

Worker Safety at MRF'S -- Where Are We Going ?

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INTRODUCTION

There is hardly a community in the United States that does not have a material recycling facility to support the area's waste management program. In the past six years, over 500 such facilities have been constructed now employing an estimated work force of over 10,000 persons. The applicability of current OSHA regulations has been a major concern, but lack of data has delayed the implementation of appropriate safety guidelines to address Material Recovery Facilities (MRF's) specifically. Leading MRF designers like RRT, have been directly responsible for advancing the industry's "Best Practices" and have yielded measurable results in quality projects. Unfortunately, many other projects were built without professional engineering guidance. Project were being developed with different interpretations of OSHA and in many cases without the input of qualified individuals and valid data.

In response and through the efforts of many operators and regulators, new guidelines, recommendations and standards have now been instituted to protect the worker. Designers will now follow a newly established "industry practice": ANSI Z245. However, is this enough? European guidelines are stricter. MRF technology keeps changing. Economic pressures are upon the industry. With these changing forces, where are we going? This paper summarizes present trends and major concerns in order to predict future design and operations requirements. This information will be beneficial to system operators, facility owners, equipment manufacturers and system designers in identifying and correcting safety shortfalls in both new and existing man/machine systems and preparing facilities to meet current OSHA safety regulations and future more stringent safety requirements which are expected to be published by the end of 1997.

HEALTH AND SAFETY RISK ASSESSMENT AT RECYCLING FACILITIES

As concluded by R.F. Weston¹ in "Environmental, Economic and Energy Impacts of Material Recovery Facilities", workers at recycling facilities do not appear to be exposed to health or safety hazards when they follow established safety requirements. Parameters analyzed by R.F. Weston included air contaminants, as dust, silica, metals, CO, Hg Vapor; PCBs and pesticides, airborne and surface samples of bacteria and fungi; noise exposure; physical safety hazards and ergonomic stressors. Based on their health and safety risk level these parameters can be classified in:

- Low Risk Parameters. Common air contaminants were found to be of low health risk. Air concentrations of dust, silica, metals, CO, Hg Vapor; PCBs and pesticides were recorded below applicable regulatory standards and in most instances below the detection limits of the recommended test methods.
- Risk Parameters to be Avoided by Following Safety Programs. Noise exposure and physical safety hazards present in MRF's can be avoided by following established OSHA programs. The operations which exceeded regulated noise exposure levels were the truck unloading activities, trommels, glass crushers and can flatteners. Employee noise exposure can be reduced to accepted levels by following the guidelines indicated in the Hearing Conservation Program. Main safety hazards can be avoided by following the Energy Control Program, the Personnel Protective Equipment Program, the Blood Borne Pathogens Program, etc.
- Parameters Requiring Additional Evaluation. Bacteria and fungi airborne samples as well as ergonomic stressors risk factors were parameters defined as to require additional evaluation because of the rapidly developing knowledge in these areas. In the case of bacteria and fungi, regulatory standards or guidelines have not been established yet. Airborne samples of bacteria and fungi were recorded consistent throughout the facility and were rated at one order of magnitude higher than the

one observed outside the facility. Most of the bacteria and fungi species detected were classified as environmental species, which are commonly found in soil and water. Pathogenic micro-organisms detected were of the opportunistic type i.e. they are most likely to affect hypersensitive people or people with compromised immune systems. Some of the pathogenic micro-organisms detected are capable of causing disease at high concentrations, although there is very little information on the required exposure levels for adverse reactions to happen. The main ergonomic stressor identified by R.F. Weston was the improper sorting station design that caused repetitive or awkward motions. Main factors identified to cause extensive repetitive motions were extremely wide sorting belts, lack of foot stools, excessive belt speed and over feeding of recyclable materials.

