental Protection Agency (EPA). Aimed at the international community, the packages focus on key environmental and public health issues being investigated by EPA. The products highlighted within these packages provide a sound technical basis for decisions regarding the development of environmental policy, abatement activities, and pollution prevention. By pooling expertise in the areas of environmental science and technology, significant progress can be anticipated to ensure a habitable environment for all nations.

"Mining Waste Management" describes the mining process, associated health and environmental concerns, and waste management options. Brochures and associated support material are available on the following topics:

- **Ensuring Safe Drinking Water** EPA/600/M-91/012
- **Mining Waste Management** EPA/600/M-91/027
- **Pesticide Waste Disposal** EPA/600/M-91/028
- **Air Quality Management** EPA/600/M-91/029
- **Solid Waste Disposal** EPA/600/M-91/030
- **Hazardous Waste Management** ..EPA/600/M-91/031
- **Small Community Wastewater Systems** EPA/600/M-91/032
- **Water Quality** EPA/600/M-91/033
- **Risk Assessment** EPA/600/M-91/034
- **Pesticide Usage Guidelines** EPA/600/M-91/035
- **Pollution Prevention** EPA/600/M-91/036
- **Environmental Impact Assessments** EPA/600/M-91/037
- **EPA Information Sources** EPA/600/M-91/038
- **Environmental Management** ...EPA/600/M-91/039

Each complete Technical Information Package (TIP) consists of a cover brochure as well as all of the documents highlighted within the body of the brochure. Generally, the cover brochures contain a section discussing the environmental issue, associated health and environmental effects, guidelines, sampling and analytical methods, as well as treatment and disposal technologies. Following this section, a bibliography is provided to identify other important sources and documents in the field. An attempt has been made to provide references that are readily available in technical libraries. Finally, a number of Office of Research and Development (ORD) technical experts followed by some additional EPA resources are listed to facilitate consultation and technical assistance. Document ordering information is provided on page 9.

The Mining Process

Mining is an integral part of the world economy. It provides a diversity of products, including coal for combustion in steam boilers or metallurgical coke ovens, the lead used in storage batteries, ammunition, and pigments; copper for electrical equipment and supplies; iron for the construction and transportation industries; zinc for galvanizing and other uses; silver for jewelry and photographic materials; gold for electronic equipment, jewelry, and medicinal use; and the uranium used by electric utilities. Mining also yields minerals such as phosphates used to produce industrial chemicals and fertilizers.

Ores containing the valuable materials occur only in certain geologic formations. Because the raw ore must be extracted from the earth, and only a small percentage of the excavated material is of use, vast quantities of material must be handled for each unit of marketable product. So not only is the earth disturbed in the process, but vast quantities of waste are produced.

"Mine waste" is the soil or rock that is generated during the process of gaining access to the ore or mineral body. "Tailings" are the wastes generated by several beneficiation processes (physical and chemical procedures used to separate the valuable metal or mineral from the interbedded rock). Some low-grade ore, waste rock, and tailings are used in dump or heap leaching, a beneficiation process that involves spraying the material with acid or cyanide to leach out metals. The final waste type is "mine water." It is water that infiltrates a mine and is discharged during its active life as well as following mine closure. Figure 1 schematically shows various types of mining waste as well as some management options.

Health and Environmental Concerns

Mining wastes may be corrosive (generally acidic) or have a high potential for forming acid. Waste constituents that may be present include heavy metals, radionuclides, cyanide compounds and asbestos. Incidents of contamination of drinking water aquifers, degradation of aquatic ecosystems, fish kills, denuded soils and related reduction of environmental quality have been demonstrated. In certain parts of the world, saline discharges are a major problem.

Surface and underground mining have caused environmental problems due to acidic discharges (commonly referred to as "acid mine drainage"). Here, exposed sulfide minerals react with oxygen and water to produce an acidic solution that dissolves metals and contains sulfate. Further reactions may occur resulting in a wide range of water quality characteristics. Additionally, sediment discharge due to inevitable erosion of the denuded soil hinders future land uses and degrades water quality. Abandoned shafts, pits, piles and ponds can lead to severe environmental degradation.

