Schedule A. Bulk fumigation of grain in upright storage

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Fumigant	Dosage per m^3	Dosage per 1000 bushels[1]	Minimum exposure (days)	Remarks
Direct mixing				
Calcium cyanide	155 g	12 lb	7	May stain white maize and polished rice
Chloropicrin	26 g	2 lb	1	Should be removed by aeration after 24 hours
Mixture EDC75:CT25	0.44 1	4 gal	3	For maize x 1.5
Mixture $CS_2$16:CT84	0.27 1	2.5 gal	3	Mixture may contain 1 to 2 % SO(2)
Mixture	0.21 1	2 gal	3	For maize x 1.5

Mixture EDB7:EDC30:CT63	0.21 1	2 gal	3	For maize x 1.5
Phosphine	1-2 g	35-70 g	4	7 days at 10-15°C 6 days at 16-20°C 5 days at 21-25°C 4 days at 26°C or above
Surface application (gravity distribution)				
Mixture EDC75:CT25	0.44 1	4 gal	7	For maize x 1.5
Mixture $CS_2$16:CT84	0.33 1	3 gal	7	For maize x 1.5
Mixture EDB7:EDC30:CT63	0.27 1	2.5 gal	7	For maize x 1.5
Carbon tetrachloride	0.55 1	5 gal	14	More often used in combination
Recirculation				
Methyl bromide	26.2	2 lb	1	Should be removed by

Methyl bromide	26 2	2 lb	1	Should be removed by aeration after 24 hours
Hydrogen cyanide (HCN)	39 g	3 lb	1	Grain should be thoroughly aerated before removal
Mixture Chloropicrin 85: Methyl chloride 15	26 g	2 lb	1	Should be removed by aeration after 24 hours
Mixture ETO10:$CO_2$90	386 g	30 lb	1	Do not use on seed
Mixture CH_3Br70:EDB30	13 g	1 lb	1	Should be removed by aeration after 24 hours

[1]Bushels and gallons are in U.S. volumetric measuraments. All dosages, unless otherwise stated, are given for a grain temperature range of 21 to 25 °C(See Chapter 7 for other fumigant mixtures similar to those listed above).

Schedule B. Bulk fumigation of grain in flat storage

Fumigant	Dosage per m^3	Dosage per 1000 bushels[1]	Minimum exposure (days)	Remarks
Application by probe				
Phosphine 1 to 2 g		35-70 g	4	7 days at 10-15°C 6 days at 16-20°C 5 days at 21-25°C 4 days at 26°C or above
Surface application (gravity distribution)				
Mixture EDC75:CT25	0.49 1	4.5 gal	7	For maize x 1.5
Mixture $CS_2$16:CT84	0.55 1	5 gal	7	For maize x 1.5
Mixture	0.44 1	4 gal	3	For maize x 1.5

EDB7:EDC30:CT63				
Methyl bromide	32.0 g	2.5 lb	1	Applied under gas tight sheet in South Africa. Must be removed by aeration after 24 hours
Recirculation				
Methyl bromide	38.6 g	3 lb	1	Should be removed by aeration after 24 hours
HCN	38.6 g	3 lb	1	Should be thoroughly aerated before grain is moved.
Mixture Chloropicrin 85: Methyl chloride 15	38.6 g	3 lb	1	Should be removed by aeration after 24 hours
Mixture CH_3Br70:EDB30	19.2 g	1.5 lb	1	Should be removed by aeration after 24 hours

[1]Bushels and gallons are in U.S. volumetric measuraments. All dosages, unless otherwise stated, are given for a grain temperature range of 21 to 25 °C,unless otherwise stated.

Schedule C. List of plants which have sustained injury from fumigation with methyl bromide

As explained in the text, many species and varieties of plants are tolerant to methyl bromide, and those which have been injured are a small percentage of the total number tested.

Some plants may show temporary injury, such as leaf burn, leaf fall or loss of bloom, followed by complete recovery. Others are either killed outright or are so seriously injured that fumigation is out of the question. Therefore, the response is divided into these two categories.

The plants listed as having been injured while nondormant will generally be tolerant when dormant. On the other hend, plants injured when dormant would be even more susceptible to injury when actively growing. The references (a to j) given after each plant variety are listed at the end of this schedule. When the reference after an item is omitted, it will be found immediately below, with the last species or variety of the same genus.

For the most part, the plants listed here have sustained the injury in fumigation at atmospheric pressure. Plants are usually much more susceptible to injury in vacuum fumigation; for that reason it is recommended only under special circumstances, as in parts of Schedules F and G.

Further information on a wide variety of plant species is given in the "Handbook of Plant Tolerances to Methyl Bromide", USDA (1977).

A. NONDORMANT GROWING PLANTS

In this group of plants, injury has been observed following treatment at rates shown in Schedule D.

