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CODE OF PRACTICE ON RADIATION PROTECTION IN THE MINING AND MILLING OF RADIOACTIVE ORES (1980)

GUIDELINES

STORAGE AND PACKAGING OF URANIUM CONCENTRATES

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Department of Arts, Heritage and Environment

Code of practice on radiation protection in the mining and milling of radioactive ores 1980.

First 1986 additional guideline

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INTRODUCTION

1. The Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores (1980) applies to:

> "a mill for the production of ore concentrates or intermediate products that contain at any stage of milling greater than 0.05 percent by weight of uranium or greater than 0.05 percent by weight of thorium".

2. This guideline is concerned only with uranium concentrates and not thorium concentrates. Uranium concentrates produced for sale will contain more than 0.05 percent by weight of uranium at the stage of storage and packaging for shipment and consequently fall within the application of the above Code.

3. The purpose of this guideline is to provide information relevant to the design, construction and operation of a uranium concentrate storage and packaging facility in which exposure to ionising radiation from uranium bearing concentrate will not only conform to the above Code, but will also be as low as reasonably achievable (the ALARA principle).

HEALTH HAZARDS

4. Concentrates from uranium milling may present both radiation and chemical hazards arising from:

gamma radiation - Health risks arising from gamma radiation in packaging areas can be minimised by good housekeeping aimed at preventing accumulation of concentrates. Gamma radiation levels in the vicinity of bulk concentrates may be of the order of 10-100 $\mu Gy.h^{-1}$ and such areas will be classified according to the requirements of the Code.

uranium concentrates - Where concentrates are unconfined there is the possibility of their inhalation or ingestion. Soluble uranium is chemically toxic and may cause kidney damage. The derived limits of soluble uranium concentration in air presented in the Code reflect this hazard. The limits of concentration in air of insoluble uranium, however, are based on the possible radiation exposure of lung tissue from inhalation of the concentrates. Dust in the atmosphere of the storage and packaging facility represents the greatest hazard and is difficult to control. The dust will contain U238, U234 and U235 and may contain small amounts of Th230 and Ra226. The potential health hazard of this dust will depend upon the radionuclide mixture, particle size and solubilities in body fluids.

radon and radon daughters - Good ventilation in the packaging area will minimise the risk to personnel.

EXPOSURE LIMITS

5. Schedules 1 and 2 of the Code specify limits for the exposure to radiation of designated employees, employees other than designated employees and members of the public. The limits are set to ensure that the health risk to people is not greater than that level considered "acceptable" in other safe industries.

DERIVED LIMITS

6. From the exposure limits, derived limits are calculated for the concentration in air and water of various radionuclides in both soluble and insoluble form. The derived limits, which are also set out in the Code, provide practical guidance for the operational situation. For uranium concentrate storage and packaging areas, airborne uranium concentrate dust is potentially the most significant form of contamination and source of radiation exposure, and thus the most significant derived limit for such facilities is the derived air concentration (DAC). The DAC is defined as that concentration of radioactive material in air which, if inhaled by a designated employee continuously for 40 hours per week over 50 weeks, would give that employee either the annual committed effective dose equivalent limit to the whole body or the committed dose equivalent to a single organ.

7. The radiation dose received by a designated employee by breathing contaminated air depends on such factors as the radionuclides present, the solubility of the inhaled material in body fluids, and dust particle size distribution. These factors should be taken into account when calculating the site specific derived limit for air contamination. At the design stage the site specific derived limit will not be known, though it may be estimated using worst case assumptions or pilot plant test work. It would therefore be advantageous to ensure that data obtained from a pilot plant includes such information as product particle size, product solubility and percentage of thorium and radium content in the product.

8. The derived limits are not in themselves regulatory standards which may not be exceeded. They are an aid to management for use during the operational phase; values higher than the derived limits indicate that the overall control system is failing to meet its objectives, and that action is required by management to rectify the situation. Designated employees working in an area where the derived limits are exceeded will not necessarily exceed annual dose equivalent limits.

PERSONAL DUST SAMPLERS AND RESPIRATORY PROTECTION

9. The level of uranium dust in the atmosphere of the packaging facility will vary with time and from place to place, and the number of hours per week spent in that environment by a designated employee will also vary. It is therefore not possible to estimate accurately an employee's exposure level from measurements of air contamination made in the general vicinity. Adequate estimates and assessment of material inhaled may only be obtained by the use of personal air sampling equipment, which will collect contamination from the ambient air in the workers' breathing zone. Knowledge of the amount of contamination collected, the flow rate of the sampling pump, the amount of air breathed by the worker, and the protection factor of any respiratory protection used will allow the amount of material inhaled and hence the committed dose to be calculated.

