

Chapter **33**

The Design of Seed Banks



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Summary

The design of seed banks centres on the provision of effective drying facilities for seed collections and, once dried and packaged, their maintenance at cool temperatures. Designs range from the very simple (using local materials and near-ambient conditions) through to those involving greater technological and hence, financial, input. As long as desired storage objectives are met, both can play a major role in conservation and utilisation. Associated facilities, such as those concerned with seed cleaning, germination, characterisation, evaluation and regeneration, are similarly determined by the goals of each programme.

The technology available to those embarking upon a programme of seed conservation is discussed. Some of the factors that need to be considered before choosing a particular design are also highlighted. Examples are drawn from a number of seed banks of different design, scale of operation and primary objective.

Introduction

Seed storage technology is nothing new. The ability to store seeds from year to year and hence select and save superior crop material is closely linked with the rise of civilisation. However, for the past fifty or so years technology has, for many species, increased seed longevity to decades and potentially centuries. This improvement has allowed the long-term conservation within seed gene banks of crop genetic resources displaced by more intensive agriculture (Plucknett *et al.*, 1987). There are estimated to be nearly 400 such germplasm collections maintained under medium- to long-term conditions (FAO, 1996). The approach is now being applied by botanical institutes to a wider range of plant species (see for instance, Smith *et al.*, 1998). Some 150 botanic gardens have some form of seed bank (FAO, 1996). In summary, seed banks offer the most effective form of *ex situ* conservation for plant species bearing desiccation-tolerant seed. At their most simple, seed banking procedures (see Linington & Pritchard, 2001) are shown in Figure 33.1.

The two key stages that influence seed bank design are drying and storage. Reasonably effective seed conservation can take place with very elementary techniques and equipment, such as silica gel drying and storage in domestic refrigerators. However, where greater certainty of long-term conservation is required or where manpower is limiting and accession intake is of sufficient scale, greater emphasis is placed on the use of low humidity drying rooms and (walk-in) freezers. Due to their widespread use, particular consideration is given here to the sizing and equipping of drying rooms and freezers. Consideration is also given to the cost implications of adopting particular designs. Although drying and freezing are of paramount importance,

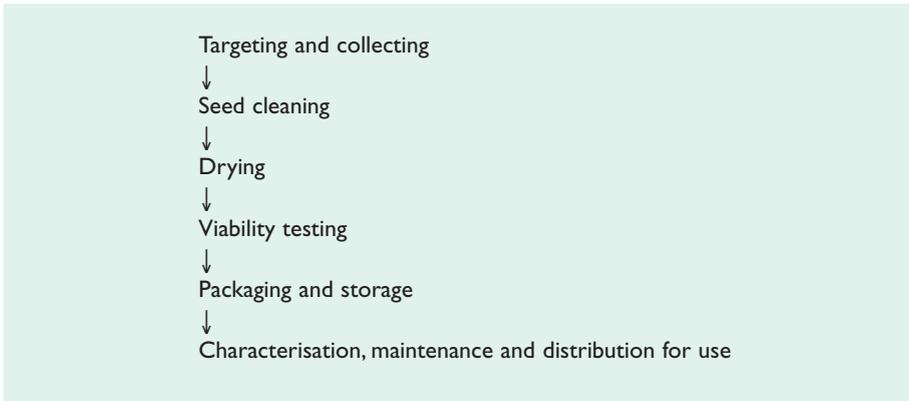


Figure 33.1 Basic seed bank procedures.

consideration must be given to the other elements of the banking procedure as they both influence the drying and freezing requirements and are integral to the overall design with implications to staff, facilities and equipment.

The facilities and storage conditions required to meet internationally accepted standards were set out in 1994 by the FAO/IPGRI Genebank Standards (see Box 33.1). Slight upward modification of the drying relative humidity has been suggested (see Buitink and Hoekstra, 2003 – Chapter 37). Otherwise, the standards are widely accepted and these strongly influence bank design.

Seed bank collections may be partitioned such that some of the seed of each collection is placed into a long-term ‘base’ store and some into a short- or medium-term ‘active’ store. A key aim of seed banks is to act as a concentrated source of intra-specific and, increasingly, inter-specific plant diversity. This diversity needs an added level of protection and consequently, a part of each collection should find its way into a duplicate store at a site well away from the main bank. The base stores hold seeds as a security measure and, usually, no material is distributed from them. Active stores release seed to users and are often (though not always) maintained at less than optimal storage conditions. For instance, they may be slightly warmer allowing more comfortable access. The relationships between base and active stores are many and varied. They can occur within the same building or, as in the case of the Southern African Development Co-operation genetic resources network, they can comprise a set of national active facilities and a regional base facility.

In this chapter, a certain emphasis has been placed on facilities to conserve wild species. While a few new crop and forestry seed banks will yet be established, a recent trend in seed conservation has been the development of banks for wild species. Most of these are currently small-scale operations. However, with the gauntlet thrown down by the Convention on Biological Diversity, these activities will expand as nations meet targets laid down in

Box 33.1 Key elements of the Genebank Standards (FAO/IPGRI, 1994) that are relevant to seed bank design

- Seeds should be maintained under best possible conditions before storage.
- There is no benefit in chemically treating seeds during storage.
- Preferred drying is at 10–25°C and 10–15% relative humidity.
- The collection should be clean and free from weed seeds, pests and diseases.
- A sealed moisture-proof container that is tested regularly for its sealing should be used.
- Preferred storage conditions are -18°C or cooler with 3–7% moisture content.
- Preferred base collection size is 1,500–2,000 viable seeds.
- Accession viability should be monitored at 5–10 year intervals using 200 seeds for the initial test and drawn at random from the collection. Subsequent tests should use 50–100 seeds.
- Initial germination should exceed 85% for most species e.g., cereals but 75% for some vegetables; even lower is possible for some wild species.
- Regeneration should be undertaken when viability falls to 85% of the initial value.
- It is desirable to use 100 or more plants for regeneration.
- Seeds used for regeneration should be as close as possible genetically to the original germplasm.
- Data on any accession should be as complete as possible.
- Seed should be sent out for exchange in suitable containers, with adequate information and germination methods; the sample should be genetically representative of the accession; seed health requirements must be satisfied.
- Every effort must be made to ensure the safety and security of the collections through adequate construction, maintenance and security controls of the installation. Of particular importance are considerations of power supply, fire precautions, security, refrigeration standards & equipment, construction & installation, and personnel safety.

national biodiversity action plans. Fortunately, the conventional long-term storage techniques appear to be more-or-less universal for all mature seeds of orthodox-seeded species.

Few texts cover the practicalities of seed bank design and most of these are now quite old, no longer in print or with limited coverage (Justice and Bass, 1978, Hendriks and Meerman, 1981, IBPGR, 1985, Cromarty *et al.*, 1990, Wieland, 1995, Schmidt, 2000). Although relatively little has changed in the basic technology, this chapter attempts to provide an update and one that is helpful to those without an engineering background. It is based on the experience gained by RBG Kew staff spanning nearly 30 years and involving the development and operation of four successive seed banks. While most seed bank installations will need expert local engineering advice, it is important that seed conservation scientists commissioning such work understand the basic principles if they are to help guide the design. It is also important to note that a well argued design increases the likelihood of it being funded.

Key Considerations before Designing a Seed Bank

The key considerations are laid out in Table 33.1 and in the approximate order that they must be considered.

Box 33.2 Comments about information presented in Table 33.1

The references indicated in Table 33.1 are as follows:

- a) Hong *et al.* (1998). This contains information on nearly 7,000 species, a summary of the seed storage literature, many relevant references and information on the predictive seed viability equations.
- b) National and regional floras – see Prendergast (1995).
- c) See for instance, East (1940) and Fryxell (1957).
- d) Cromarty *et al.* (1990). Note that they suggest that the thousand seed volume (cm^3) might be derived by multiplying the thousand seed weight (g) by a factor of between 1.2 and 1.5. The volume occupied by uncleaned seed heads needs to be determined empirically. However, thousand seed volume as a percentage of total uncleaned matter containing those seeds probably most often lies in the range 2–30%. A more extensive set of data on seed weights is to be found in the Seed Information Database (see Bone *et al.*, 2003 – Chapter 18). Furthermore, reference to some 4,200 collections of wild species held in the Millennium Seed Bank suggest that thousand seed weights are distributed:

≤ 1 g	28%
1–10 g	36%
≥ 10 g	36%
- The average thousand seed weight is 23.7 g and the median value is 1.96 g.
- e) Eckey (1954).
- f) Ellis *et al.* (1985) and Baskin and Baskin (1998).
- g) Meteorological tables. These are widely available as is information on the internet.
- h) See for instance Moss and Guarino (1995) and Hawkes *et al.* (2000)

Table 33.1 Basic questions to be asked having targeted a set of species for conservation (see Box 33.2 for comments)

Aspect	Questions	Source of information/ relevant questions ^{reference}	Implication to design
(A) Target species	For species (x, y, z...): 1. Seed storage type? 2. Conservation ± despatch to users? 3. National, regional or world status? 4. Ecology? 5. Breeding system? 6. Fruiting phenology? 7. Seed head/fruit type? 8. Fecundity? 9. Seed size? 10. Seed oil content? 11. Seed maturation moisture content? 12. Seed longevity? 13. Seed dormancy?	Literature ^a Fundamental decision Herbarium/literature ^b Literature ^b Literature ^c Herbarium literature ^b Literature ^b Literature ^b Literature ^d Literature ^e Literature ^a Literature ^b Literature ^f	Overall strategy Seed number required (volume) Collecting strategy Collecting strategy Collecting strategy Collecting logistics Collecting logistics, volume Seed number possible (volume) Collection volume and size of facilities Amount of drying required Amount of drying required Drying and storage conditions Germination facilities and cost
(B) Collecting	14. Seeds per collection? 15. Field temperature and relative humidity? 16. Collecting logistics (e.g., no. of collectors)? 17. Collecting equipment? 18. Number of collections per annum? 19. Data to be recorded? 20. How many years of collecting?	2 and 8 Literature ^g 3,4,5,6 and 7 16 16 Decision guided by literature ^h Decision guided by 3,4 and 5	Collection volume and size of facilities Field drying, viability loss Cost Cost Size of drying facilities and cold store Accessioning Size of cold store
(C) Cleaning	21. Temperature and relative humidity of pre-cleaning storage? 22. Length of pre-cleaning storage?	Measurement or literature ^g Decision guided by 21 and cleaning throughput	Viability loss, if pre-cleaning storage = drying then volume implication to drying method Number of cleaners and cost, viability loss

Table 33.1 continued

Aspect	Questions	Source of information/ relevant questions ^{reference}	Implication to design
D) Drying	<p>23. Drying of cleaned or uncleaned material?</p> <p>24. What method of drying and monitoring?</p> <p>25. Will thin-layer drying be possible?</p> <p>26. What is the drying rate?</p> <p>27. What storage life is required?</p> <p>28. What volume of material at peak?</p> <p>29. What method of laying out material in drying system?</p>	<p>Decision guided by 21 and 22</p> <p>Decision guided by cost and 23 24</p> <p>24 and predictive model^d</p> <p>24, 34 and predictive model^a</p> <p>7, 9, 14, 18 and 23</p> <p>25 and decision guided by 26</p>	<p>Volume</p> <p>Cost (including staff cost)</p> <p>Drying throughput</p> <p>Drying conditions and cost</p> <p>Size of facilities, number of staff and cost</p> <p>Size and cost of drying facility</p>
(E) Viability testing	<p>30. Initial testing before or after banking?</p> <p>31. Testing by germination or tetrazolium (TZ)?</p> <p>32. Criteria for viability assessment?</p> <p>33. Frequency of re-testing?</p>	<p>Seed storage behaviour known or not (see 1)</p> <p>Decision guided by seed dormancy problems, TZ methodology repeatability 31</p> <p>Decision guided by likely rate of loss of viability (see 27)</p>	<p>Type and cost of container</p> <p>Germination facilities</p> <p>Cost (staff time) and growing facilities</p> <p>Number of staff and their cost, size and cost of facilities</p>
(F) Storage	<p>34. What storage life is required?</p> <p>35. What frequency of access to the collection is required?</p> <p>36. What is the volume of a cleaned collection?</p> <p>37. What type and size of containers?</p> <p>38. Number of containers of each type and size</p> <p>39. What method of organising & holding containers?</p>	<p>24 and predictive model^a</p> <p>Decision guided by amount of distribution from sample and 30, 33 9 and 14</p> <p>35 and 36</p> <p>18, 20 and 37</p> <p>35 and 38</p>	<p>Storage conditions, regeneration and costs</p> <p>Type and cost of container</p> <p>Size and cost of container</p> <p>Size and cost of facility</p> <p>Size and cost of facility</p> <p>Size and cost of facility</p>
(G) Use	<p>40. Seed available to whom and advertised how?</p>	<p>Incl. 2</p>	<p>Amount of distribution, staff and costs</p>
(H) Other	<p>41. Will the material be characterised (including identified) or evaluated?</p>	<p>Incl. 40</p>	<p>Growing and herbarium facilities plus costs</p>

Seed Drying

The aim of seed bank drying is to reduce the moisture content of the seed-lots to be conserved to between about 3.5% (high oil content seeds) and 6.5% (low oil content seeds) and in a way that preserves viability. These moisture contents equate to an equilibrium relative humidity of about 15% at 15°C. Apart from improved longevity in orthodox species, dry seeds are protected from freezing damage and insect attack. Obviously, germination is also prevented.