1. PLANTS SHOWING TEMPORARY INJURY AFTER TREATMENT, FOLLOWED BY COMPLETE RECOVERY

Acacia appears susceptible to temporary injury. The following species showed leaf fall, then recovery (c,d):

A. baileyana, A. decurrens, A. melanoxylon, A. verticillata

Aglaonema sinensis (a)
Aloe spp. (e)

Amphicome arguta (e) (see Incarvillea)
Araucaria excelsa (Norfolk Island Pine) (a)
Azara microphylla (c,d)
Banksia spp. (c)
Begonia fuchsioides (h)
Berberis spp. uninjured, except:

B. gagnepainii
B. julianae, which should be fumigated when dormant (e)

Bouvardia var. Giant Pink (a)
Bouvardia humboldtii (a)
Bryophyllum spp. uninjured, except 3 species (e):

B. aliciae, mature leaves lost.
B. miniatum, mature leaves lost
B. tubiflorum, lower leaves burned

Cactus spp. found tolerant by (a) and (e), but fumigation not recommended by (c)
Calathea vandenheckei (a)
Capsicum frutescens (red pepper) (c,d)
Cinchona spp. are tolerant, except:

C. pubescens
C. officinalis, showed slight tip burn (e)

Clerodendrum speciosissimum (glory bower) (c, d)
Cotoneaster franchetii (b)
Cotyledon spp., occasional tip burn only (e)
Crassula arborescens (a)
Cytisus racemosus (broom). Other species tolerant (c,d)
Elaeagnus pungens (c,d)
Erica spp. (heath) (d)
Erythrina crysta-gallii (cockspur) (c,d)
Eupatorium ligustrinum, tip burn on very youngest leaf (e)
Euphorbia fulgens (scarlet plume), probably subject to leaf drop (a)
Fatsia japonica (c,d)
Ficus pandurata (fig) (d,e)
Fuchsia spp. (c,d,i)
Gardenia veitchii. Other species tolerant (a)
Genista monosperma (broom) (c,d) -
Geranium spp. (c,d)
Hibiscus spp. (c,d)
Hoheria spp. (c)
Howea forsteriana (a)

Hoya carnosa (wax plant) (c,d)
Incarvillea (e)
Jacaranda spp. (e)
Kitchingia (Kalanchoe) peltala (e)
Lantana spp. (lion's ear) (c,d)
Leonotis leonurus (c,d)
Leptospermum. All species (c)
Luculia. All species (c)
Maranta spp. (c,d)
Myrtus communis (myrtle) (c,d)
Nephthytis afzelii
Nephthytis liberica (a)
Nerium oleander (c,d)
Nothofagus. All species (c)
Oncoba routledgei (e)
Osmanthus ilicifolius (aquifolium) (c,d)
Pandanus veitchii (screw pine) (c,d)
Philodendron cordatum, P. dublum (a)
Pittosporum spp. (c,d,e)
Pothos wilcoxi (f)
Psidium guajava (guava) (c,d,e)
Solanum pseudocapsicum (Jerusalem cherry). Many other species not injured

(c,d,e)
Spartium juncoum (Spanish broom) (c,d,e)
Spirea reevesiana (b)
Theobroma purpureum (e)
Viburnum macrophyllum
Viburnum odoratissimum (f). Many other species not injured (a)
Vitex lucens-puriri (c)

2. PLANTS KILLED OUTRIGHT OR SERIOUSLY INJURED

Abelia grandiflora (c,d)
Adiantum (maidenhair fern) (c,d)
Allamanda johnsoni (j)
Areca palm (c,d)
Asplenium nidus (bird's nest fern) (c,d)
Aster fruiticosus (c,d). Many other species tolerant
Begonia semperflorens (c , d)
Begonia tuberhybrida (c , d)
Billbergia alberti, B. nutans (a)
Camellia spp. seem to be tolerant, except C. thee, which has been seriously injured (b)
Cardiospermum integerrimum (heart seed) (e)

Celosia cristata (c,d)
Chamaecyparis spp. (false cypress) (c,d,f)
Chryeanthemum spp. may be fumigated when fully dormant (c,d,i)
Coleus blumei (c,d)
Cuphea hyssopifolia (c,d)
Cupressus arizonica, C. macrocarpa showed initial injury but soon recovered (c,d)
Cupressus sempervirens (cypress) intolerant
Dracacna warneckii (j)
Euphorbia (c,d)
Fremontia (Fremontodendron) californica (flannel bush) (c , d)
Griselinia littoralis (c,d)
Kalanchoe synsepala (e). Many other species tolerant
Lavandula pedunculata (lavender) (c,d)
Leucospermum. All species (c)
Monstera deliciosa (a)
Musa spp. (banana) (c,d)
Pelargonium hortorum (i)
Poinsettia (Euphorbia) spp. (c, d)
Pyracantha formosana (firethorn), P.yunnanensis (f). Some other species tolerant (e)
Retinospora ericoides, R. pisifera filifera, not injured (f)
Retinospora (Chamaecyparis) pisifera var. filifera aurea, and var. plumosa aurea

(f)
Saintpaulia ionanthus (c,d)
Sedum adophii (stonecrop). Other species tolerant (a)
Sinningia speciosa (gloxinia) (c,d)
Stephanotis floribunda (c,d)

B. FOLIATED DORMANT PLANTS

Injury has been sustained after treatments at rates shown in Schedule E.