USE OF RESPIRATORY PROTECTION

10. The design of the mill should be such that the processes of final drying, packaging and sampling of uranium concentrates are isolated, and are automated to the extent necessary to avoid the need to wear respirators or protective clothing routinely. Nevertheless, during initial operations in the packaging facility it may be necessary to protect employees by the use of respirators until dust levels are demonstrated to be consistently below relevant limits. Routine dependence on the use of respiratory protection is discouraged as the degree of protection afforded cannot be guaranteed, notwithstanding that respirators are available with protection factors of up to 1000, because specialised attention is required to ensure that respirators are properly maintained and worn, and because discomfort discourages their continuous use. In practical terms this would be achieved when it can be demonstrated from monitoring records that airborne concentration levels are consistently below about 30 percent of the derived limit. Thus the keeping of detailed and comprehensive records from commencement of operation is desirable. Where respirators are required they should be properly maintained, employees should be trained in their correct fitting and use, and management should ensure that appropriate procedures are adhered to.

11. The highest airborne concentration levels are usually encountered during maintenance and repair work, and generally it is not possible to predict exactly what these levels will be. Thus maintenance workers carrying out repairs on items of equipment which could, under any circumstances, release additional radioactive dust into the air should wear respirators or have other respiratory protection. Similarly, respiratory protection should be used by any other employees necessarily present in the area whilst maintenance work is in progress. (See the guideline "Personal Respiratory Protection" for details.)

12. Good protection for maintenance workers can be obtained by the use of supplied air respirators. Where a reticulated air supply exists (e.g. for tools used for tightening ring clamp bolts) this air supply, when filtered to remove oil mist etc, and if necessary humidified, should be suitable for personal use. Hence in the design stage consideration should be given to the number of air take-offs in each area. In particular one air point should be provided near the drum filling enclosure and another in the vicinity of the rotary feed valve; provision of other air points would depend on the final layout design.

WORK PERMIT SYSTEM

13. A work permit system is a useful managerial tool for ensuring compliance with specified protection procedures. The simplest form of system involves routing of written requests for maintenance work from the operations section through the Radiation Safety Officer, who can ensure that the necessary planning work takes place and that all radiation protection procedures are adhered to.

14. An informal system of calling in maintenance workers on an ad hoc basis by telephone or radio should be actively discouraged. However good the overall design of the packaging and storage facility, only continuous and visible managerial control will achieve the lowest employee exposure levels.

ACCESS TO CONTROLLED AREAS

15. Access to the precipitation, drying, storage and packing facility should be restricted to those employees, maintenance workers and supervisors necessary for the operation of the plant. Plant security considerations may also warrant the limitation of access in larger plants. An efficient way of ensuring that access is restricted is by the use of key cards, which has the additional advantage that through linkage to the mill computer details of individuals' time spent within the area can be tabulated.

16. To prevent contamination being spread outside the controlled area by the movement of personnel, consideration should be given to a separate change room facility specifically for access to the controlled area; soiled clothing should be bagged and directed either to a central laundry facility or, in the case of badly contaminated clothing, disposed of in accordance with the Code of Practice on the Management of Radioactive Wastes from the Mining and Milling of Radioactive Ores (1982). (See guideline "Decommissioning and Rehabilitation of Uranium Mine, Mill and Waste Disposal Sites".)

17. Separate areas outside of the packaging area are required for eating, drinking and smoking. Monitoring facilities should be provided at the entrance to such areas so that hands and clothing may be checked for contamination before entry. (See guideline "Meal/Smoking Areas and Personal Hygiene Facilities".)

18. To prevent radioactive dust entering the control room from the operational area, the control room should be supplied with ducted clean air and kept at a positive pressure.

ENGINEERING DESIGN

19. The potential problems associated with dust generation and removal within uranium packaging areas should be minimised by appropriate engineering design. A typical facility within the controlled area will provide for the following activities:

- precipitation of a uranium concentrate;
- washing of the precipitate;
- drying or calcining the precipitate;
- lump breaking;
- intermediate concentrate storage;
- packaging of concentrate;
- sampling of concentrate for analysis;
- weighing and metallurgical accounting;
- storage of packaged concentrate; and
- lidding.

20. From a physical standpoint, the storage and packaging facility comprises that part of the mill which handles the production process from intermediate storage of the dried or calcined uranium concentrate to storage of the packaged product.

21. The distances between the individual component elements of a plant should be minimised so as to restrict the distance through which dried concentrate needs to be moved and thus the opportunities for release of dust to the packaging area environment. Optimum use should be made of gravity flows since other methods of movement of the concentrate involve equipment, which from time to time will require maintenance and consequent release of concentrate dust at that time. Obviously individual items of plant should not be so close together as to make service and repair operations difficult. (For example, whilst it may be efficient to place the drier and intermediate storage bin at the same level, and move the concentrate from drier to bin by, say, a bucket elevator, adherence to the ALARA principle and best practicable technology may require placing the drier above the storage bin and gravity feeding through a simple chute (Figure 1)).