Drying is achieved by manipulating the water potential gradient that exists between the inside and outside of the seed. If the gradient is steep, such as when wet seed is placed in a dry environment, drying is rapid. As equilibrium is achieved, the gradient reduces towards zero. Thus the moisture content of most mature orthodox seeds reduces against time under any drying condition in an asymptotic fashion. Manipulation of the water potential gradient to speed drying includes optimising airflow over the seed and spreading the seed in a thin layer. Both discourage a humid layer of air from developing around each seed (in the latter case, around those that lie deep inside a seed bag). This humid layer of air reduces the gradient. Increasing the drying temperature promotes evaporation of moisture from the seed's surface. However, high temperatures (greater than say 40°C) can be detrimental to viability, longevity and field emergence, particularly when applied to wet seed-lots. Large-scale commercial seed drying of necessity often involves such high temperatures. However, seed-lots are usually sown within a year or two of drying and the extreme seed longevity that makes seed banking so efficient is not required.

Many (though not all – see FAO, 1996) major seed banks have adequate drying facilities and these are usually in the form of seed drying rooms. Most of these operate by means of chemical drying of the air. This allows drying to take place under relatively cool and controlled conditions. Before examining the use of drying rooms and their design, it is useful to consider some other methods by which seed might be dried for long-term storage. By comparison, such methods have limitations, uncertainties or extra management inputs.

1. Local Shaded Environmental Conditions

Harvested seed will be shed from wild plants at moisture contents in the range 30–65% on a fresh weight basis (Smith, 1995) and below this for many crop species. Mean daily ambient relative humidity (and temperature) varies at harvest, for example, between 35% (16°C) in Windhoek, Namibia during May to 91% (26°C) in Belem, Brazil in August. Cromarty *et al.* (1990) provide a predictive equation for equilibrium moisture content. If daily cycles of relative humidity are presumed to have an effect represented by the mean daily value, moisture contents of 10% and 19% (fresh weight basis, fw) would be obtained in the respective locations given a seed oil content of 1% (dry weight basis). Some drying may be possible using ambient conditions but artificial drying is usually necessary.

2. Sun Drying

The use of sun drying to dry seeds for long-term storage is probably less harmful than once thought provided the seeds are spread in a thin layer, turned regularly and removed to shade as soon as sufficiently dry. The effects of sun drying on seed viability have yet to be fully investigated, though see comments by Probert and Hay (2000).

3. Two-staged Drying

Two-staged drying operates by rapidly dropping the moisture content to a level above that desired using, for instance, ambient conditions. A slightly more severe regime can then be used to drop the moisture content to the level desired for long-term storage. Because the seeds are at a relatively low moisture level during this second stage, they are less adversely affected by use of drying temperatures that might otherwise be avoided such as 35–40°C (in an oven).

4. Sealed Container of Drying Agent

Perhaps the commonest seed drying agent is silica gel (see for instance Tao, 1992). Figure 33.2 shows the main components.

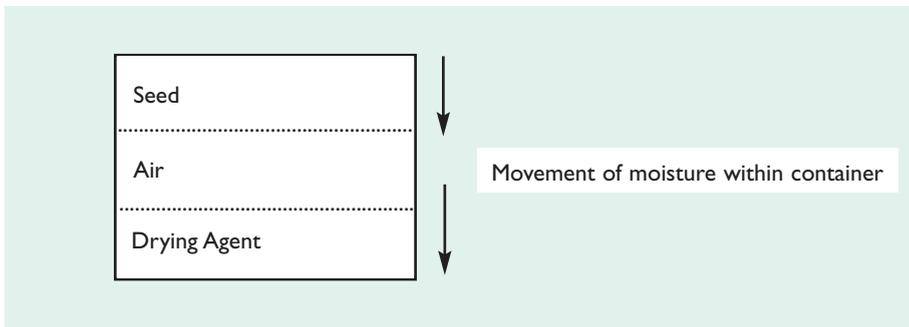


Figure 33.2 Components involved in the drying of seed with silica gel.

Based on the known properties of fresh silica gel and the equilibrium moisture content predictive equation, it is possible to estimate the weight of silica gel required to dry a given weight of seed from one moisture content to another at 20°C (see Cromarty *et al.*, 1990):

$$\text{Wt of Silica gel} = (a*(b-c))/((100-c)*0.66*r)$$

where

$$r = (1 - \text{EXP}((-1/440) * (\text{POWER}(((100 * c) * (1.1 + (e/90)))) / ((100 - c) * (1 - d)), 2))))$$

and where

a = weight of seed to be dried (kg)

b = initial moisture content of seeds (% fresh weight basis)

c = final moisture content of seeds (% fresh weight basis)

d = seed oil content (decimal% dry weight of seeds)

e = temperature (°C)

r = equilibrium relative humidity of dried seeds (decimal%)

Note: Formulae are given in a form that is directly usable in the spreadsheet program Microsoft Excel.

For example, to dry 0.5 kg of barley seeds (1.7% oil content) from 20% to 5% moisture content (fwb) requires 1.11 kg of fresh silica gel. However, it should be remembered that this is a theoretical prediction and there is no substitute for experimentation. As will be obvious from the equations, to determine the amount of silica gel required needs an estimation of the initial moisture content of the seeds. This is rarely practical and so a degree of pragmatism is useful. Using the equation above, it is possible to model the amounts of silica gel required under two extreme conditions. Using a ratio of 3:1 fresh silica gel: seed, sesame seeds with a high oil content (48%) but low initial moisture content (20%) would dry to 2.5% moisture content. Seeds, such as those of barley, with low oil content (1.7%) but at higher initial moisture content (65%) would dry to 8.5% moisture content with the same ratio of gel to seed. The final moisture contents are rather too low and too high respectively but this ratio would probably be satisfactory in most cases, causing neither over- nor under-drying. The drying time might sensibly be about one month. It may however be wise to reduce the ratio nearer to unity if the seeds are known to be very oily. Similarly, if the silica gel is changed frequently, the ratio could be reduced or the drying time curtailed.

There are several points to note when using silica gel:

- Avoid breathing in silica gel dust. Furthermore, the blue cobalt chloride indicator silica gel (blue when fresh; pink when activity is reduced) is now no longer available in some countries due to potential health risks. Alternative indicators are available. Of these, methyl violet gives the most clear-cut colour change (MSB Project, John Adams, pers. comm.).
- It is advisable to maximise the contact between the seeds and the fresh silica gel. Minimising the air inside the airtight container also probably helps.

- Cromarty *et al.* (1990) suggest that silica gel is regenerated at 175°C for 6 hours or 125°C for 16 hours. However, recent work by the Millennium Seed Bank (MSB) Project suggests that silica gel beads are effectively dried, and without damage to the indicator, when placed in a thin layer inside a fan-blown oven at 100°C for one hour. Regardless, it is important that the gel is not burnt as this reduces its effectiveness. If burning can be avoided, silica gel could possibly be dried on trays in the sun. This subject would benefit from more experimentation.
- Adsorption by the gel creates heat but this is offset by evaporative cooling on the seeds.
- Alternatives to silica gel include dried seeds (e.g., rice, see Sadik and White, 1982), drierite (calcium sulphate), dried charcoal or even powdered milk (RAFI, 1986). All of these agents should be oven-dried immediately prior to use. Quicklime (calcium oxide) is not recommended (Wieland, 1995).
- It is worth noting that a small sachet of moist indicator silica gel (e.g., pink when wet) placed next to the seeds within the container will indicate (e.g., by turning blue) when the seeds have dried (MSB Project, John Adams, pers. comm.).

5. Saturated Salt Solutions

Certain saturated salt solutions when placed in an airtight container control the relative humidity to fixed values at given temperatures. For instance a saturated solution of lithium chloride at 20°C controls the relative humidity to about 13%. Similarly, a saturated salt solution of potassium acetate maintains 25% relative humidity at 20°C. It is worth noting that this chemical can be troublesome to dissolve at some temperatures. The seeds are placed on a tray above (but not in contact with) the solution and dried to constant weight. In effect, a miniature drying room is created that is useful for drying small seed-lots.

6. Air-conditioned Room

Compared with ambient conditions, effective drying can be achieved with certain air-conditioned facilities. Other methods may subsequently be required to reduce the moisture to levels required for storage.

7. Incubator

Ongoing work by the MSB Project (John Adams, pers. comm.) suggests that certain cooled incubators *with a defrost drain to the exterior* are able to maintain the kinds of conditions found in seed drying rooms (e.g., 15% relative humidity at 18°C). Costing less than £3,000 (about US \$4,350) in the UK, this approach to seed drying may well be suitable for botanic gardens and similar

institutes that wish to work on a small scale with limited outlay. The amount to which relative humidity might be reduced under tropical environments has yet to be established. A major advantage is that when drying is complete, the incubator can then be used for germination testing.

8. Controlled Humidity Drying Room

8.1. General comments

This is the most expensive option, but one that allows seeds to be left in a safe, dry environment until cleaning is practicable. At the Millennium Seed Bank in the UK, losses in viability inside the drying room can be calculated to be up to fifty times slower than would be the case under ambient conditions. In the warm, humid tropics, the difference would be even greater. With respect to cleaning, it is important to note that dried plant material becomes more brittle. This aids cleaning but does make the seeds more susceptible to breaking.

The aim is to create, and then cheaply maintain, the dry, cool conditions recommended by the Gene Bank Standards (FAO/IPGRI, 1994). Consequently, the room needs to be constructed of a moisture-proof material. Preferably, it should have an airlock to minimise moisture ingress from outside. The air is dried by dehumidifiers preferably located external to the room and linked by ductwork. Sorption dehumidifiers (using silica gel, lithium chloride or molecular sieve) tend to be more electrically efficient at maintaining low relative humidity conditions than are refrigeration dehumidifiers and are thus most commonly used. Air passing through a sorption dehumidifier does pick up heat and thus needs to be cooled on or before delivery to the room.

When putting together a design for a drying room, the air conditioning engineer will need to be provided with several pieces of information that only the commissioning seed conservation scientist can provide. These are: (a) the conditions to be maintained; (b) the volume of the room; (c) the seed moisture load; (d) the number of staff occupying the room; and (e) the number of times per day the door is opened.

8.2. Drying room conditions

Internationally, 10–15% relative humidity at 10–25°C is recommended for drying rooms (FAO/IPGRI, 1994) with the air circulating at a rate through the dehumidifier to give about six changes per hour. Experience has shown that mature, orthodox seeds of most species would normally have reached equilibrium with the recommended conditions in less than one month. There is probably little benefit of drying the air below 10–11% relative humidity as this equates to the lower critical moisture content values on the longevity/moisture content graph (Ellis *et al.*, 1989). However, it is worth noting the suggestion elsewhere within this book that a relative humidity as low as 10% may now be considered inadvisable. It should also be noted that sorption dehumidifiers operate in a rather inefficient manner controlling conditions to such low levels as they are working at the limits of their operation.

It is important that the temperature and airflow used within the drying room is not too cold to discourage extended working. For instance, such work may include packaging of seeds and opening (warmed) containers removed from the freezer. It is ideal if the drying room can be located adjacent to the cold store. In this way, the drying room can act as an airlock to the cold room. This ensures that the air is very dry within the cold room and that the minimum of moisture condenses on the cooling coils within the cold store. It also minimises the amount of warm air entering the cold room.