THE INDUSTRY RESPONSE

The ANSI Z245 Report : Facilities for the Processing of Commingled Recyclable Materials - Safety Requirements

Safety practices at Material Recovery Facilities are currently regulated by the Occupational Safety and Health Administration (OSHA) under the Code of Federal Regulations 29 CFR 1910² for general industry. The American National Standards Institute (ANSI) Z245³ document is independent of OSHA 29 CFR 1910 and is currently being developed to provide detailed information and voluntary standards regarding safety practices at MRFs to be used by operators, engineers, equipment manufacturers and OSHA inspectors. ANSI documents, while voluntary, are typically used for interpretation by both OSHA inspectors and by the legal profession in the settlement of cases. ANSI is recognized by the Federal Government as a major source of National Consensus Industrial Standards. Additionally, ANSI standards are frequently cited in the OSHA regulations, and thus become part of the National Standard for which industry must comply⁴; examples of this include industrial forklifts, balers and compactors.

The ANSI document strives to address in detail, system safety requirements, and is currently in draft form. The intent is to receive approval by the ANSI Board of Standards Review so it can be published by the end of 1997, whereby ANSI can petition OSHA to "incorporate by reference" the documents in accordance with 1 CFR part 51. The legal effect of incorporation by reference is that the material is treated as if it were published in full in the Federal Register. Regarding compliance with ANSI Z245, existing facilities will have 5 years after the approval date to comply with Sections 5, 6, and 7. Section 8, which concerns training, will be effective 18 months after approval. New facilities placed in operation 18 months after the approved date of the standard will have to comply with the entire standard.

The ANSI Z245 report provides two major benefits to the industry. The first, it establishes a complete, standard worker protection approach by including ergonomic factors, system design parameters and real operation safety needs, which were not considered when following the previous general ANSI guidelines. The second benefit is that it provides the facility operators and owners with a set of total system safety guidelines that their engineers/systems providers need to follow. This, for example, will direct the type of acceptable equipment that can meet minimum safety guidelines. Current practice is to rely on equipment vendors for what is purchased, however many vendors exclude from their scope the responsibility to comply with regulations regarding safety. Furthermore, the expertise for engineering and safety issues is typically not held by manufacturers beyond their own machines and disclaimers.

The document covers four major topics and is divided into eight (8) Sections.

- General information and definitions (Sections 1-3).

- Site requirements (Section 4), reserved for future preparation.
- Mobile equipment, physical plant and processing machinery requirements (Sections 5-7).
- Safety programs and Safety requirements that apply to MRFs (Section 8).

Following are the highlights of the principal standards, Sections 5-8:

Mobile Equipment (Section 5): Mobile equipment is classified into two categories: Collection and Transportation Equipment and Powered Industrial Trucks. Each equipment category should be operated in accordance with its related ANSI standard. The major concerns to ensure the safe use of mobile equipment are:

- The employment of certified drivers and equipment operators by facility owners and users. Truck drivers loading or unloading material at the facility should be trained as required by OSHA standards specified in the Code of Federal Regulations Part 29 Subpart 1910.178.
- The accessibility and control of personnel in traffic areas such as the tipping floor and loading docks.
- The importance of awareness training and supervision by employers.
- The use of personal protective gear that meets specified ANSI standards.
- The fabrication and use of mobile equipment that meets specified technical requirements.
- The adequate maintenance and periodical inspections by service providers and employers.
- The report of safety related conditions by employees.

An example of a specific requirement for a piece of mobile equipment, used in or around the facility, is a backup alarm capable of emitting a warning signal 10 dBA above ambient noise level (ANSI/SAE J994b) and a protective shield or cage that will protect the operator from any falling objects.

Buildings and Plant Systems (Section 6): Facility operators are responsible for the safety training and supervision of their employees and the performance of regular maintenance and safety inspection programs. Facilities should have a traffic plan and use all necessary devices to minimize safety risks through the utilization of barriers, signs, separation partitions, communication devices, etc. In addition, the facility operator should designate Special Work Areas and limit employee access within 1.8 m (6 ft.) around them. Special Work Areas are distinctly identified areas where the use of guards and railings is functionally impractical and where specific training of affected employees is effective to avoid hazards within it.

With regard to the engineering of building and plant systems, the following are examples of new standards:

Facility Design Considerations. Building design should account for a minimum of six air changes per hour, have a fire exposure control and evacuation plan.