DUST COLLECTION SYSTEMS

22. Dust loadings on the dust collection systems should be considered during the design of the plant with a view to minimising loadings and the proportion of fine grained particles in the mill product which may give rise to dust.

23. The use of separate duct registers to ensure that airborne dust is captured close to its source is recommended. Thus, for example, the filling, sampling and lidding stations should have individual extract registers. By using slotted take-offs at relevant places in the plant, it should be possible to reduce overall air flows in the plant and subsequently allow smaller scrubbers to be used.

24. It may be preferable for venturi wet scrubbers to be used, rather than bag house scrubbers, in the dust collection systems because of the former's better control of dust emissions, the elimination of problems arising from bag splittings and leakages, and the absence of a dry product; the latter advantage means that maintenance workers do not come into contact with a dry product which would be the case if a bag house scrubber was used.

25. The performances of the dust collection systems should be monitored by sampling the stack emissions regularly by an approved method throughout the life of the plant. During and shortly after commissioning the plant, frequently taken, and sufficient, samples of stack emissions should be used to determine the performance of the dust collection systems and to ascertain if the systems need to be modified to meet performance criteria. Good access to stacks, complete with suitable working platforms, should be recognised as being required during the design stage and subsequently provided. Two sample ports, located two to three metres below the top of each stack, several stack diameters downstream of the nearest bend and at right angles to each other, should be provided.

26. The plant's computer alarm system should be designed to detect failure of the dust collection systems and triggered by relevant significant changes in the plant's process parameters, such as fan current, water flow and water pressure.

27. It is desirable for the intermediate storage bin not to be integrated with dust collection systems set up for the packaging and drum filling facility and for it to be vented only through the drier. This should reduce the gas flow required for scrubbing and, subsequently, lead to reductions in the scrubbers' dust loads.

28. Any device that increases the amount of fines in the concentrate will increase dust loadings and the dust problem in general. Whilst it is necessary to interpose some form of lump breaker between the drier and the storage bin, devices such as hammer mills should be avoided.

STORAGE BIN

29. The storage bin should be provided with a high level detector to prevent overfilling and backing up of the concentrate into the lump breaker. A high temperature admittance type level detector rated to 750°C would be suitable for a calcined ammonium diuranate product and lower temperature ratings would be suitable for drying applications.

30. Sticking (hang-up) of concentrate in the storage bin has been a problem from time to time in existing plants and may be largely avoided by the use of a live bottom bin. Gravity flow of concentrate from the storage bin to the product drum is preferred. Offsetting the drum filling station with respect to the storage bin and moving the concentrate by, for example, a screw feeder, only serves to increase the maintenance requirement of the facility and adds further to the points from which dust may escape. Where a rotary feeder is used to control material flow from the storage bin to the drum filling feed spout, it will require some maintenance and will at some stage have to be removed. For this reason a manually operated knife gate valve should be fitted above the rotary feeder to minimise the release of concentrate when removing the feeder from its location. Correct planning and the use of respirators should ensure negligible exposure of individual maintenance workers during this type of operation.

31. As mentioned above (see para 21), the distance travelled by the concentrate should be minimised, while allowing ease of access for maintenance. Cramped conditions should be avoided as these will inevitably lead to poor work practices and a consequent lowering of standards.

CONCENTRATE SAMPLING

32. Samples of concentrate are required for the purpose of metallurgical accounting, reconciliation with the convertors, etc. Samples must be representative of the concentrate as a whole, and cutting a falling stream of material offers the best possibility of achieving this. It is common in the uranium milling industry to take samples of concentrate by augers from the full product drum or even by means of a scoop from the top of a drum. Such methods are undesirable sampling procedures and may be the cause of avoidable dust emission. Preferably samples should be taken from the stream of material falling from the storage bin discharge. An automatic sampler installed at this position should provide reliable samples and may be a completely sealed unit so as to eliminate dust problems. Samples should be directed down to suitable sample bottles through a delivery tube without bends or internal surfaces likely to cause blockages. The sample bottles, one for each drum filled, should be located on a bench provided with dust extraction within the drum filling enclosure. The bottles should be large enough to easily accommodate the sample of each drum, and they should be fitted

with a secure, air tight top. As a calcined product may sometimes be packaged hot, plastic bottles may not be suitable. Where the concentrate is to be sold in 'lots' comprising, say, 30 drums, consideration should be given to the provision of a 'lot' sample rather than individual drum samples. This would reduce the handling time of sampling containers to about 1/30th of that required for individual drum sampling. A larger sampler bottle should reduce the dust problem by permitting the use of a slot type dust collection take off to concentrate dust at the point at which dust arises i.e. the mouth of the sample bottle.