8.3. Determining drying room size

It is important that the room is neither too small such that it is impractical nor too large such that capital and running costs are high. The suggested steps are as follows (also see notes in Table 33.1):

- **Determine peak intake.** This is best done by drawing up a table of the likely intake of species during the course of a typical year. Bear in mind that the lifespan of a high quality prefabricated drying room is likely to be in the order of 20–25 years, so predictions need to take a long-term view. Roughly estimate the volume of material that would need to be accommodated each month bearing in mind whether the collections will or will not be cleaned before placing in the room. Assume that the collections will be present within the room for one month. Find the month that has the highest volume of material.
- Although fixed shelving can be used, slatted, self-stacking crates on wheeled trolleys allow more flexibility. Assuming the crate option is adopted, for the species and their collections within that month, **estimate how many crates of a sensible size (especially depth) would be required** such that the collections can be spread out to properly aerate. These crates would require a paper insert on which the collection(s) can rest when spread out.
- **Estimate how many crates can sensibly be fitted on top of one another in a stack** within the room. Allowance should be made for the crates to sit on top of a trolley designed to hold the crates. It is best to avoid putting crates directly onto the floor as airflow under the slatted crates will aid drying. Additionally, the risk of temperature conductance through the floor to the drying seed is avoided. Assume that the room height will be in the order of 2.5 m. However, do not stack the crates to the top of the room.
- **Estimate the floor area occupied by the required number of crate stacks.**
- Roughly **double the floor area** to allow for air movement, access and working space within the room. For instance, if the room is used for packaging and opening containers, bench space may need to be allocated. For a bank processing several hundred uncleaned collections per year, a sensible floor area might lie in the range 10–50 m².

- Multiplying the floor area by the height gives the room volume (this will be required when dehumidifier size is determined).
- Design the room to be long and narrow rather than square as this improves air flow if the intake and exhaust ducts are positioned at their furthest apart. Allow for an airlock that is sufficient for at least one member of staff with a crate to enter. It is probably best to avoid using plastic strip or air curtains instead of air locks. Although they reduce moist air intake, they can create problems when carrying trays of seed. Should space for an airlock be limited, it would be worth opening the drying room door into an existing room that has a tight-fitting door and sealed windows. This could substitute as an airlock. It is useful (and in some countries a legal requirement) to have a secondary route of escape out of the drying room for use in emergency. This door does not need an airlock. Finally, bear in mind the position of drying/cooling equipment which should be external to the room (preferably separated by a wall with fire retardant properties) and also, if a modular material is used, the possibilities for future expansion.
- When happy that the dimensions are about right, mark out the room on some ground to check out the practicality of the design.

8.4. Drying room construction

Ideally, a prefabricated system should be used for construction of the drying room. Panels of the design shown in Figure 33.3 are increasingly common (and used for constructing food cold stores).

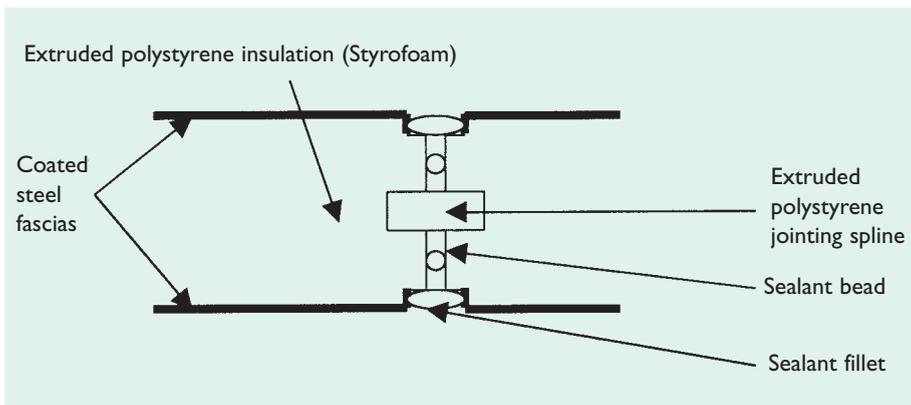


Figure 33.3 Cross section through a prefabricated insulation panel used in the Millennium Seed Bank. Diagram slightly exaggerated in order to show features.

Figure 33.3 represents the jointing of typical drying room insulation panels in plan form. Insulation is often extruded polystyrene. This closed cell material is more effective as a moisture barrier than the open cell expanded polystyrene and is stronger. It also has better insulation properties as illustrated in Table 33.2. This table also demonstrates the greater the thickness of the chosen insulation, the lower the energy costs. For most situations, panels 10 cm thick are sufficient for dry rooms. The same type of panelling can be used for cold rooms (see below) but 20 cm thick insulation is used. The extruded polystyrene (usually sold under the name ‘Styrofoam’) insulation panels have treated steel faces that are bonded to both sides of the panels and turned in at the ends. Two vertical semi-circular grooves are cut into the edges of the insulation such that silicone beads can be inserted prior to butt-joining the panels together. These assist the reduction of vapour transfer from one side of the construction to the other. A rectangular groove in the centre of the insulation faces accepts a tight fitting spline to ensure a true alignment when the faces are joined. After final construction, a clear sealant is applied to the grooves formed by the folded-back steel facing edges and dressed to form a clean surface and additional protection against water vapour transfer. In the Millennium Seed Bank, the corner joints of the walls and ceilings are fitted with aluminium angles internally and flat sections externally, the edges of which also have clear silicone fillets (see Figure 33.4)

In the case of a drying room attaching to a cold room, it is advised that the entire structure should be raised off the host building floor (if it is in direct contact with the soil) with piers to prevent possible effects of permafrost (see later).

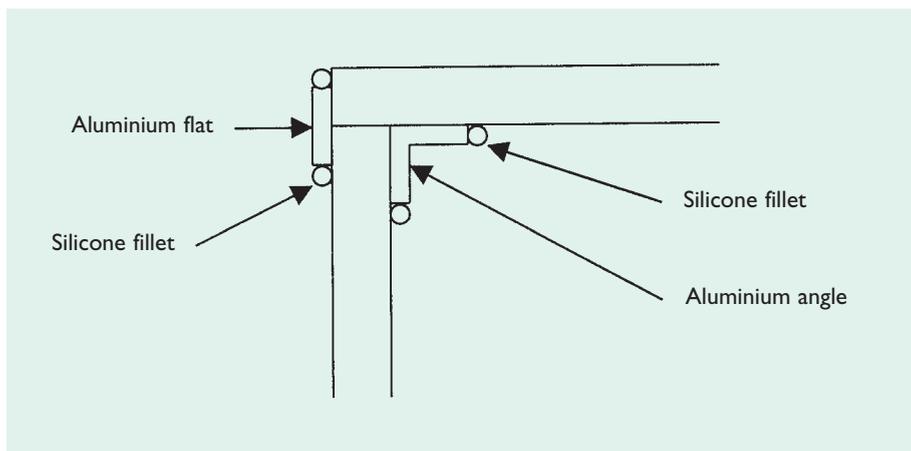


Figure 33.4 Corner insulation panelling joint used in the Millennium Seed Bank. Not drawn to scale.

Table 33.2 Illustrative calculations of electricity consumption for different-sized cold rooms insulated with panels of different thickness and type. Based on equations presented in Cromarty *et al.* (1990) and using their factors for cooling loads, performance and consumption.

Panel thickness	Polystyrene	Thermal transmittance or U value (manufacturer's data)	External surface of room	Temperature difference across panel	Annual electricity consumption
m		W m ² K ⁻¹	m ²	K (or °C)	kWh
0.05	Extruded	0.4621	70	40	7,128
0.1	Extruded	0.2402	70	40	3,705
0.2	Extruded	0.1225	70	40	1,890
0.1	Extruded	0.2402	70	30	2,779
0.1	Extruded	0.2402	70	20	1,853
0.1	Extruded	0.2402	70	10	926
0.1	Extruded	0.2402	35	40	1,853
0.1	Expanded	0.3040	35	40	2,345

Assembled well and not subjected to excessive misuse, such a structure should last 20–25 years before the insulation properties decrease. Obviously, for the structure to work efficiently, the ceiling needs to be constructed of the same material and the floor similarly insulated. With the latter, the structure might comprise slabs of insulation laid on top of a moisture proof membrane, topped with marine plywood which in turn is covered by an epoxy resin screed. The latter should be covered up at the edges to aid cleaning and prevent the establishment of dust pockets. The doors should be constructed in a similar way to the panels and preferably have a small (double-glazed) window to prevent accidents when opening. The room should be entered through an airlock (see above). Where possible, puncturing of the panels (e.g., by bolting items on) should be kept to a minimum. Bolts will act as conductors of heat through the structure. To limit claustrophobia, it is advisable to install at least one window (preferably double-glazed) into the room, especially if staff are going to be present in there for any length of time.

A possible layout of drying room facilities is shown in Figure 33.5.

If circumstances dictate that an existing room is converted to create a drying facility, moisture proofing of the structure will be necessary if excessive energy bills and potential damage to the room are to be avoided. Where possible, the room should be moisture proofed on the outside as this will reduce the possibility of condensation developing within the walls. Condensation could

liquid. The amount of water removed by the dehumidifier is a measure of drying performance (see Cromarty *et al.*, 1990). Dehumidification by refrigeration has limitations to the degree of cooling and moisture removal. For example, the dew point of the required supply air condition must be above 0°C (or a moisture content of 0.003789 kg moisture kg⁻¹ dry air) otherwise ice will form on the cooling coil thus making it ineffective. Such conditions would include, for instance, 15°C and 35% relative humidity and 25°C and 19% relative humidity. Consequently, the use of refrigeration dehumidifiers is precluded where the internationally recommended drying conditions mentioned previously are required.

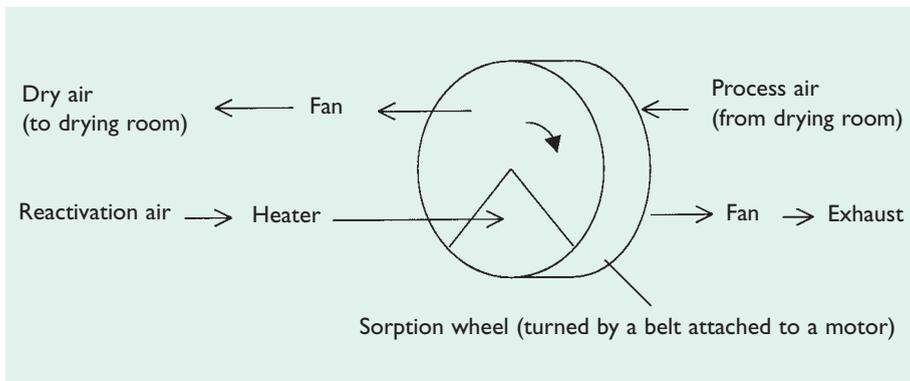


Figure 33.6 Operation of a typical rotary sorption dehumidifier.

As will be apparent from Figure 33.6, there are two airflows through the dehumidifier. The process airflow is that flow related to the movement of air between dehumidifier and drying room and is essentially a closed system. Consequently, for human safety, fresh air may need to be brought into the circuit (see Figure 33.5). If this happens, it is more effective to close this intake off except when carbon dioxide levels increase in the room. A carbon dioxide monitoring system is then necessary. The reactivation airflow is that involved with the regeneration of the desiccant within the drying wheel. The dehumidifier is relatively simple and thus tends to be reliable. Apart from the drying wheel, the main components are the fans, motor and the reactivation air heater. Heat from the latter, when added to the heat of sorption by the desiccant, means that both the dried process air and reactivation air is warm (dry and wet respectively). Consequently, the dehumidified process air usually needs to be cooled to supply the cool, dry conditions required within the drying room (e.g., from 26°C, 5% relative humidity when leaving the dehumidifier to 15°C, 15% relative humidity in the drying room). This cooling also has to help cool the sensible heat load within the room (see following). Additionally, the location of the dehumidifier needs to be carefully considered as it adds heat to the room in which it is stood. Ideally, the

arrangement shown in Figure 33.5 should be achieved with the sorption dehumidifier located outside the room (within a ventilated weatherproof space) and with the dried process air passing through a chiller prior to delivery. An alternative might be to locate the dehumidifier within a drying room that was independently chilled. In this case it is beneficial to ensure that ducting or a fan is used to ensure the delivery of the dried air to the furthest part of the room. With this arrangement, the reactivation air should be brought into the room and, having passed through the reactivation sector of the wheel, be exhausted to the outside of the room and, of course, well away from where it was brought in. Some dehumidifiers are supplied with a condenser (and water drain) to remove moisture from the reactivation air.