Tipping Areas. Mobile equipment traffic and sorting activities should be considered when designing tipping areas. Safety markings and signs to be used must comply with ANSI standards, audible alarms must emit a signal of at least 87 dBA or 10 dBA above ambient noise level and visual alarms must be visible from all affected areas. In addition specific signs are required in higher risk areas in order to limit personnel access. Higher risk areas include: unloading pit areas, the tipping floor, bale stacking and storage areas, industrial truck operating areas (such as aisles), etc.

Unloading Pits. As long as toeboards and guardrails which comply with ANSI A1264.1-1989 standards do not interfere with mechanized unloading operations, they should be installed on all sides of unloading pits or bunkers adjacent to walking or working areas. In the case of trucks unloading into pits, warning signs as barricades, stop logs, hand or mechanical signals should be provided.

Visitor/Public areas. Access by public visitors is prohibited during any time the facility is in operation. Access is limited to observation rooms and work areas not in operation.

Material Storage Areas. Fire protection procedures in these areas should follow standards specified in NFPA 101, Life Safety Code. Storage areas layout should provide access routes for employees that consider a minimum of 1.2 meters (4 feet) of separation from mobile equipment operating areas. Floor loading limits and lateral wall loading limits, if applicable, shall be posted. Bale stacking is allowed for stable, homogeneous, properly tied bales. Bales stacks shall be limited to four (4) high, any higher stacks should be arranged in a stair stepped fashion, interlocking fashion or use supplemental restraint devices. Bale storage areas are considered special work areas and have limited personnel access. Bales in stacks should be inspected daily for integrity.

Processing Machines and Systems (Section 7): Facility operators are directly responsible for the compliance of their systems. System engineers, machinery manufacturers, employees and service contractors (for maintenance, modification or remanufacture of machinery) are to follow the standards applicable to them. Major duties for above mentioned parties are:

- Proper operation and maintenance of machinery. The machinery manufacturers and system engineers should provide the system operator with a recommended operations and maintenance manual that includes safety features. The maintenance program must be performed by the system operator. The system engineer should provide adequate work area around each machinery for safe maintenance and inspection.
- Training, supervision and safety audits. The system operators must provide training to their employees, supervision and perform safety audits to verify the correct performance of the system safety features. Employees should only operate equipment for which they have been previously trained.
- Energy Control Program. The operator is responsible to perform an Energy Control Program and lockout/tagout of energy sources prior to performing servicing or maintenance. The machinery manufacturers and system engineer should provide the system operator lockout/tagout instructions compatible with 29 CFR Part 1910.147.
- Operator protection: Work surfaces or platforms at distances equal or less than 2.1 meters (7 ft) from unguarded points of operation should have railings no less than 1067 mm (42 in) high.
- Automatic mode equipment. Equipment functioning in automatic mode should not have its loading chamber accessible to employees.
- Riding on conveyors should not be permitted unless they have been designed for this purpose.
- Access to Special Work Areas within 1.8 meters (6 ft) is restricted to employees with the training and experience to avoid hazards.
- Equipment modifications. The contractor must obtain written permission from the operator to perform any modifications. If applicable, new operation, maintenance or safety precautions instructions will be issued. A label on the modified equipment shall list the contractor's name and the date the equipment was modified.

Control Systems. One of the most advanced features of ANSI Z245 is the controls and energy control systems standards. Aspects covered are control system design guidelines, location and equipment control features:

- Must be labeled.
- Must be designed and located to prevent unintentional activation (i.e. start buttons).
- Must meet minimum dimensions (minimum button surface is 1 inch, full hand controls activation surface is minimum 4.25 in.).
- Must be accessible.
- Must use one master control panel per processing system. It should override local controls with exception of emergency stops and discharge end controls. It should be located in manner that all affected operations are visible from it.
- Emergency buttons must be easily noticeable (in red and of larger size).