DRUM FILLING VENTILATION

33. As the concentrate falls into the product drum, air is displaced carrying with it some of the fine concentrate produced as an inherent part of the milling process. These fines are removed to the packaging area dust collection system by a dust hood which has been lowered onto the drum before filling commences. The raising and lowering of the hood should be an automatic part of the drum filling sequence. The movement of the filling spout and hood should be directly up and down, with positioning being accomplished by moving the drum rather than the hood.

34. Several designs of filling hoods are available but an Eldorado type is preferred (Figure 2). This unit draws air from around the drum which can result in the lip retaining a certain amount of dust. An example of a drum filling system using a smaller filling hole and hood is shown in Figure 3. The use of smaller holes permits automatic crimping of caps.

FILLING SEQUENCE

35. A concentrate filling sequence has a number of elements:

- tare weighing of drums complete with lids;
- labelling of drums, lids and sampling bottles;
- placement of drums on motorised roller conveyor, and the sample bottle in the holder;
- roller conveyor starts and moves the drums around to the filling enclosure and locates the first drum in position;
- confirmation of drums and sample bottle in position allows the feed spout and hood to move down to the drum level;
- confirmation of hood in position starts the rotary feeder and storage bin activator;
- feeder stops at first pre-determined weight setting;
- vibrator is raised and the drum vibrated for set period;
- vibrator is lowered and feed recommences;
- feed stops at second pre-determined weight setting;
- vibration sequence repeats;
- feed recommences to complete fill; and
- feed stops and the hood is raised.

36. The employee could be absent from the filling enclosure during the filling of each drum, and could return to replace the sample bottle before initiating the filling of the next drum. The transfer of the full drum from the lidding station through the wash station to the weigh station could be initiated separately from the control panel.

37. This sequence reflects the fact that part way through the drum filling process - for example, once 200 kg had been loaded - it may be necessary to vibrate the drum to pack down the concentrate. This would entail filling the drum on a load cell platform until the pre-determined weight was reached when drum filling would cease and a vibrator would be raised through the platform to make contact with the under side of the drum. It is probable that relatively more rapid compaction will result from the bars of the vibrator making direct contact with the bottom of the drum. It may be found in practice that drum vibration is required at two stages of filling and this may be incorporated into the program. Pneumatically operated vibration units are generally more reliable than electric units, but whichever weighing and vibration units are selected, allowance should be made for access and maintenance. As the act of drum filling creates the possibility of concentrate spillage at this point, the use of a pit which would make cleaning more difficult should be avoided. The units should be placed at floor level and the height of the motorised roller conveyor raised accordingly.

38. Correct location of the empty drum at the filling station is an important part of the drum filling sequence and is easily automated by the use of limit switches or photo-electric cells. The incorporation of a motorised roller conveyor can enable empty drums to be moved into the filling enclosure and correctly positioned as a part of the overall automated drum filling sequence.

39. Drums of concentrate may be filled to a weight or to a level. In the case of filling to a weight, the load cell system mentioned above may be utilised to stop drum filling when a set weight is reached. (The precise tare and gross weighings take place outside the drum filling enclosure.) Whichever full drum limit is chosen, some instrumentation should be provided to prevent accidental overfilling. A simple device which has been used successfully in North America consists of a nitrile rubber air tube running through the dust hood and extending down into the top of the drum. When the concentrate level reaches the nitrile tube the small back-pressure which is created triggers a micro-switch and stops the rotary feed valve via a relay. A more sophisticated alternative could be a radioactive level gauge, which has also been used successfully in North America. This type of device could be used for drum filling to a pre-set level with the air tube used as a backup.

POST FILLING OPERATIONS

40. Following completion of the drum filling sequence, the full drum should be moved and located at the lidding station at the same time as the next empty drum is located at the filling station. Drum lidding could also be automated but this would be costly. With care the lidding operation need not be a processing area for undue concern. Clamping the drum automatically against sudden movement and providing good dust collection venting around the drum lip at either side of the roller conveyor should ensure that dust escaping from the top of the drum is removed safely. An air tool may be used to ensure satisfactory tightening of the lid ring clamp bolt.

41. After washing if necessary, the full drum may be transferred by a motorised roller conveyor to the weigh station for final gross weighing. The weigh station should be automated in a manner designed to limit time spent by employees near the drums as a means of enhancing radiation protection. The weigh scale forms part of this automated system, retaining within a memory information for production quality control, transport requirements and weigh tickets. Some weigh scales print tickets containing the above information for each drum. Three copies, showing the drum tare weight and the drum identification number, should be printed on labels to be affixed one apiece to the drum, drum lid and sample bottle. Self adhesive labels are recommended as they can be rapidly attached to drums and avoid the need to lick gum labels.