The drying room runs continuously during the post-harvest period (and in most large banks all year). The humidity maintained by the dehumidifier is controlled by feedback from a humidistat located in the return air duct from the drying room and operates by adjusting both the speed of rotation of the sorption wheel and the temperature of the reactivation air. Locating the

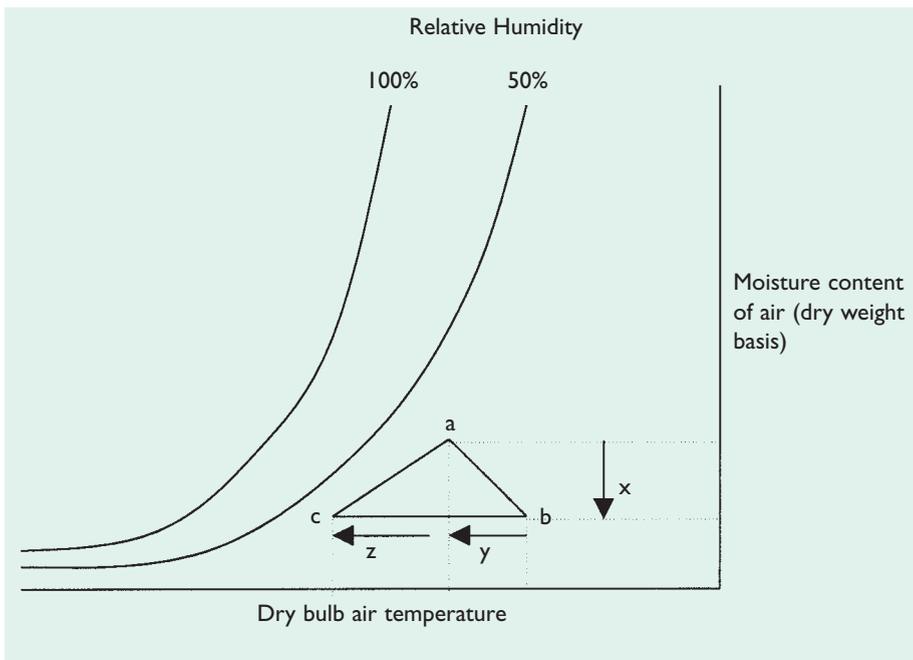


Figure 33.7

Stylised psychrometric chart showing condition of air in seed drying room near the humidistat (a), process air having left dehumidifier (b) and at point of delivery to room (c). The amount of moisture removed by the dehumidifier is indicated (arrow x) as is the cooling necessary to offset the heat from the dehumidifiers (arrow y) and that necessary to offset sensible heat gains to the room (arrow z). Therefore line c – a represents the total heat gains (sensible and latent) to the space.

humidistat in this position ensures that air within the room is at least as dry as it is at this point. The danger is that air near the point of delivery may be significantly drier. This may be detrimental if over-drying is a risk. However, it is important to note that there will be ‘dead spots’ in the room where the drying air flow does not reach. These should be checked for by means of a portable hygrometer. Similarly, the positioning of the thermostat (feeding back as a simple on/off control to the compressor of the chilling system) is important. Ideally, the room should be controlled to within about $\pm 5\%$ relative humidity and $\pm 3^\circ\text{C}$. Audible alarms should be fitted to signal if the room is falling significantly outside these limits.

Many facilities utilise two dehumidifiers in parallel, each running at two-thirds maximum capacity. They are arranged to run alternately such that neither deteriorates more rapidly than the other and so that both can operate at times of extreme moisture load. This arrangement also allows the removal of one machine for service or repair without closing the operation down.

The supplier of the dehumidifier will advise on the size of machine(s) required. However, if desired, it is possible to calculate maximum moisture load for a given machine. For instance, if the air leaving the room is to be maintained at 15% relative humidity and 15°C , the air entering the dehumidifier has a moisture content of $0.0016 \text{ kg moisture kg}^{-1} \text{ dry air}$ (point a in Figure 33.7). By reference to a psychrometric chart (see for instance, Probert, 2003 – Chapter 19) its specific volume under these conditions is $0.818 \text{ m}^3 \text{ kg}^{-1}$. The dehumidifier’s data might, for instance, show that the air leaving the dehumidifier has a moisture content of $0.0005 \text{ kg moisture kg}^{-1} \text{ dry air}$ and is at 26°C (point b in Figure 33.7). The dehumidifier is thus capable of removing $(0.0016 - 0.0005) = 0.0011 \text{ kg moisture kg}^{-1} \text{ dry air}$ processed. The dehumidifier’s air throughput might, for instance, be $500 \text{ m}^3 \text{ h}^{-1}$. The maximum load for a single machine would thus be:

$$(500/0.818) \times 0.0011 = 0.672 \text{ kg moisture h}^{-1}$$

The moisture (latent heat) load comprises moisture from the following sources:

- (1) Wet seeds. This moisture load is quite difficult to estimate as it is not in a steady state. For instance, a hundred collections of 1kg of seed dried from 30% to 5% moisture content (fwb) would loose 26.3 kg of water. Much of this water (perhaps 50%) would be lost in the first day of drying but equilibrium might not be achieved for two to four weeks. Unless batches of very wet seed-lots are to be placed in the room at frequent intervals, it is not worth designing for the very worst situation i.e., $(26.3 \times 0.5)/24 = 0.55 \text{ kg h}^{-1}$. The system may go outside the design condition for a short period. However, it is worth noting that the dehumidifiers will start to work more efficiently and should quickly return the room to condition. A compromise might be to halve the above rate i.e., 0.275 kg h^{-1} .

- (2) Personnel time in the room (approximately $60 \text{ g h}^{-1} \text{ person}^{-1}$ for relatively non-strenuous work). Suppose occupancy was usually not above 30 person minutes per hour, then moisture load would be 0.030 kg h^{-1} .
- (3) Permeation through the fabric (should be negligible).
- (4) Infiltration when the door is opened (a function of frequency of door opening, air-lock size and external air conditions). Suppose the door was opened twice every hour on average; that the air-lock was 8 m^3 ; internal room conditions were 15% relative humidity, 15°C , moisture content of $0.0016 \text{ kg kg}^{-1}$; and external conditions were 40% relative humidity, 27°C , $0.0091 \text{ kg kg}^{-1}$, specific volume $0.8624 \text{ m}^3 \text{ kg}^{-1}$. The moisture load would be:
- $$2 \times 8 \times (0.0091 - 0.0016) / 0.8624 = 0.139 \text{ kg h}^{-1}$$
- (5) Fresh air intake (a function of room occupancy). A fresh air quantity of $12 \text{ litres sec}^{-1}$ ($43.2 \text{ m}^3 \text{ h}^{-1}$) should be allowed for each occupant. Suppose the overall room occupancy was one person for half an hour every hour, the moisture load would be:
- $$0.5 \times 43.2 \times (0.0091 - 0.0016) / 0.8624 = 0.188 \text{ kg h}^{-1}$$
- (6) That delivered through leakage into the dehumidifier (depends on make, for a well-sealed machine assume it is zero).

Combining the moisture loads from the above examples gives a total load of 0.632 kg h^{-1} . Thus the dehumidifier above alone could cope with this load.

The last four sources of moisture listed are influenced by the ambient conditions of temperature and relative humidity at the site. As mentioned previously, any design engineer will need to know the moisture load and the frequency of personnel entry to the facility. The dehumidifier(s) must be capable of delivering sufficient air not only to dry the moisture load but to cool the room sufficiently and to provide sufficient air movement.

The cooling load (see Figure 33.7) includes sensible heat gain from:

- (1) The dehumidifier (11°C temperature differential in example above). Assuming a specific heat capacity of air close to $1 \text{ kJ kg}^{-1} \text{ K}^{-1}$ and using the basic equation (where temperatures are more accurately expressed in degrees Kelvin; numerically, $\text{temperature}^\circ\text{C} + 273 = \text{temperature K}$), the heat load is:
- $$\begin{aligned} \text{Mass flow rate (kg sec}^{-1}) \times \text{sp.ht.cap. (kJ kg}^{-1} \text{ K}^{-1}) \times \text{temp. differential (K)} \\ = \text{Load (kW)} \\ (500 \text{ m}^3 \text{ h}^{-1} / 0.818 \text{ m}^3 \text{ kg}^{-1}) \times 1 \text{ kJ kg}^{-1} \text{ K}^{-1} \times 11 \text{ K} \times (1/3,600) \text{ h sec}^{-1} \\ = 1.868 \text{ kJ sec}^{-1} \text{ (kW)}. \end{aligned}$$
- (2) The lights. Say three 150 W lights i.e., 0.450 kW.
- (3) Personnel. From engineering tables this is about 110 W per person. Using the above example of occupancy this equates to 0.055 kW.

- (4) Permeation through the fabric (a function of room surface including floor, fabric U values and the temperature differential inside to outside). Suppose the surface area of the room is 72 m^2 , and remembering that the temperature differential is 12 K ($27 - 15^\circ\text{C}$) and assuming the U value is $0.2402 \text{ W m}^{-2} \text{ K}^{-1}$, the heat load is:

$$72 \text{ m}^2 \times 0.2402 \text{ W m}^{-2} \text{ K}^{-1} \times 12 \text{ K} \times (1/1,000) \text{ kW W}^{-1} = 0.208 \text{ kW}$$

- (5) Infiltration (a function of frequency of door opening, air-lock size and temperature differential). The heat load, using the moisture load example above is:

$$\{(2 \times 8) \text{ m}^3 \text{ h}^{-1} \times 12 \text{ K} \times 1 \text{ kJ kg}^{-1} \text{ K}^{-1} \times (1/3,600) \text{ h sec}^{-1}\} / 0.8624 \text{ m}^3 \text{ kg}^{-1} \\ = 0.062 \text{ kW}$$

- (6) Fresh air intake (a function of fresh air make-up and temperature differential). The heat load, using the example above is:

$$\{(0.5 \times 43.2) \text{ m}^3 \text{ h}^{-1} \times 12 \text{ K} \times 1 \text{ kJ kg}^{-1} \text{ K}^{-1} \times (1/3,600) \text{ h sec}^{-1}\} / 0.8624 \text{ m}^3 \text{ kg}^{-1} \\ = 0.083 \text{ kW}$$

The relative sensible heat loads from the different sources is instructive. The cancellation of units should be helpful to those unused to such calculations. The chiller capacity will thus need to cope with a sensible heat load of 2.726 kW . An appropriately sized refrigeration system can be determined from this heat load by the refrigeration manufacturer. The dehumidifier is supplying $611 \text{ kg air h}^{-1}$ to the room. Therefore, the temperature of delivery (point c in Figure 33.7) must be calculated using:

$$2.726 \text{ kW} = 611 \text{ kg h}^{-1} \times 1 \text{ kJ kg}^{-1} \text{ K}^{-1} \times ((273 + 26) - t) \text{ K} \times (1/3,600) \text{ h sec}^{-1} \\ t = 283 \text{ K or } 10^\circ\text{C}$$

The ductwork needs to be sufficiently wide not to impede airflow. A slight positive pressure is required within the room. Dampers may be required to ensure the correct airflow.

The conditions in the drying room limit insect activity. Combined with the fact that the room is a contained space with an air-lock means that it has value for handling material that may have quarantine status. Finally, it is worth noting that the dry conditions within a drying room contribute two problems. Firstly, staff may become dehydrated through prolonged work within the room and must be encouraged to go outside regularly to drink water. Secondly, static electrical charge can be a problem that is particularly trying when handling small seeds. The use of anti-static footwear or an anti-static gun can help. Obviously, all internal fittings should also be thoroughly earthed.