Energy controls must meet additional requirements to ensure that machinery will stop right on time, for the period desired and will re-initiate operations without creating any hazardous conditions. Energy controls are used to stop machinery when it is necessary to inspect, maintain, clean, unclog, remove contaminants etc. The most important recommendations are:

- Use of a Power Disconnect (lock in the off position).
- Use of Emergency Stops (E-stop) of the maintain contact type. (should be accessible to all affected employees and within 914 mm or 3 ft. of the Point of Operation or Feed Point Chute).
- Use of Pause/Resume control for regular system stops.
- Use of an interlock on all machinery access doors.
- Provide a key lock switch at discharge points not visible from the operator station.
- Hydraulic and electrical systems must comply with ANSI/NFPA related regulations.

Warnings, Signs and Alarms. Warnings, signs and visual alarms must comply with their related ANSI standards and be placed in areas where they are visible by all affected employees. Audible alarms must provide a pulsing or intermittent signal of at least 87 dBA or be preset to at least 10 dBA above ambient noise level to ensure workers response. System start-up alarms should be audible and visual and provide a initial 5 seconds signaling and a minimum 15 second delay to the start of the main motor. Equipment manufacturers are required to locate specific machinery warning signs on all equipment with moving parts. For example an access point warning would be to locate a sign next to a baler, commanding employees to disconnect and lock out power before opening a baler chamber gate.

Machine Guarding. Guards or enclosures are required for all equipment comprised of moving components which contain a Pinch Point or create a safety hazard. A Pinch Point is a point at which it is possible for a person's member or clothing to be caught between moving parts or between moving and stationary parts of a piece of equipment. Guard access covers should be secured by lock or require hand tools to be opened. Guarding is also used to control material flow particularly during transitions to prevent overflows within a reach of 2.1 m (7 ft.). In the event that it is impossible to install a guard in a point of operation, an E-stop and a control to either reverse, open the pinch point or disengage the mechanism is necessary.

Conveyors. Conveyor safety requirements are as a minimum the existing ANSI/ASME requirements. Equipment manufacturers should provide detailed information on the type, volume and weight the conveyor is capable to transport. Additional safety concerns are:

- Use of guards and skirts (elevated conveyors) to prevent a reach within 2.1 m (7 ft.) of the intersection or transition of conveyors.
- Provide guards for mechanical mechanisms and the return side (bottom) of conveyors.
- Conveyor sections transporting material next to sorting stations should be fully enclosed.
- Conveyor pits should use either an access cover, rails with gates interlocked to an E-stop or all moving elements of the conveyor fully enclosed.
- Sub-floor conveyors are considered Special Work Areas and have restricted access.

Sorting Stations. The sorting station standards section is probably one of the most interesting parts of the ANSI document because in addition to covering traditional safety features, it also includes ergonomic design considerations and engineering design parameters to define the system standards. Engineering parameters to be factored are Average Flow Rate, Material Density, Conveyor Belt Width, Average Belt Speed and Average Burden Depth. Furthermore, the standard recommends that engineers and equipment manufacturers apply ergonomic design features for repetitive physical tasks during their designs. The main factors discussed are:

- Work environment. For proper ventilation, a nominal air flow rate of 0.425 cubic meters (15 cubic meters) per employee or six fresh air changes per hour, whichever is greater, should be provided.
- Safety controls. Installation of E-stops within 0.9 meter (3 ft.) of each employee working position are required. The E-stop should interrupt all upstream feed and any system immediately downstream of the sorting line.
- Layout. The conveyor sort belt height should be no less than 762 mm (30 in.). The conveyor should include a toe cut-out to account for proper sorter posture. The toe cut-out dimensions should be 127 mm (5 in.) deep and 125 mm (5 in.) high. The sorting chute height should be no less than 762 mm (30 in.) on the loading side and 1067 mm (42 in.) on the others. In the event that the conveyor height plus the average burden depth height is greater than 1016 mm (40 in.) a riser should be added.
- Communication. All working positions should be visible from the control panel position and all sort station employees should be able to communicate with the control panel operator.
- Safety Features. Floors should be made of slip resistant material and be easy to clean. Guard rails should be provided for elevated sorting stations according to existing ANSI standards.