INTERLOCKS

42. Various instrumentation interlocks should be built into the above system to prevent drum filling unless the following conditions are satisfied:

- packaging area ventilation systems are operating;
- drum and hood are in position;
- drum weight below maximum;
- concentrate in drum below maximum level;
- sample bottle in position; and
- dust collection system parameters are normal.

These interlocks should be tested periodically.

TYPICAL LAYOUT

43. A typical packaging area layout is shown in Figure 4. The system has been automated as suggested above to be operated by only one employee who spends a limited time per shift within the filling enclosure. Access to the filling enclosure could be by key card, automatically recording the time spent there for the calculation of the employee's integrated exposure. With a drum filling cycle of 15 minutes, one employee should be able to handle the packaging of 10 tonnes of concentrate per eight hour working day.

AREA CLEANING

44. By separate enclosure of the actual filling station the balance of the packaging area becomes a relatively clean area within the context of a uranium milling operation. The filling enclosure should be operated under a slight negative pressure to preclude the egress of dust. A central vacuum cleaning system is often built into the dryer/calciner area and when present should be extended down into the filling enclosure. Alternatively, a vacuum cleaner should be available for use in that area to cater for any spillage that may occur. This cleaner should be provided with good exhaust filtration to avoid spreading the contamination over an even greater area.

45. The whole of the packaging area should be designed to limit the possibility of dust build up and to permit easy wash down. To assist in identifying dust build-up, the colour of the paint work should contrast to that of the dust. Horizontal surfaces should be avoided wherever possible and pipework, cable runs, etc. should be enclosed within smooth walls. All electrical and instrumentation equipment should be housed to a standard that will allow hose down, and a regular end-of-shift hose down of the entire area should largely prevent the accumulation of radioactive dust.

46. Consistent with the need to regularly hose down the area, floors should have a smooth finish and be adequately sloped to a single sump pump. Floor drains and channels should not be used as material will tend to accumulate in them.

CONCENTRATE STORAGE AREAS

47. The storage area for drums of concentrate should adjoin the packaging facility. This limits the distance that the drums will have to be moved and contributes to minimising possible radiation exposure to personnel other than the designated employees in the event that concentrate escapes from damaged drums. It also limits the distance that escaped concentrate will have to be moved to be re-introduced into the processing facility. In order to minimize spillages of concentrate from damaged drums, drum handling machinery should have orthodox drum clamps rather than forklift tynes.

48. Where the storage area is adjacent to other operational areas, the storage area should be at least 3 metres from these other areas where they are outside of buildings. For indoor operations, walls of buildings between other operations and the storage area may provide adequate shielding from radiation for employees.

49. Storage area floors should be sloped to assist washdowns to a single sump.

METALLURGICAL DESIGN

50. A relationship exists between product particle size and crystal size formed during precipitation. To limit the production of fines within the dried concentrate (which may readily become airborne), crystal growth should be optimised, and this is best achieved with a two stage precipitation process than with a single stage process. During operation, control of the precipitation variables such as pH, temperature and agitation should be given close attention to ensure optimum conditions for crystal growth.

51. As particle size at precipitation has an important bearing on final product sizing, it may be advantageous at the design stage to consider alternative methods of precipitation. One method which promises a very much coarser precipitate is fluidised bed precipitation. It has been claimed that the reaction efficiency is increased with lower reaction times leading to smaller plant and lower capital costs. It is thought that this method may be applicable to the precipitation of ammonium diuranate (ADU): it has been successfully tried with sodium diuranate and uranyl peroxide. In the latter case a very coarse and pure product results which requires only drying rather than calcining and crushing as is currently the Australian practice for ADU. The cost reductions resulting from the production of a 93% pure product through the adaption of fluidised bed precipitation to ADU production versus 97% pure product in the case of calcined ADU would have to be balanced against the increased shipping costs. However, drying a coarse granular product at 150°C offers benefits in terms of radiation exposure levels and cost when compared with high temperature calcining of a finer product. In any specific uranium mill, economic and feasibility studies may or may not favour fluidised precipitation, but the process should be examined to provide an indication of the cost compared with the environmental benefits expected.

REFERENCES

52. The following references should also be consulted:

1. Guideline: "Personal Respiratory Protection". Guideline to the Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores (1980), AGPS, 1983.

2. Guideline: "Decommissioning and Rehabilitation of Uranium Mine, Mill and Waste Disposal Sites". Guideline to the Code of Practice on the Management of Radioactive Wastes from the Mining and Milling of Radioactive Ores (1982), to be published by AGPS.

3. Guideline: "Meal/Smoking Areas and Personal Hygiene Facilities". Guideline to the Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores (1980), AGPS, 1981.