- EPA/440/1-76/059-a *"Development Document for Interim Final Effluent Limitations Guidelines and New Source Performance Standards for the Mineral Mining and Processing Industry Point Source Category"* - This document provides additional information on the mining of various metals, the wastes produced, health and environmental concerns, methods for waste minimization and treatment, and cost considerations.

- EPA/440/1-82/057 *"Development Document for Effluent Limitations, Guidelines and Standards for the Coal Mining Point Source Category - Final"* - Information is provided on the mining of coal, the wastes produced, health and environmental concerns, methods for waste minimization and treatment, and cost considerations.

- *"IRIS Database"* - Integrated Risk Information System (IRIS) is a recommended source for the latest human health and environmental effects information on the contaminants that may be found in mining waste. It contains current U.S. drinking water and ambient water quality standards together with summaries of health risk and regulatory information and authoritative consensus opinions on a range of chemicals and other agents.

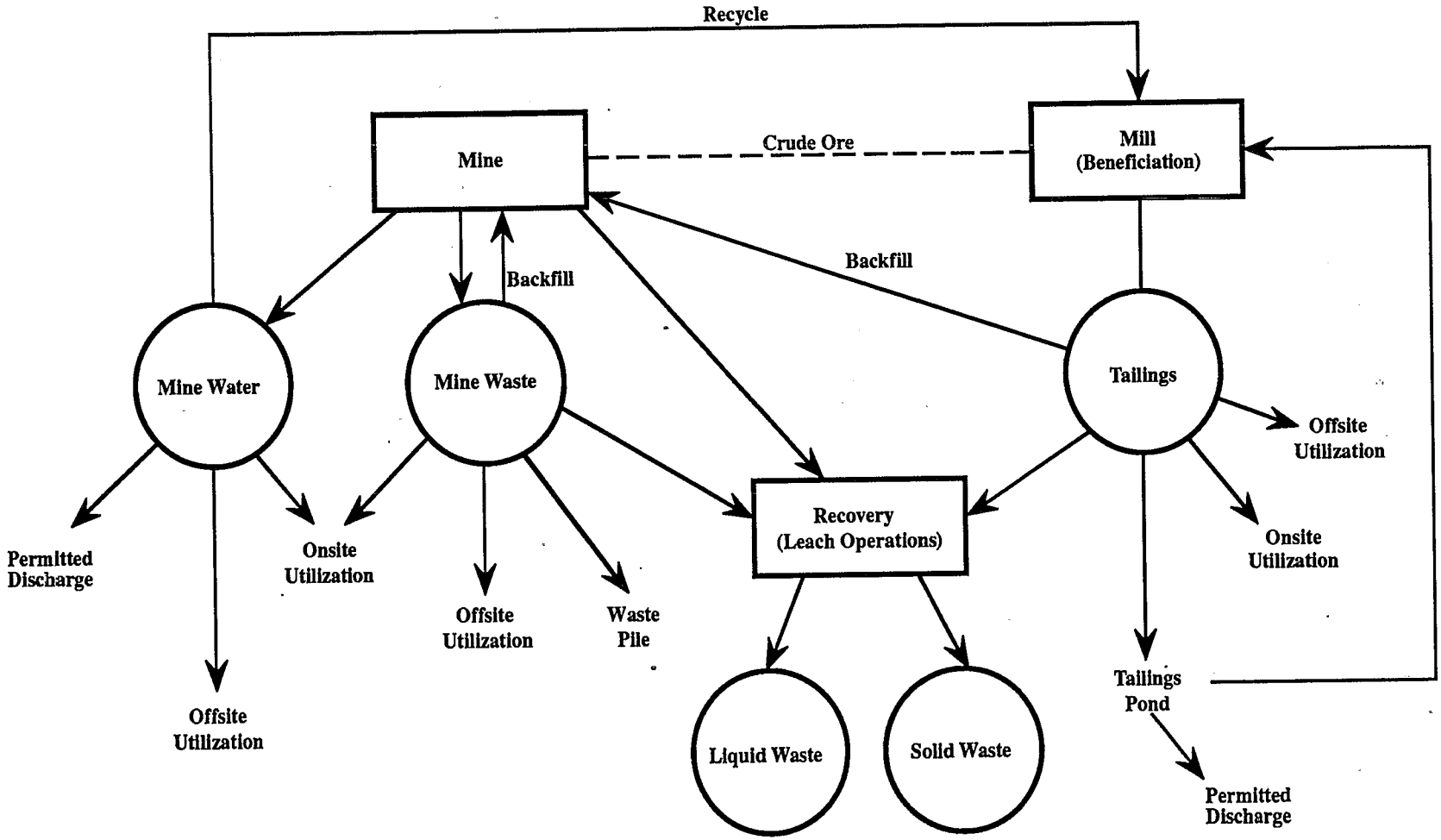

FIGURE 1. The mining waste management process

Defining the Need for Management

Table 1 indicates the need for characterization of mine waste, tailings, mine water and/or runoff (drainage), and liquid and solid waste from the recovery/beneficiation steps. From these determinations, one can learn the types and amounts of contaminants that could possibly cause harm to the environment and institute preventive measures. It is similarly important to know the character of the soil, ground water and surface water in the area. These measurements indicate if these media are already contaminated and the degree of preventive measures and/or remedial steps necessary.

- EPA/600/2-78/054 *"Field and Laboratory Methods Applicable to Overburdens and Minesoil"* - Incorporated within this manual are step-by-step procedures on field identification of common rocks and minerals; field sampling techniques; processing of rock and soil samples; and chemical, mineralogical, microbiological, and physical analyses of the samples.

- EPA/625/6-90/016a *"Technology Transfer Handbook: Ground Water"* - This handbook provides the scientific and technical background for assessing and protecting the quality of groundwater resources and includes chapters on monitoring well design and construction, groundwater sampling, groundwater quality investigations and groundwater restoration.