Cooling the Dried, Packaged Seeds

1. Alternatives to a Conventional Cold Seed Storage Room

- **Low technology** though effective short-term storage is achieved by many community seed banks (see RAFI, 1986) and other non-governmental organisations (see Cherfas *et al.*, 1996). These stores use a combination of traditional and modern techniques. In many such stores within developing countries, low- or sub-zero-temperature storage is not feasible given the cost or absence of reliable electricity supplies. The amounts of seed (often many kilograms per collection) also mean that a very large volume of space would need to be kept frozen. Additionally, storage is required for one or two years under most circumstances. Consequently, emphasis is placed on drying the seeds and keeping them relatively dry in a variety of containers ranging from plastic drinks bottles to large plastic drums. A key element is keeping the collections safe from rodents and insect pests. Use of cool sites (see below) helps prolong the life of the packaged seed. In theory, dried seeds placed inside re-corked wine bottles sealed at the top with wax and sat within wet ceramic pots (cooled by evaporation) would enable very satisfactory storage at little capital cost though with a high manpower input. Such cooling technology was used in ancient Egypt.
- **Cool local conditions.** At its simplest, control of ventilation (open when cool, closed when hot) can improve storage conditions for stored seeds within a well-insulated building (IBPGR, 1985). If the seeds have been dried and are properly packaged then storage in air-conditioned (or other) rooms can be quite effective. Use of natural rock (though in some cases there is a limited risk from natural radioactivity) and high altitude stores might be possible. The latter have the particular difficulty of access and their remoteness may reduce the level of security that might be provided (see IBPGR, 1985). Use of permafrost has been established for long-term duplicate storage of seed in places such as Svalbard (see Jadav *et al.*, 2003 – Chapter 50). Although the dependence upon electricity is cut, such stores are usually unable to match the lowering of temperatures possible in conventional base storage conditions. The coldest natural storage on Earth is provided by ice within Antarctica where a condition of -58°C is possible and this has been considered (see IBPGR, 1985; Shibata and Etoh, 1997). Apart from the difficulty of access and treaty considerations regarding the introduction of exotic germplasm to that continent, there is the problem of continuous ice flow.

- **Domestic refrigerator (+4°C).** Small collections of well-dried seed can be stored over several years or even decades in domestic refrigerators. If the refrigerator door is rarely opened then moisture present in the air inside collects on the cooling coils and the relative humidity drops thereby reducing the risks from imperfectly sealed containers. Obviously, due to the poisonous nature of some seeds and fruits, such refrigerators and freezers (below) should not be used for food storage.
- **Domestic or laboratory deep freezer (-13 to -20°C).** These are recommended rather than having a cold room if the total required storage volume is less than about 10–15 m³ (Cromarty *et al.*, 1990). In early 2002, one upright -20°C deep-freezer with 0.23 m³ space cost £440 (about US \$ 640) in the UK. By comparison, a -20°C cold room of 40 m³ volume might cost very approximately £30,000 (about US \$ 44,000). Per unit volume (though not necessarily per collection stored), the upright deep-freezer is more than twice as expensive as the cold room. Use of deep freezers has the benefit that they are relatively cheap and if one breaks down then it can be replaced with relative ease. Deep freezers are also movable and this has the benefit of allowing flexibility within any facility. When calculating requirements, it should be assumed that the operational life is between 5–10 years. They can be supplied with an audible alarm to indicate that temperature has risen inside or that there has been a power failure. Ambient operating temperatures may range up to about 32°C. Special freezers may be required above this ambient temperature. Two general types of freezer are available. These are chest freezers (with lids) and upright freezers (with doors). Until recently, the latter had the disadvantage that cold air inside could fall out when the door was opened. Now, most upright cabinets are fitted with internal compartment doors that reduce this. Icing up can be a problem with both freezer types and a regular programme of de-icing needs to be implemented.
- **Mobile cold store.** Refrigerated lorries are available in many countries and can be hired in the event of an emergency problem with a cold store.
- **Freezer (-80°C).** Freezers capable of maintaining a storage temperature of -80°C cost approximately £5,600 (about US \$8,120) in the UK. Even lower temperature freezers are also available but are more expensive. Such freezers are only applicable to very small seed collections and the high costs are probably not warranted in most cases.

- **Seed storage at ultra-low temperatures** (cryopreservation) using liquid nitrogen. Seed samples are normally held in polypropylene (or similar) screw-cap containers placed in either the vapour phase above liquid nitrogen (about -160°C) or immersed in liquid nitrogen (at -196°C) within a specially constructed Dewar. While seed metabolism is virtually suspended under these conditions, the methodology does require a ready supply of liquid nitrogen and a great deal of care. Liquid nitrogen expands 610 times on vaporisation and a spillage can severely threaten the oxygen supply of a room in which it is kept. There is also the risk of cold burns to the skin. The technique requires care on rates of freezing and subsequent re-warming that can vary between species. Quantities of seed that can be conserved in this way are limited and this specialised technique is probably only warranted for the conservation of highly valued, small and very short-lived orthodox species. Detail of the methodology and equipment is outside the scope of this chapter and readers are recommended to read the reviews by Stanwood (1984) and Pritchard (1995).

2. Conventional Cold Store

2.1. General comments

For long-term storage, the temperature within the cold store might ideally be about -20°C . Lower temperatures, although giving greater seed longevity (see Dickie *et al.*, 1990), will create unpleasant and more dangerous working conditions for staff. In some cases, medium-term storage at higher temperatures than -20°C may be desirable. The reasons for this are usually cited as ease of access, cost and/or the absence of a need for extended longevity. Some seed stores are operated under such conditions so that breeders can have frequent access to the material (active collections). In many forest seed centres and community seed stores, maintaining very low temperatures is economically untenable given seed turnover or limited resources.

2.2. Determining cold room size

It is worth spending some time on getting the correct size of room for the perceived need. Too large a facility could result in excessive running costs or disused equipment that rapidly deteriorates. If anything, it is better to err on the side of caution and risk designing a facility that is slightly too small. This risk is minimised if a modular construction is used that can be easily expanded.

- **Choose a suitably sized container** for each dried, cleaned collection (see Manger *et al.*, 2003 – Chapter 34). In some cases, double packaging for extra security may be advisable. Estimate how many containers are required per collection. Where possible this number should be kept to a minimum. Determine the weight of the filled containers. This value, divided by the base area of the container, will give an idea of the weight loading on the shelves.

- Using the table of intake developed for the drying room design, *estimate how many containers of each type per year* will need to be stored.
- **Decide how many years' intake of collections will need to be stored.** Alternatively, the life-span of the cold store can be used as a limit. If the same prefabricated material is used as for the drying room (see above), this could be in the order of 20–25 years.
- Multiply the number of containers of each type per year by the number of years to **determine the total number of containers of each type that the room must hold.**
- **Decide on a shelf width** (this should not be too deep as either the drawers that sit on them will become unwieldy or, if the containers will sit directly on the shelves, those at the back will not be accessible). A width of 45 cm might be sensible in many cases.
- For each container type, work out **how many containers fit across the width of the shelf.**
- **Determine how many stacks of shelves are possible given the room height for each container type.** Do not use the entire height of the room. Some space needs to be allowed at the top for air circulation and below so that the containers are not on the floor. Also, the maximum convenient reach height is about 2 m. Ideally, the number of shelves should be estimated using the following pattern of dimensions up the height of the room:

Shelf depth/container height/space above container *et seq.*

The space allowed above the container should be sufficient to allow the container at the back of the shelf to be removed over the top of those at the front (if containers do not sit in drawers).

- **Estimate how many metres of shelving stacks are required for each container type and then calculate the floor area occupied by shelving.**
- **Decide whether static or mobile shelving is required.** If the former, assume perhaps that 30% of the floor area will be occupied by shelving. If the latter, 70% may be possible. This factor allows for walkways. It is worth noting that the actual volume of the room containing accessions is a relatively small fraction of the total. Mobile shelving is more expensive and more demanding with respect to installation than static shelving. However, it allows a smaller room to hold the same number of accessions as a larger room fitted with static shelves. The smaller room is cheaper to construct and has lower running costs. Sensible floor areas range from say 15–20 m² (a small collection of a few 1,000 accessions on static shelving) to several 100 m² (major international seed bank with several 100,000 accessions on mobile shelving). One of

the largest stores is the 465 m² conventional storage vault at the USDA National Seed Storage Laboratory, Fort Collins that is capable of storing 750,000 samples. Another very large facility is that at the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) in Mexico where the floor area totals about 350 m² (50:50 medium- and long-term storage) and the capacity is 390,000 wheat and 67,000 maize accessions (Pardey *et al.*, 2001). If a large cold store is planned, it may be better to divide the space into several small rooms, such that only the volume required at any point in time is frozen. In this case, it is better to install the refrigeration system for each room as it is required. If a modular structure is used, then it is important to bear in mind possible future expansion into surrounding space. For instance, the vault of the Millennium Seed Bank currently comprises three 48 m² cold rooms but has expansion space for six more. When fitting prefabricated rooms inside other structures it is important to allow access to the outer surfaces of the rooms such that repairs can be made. Furthermore, Cromarty *et al.* (1990) recommend that cold rooms with a volume greater than 20 m³ should have an air lock. Ideally, this is the drying room (see above) which in humid tropical countries will help reduce condensation around the cold room door. If, in turn, the adjacent drying room has an airlock then the cold room is doubly protected. Under these circumstances, a secondary means of exit from the cold room becomes even more important (see comments under Drying Room).

- Multiply the floor area by the height (perhaps 2.5 m) to give the volume.
- When happy that the dimensions are about right, mark out the room on some ground to check out the practicality of the design. See Figure 33.8 for an example of a layout.

2.3. Cold room construction

The cold room should be constructed from insulated panels as referred to under Drying Room Construction. The panel thickness will strongly influence the electricity usage (see Table 33.2). However, in temperate countries, the floor should have an under-floor, low voltage, thermostatically controlled heating mat to prevent frost heave. This mat should be maintained at 4°C. Cromarty *et al.* (1990) recommend 5–10 W m². The heating and potential maintenance problems can be avoided if the room is on a raised platform. The latter is used in the Millennium Seed Bank and acts as an added protection against the risk of flooding. If shelving is to be fixed to the floor (essential with mobile shelving), it is important that damage to such heating mats and to the insulation fabric is avoided. Additionally, mobile shelving should be capable of

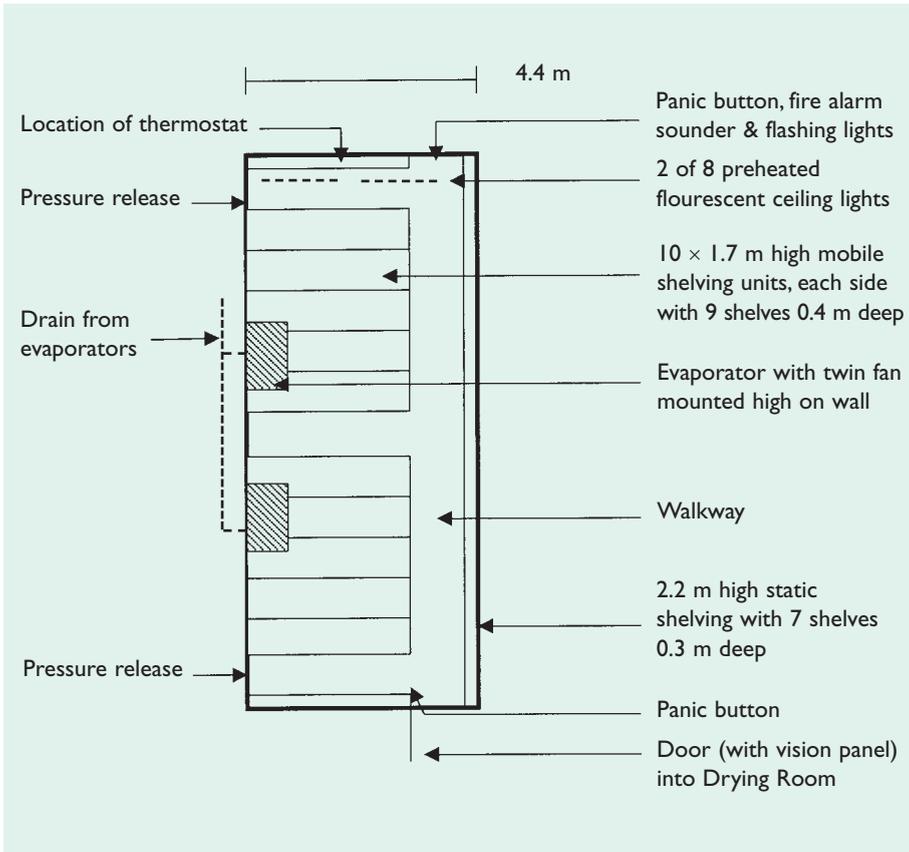


Figure 33.8 General layout of one of the cold rooms within the Millennium Seed Bank, UK. 48 m² floor area (3.0 m internal height) room constructed with 0.2 m thick extruded polystyrene panels, cooled by a direct expansion refrigerant system (4 kW consumption) and designed to hold approximately 25,000 collections (some 6,000 litres of seeds).

withstanding the cold room conditions and its rails should not present a trip hazard. The point loads created by the loaded shelving will need to be considered but this is usually determined by the installation agents. Ideally, all shelving in the centre of the room should have perforated back plates to facilitate air movement. Incidentally, it is best to add collections to the next available space rather than add collections in serial number or taxonomic order. The latter creates gaps as accessions are permanently removed and can lead to the freezing of a large amount of unused space. Numbering and labelling systems used within the room must be capable of surviving the low temperatures in the room.