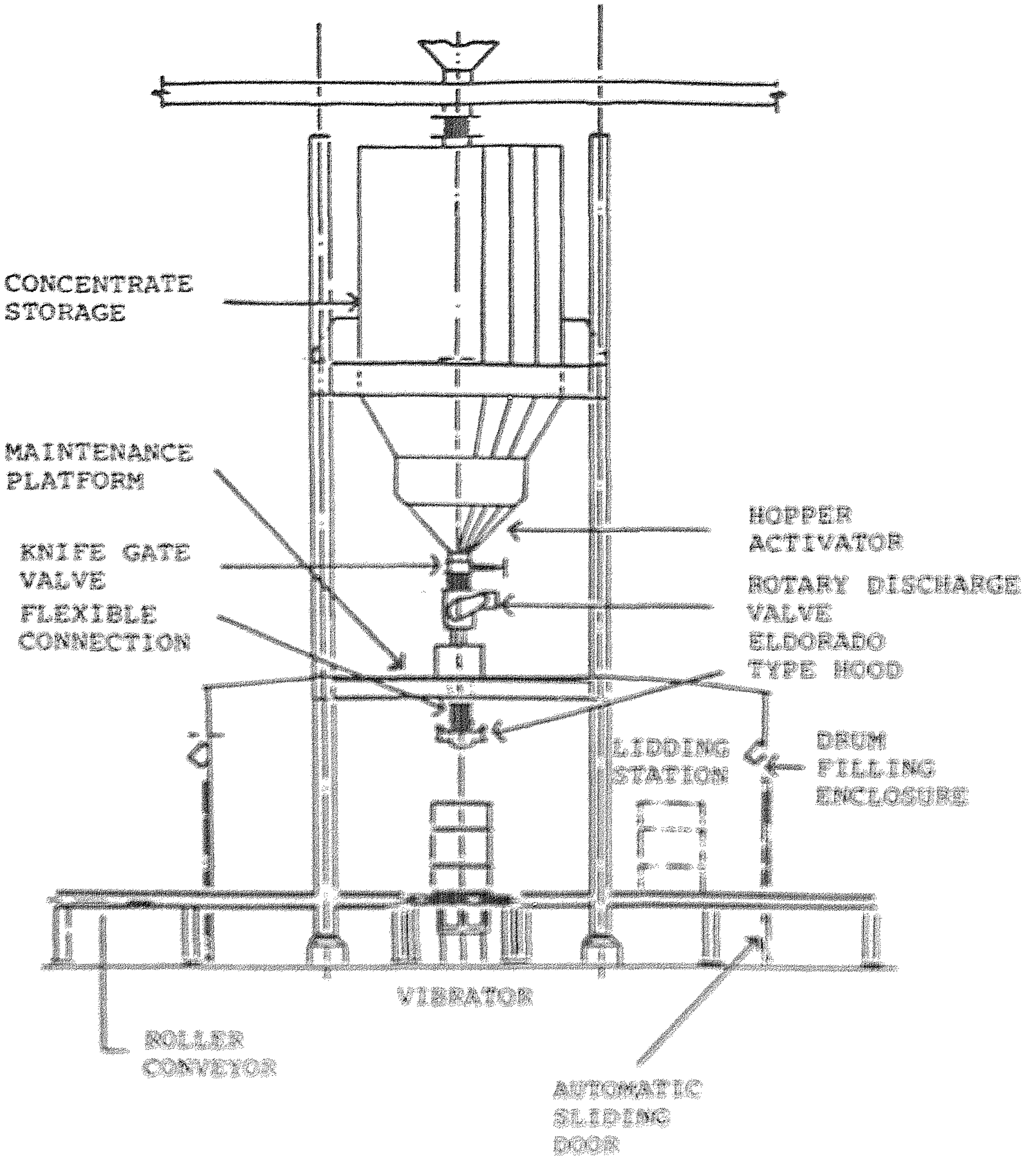

FIGURE 1: ELEVATION FOR PACKAGING AREA

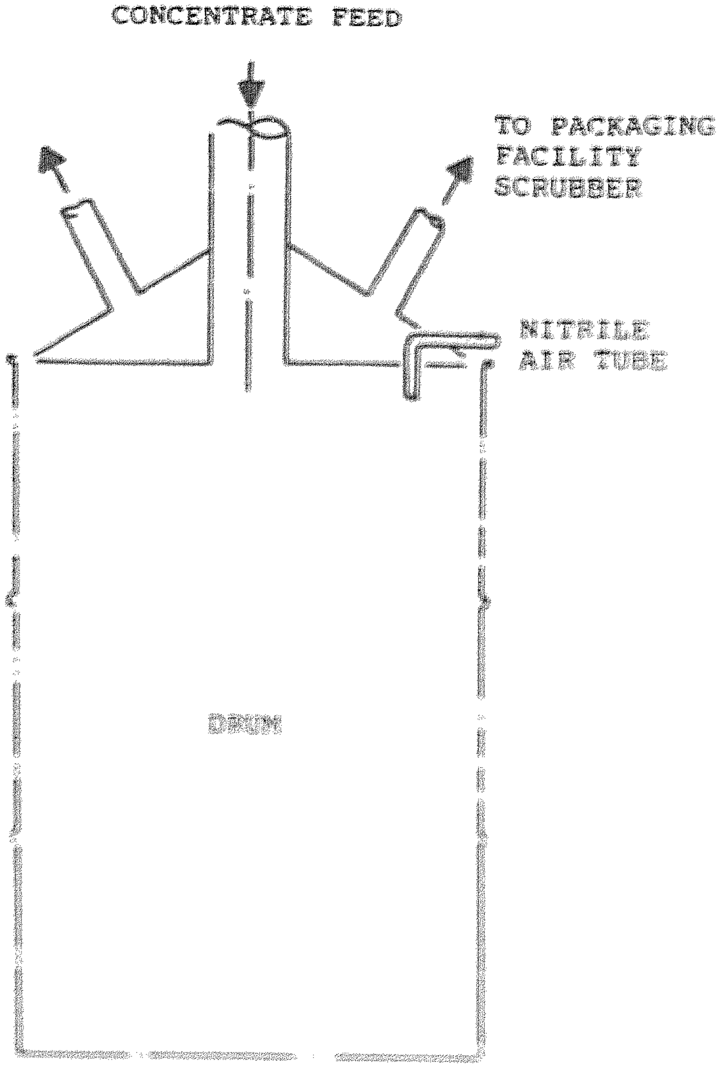