- EPA 600/4-79/020 *"Methods for Chemical Analysis of Water and Wastes"* - The manual contains chemical analytical procedures for the examination of ground and surface waters, domestic and industrial waste effluents, and treatment process samples. It provides test procedures for the measurement of physical, inorganic, and selected organic constituents and parameters.

Several methods are available for predicting the quality of acid mine drainage. There are difficulties in utilizing any method because of the heterogeneous nature of the materials and the non-uniformity of the environmental exposure (aerobic/anoxic, karst conditions, etc.).

- EPA/600/3-91/046 *"Application of a Water Quality Assessment Modeling System at a Superfund Site"* - The report presents water quality model studies and related exposure assessment for two uncontrolled mining sites in the Upper Clark Fork river basin in Montana to demonstrate the capability to assess the fate of metal mining waste pollutants. A linked assessment system – consisting of hydrology and erosion, river hydraulics, surface water quality, metal speciation, non-point source, and ground water mixing and transport models – was applied at the sites to show the utility of such modeling schemes and the complexities involved in their application. Graphs of the water quality parameters showed good correlation between the measured and predicted concentrations at some stations.

Waste Management

Mine wastes are managed in a variety of ways, as shown in Figure 1. Since site selection must be associated with the ore body, very few siting options exist. Proper mine and facility design, however, is very important in controlling environmental damages. Following this, reduction of inflow, including stream diversion, dewatering of aquifer, grouting, sealing, and sediment control are useful measures to reduce environmental contamination. Most mine waste is disposed of in piles, and most tailings are stored in impoundments. These practices increase potential for water quality degradation. Through recycling and reuse, this damage potential can be reduced. Mine waste and tailings can be used for supplementing soil, wallboard production, brick/block production, ceramic products, and aggregates. Mine water can be recycled through the mill and used for other purposes on site.

Offsite use of mine waste and mill tailings is limited. While additional options for recycling and reuse are explored, management measures (e.g., source separation, treatment of acids or cyanides, and waste stabilization) must be implemented throughout the mining industry.