Electromagnetic Radiation Equipment. System layout and management should include provisions to maintain worker exposure to electromagnetic field emissions (EMF) under regulated maximum limits. As a minimum, guarding should be installed to prevent access within 1 meter (3 ft.) of the EMF source. The equipment manufacturer is required to provide data regarding field strength and flux density at a radius of 1 meter (3 ft) from the radiation source, both at a continuous average and at maximum continuous power. The system operator is responsible to verify equipment manufacturer information in the field and monitor EMF exposure at a work station closest to the EMF source. The radiation should be monitored for eight hour periods and their weighted average should not exceed the following limits:

- Magnetic Flux ≤ 1 mT (milliTesia) or
- Field Strength ≤ 25 kv/m (if the frequency is less than 100 Hz)
- Field Strength ≤ 625 kv/m (if the frequency is greater than 100 Hz)

Safety Program and Training (Section 8): Facility operators are responsible to perform a hazard assessment survey and an evaluation of the proper methods for controlling these hazards in accordance

with industry and regulatory requirements. As a result the facility's engineer in cooperation with the operator should develop a written program which would include all operation, inspection, maintenance and training procedures necessary to comply with existing regulations. In order to comply with the program, the personnel should be trained at the start of new assignments and refresher training should be given periodically as required. Training records detailing date and content should be maintained as required by applicable regulations. The training curricula should comply with OSHA or other federal agency requirements. Training can be classified as general safety training mandatory for all the personnel, detailed safety training for specific positions or awareness training for the recognition and avoidance of hazards. Following is a list of the written safety programs required.

Site Safety Orientation. Includes general work rules and regulations, familiarization with facility processing, explanation of signs and other prevention warnings, the emergency action plan and accident reporting.

Basic Hazard Communications (Hazcom). Used to inform employees about any hazardous material they may be exposed to in the work areas. Material Safety Data Sheets (MSDS) are also used for this purpose. Employees are instructed as how to read and interpret MSDS's information, the location of this information and the facility protection measures.

Walking - Working Surfaces. Employees are trained to recognize and avoid hazards encountered in special work areas of the facility as ladders, platforms aisles, etc.

Spill Response Program. It instructs employees to identify and handle unauthorized material, as for example hazardous waste inadvertently delivered with the recyclable material to the facility.

Blood Borne Pathogens Program. It provides training to employees regarding the hazards of infectious diseases as Hepatitis B or HIV.

Energy Control Program. It explains the risks of unexpected energizing or starting up of a machine and the lockout/tagout procedure.

Confined Space Program. Also called the permit spaces program, it provides training to prevent the hazards of working in confined spaces.

Heat/Cold Stress Program. It provides training to prevent or minimize safety or health risks caused by heat and cold stress.

Personal Protective Equipment Program. The employer should provide personal protective equipment appropriate to the job duties as required by 29 CFR 1910.132 and in compliance with its related ANSI standards.

Hearing Conservation Program. It provides awareness training regarding the hazards of high noise level exposure, prevention and protection instructions.

Traffic Control Program. Employees are trained on basic operational procedures that regulate mobile equipment traffic in the MRF as flow/routes, signals/markings, hazards, vehicle types, pedestrian routes and safety rules. The use of enhanced visibility clothing is an example of compliance.

Material Processing Equipment Program. Previous to the operation or maintenance of any piece of equipment in the facility, the employee must receive a comprehensive training on operation, maintenance and safety procedures.

Ergonomics Program. It provides information on ergonomic risk factors and preventive actions including the description of cumulative trauma disorders, recommended lifting and sorting techniques.

Electrical Safety Practices Program. Awareness training as well as specific training in electrical safety issues are to be provided to all employees according to the levels of risk at which they are exposed. Recommended work practices should comply with NFPA standards.

Fire Safety Program. It includes a fire safety awareness training and a task specific training for employees who are members of the incipient fire response program.

Material Control Program. Training is provided to minimize safety and health risks because of the handling and storage of materials around the facility. Employees are instructed on materials being processed, plant layout, traffic routes, etc.