FIGURE 2: ELDORADO DUST HOOD

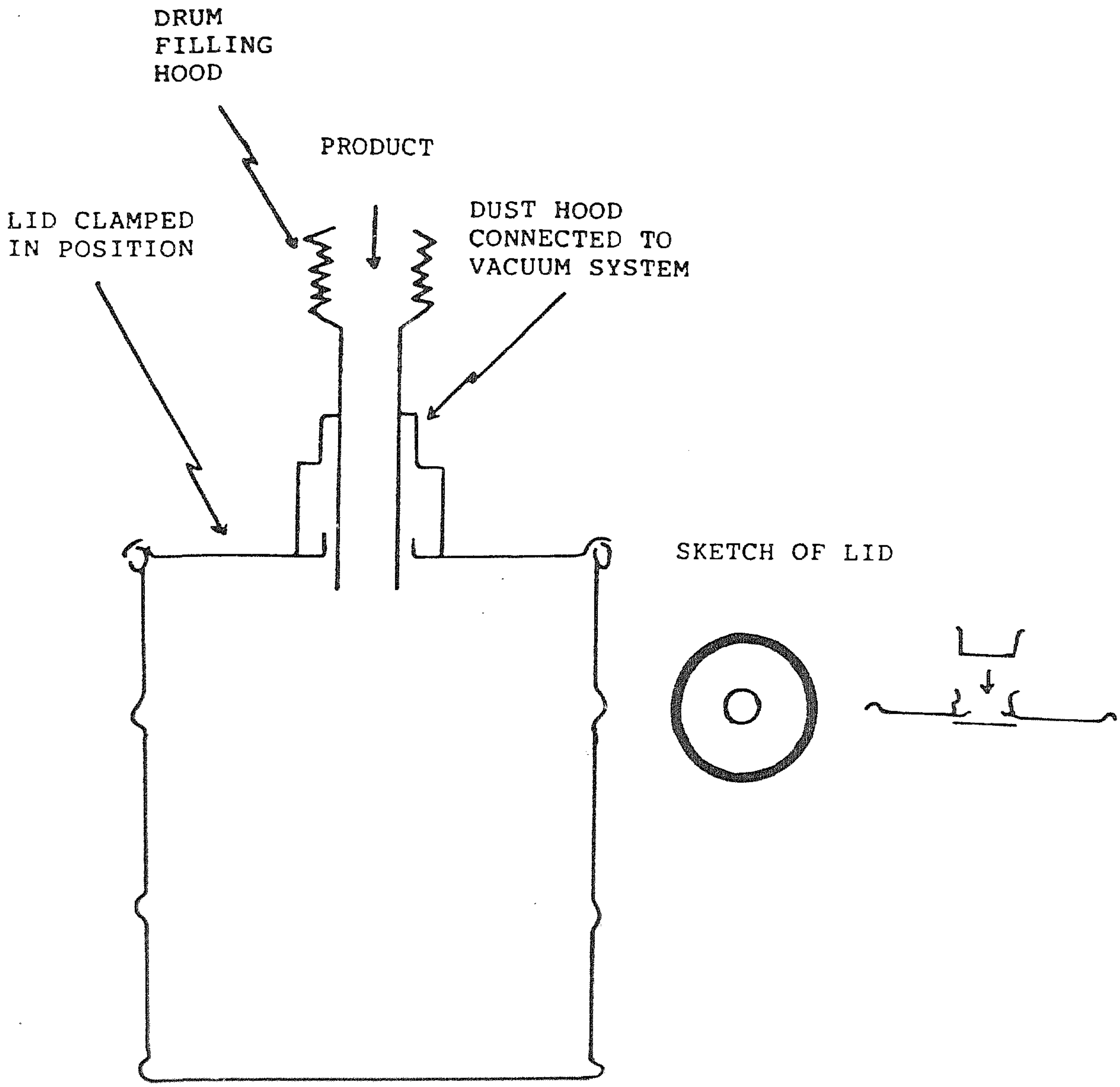

FIGURE 3: LIDS FOR