Few methods are available to reduce the amount of solid waste generated by mining and milling, but process modifications can reduce the water content and potential toxicity of these wastes. Many methods are available to design, site, maintain, and close disposal facilities in an environmentally acceptable manner. Groundwater monitoring is a commonly used mitiga-

TABLE 1. MITIGATIVE MEASURES BY STAGE OF MINE LIFE

Stage of Mine Life	Mitigative Measure	Purpose
Active Site Life	Hydrogeologic evaluation and ground-water monitoring	Detection of contaminants
	Run-on/runoff control	Liquid control
	Liners	Containment
	Cutoff walls	Containment
	Leachate collection, removal, and treatment systems	Liquid control
	Security systems	Security of control systems and public health
Closure	Continue measures initiated during active site life	All purposes mentioned above
	Wastewater treatment	Liquid control
	Pond sediment removal	Waste removal
	Dike stabilization	Liquid control
	Waste stabilization	Liquid control
	Installation of leachate collection, removal and treatment systems at surface impoundments	Liquid control
	Final cover	Liquid control
Post-closure	Ground-water monitoring	Detection of contaminants
	Inspect/maintain all existing systems	All purposes mentioned above
Corrective action	Interceptor wells	Containment
	Hydraulic barriers	Containment
	Grouting	Containment
	Cutoff walls	Containment
	Collection	Treatment

Source: Meridian Research, Inc. 1985.

tive measure at leach operations. For other types of mining operations, stabilization of waste, installation of some kind of cap, and revegetation during the closure phase are common approaches to mitigation. Available corrective action methods, although not widely used, include interceptor wells, underground barriers to prevent the spread of contaminated ground water, and liners to contain the leachate.

• EPA/530-SW-85-033 *"Report to Congress: Wastes from the Extraction and Beneficiation of Metallic Ores, Phosphate Rock, Asbestos, Overburden from Uranium Mining and Oil Shale"* - The report provides in-depth information on the mining process, the wastes produced and associated health and environmental effects, ways to minimize waste production and the means to treat and dispose of the wastes as well as mine closure procedures and costs.

Prevention, Treatment and Disposal

Several management alternatives such as prevention and chemical, physical, and biological treatment are available to minimize the impact of mine drainage on the environment.

Prevention

Diversion techniques, dewatering of the aquifer, grouting and sealing techniques are all important methods to reduce the amount of water flowing into or onto mine waste and consequently reduce the volume of drainage from a mining operation.

Pollution prevention through erosion and sediment control should be a significant part of every mining waste management strategy. To implement the appropriate control mechanisms, flow characteristics of the water as well as the nature of the particles being transported need to be identified.

Every effort should be made to control the sediment at, or near to, its source (as opposed to relying on one or more large sediment settling basins offsite and in the major drainage ways). It is more desirable to segregate the sediment-laden waters from the rest of the surface flow. To effectively reduce the entry of sediment into major channels, all sources of sediment must be identified and controlled—including runoff from access roads. Although the nature of the transported particles cannot easily be controlled, the velocity and turbulence of sediment-laden water can often be adjusted (via settling basins, expansion and slope reduction of drainage channels, and well-placed obstructions) to reduce erosion and allow sediment to settle out.

• EPA/625/3-76/006a & b *"Erosion and Sediment Control: Surface Mining in the Eastern U.S.: Volume 1 - Planning; Volume 2 - Design"* - These manuals include general information on the problem of erosion and sedimentation, descriptions of a number of control techniques, guidance in developing control plans, design and construction considerations for erosion control structures, and a sample control plan.

Chemical methods may be utilized for reducing the formation of acid mine drainage. Exposure of water with alkaline material or phosphates prior to contact with the minerals has been successful.

Treatment

Water pollution from acids and heavy metals discharged from mines must be considered in addition to sedimentation. While long-range programs should be directed at prevention of acid mine drainage, neutralizing agents such as limestone continue to be used as a necessary short-term treatment measure (see Figure 2). Heavy metals and high levels of sediment are removed from mine discharge through various types of settling basins and lagoons. The treatment techniques often result in the generation of sludge and waste products that must be disposed of properly.