The floor surface should have a metal chequer-plate finish to prevent slipping by staff. The doors should have similar thickness insulation to the room and should have heated double-glazed vision panels and the door-frames should be fitted with heating elements to prevent icing. The doors should not be lockable such that they cannot be opened from the inside. To allow the door to be easily closed, it is wise to insert an air pressure equalisation valve through the wall. Doors should be fitted with kick plates to limit damage to them.

The freezing system will usually be a conventional system as shown in Figure 33.9.

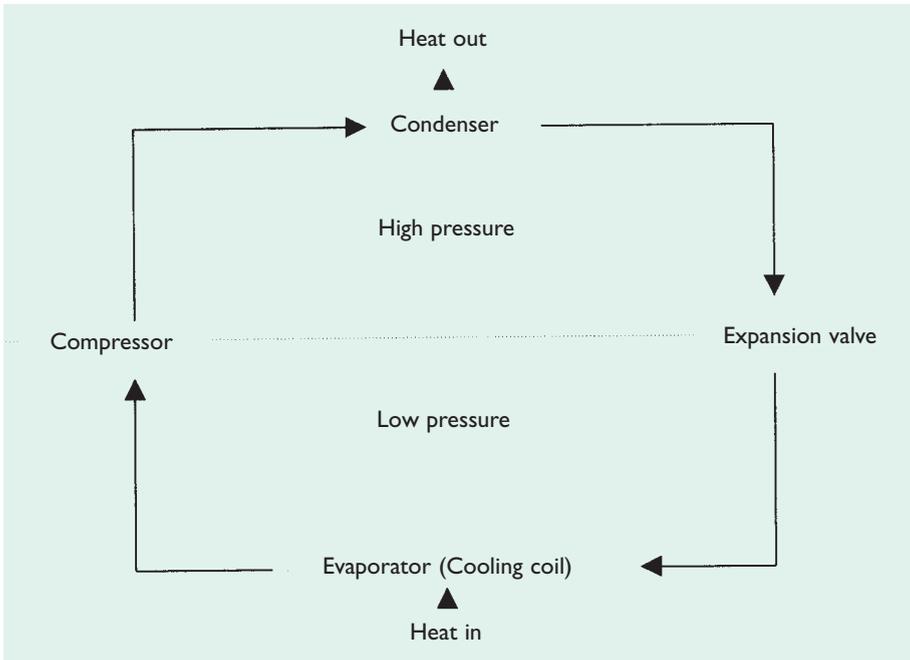


Figure 33.9 Schematic of a typical conventional vapour compression refrigeration system.

The system contains a liquid refrigerant that boils under low pressure at a temperature below that to be maintained in the cold room (e.g., -30°C) and that condenses under high pressure at a temperature above ambient. The expansion valve controls flow thereby creating a pressure difference between the cooled (evaporator) and heated (condenser) sides of the system. Liquid refrigerant at high pressure, on passing through the expansion valve, loses pressure and this causes its temperature and boiling point to be reduced. The cool liquid refrigerant passes into the evaporator coils located in the cold store where it absorbs latent heat from the warmer room and vaporises. As the cold refrigerant gas is drawn through the compressor, its temperature and pressure and, consequently, its boiling point are increased. This is the stage at which work energy is expended on the refrigerant. On passing through the

condenser, the gas which is warmer than the surroundings is condensed to liquid and latent heat is released. The liquid is collected before returning to the expansion valve for a repetition of the cycle. Air is blown across the evaporator by means of a fan to help distribute cold air throughout the store. The fan must be sufficient to recirculate the air no less than 5–10 and preferably 40–50 times per hour. This creates a wind-chill that means that the air feels colder than the design condition for the room. For instance, an air speed of 4 m sec⁻¹ from the evaporator fan in a -20°C cold room creates a wind-chill equivalent temperature of about -27°C. A fan also blows air across the condenser to help it lose its heat. The condenser coil (and indeed, the evaporator coil) may also be fitted with copper fins that help with heat dissipation by conduction, convection and radiation. The difficulty of cooling the condenser will influence running costs. Thus costs will not only be affected by the cold room temperature (see Table 33.2) but also by the ambient environmental temperature at the location (see Figure 33.10). The compressor and condenser are ideally in an outhouse to reduce the risk of fire damage to the store and to increase ventilation and hence heat dispersion. The pipe-work connecting the equipment in the outhouse with the evaporator should be properly insulated. In no case should the compressor be mounted directly on the outside of the cold room because vibration could damage the insulation properties of the wall.

All refrigeration systems should use as ‘ozone friendly’ a refrigerant as is possible although they are less efficient than the earlier and widely used ones such as R22. The refrigerant used in the Millennium Seed Bank is R404A (which is a blend of R143A, 52%; R125, 44%; and R134A, 4%). As with the dehumidifiers for the drying room, it is advisable to have two independent refrigeration systems for each room, each capable of achieving 67% of the design conditions such that one can be ‘on duty’ and the other ‘on standby’. This is especially valuable in the tropics where heat gain in event of failure will be greater. Two plants also allow for repair of the cold room evaporator without switching off the entire system and, when run alternately, allow defrosting to take place during the idle phase. Having commented on system failure, too much is often made of this as a weakness of seed banking. In a bank where the collections are properly dried and packaged and where the cold room is well insulated, little damage will result from short power interruptions leading to temperature rise. With the door kept closed, temperature rise will be slow in most facilities due to the thermal mass of collections and shelving. Even if temperature rises to ambient for a short time, only a few days of storage life in potentially many years of storage may be lost.

The cooling system needs to go through a daily defrost cycle. A timer and thermostat should carefully control this cycle. The thermostat for the room should be placed centrally and control the room to $\pm 1^\circ\text{C}$. It is important that the water that melts from the evaporator during de-icing is drained to the exterior of the room down a heated pipe. Similarly, it is important that the fan blowing air across the evaporator does not come on too soon after the defrost cycle. Should this happen, water will be blown across the shelving which will quickly turn to ice.

If possible, and where flooding is not a risk, the cold store could be placed below ground level. This ensures a cooler and more stable background against which the refrigeration system must work and consequently reduces energy consumption. As with the drying room, the cooling system for the store needs to be sized against the heat load (see above under Drying Room Equipment). One heat source is the infiltration of fresh air into the room. This is important because often there is no fresh air supplied to the cold room. However, staff occupancy of the room is limited and carbon dioxide level increases are unlikely to be significant.

It is usually inadvisable to attempt to dry the cold room air as this will be expensive and will fail in the event of a power cut. It is much more important to have high quality containers that keep the seeds dry. This said, it is advisable that the air inside the room is not allowed to rise in excess of 65% relative humidity as rusting of structural materials could result.

2.4. Safety of the collections within the cold room

A back-up generator in the event of a power failure is a useful though not essential component of any facility. It is perhaps most important in very warm countries. However, it should be located a safe distance from the facility as should its fuel supply. The greater need of a generator is to maintain the drying power of the drying room and the even conditions within germination incubators. Voltage fluctuations of 10–15% are usually not a problem to the operation of cold rooms although anything larger could cause electrical components to trip out.

Each room should be fitted with an alarm that sounds in the event of the room temperature going significantly outside the design condition. As with all alarm systems, they need to be regularly checked for effectiveness. Often, high (in compressor and condenser part of system) and low (the evaporator part of system) refrigerant pressure gauges are provided. Finally, it is worth developing some emergency plans with the local fire service such that they are aware of the nature and value of the material conserved and particularly its potential damage from water.

2.5. Personnel safety in the cold room

Staff should be equipped with proper cold room clothing that should preferably be labelled with likely exposure conditions to alert medical staff called to an emergency. Furthermore, the amounts of time that staff are permitted to stay within cold rooms should be limited. It should be noted that certain medical conditions will preclude staff from working at low temperature. Advice should be obtained on both matters from local health and safety experts. It is worth noting the potentially adverse medical effects when moving directly from warm outside conditions, say +30°C to those at -20°C, a temperature change of 50 degrees in a few minutes.

With respect to personnel safety, a second exit (to ambient) has already been mentioned. Emergency lighting (especially above the exits) and safety alarms should be fitted. The Millennium Seed Bank has a timed system, switched on by staff as they enter each cold room and which rings an alarm to the building's reception desk if not switched off in a given time. It is also fitted with similarly ringing panic alarms in each cold room. Apart from having a telephone close to the cold room entrance, other safety features that can be incorporated include occupancy lights outside the room and viewing mirrors that allow someone at the entrance to quickly check the room for occupants without entering. To reduce staff time at sub-zero temperatures, a few seed bank cold rooms, such as one at the National Institute of Agrobiological Resources (NIAR), Japan, have mechanised banking/retrieval systems. The use of such systems has implications to energy consumption by the bank.

2.6. Use of alternative energy sources

IBPGR (1985) suggested a number of alternative on-site energy sources for long-term seed stores including solar radiation, thermo-electric cells, absorption chillers and radiation cooling. A parallel use of such technology and particularly solar photovoltaic refrigerators is in the cold storage of vaccines (see Charters and Oo, 1987). Consideration needs to be given to

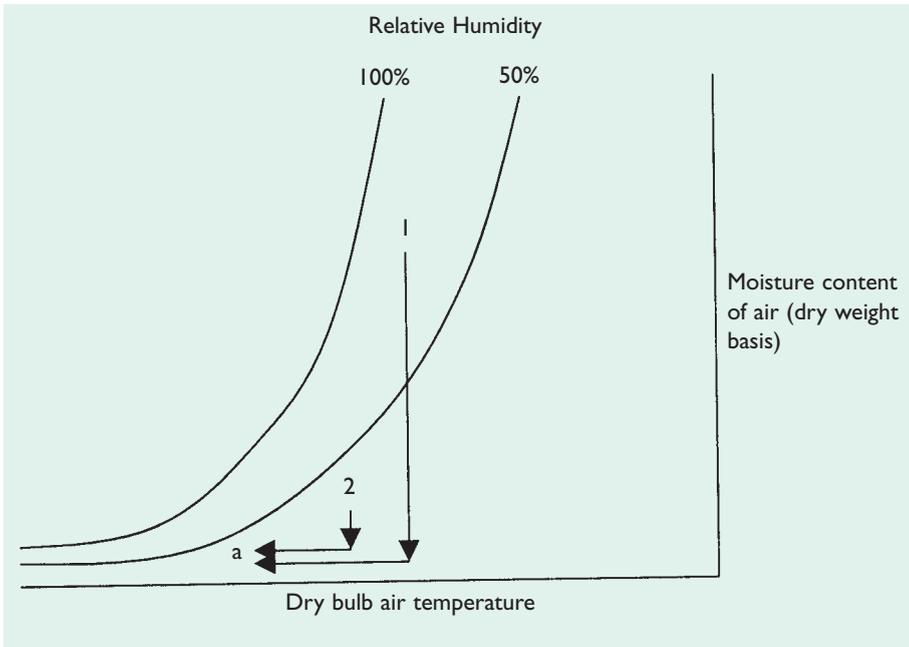


Figure 33.10 Stylised psychrometric chart showing environmental design conditions at two locations (1 and 2) and a seed drying room (a) and indicating the different amounts of air drying (downward arrows) and cooling (left-pointing arrows) necessary at both.

powering the refrigerator during cloudy periods. Two approaches to this problem are ice storage within the refrigerator and draining down of the battery. The latter is charged by the photovoltaic unit and in turn powers the compressor. Specifications and test procedures for photovoltaic refrigerators used in vaccine storage can be found on the World Health Organisation web pages (www.who.int). As this technology improves and reduces in cost, it might be anticipated that remote seed banks in tropical and sub-tropical regions storing very small volumes of precious seed might utilise solar power. Because even larger-scale facilities (21 m³ for 10 tons of frozen fish) have been powered by photovoltaic systems (Nagaraju *et al.*, 2001), the long-term prospects for use by larger seed stores seem reasonable.