What Is Happening in Other Countries? The Germany Example

Safety regulations for the Germany Recycling Industry⁵ were published in July 1995 to ensure proper work conditions of approximately 11,000 workers employed at 300 sorting plants. The document was prepared by the Committee for Industrial Protection and Safety together with the representatives of the Federal Institute for Industrial Protection, the Federal Institute of Industrial Medicine and the various responsible vocational associations. The major safety concern in this document is to reduce the exposure of workers to micro-organisms (bacteria, fungus, viruses, etc.) that may cause diseases. With these concerns, as well as others, the German regulations for system design are more stringent than the ANSI Z245 report. Examples of the more stringent German regulations are listed below:

- **Tipping Floor.** In contrast with US standards, German regulations specifically do not allow personnel to sort materials in the tipping floor area. Tipping areas must be physically separated from sorting areas.
- **Mobile Equipment.** The operator's cabin should additionally include a filtering device or a pressurized air tanks system to ensure proper air quality.
- **Mechanical pre-sorting.** Trommels and vibrating screens should be enclosed and have dedicated dust collection and exhaust systems.
- **Sorting Stations.** Standing sorting positions from one side of the belt should be designed considering a reach of 0.6 m (23.6 in.). For sort stations picking from both sides of the belt, the maximum belt width should be 1 meter (39.4 in.). Sorting stations should be designed to be a combination of standing and sitting work stations. The belt speed should not exceed 10 meters/minute (32.8 fpm). Ventilation devices should be periodically checked for micro-organisms present in the air.
- **Hygienic Arrangements.** The clothing storage areas (lockers) for work clothing and street clothing should be separated by a washroom with showers. Break-rooms are to be accessed by going through wash facilities.

- **Physical Examinations.** An initial physical screening and follow up examinations should be performed in 12 or 24 month intervals in order to establish a history and a follow up of any changes in physical conditions. This information will be the basis for a better understanding of the potential long term and short term conditions caused by micro-organisms commonly present in recycling manually sorting environments.

What are Present Industry Practices? The RRT Example

The recycling industry growth in the recent years has diversified work conditions and technologies across the country. Many facilities will require extensive retrofits in order to comply with safety standards being developed today, in particular those that were not designed and integrated by a professional engineer. The ANSI Z245 Report will guide the MRF owners' systems engineer when determining upgrade requirements. Facilities designed to exceed the minimum health and safety standards will reward their owners by minimizing lost time accidents and reducing insurance premiums.

Industry safety practices can be classified into two categories: operational practices and system engineering practices. Compliance is achieved when both the operator and system engineer follow established requirements. "Potential Hazards Associated with Municipal Solid Waste Recycling" were well documented⁶ in 1991. As a leading systems engineer, RRT has been including in their designs since the early 1990's the safety features only now being enacted by ANSI. Four (4) examples of these features are highlighted below:

Comprehensive Control Systems. The layout of system controls at RRT facilities follow the NFPA 79 Electrical Standard for Industrial Machinery. The process system motor control enclosure (MCE) is housed in a UL inspected, NEMA 12 enclosure using standard IEC/NEMA components including a programmable logic control (PLC) and a modem for remote interfacing. In automatic mode the system sequentially starts equipment in a preprogrammed logic which prevents the feeding of stopped equipment. In the event of a failure occurrence, equipment upstream will be stopped. Upon restarting, equipment will start in sequence in automatic mode after sounding a safety horn. The panel is equipped with mimic status lights indicating process conditions including equipment, emergency stops and pull cord lanyards. The system has a manual mode of operation for maintenance and adjustment activities.

Operator control stations including start/stop buttons, variable speed potentiometers, and E-stops are provided at the sorting stations for local control. Sorting conveyors are equipped with safety lanyards. Additional safety switches are used on various equipment as necessary. Each motor is interfaced with the PLC to signal running equipment through the status of the disconnect. Knife-style disconnects including the capability for local safety lock-out are typically specified. In the event an emergency stop is pushed, all equipment in the process system shuts down. There are emergency stops strategically located throughout the facility for safety purposes. The corresponding E-stop light on the mimic board indicates the specific location of the affected area.