• EPA/600/2-83/001 *"Design Manual: Neutralization of Acid Mine Drainage"* - This document was prepared to assist mine drainage treatment programs identify and select appropriate processes, equipment, and procedures for the particular wastes that are faced. A review is provided of neutralizing agents and the methods used to handle, prepare, and feed these alkalies. Sludge dewatering and disposal are

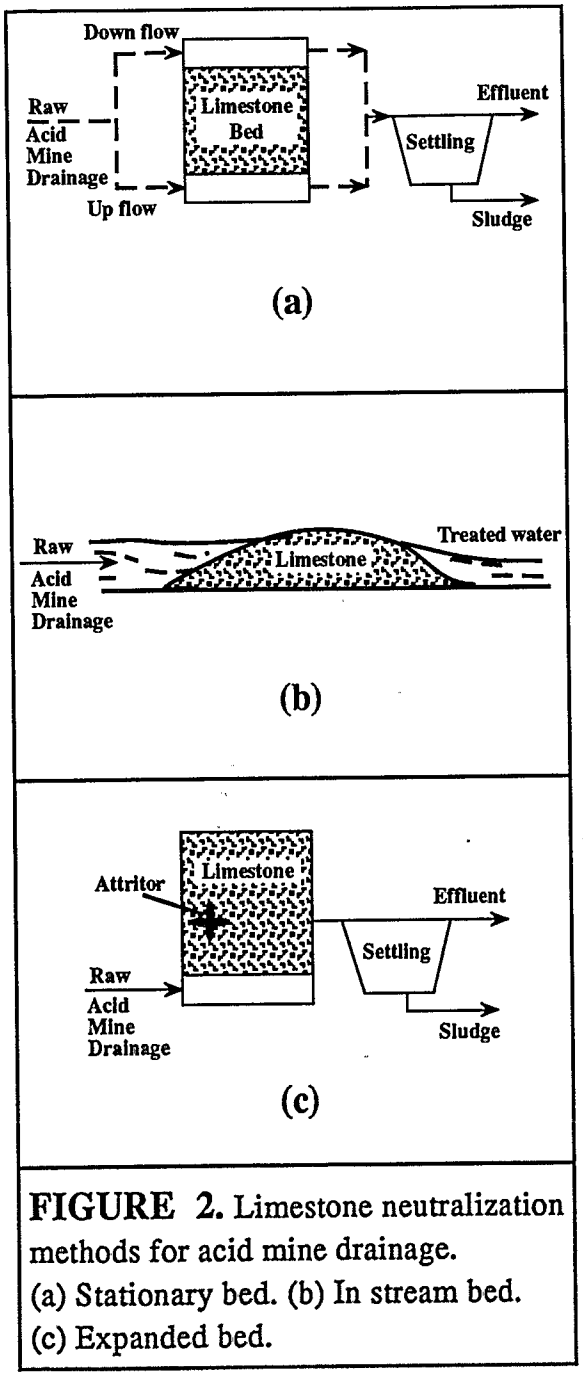

FIGURE 2. Limestone neutralization methods for acid mine drainage.
(a) Stationary bed. (b) In stream bed.
(c) Expanded bed.

explained and two sample treatment facility designs are provided.

Constructed wetlands have proven to be quite effective in lessening the adverse impact of mine drainage (as well as other types of wastes) upon the environment.

- EPA/625/1-88/022 *"Design Manual: Constructed Wetlands and Aquatic Plant Systems for Municipal Wastewater Treatment"* - The publication is a compilation of all available design and operating criteria for the various constructed wetlands and aquatic plant systems. Design, construction, and health and environmental impact are discussed and supported by case studies and design examples.

The application of sewage sludge to disturbed land, like that associated with mining activities, has been effective in reconditioning the soil for revegetation. Because of mining, disturbed soil often lacks nutrients and organic matter, has a low pH, and exhibits various other physical properties unfavorable to plant growth. A one-time application of sewage sludge usually allows the revegetation necessary for reclamation of mined areas.