Seed Bank Design – General Comments

1. The Building Housing the Bank

Consideration should be given to the type of building in which the seed bank is located. In warm climates, it should be designed with a sloping roof that shades the walls, thereby limiting solar gain. It should also have a ventilated roof space to allow any accumulating heat to escape. The building should be rodent-proof.

2. Location

While the location of the facility will be guided by many practical factors such as the location of parent or associated institutes and centres of habitation, several other aspects are worth consideration. The ambient relative humidity and temperature at the site will influence the energy usage of the bank. Engineers will determine equipment requirement using the ‘design condition’ for the site. The month with the highest average monthly maximum dry bulb temperature is chosen. This is the design temperature. Reference to a psychrometric chart allows the design air moisture content to be determined by using that month’s average daily maximum dry bulb temperature and average relative humidity minimum. The design condition helps the engineer ensure that the facility will be able to provide the specified drying or storage conditions under most annual circumstances. Figure 33.10 indicates how the location’s design condition might influence energy consumption. Note, however, that if a drying room is to be used only at harvest time, the average daily harvest month temperature and relative humidity may be more appropriate than the design condition. Where possible, banks should be located in cool, dry locations. Unfortunately, these do not tend to correspond to the world’s main biodiversity hotspots.

The security of the location of the bank is also important. Risks that need to be considered and preferably reduced by design include those of impact (from trees and collapse of buildings including the effects of hurricanes), explosion and fire (from nearby chemical or fuel storage), earthquake, flooding, vandalism and radiation fallout from nuclear power stations. Containing the facility within an enclosed brick or concrete structure can reduce the latter risk. An ability to automatically close off the fresh air make-up to the drying room by linking it to a suitable monitor is also important. The Millennium Seed Bank is inside an underground concrete vault and the Berry Botanic Garden Seed Bank (see Table 33.3) is within a concrete shell. The main vault at the National Seed Storage Laboratory at Fort Collins in the USA is on an upper floor to minimise the risk of impact from building collapse due to earthquake. It is also capable of withstanding impact damage from a 2500 lb. (1.1 tonne) object dropping at 125 mph (200 kph). The wheat and maize seed bank at CIMMYT in Mexico consists of a two storey, fortified concrete bunker with the active store at ground level and the base store below ground (Pardey *et al.*, 2001). Risks such as volcanic activity can only be avoided by choice of site. Political instability is obviously another risk that will influence international funding agencies in their support for new facilities. It is worth pointing out that all of the risks noted apply to both *ex situ* and *in situ* conservation. As mentioned earlier, duplication of the collections cuts the risks to the survival of material. A degree of disaster planning at an institutional and national level is also important.

3. Ancillary Equipment and Facilities

The following equipment and facilities are those that will most need to be considered when establishing the costs of a seed bank. They are additional to those likely to be supplied as part of a drying and freezer installation.

- **Targeting:** maps and Geographical Information System (GIS) computer.
- **Collecting:** cloth bags, herbarium presses, Geographical Positioning System (GPS), vehicle and general expedition equipment (see Hawkes *et al.*, 2000).
- **Accessioning:** computer with Uninterrupted Power Supply (UPS).
- **Seed cleaning:** sieves, aspirator, washing facilities, dust masks/extraction and low-powered binocular microscope.
- **Analysis of cleaning:** X-ray machine, dark room and light box.
- **Drying:** Crates, general hygrometer and temperature/relative humidity logger.
- **Moisture content determination:** equilibrium relative humidity hygrometer, ovens (103/130°C), crucibles and 4–5 decimal place balance.

- **Seed quantity determination:** seed counter and balance (see above).
- **Viability testing and retesting:** incubators fitted with fluorescent (red rich) lights and capable of alternating temperatures (at least two of 250 l and more depending upon the quantity of collections to be tested, not forgetting re-tests, and diversity of species) and chemicals.
- **Packaging:** foil bags, bag sealer, labelling, cans and bottles.
- **Freezing:** cold room clothing, generator and logger (see above).
- **Characterisation/identification:** herbarium cabinets and field/glasshouse facilities.
- **Regeneration and evaluation (as appropriate):** field/glasshouse facilities (see above).
- **Seed health testing (as appropriate):** see for instance, Neergaard (1977).
- **Miscellaneous:** appropriate fire-fighting equipment; office accommodation and associated facilities plus storerooms for equipment and consumables.

It is useful if the rooms housing the above equipment can be arranged so that collections pass through the facility in a logical way that maximises efficiency. The cost of the building housing the facility, if not already available, should not be forgotten. It is worth noting that some of the seed bank equipment such as the rotary dehumidifier and refrigeration may require (or benefit from) a three-phase electricity supply. Any cost scheme should include a certain supply of spare parts for key items of equipment, particularly if delivery of those parts may be subject to long delays e.g., if they need to be imported.

Some of the above facilities and equipment may be found at other local institutes. Special arrangements may allow their use and consequent savings can be made.

Suppliers for much of the above equipment can now be found by searching the internet. Some examples of current UK and other European website and e-mail addresses that may be useful are those for: aluminium foil bags (barrierfoil@aol.com); aspirators (Selectam@WXL.NL); general chemicals and equipment (www.fisher.co.uk and www.scientific-labs.com); laboratory equipment including incubators; microscopes and sieves (www.jencons.co.uk); relative humidity and temperature loggers (www.rotronic.co.uk and www.thermospeed.co.uk); silica gel (www.baltimorechemicals.co.uk); sealers for foil bags (www.hulmemartin.co.uk); sorption dehumidifiers (www.munters.co.uk); and X-ray machines (www.toddresearch.co.uk). Obviously, inclusion of these and other addresses does not necessarily represent an endorsement of the suppliers by the author or his institute.

Costs

Capital and running costs will depend upon a number of local factors and there is consequently little to be gained from detailed discussion of costs incurred by given seed bank operations. As a *very* approximate guide, a standard cold room and drying room, each of 15 m² might cost in the order of £30,000 (about US \$44,000) and £70,000, respectively, at 2002 values. A small sorption dehumidifier might cost something less than £5,000 in the UK. A bank constructed in 1995 within the UK and comprising a -20°C cold room and a 10% relative humidity, 10°C drying room, each of 40 m² and a -40°C cold room of 15 m², cost, at 2002 values, just less than £ 300,000. Some idea of the effect of scaling up is given by the costs of a facility built at CIMMYT in Mexico. This comprises about 350 m² (960 m³) storage space (half medium-term at -3°C/25–30% relative humidity and half long-term at -18°C) that cost approximately £720,000 elevated to 2000 values (Pardey *et al.*, 2001; Pardey, pers. comm.).

In any long-term budgeting exercise, it is also important to consider the financial write-off times that may or may not coincide with replacement times for equipment over the lifetime of the bank's operation.

Case Studies

Five case studies of seed banks involved in different types of seed conservation around the world are shown in Table 33.3 and illustrated in Figures 33.11 and 33.12.

Details of other seed banks can be obtained by reference to the internet. Useful sites include those of: the USDA National Seed Storage Laboratory (www.ars-grin.gov/ars/NoPlains/FtCollins/nsslmain.html); the Institute of Crop Germplasm Resources, CAAS, Beijing, PR China (<http://icgr.caas.net.cn/cgrisngb.html>); the International Center for Agricultural Research in Dry Areas (ICARDA), Syria (www.icarda.cgiar.org/Research/Research2/genebank.htm); the Nordic Gene Bank (www.ngb.se); and the Millennium Seed Bank Project (www.rbgkew.org.uk/msbp/). Others can be found by reference to the links pages of the webpages of the International Plant Genetic Resources Institute (www.ipgri.cgiar.org) and the Seed and Plant Genetic Resources Service of the Food and Agriculture Organisation of the United Nations (access via www.fao.org). Obviously, with any website, the address may become out-of-date and it may be necessary to search using the organisation's name.

Table 33.3 Case studies of five different seed banks

Website					National Plant Genetic Resources Centre (NPGRC) of Namibia	Threatened Flora Seed Centre, Western Australian Herbarium, Department of Conservation	Berry Botanic Garden Seed Bank for Rare and Endangered Plants of the Pacific Northwest
Location	www.maich.gr	www.hri.ac.uk/gru/	www.calm.wa.gov.au	www.berrybot.org			
Types of resources conserved	Chania, Crete, Greece Endemic and threatened plants of Crete and old varieties of vegetables and legumes	Wellesbourne, UK Vegetables (mainly small seeded)	Perth, Australia Rare and threatened species	Portland, Oregon, USA Rare and endangered seed plants of the Pacific Northwest region of the USA			
No. of collections (in 2001)	350	13,466	920	9,225 (314 taxa)			
Average collection size (approx.)	N/a	25g	Aim: Grains – 20,000 seeds Legumes – 10,000 seeds Cucurbits – 10,000 seeds Wild species – 1,000 seeds	Average of 230 seeds but very high variance. Newer collections – seeds from each plant held separately			
Approx. potential capacity	10,000 accessions	17,500 accessions	10,000 accessions	Several 1,000 accessions			
Method of drying	Drying Room	Drying Room	Modified incubator	Drying Room			
Drying Room floor area	8.25 m ²	19.11 m ² (9.1 × 2.1 m) – used for packaging	N/a	12.5 m ² (5.0 × 2.5 m)			
Airlock floor area	N/a	No airlock	N/a	4m ² (2.5 × 1.6 m)			
Drying Room internal height	2.8 m	2.4 m	N/a	2.4 m			
Drying temperature and % RH	15–20°C, 15–20% RH	15°C, 15%	15°C and ±5% RH	15°C, 15%			
Method of drying and cooling air	Rotary dehumidifier (10 air changes/hour). Air cooled by refrigeration plant	Lithium chloride rotary dehumidifiers (2 in parallel) and 2 air conditioning systems operating independently of dehumidifiers	N/a	Rotary dehumidifier			
Shelving system for room	Mobile, aluminium shelves	Static, wooden shelves along walls	N/a	Fixed, aluminium shelves			
Shelving system for room							Plastic coated metal wire shelving (approx. 0.5 m deep)

Table 33.3 continued

Base, active and duplicate collections	Seed Bank of Mediterranean Agronomic Institute of Chania	Genetic Resources Unit, Horticulture Research International	National Plant Genetic Resources Centre (NPGRC) of Namibia	Threatened Flora Seed Centre, Western Australian Herbarium, Department of Conservation	Berry Botanic Garden Seed Bank for Rare and Endangered Plants of the Pacific Northwest
	Base and active	Base and active collections (duplicates of material held elsewhere). Bank also holds duplicates from other banks	Active (base and duplicate collections held elsewhere)	Base plus subsamples for monitoring. Some duplication of rare taxa at botanic gardens and duplication of priority taxa at Millennium Seed Bank	Collection split into two equal fractions. Intention to send one to NSSL. Seed removed from one fraction only
Storage containers	Aluminium cans (with Teflon)	Foil laminate bags (98%); spined fruits and large seeds in glass Kilner jars	Active collections – laminated aluminium foil bags; base collections – glass bottles; duplicate collections – Millennium Seed Bank (various)	Laminated aluminium foil bags	Laminated aluminium foil bags (labelled internally and externally). Several collections inside Glascine envelopes may be placed in each bag
Storage temperature	-18°C to -20°C	-20°C (single store)	Active collections: -20°C	Base collections and subsamples: -20°C Samples for research in near future: 4°C	-18°C. Seeds for Index Seminum exchange held at 15°C
Storage room internal floor area/volume and number of freezer chests	17 m ² 1 Domestic freezer	43.24 m ² (9.4 × 4.6 m)	Freezers: 15 × 250 l upright 2 × 300 l chest	-20°C; 8 m ² (3.2 × 2.5 m) 4°C; 8 m ²	0.85 m ³ Chest freezer inside 'shell' but with compressor/condenser outside vault
Airlock floor area	Access via drying room	Access via drying room	N/a	N/a	N/a
Storage room internal height	2.8 m	2.4 m	N/a	2.4 m	Housed inside drying room
Shelving system	Mobile with metal drawers	Mobile with metal drawers	N/a	Fixed, aluminium shelves along walls	N/a
Generator	Not yet	Yes	Yes	No	Yes (gas powered) but never used
Annual intake	N/a	300–350 collections	± 100 new collections plus 120 multiplied crop seed batches	Approx. 100 collections	N/a