AUTOMATIC CAPPING

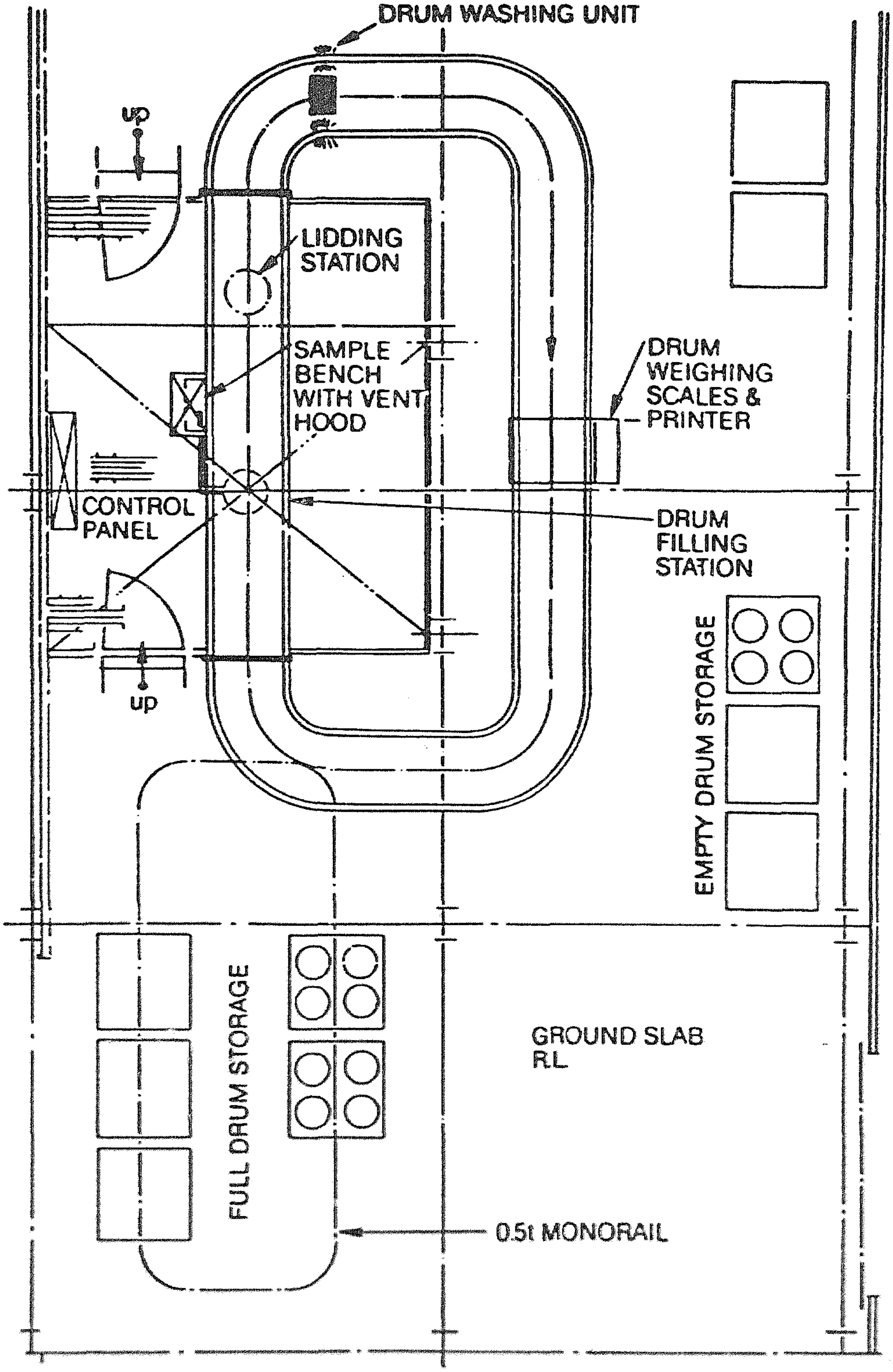

FIGURE 4: TYPICAL LAYOUT OF A PACKAGING AREA