- EPA/625/1-83/016 *"Process Design Manual - Land Application of Municipal Sludge"* - The manual presents state of the art techniques in land application of municipal sewage sludge for use in agriculture, forestry, and land reclamation.

Disposal

Having recycled, reused, and reduced mining wastes as much as possible, some waste still must be treated. Final wastes generated in the treatment processes must be disposed of.

Sludge from treatment of acid mine drainage is generally disposed of by deposition into a deep mine, permanent retention ponds, disposal at an active coal refuse area, or onsite burial. Of these choices, deep mine deposition is most frequently practiced and has been found to be the most environmentally sound of the listed choices. Clearly, all possible precautions should be taken to protect local ground water from contamination and monitoring must be part of the overall strategy to protect the quality of the aquifer.

- IC 8857 *"Mine Waste Disposal Technology. Proceedings: Bureau of Mines Technology Transfer Workshop"* - This Bureau of Mines document discusses monitoring systems, seepage prediction and control techniques, and coal mine waste disposal.

Additional References

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Nathan, T. 1979. Mining Urban Ore. EPA Journal. 5(2):24-26.

Klee, A.J. and J.G. Gordon. 1979. Resource Recovery as a Pollution-Control Device. Waste Age. 10(4):49-52.

Moore, J.N. and S.N. Luoma. 1990. Hazardous Wastes from Large-Scale Metal Extraction. Environ.Sci.Technol. 24:1278.

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Skousen, J., et al. 1990. Acid Mine Drainage Treatment Systems: Chemicals and Costs. Green Lands. 20:31.

Additional Information

Additional information on mining research may be obtained by contacting the U.S. Department of the Interior's Bureau of Mines at the following address:

Office of Technology Transfer
Bureau of Mines
2401 E Street, NW., M.S. 6201
Washington, D.C. 20241
202-634-1224 Telephone
202-634-4857 Fax

Mining Waste Management Expertise List

Technical Area	Contact	FAX
Analytical Methods	Tom Hinners	702-798-2142
	Bill Potter	513-569-7424
Health Effects	Judith Olsen	513-569-7475
Fate, Transport and Modeling	Robert Ambrose	404-546-3340
	David Brown	404-546-3340
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*U.S. GOVERNMENT PRINTING OFFICE:1991-548-187/40629

Additional Opportunities for Obtaining Technical Information

ORD-BBS – The ORD Electronic Bulletin Board System, in addition to fostering communication among officials, researchers and the private sector, facilitates the exchange of technical information and ORD products in the form of electronic messages, brief bulletins about ORD products and activities, files for downloading, participation in conferences, and on-line databases for identifying ORD publications. For additional information and assistance in using the BBS, call 513-569-7272 or write to: CERI, U.S. Environmental Protection Agency, ORD-BBS, G-76, Cincinnati, OH 45268.

Ordering Technical Documents

The EPA documents mentioned in the Technical Information Package brochures can be ordered at no charge (while supplies are available) from the Center for Environmental Research Information (CERI). Once the CERI inventory is exhausted, clients will be directed to National Technical Information Service (NTIS) where documents may be purchased. Orders can be placed by mail, phone, or FAX. To order documents, have the document number or the EXACT title ready. The journal articles listed in the *Additional References* section may be ordered from the U.S. National Focal Point of INFOTERRA. The Bureau of Mines document discussed on page 6 may be ordered at no charge from the Branch of Publication Distribution address below.

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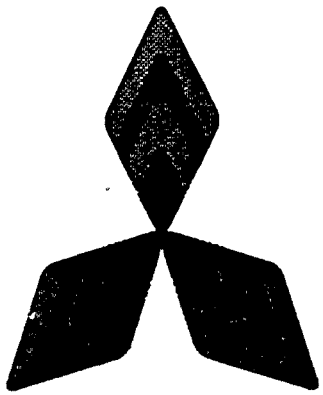

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Technical Information Packages