Restricted Pedestrians Access to Mobile Equipment Traffic Areas. In some facilities, materials are floor sorted at the baler infeed areas because elevated sorting platforms are not available, or in other cases pre-sorting of reject material is performed at the tipping floor because of the system design limitations. At RRT facilities, an elevated conveyor serving as an initial quality control station is provided where reject material is sorted and directed to a separate storage area.

Operations, Maintenance and Safety Manuals. Prior to the start-up of any new or modified recycling facility, RRT provides the owner/operator formal operation, maintenance and safety guidelines for the equipment. This includes both hands-on and classroom instructional programs in the following areas:

- Process flow and system operation
- Safety training
- Baler training
- Sorter operations
- Quality control
- Mobile equipment operations
- Maintenance and repair procedures
- Preventive maintenance training
- Housekeeping

Future employees are trained in order to comply with system safety standards, design throughput and quality specifications. RRT's safety training emphasizes the use of personal safety equipment and safety controls including restarting and troubleshooting system failures. Additionally, employees are trained to handle medical wastes and sharps that may have been erroneously disposed with the recyclable material.

Ergonomics Considerations. RRT's ergonomic considerations during the design of recycling sorting systems are intended to minimize risks associated with Repetitive Stress Injuries (RSI's). The main affected areas for MRF workers are the upper extremities and the back. Sorting conveyor design considerations propose to optimize posture and angular deflection of joints while reducing worker's exposure to vibration. As a result, optimum sorting conveyor width, height, side skirt height, chute positioning and dimensions have been determined. Operation parameters, such as sorting belt speed and average burden depth, are correlated to the infeed stream composition in order to determine an optimum presentation of materials. Additionally, sorting station design includes proper lighting and ventilation. Working under ergonomically correct standards promotes a healthy work environment, improves productivity rates and reduces operating costs.

A comparison of ANSI Z245, German and RRT sorting station design standards is presented in Table 1. Similar design standards among all sources were observed for factors as ventilation, illumination, working height, toe cut-out room and chute height. Differences were observed for sorting belt width, sorting belt speed and burden depth considerations. The observed regulatory agencies trend is the use of narrower, slower and more heavily loaded sorting belts. The potential adverse effect of the institution of these standards is the considerable increase of operation costs because of the lower productivity per worker.

- Belt widths recommended in the ANSI and German documents were rated at 60 to 80% of present industry practices. RRT standards are based on ergonomic design consideration in addition to extended time and motion studies⁷ in existing facilities. These case studies were oriented to define sort station design standards that maximize productivity by providing the most comfortable work station.
- The importance of setting appropriate burden depth levels should not be underestimated. Systems running at high burden depths offer a poor presentation of materials thereby increasing sorting difficulty. Determination of optimum burden depth depends on the type of material being sorted and the stream composition, e.g. the optimum burden depth for a residential fibers mix is different from a commingled containers stream.

- Belt speed considerations were only found in the German document as they are still being developed for the ANSI Z245 report. The recommended German sorting belt speed is 40% to 50% of RRT standards. RRT case studies indicate that for different composition streams sorting belt speeds should vary between 80 - 100 fpm. These higher speeds ease burden depths and have not been shown to be detrimental to the employee. As such ANSI Z245 does not limit speed of belt travel.
- RRT includes among its standards, chute design considerations depending on the material being sorted. Practical experience shows that “toss-across” chutes are more appropriate for commingled containers sorting lines, while “toss-to-the-side” chutes provide better ergonomics for paper lines.

During 1996, fifty sorting systems designed and built by miscellaneous companies around the nation were analyzed by RRT. Most of them presented one or more deficient ergonomic design or operating features which were reflected in lower sorting rates and higher work force requirements. Commingled containers sort rates were typically recorded to be below 75% of acceptable sorting standards and as low as 35%. Major ergonomic design considerations leading to poor ergonomic conditions were thick burden depth, low sorting belt heights and the use of floor sorting operations. All of these pose safety risks to the worker.