Table 33.3 continued						
	Seed Bank of Mediterranean Agronomic Institute of Chania	Genetic Resources Unit, Horticulture Research International	National Plant Genetic Resources Centre (NPGRC) of Namibia	Threatened Flora Seed Centre, Western Australian Herbarium, Department of Conservation	Berry Botanic Garden Seed Bank for Rare and Endangered Plants of the Pacific Northwest	
Number of staff involved in processing and collection maintenance	2 MSc and 1 assistant	3 staff and summer assistants	2 MSc, 2 Diploma in agriculture (1 employed by another division), 1 with high school certificate and 4 temporary staff	2, both with degrees	2, 1 with PhD and 1 graduate. Intention to add 0.5 post. Assistance from interns and volunteers	
Ancillary facilities	4 growth chambers, 1 dark room, 1 analytical balance, 2 stereo-microscopes, 12 sieves, 1 fume hood	See also Figure 00.11, PCs, aspirators, sieves, dust extraction, 2 illuminated, temperature controlled incubators for germination tests	3 offices, 1 laboratory (germination, seed mc etc), 1 short-term cold room (15°C) and 1 seed threshing room. As part of the National Botanical Research Institute, access is available to facilities of herbarium, vegetation ecology and botanic garden	Laboratory facilities that house laminar flow area, wet area and bench space for microscopes and balance	See Figure 00.12. Cleaning by hand. 4 germination chambers with fluorescent lights – alternating temperatures possible, domestic refrigerator for stratification, microbalance, laminar flow hood, dissecting microscope	
Details of running costs per year	N/a	N/a	US\$ 45,000 incl. salaries	Consumables approx. \$AUS 1,000	N/a	
Purpose-built facility	N/a	Yes	No	N/a	Yes	
Plan	N/a	See Figure 00.11	N/a	N/a	See Figure 00.12	
Notes						
Genetic Resources Unit, Horticulture Research International. A further -20°C store (9 × 7 m) and drying room (9 × 3 m) will be built by the end of March 2003. These will have a similar design to the existing facility and will increase potential capacity to 30,000 accessions. The collections will be held within the new cold store on mobile, metal shelves plus plastic boxes.						
Berry Botanic Garden Seed Bank. The seed vault has 20 cm thick steel reinforced concrete walls and sits on its own foundations. To prevent moisture from wicking up from the ground, the foundation wall is topped with a moisture-proof bituminous compound. The concrete floor is treated with concrete sealer and covered with vinyl flooring. The floor has been poured on a base of compacted gravel covered with a moisture barrier and rigid foam insulation. The vault is insulated internally with 9 cm thick metal-coated polyurethane panels. The insulation was installed once the concrete shell was built. The vault is secured by a steel door with a three hour fire rating. Fusible link metal curtains close other openings into vault. should the temperature become sufficiently high. The vault is approached through a short hall that serves as an air lock. The room within the vault is designed for drying but also houses the freezer. This has fire safety and operating cost benefits. A system of relays cuts off power in the event of a problem.						

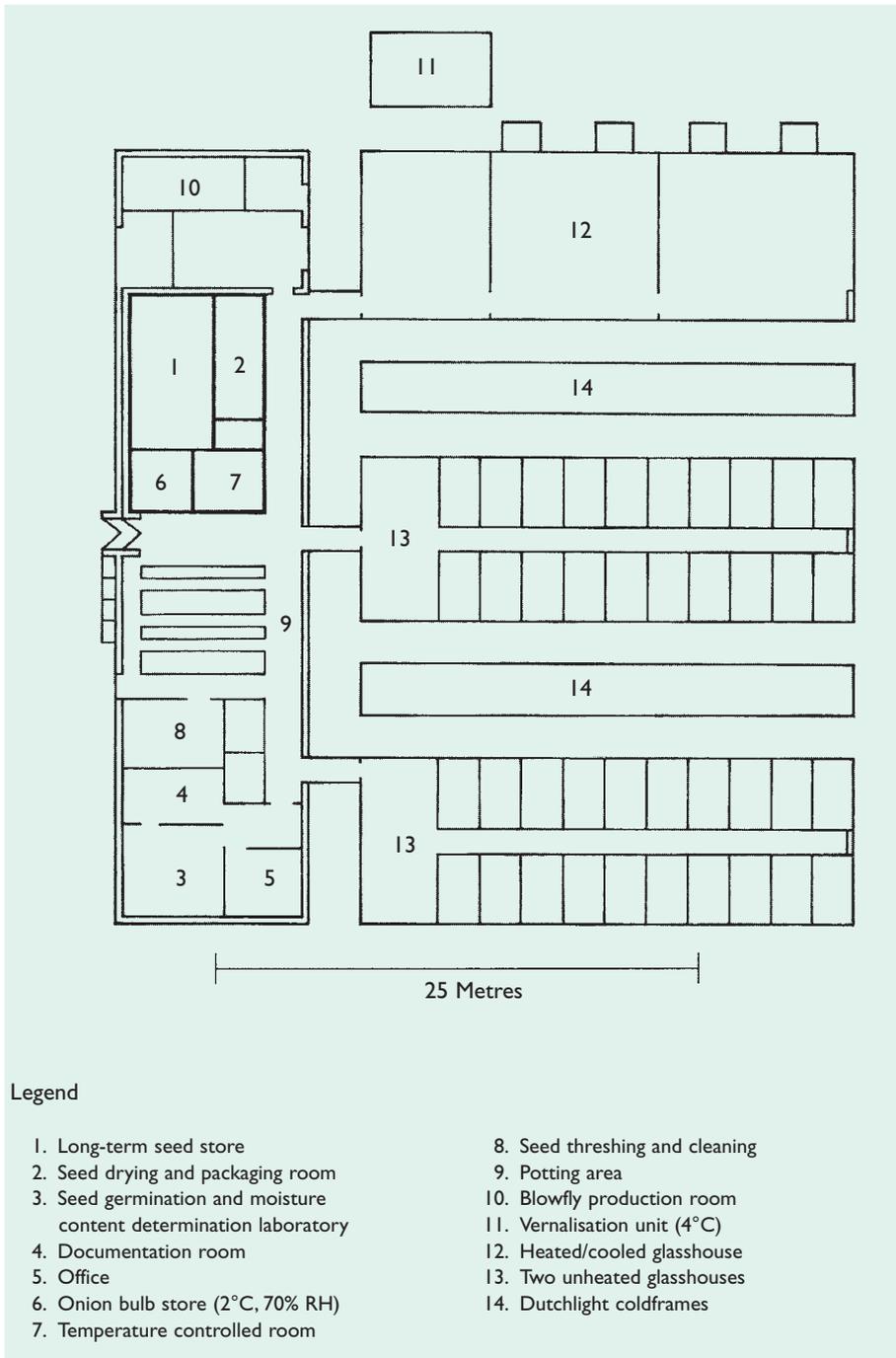


Figure 33.11

Plan of the Genetic Resources Unit, HRI, Wellesbourne, UK.

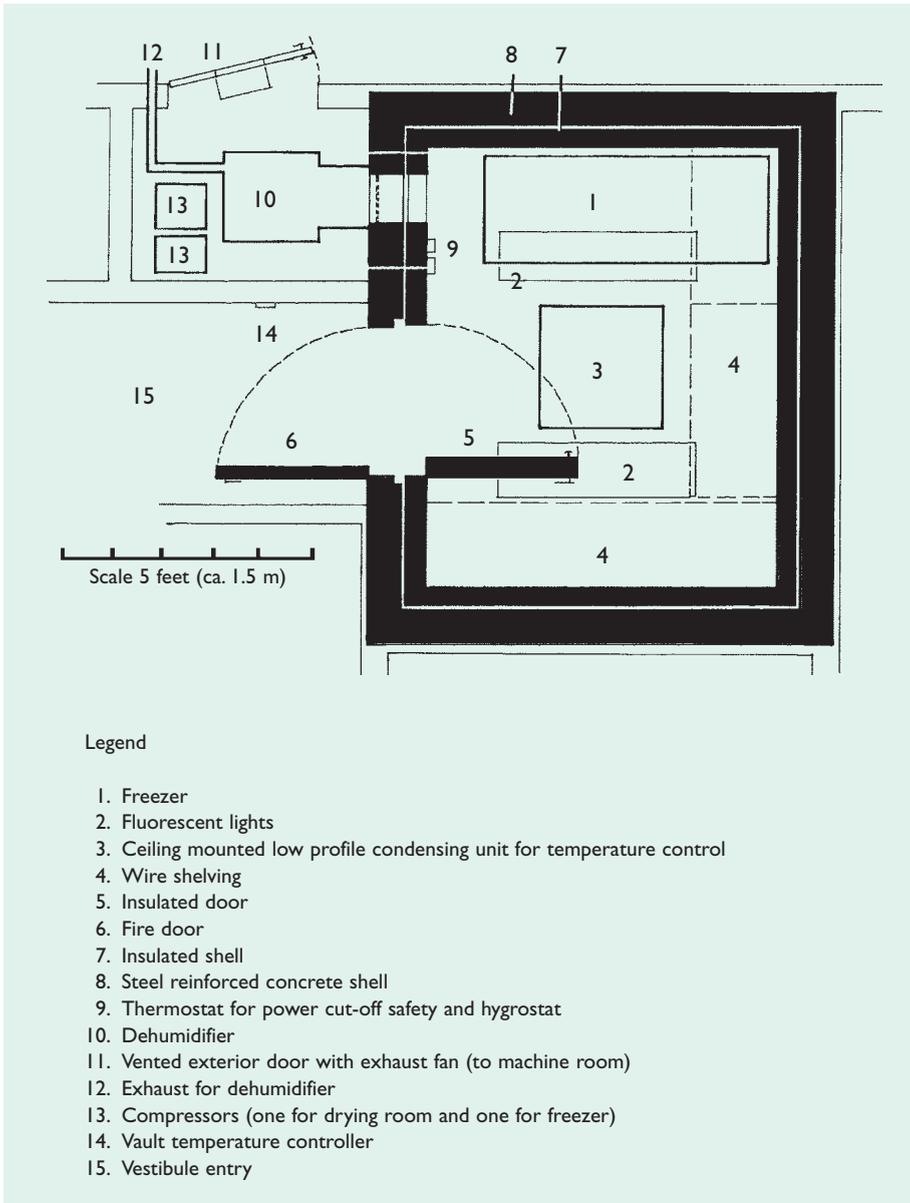


Figure 33.12 The Berry Botanic Garden Seed Vault.

By comparison to the five long-term seed bank case studies in Table 33.3, it is useful to outline an example of a high-throughput forest seed store. The Kenya Forestry Seed Centre at the Kenya Forestry Research Institute (KEFRI), Muguga, Kenya holds 600 collections of trees and shrubs. Collection size is 5–10 kg depending upon seed size. The bank has the potential to hold 7,000 kg of seed. The annual throughput of material is about 4–5 tonnes. Sun drying within specially designed drying beds and air drying on wire mesh shelves within a 20 × 10 m room is used. About 90% of the accessions comprise the active collection and 10% are for research. Dried seeds are stored at 1, 5 or 10°C within various sizes of plastic containers with tight lids. The total floor area of storage is 150 m² and the rooms are 5 m high. The centre employs 100 support staff and one graduate. Ancillary facilities include seed packaging and despatch equipment and rooms plus standard seed testing facilities. A generator is available on site.

Expert Advice

This chapter has attempted to highlight many of the considerations facing those wishing to set up a seed bank. The information and calculations provided should be seen only as a guide and the advice given may not be appropriate under all circumstances. It is therefore essential that expert local advice on refrigeration, drying and ancillary installations is taken when setting up any facility. The provision of suitable facilities to match local needs and conditions is a key step on the road to successful seed conservation.

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