- Thick burden depth was observed because of poor engineering and in some cases lack of engineering. Sorters were frequently observed “rummaging” through or “digging” into the material instead of sorting.
- Low sorting belt heights were observed at facilities where sorting stations were added to existing baling systems. Low sorting belt height and high burden depth situations often occur simultaneously. These systems record the lowest productivity standards.
- Floor sorting operations are frequent for commercial fiber streams (old corrugated containers mixed with trash) when mechanical means of separation were not available.

CONCLUSIONS

Workers at recycling facilities do not appear to be exposed to health and safety hazards when they follow prescribed safety requirements and facilities are properly designed. The development of safety standards specific to the recycling industry will provide comprehensive safety coverage for the worker. ANSI Z245 addresses these issues clearly for the engineer and operator. The main improvement over current standards will be the optimization of employee work conditions by the integration of ergonomics, safety and health features. These improvements come with a cost and with the continuing increase in manual sorting costs, research and experimentation on mechanical sorting separation systems will be further stimulated. The technology of recycling facilities will also be further expanded through the extensive use of integrated logic controls including energy controls and alarm systems. Maintenance, employee training and housekeeping operations will become more important as their role in the prevention of health and safety risks becomes more explicit. Further research will be performed in order to obtain a better understanding of the health risks associated with micro-organisms exposure and ergonomic stressors in recycling operations. It is the opinion of the authors that future requirements will adopt the “good, generally accepted practices” already found in the German regulations. Certainly many of these measures will derive mixed views. Controversy with regard to the analysis for justification of cost versus savings will continue as the industry matures.

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Table 1. Sorting Station Design Standards¹

Parameters	ANSI Z245 Report version 2/10/97	German Regulations ³	RRT Design Standards
1. Ventilation	6 fresh air changes per hour 0.43 m ³ /minute-employee (15 cfm/employee) or		6 fresh air changes per hour
2. Illumination		500 lux (46.45 foot-candles/ft ²)	538 lux (50.00 foot-candles/ft ²)
3. Sorting Conveyor			
3.1 Sorting belt width			
a. Picking from one side of the belt	≤ 0.46 m (18 in.)	≤ 0.60 m (23.6 in.)	≤ 0.76 m (30 in.)
b. Picking from both sides of the belt	≤ 0.91 m (36 in.)	≤ 1.00 m (39.4 in.)	≤ 1.52 m (60 in.)
3.2 Sorting belt height	≥ 0.76 m (30 in.)		= 0.86 m (34 in.)
3.2 Side skirt height	≤ 0.26 m (10 in.)		0.10 - 0.15 m (4 - 6 in.)
3.3 Working height ²	≤ 1.02 m (40 in.)		
3.4 Toe cut-out	depth = 0.13 mm (5 in.) height = 0.13 mm (5 in.)		depth ≥ 0.13 mm (5 inches) ⁴ height ≥ 0.13 mm (5 inches)
3.4 Chutes height	loading side ≥ 0.76 m (30 in.) other sides ≥ 1.07 m (42 in.)		0.97 - 1.02 m (38 - 40 in.)
4. Sorting belt speed		10 m/min (32.8 fpm)	containers 18.3 - 30.5 m/min (60 - 100 fpm) paper 24.4 - 36.6 m/min (80 - 120 fpm)
5. System controls	E-stops at 1m (3 ft) from each work station		Lanyard and local control panel
6. Flooring	Slip resistant material		Diamond plating floors
7. Platforms	Guard rails, toe plates		Guard rails, toe plates. Chains are provided on all ladders.
7. Additional considerations		Sorting stations should be a combination of standing/sitting work. Padded belt frame.	Drop chutes have a "rolled" or "square" edge avoiding sharp edges to hurt employees

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¹ This table compares US ANSI standards (2/10/97), German LASI standards and RRT standards.

² Is equal to the conveyor belt height plus the side skirt height. If the working height exceeds the specified limit a riser should be provided.

³ As indicated in "Guidelines of Industrial Protection in Commodity Sorting Plants" 1995.

⁴ Conveyors legs are supported by platform steel avoiding the use of many legs. This provides spacious foot room underneath the conveyor and facilitates cleaning.