1. PLANTS SHOWING TEMPORARY INJURY

Acer palmatum atropurpureum (Japanese maple) (c)
Daphne spp. (a)
Enkianthus campanulatus (a)
Hemerocallis spp. (day lily) (a)
Hydrangea spp. (a)
Hydrangea macrophylla (c , d)
Hydrangea paniculata (a)
Ligustrum ovalifolium (e)
Ligustrum quihoui (privet)
Ligustrum quihoui pendulum (b)

Philadelphus laxus (mock orange) (e)
Symphoricarpos chenaultii (a). Other species not injured
Tsuga canadensis pendula and T. canadensis sargentii (hemlock)(a)

2. PLANTS KILLED OUTRIGHT OR SEVERELY INJURED

Azalea var. Coral Bells, and var. Salmon Beauty (Salmon Queen) (c,d); these two varieties are quite exeptional. Azaleas generally are very tolerant (g)

Juniperus chinensis foemina (sylvestris)

Juniperus chinensis japonica

Juniperus chinensis sargentii. Partially or completely defoliated, but not killed (b)

Juniperis communis depresa plumosa

Juniperus japonica oblonga is subject to serious injury (b)

REFERENCES

(a) Donohoe and Johnson (1939)
(b) English and Turnipseed (1946)

(c) Greig (1950-56)
(d) Harper (1942-57)
(e) Latta and Cowgill (1941)
(f) Livingstone and Swank (1941)
(9) Lounsky (1939)
(h) Mackie and Carter (1937)
(i) Richardson et al (1943b)
(j) Roark (1939)

For general information see also USDA (1976) Plant Protection and Quarantine Treatment Manual, Revised April 1976, with periodic updated additions.

Schedule D. Methyl bromide fumigation of actively growing plants

The schedule is recommended for use only within the specific limits outlined below. However, in conjunction with the information on plant tolerance contained in Schedule C, it could be made the basis for experimentation on other groups of insects and varieties of plants.

MATERIAL

Glasshouse or herbaceous plants infested with armoured scales, mealybugs, thrips, red

spiders, whiteflies, aphids or leaf miners. This schedule may not be effective against soft scales and borers. For these, the vacuum fumigation treatments given in Schedule F may be attempted at the risk of plant injury.

For cyclamen mites use Schedule F. For orchids use Schedule G.

PLANT TOLERANCE

See Schedule C for list of plants sustaining injury.

Extensive experimentation on plant tolerance during the last 30 years has shown that many genera and species may be treated without injury. As a general rule, therefore, it may be said that any common glassshouse or herbaceous plant not listed among the exceptions in Schedule C may be subjected to these treatments.

Rooted cuttings of chrysanthemum are not tolerant and another method of control should be employed.

Vacuum fumigation is not recommended for actively growing plants (see remarks above concerning Schedule F).

DOSAGE

The following dosage schedule is based on Latta et al (1950). Treatments at temperatures above 30°C should be made only if unavoidable.

In conducting these treatments, the concentrations should not fall by more than 25 percent of the applied dosage in the first half hour and not by more than 50 percent during the two-hour period, e.g. for a treatment at 16 - 20°C with a dosage of 40 g/m³ the concentration, as determined by gas analysis, at 30 minutes should be 30 g/m³ and at 2 hours 20 g/m³ (USDA, 1976).

Atmospheric fumigation with methyl bromide with 2-hour exposure

Temperature		Dosage g/m³ (oz/1 000 ft³)
°C	ºF	
4 - 10	39 - 50	56
11 - 15	51 - 59	48
16 - 20	60 - 68	40
21 - 25	69 - 77	32
26 - 29	78 - 85	24
30 - 32	86 - 90	16

Schedule E. Methyl bromide fumigation of foliated dormant plants

A list of foliated dormant plants susceptible to injury is given in Schedule C.

MATERIAL

Broadleaved evergreens. azaleas, rhododendrons, camelias, flex, etc. Coniferous evergreens: these are susceptible to injury and care must be taken to fumigate them when fully dormant. They are particularly sensitive at the time of breaking dormancy. Exception. Araucaria - use Schedule D.

INSECTS

Two schedules are given below; the first is for external infestation generally; the second for internal feeders and species or stages of insects which are difficult to kill, such as Brachvrhinus sp. Internal feeders include such species as the European pine shoot moth Rhyscionia

Atmospheric fumigation with methyl bromide

Temperature	Dosage g/m³ (oz/l 000 ft³)	Exposure period (h)	Suggested minimum c x t product in free space of chamber

				(mg h/l)
°C	**°F**			
External infestation[1]				
4 - 10	39 - 50	40	3.5	80
11 - 15	51 - 59	40	3	72
16 - 20	60 - 68	40	2.5	64
21 - 25	69 - 77	40	2	56
26 - 29	78 - 85	32	2	48
30 - 32	86 - 90	24	2	40
Internal infestation2 (and insects difficult to kill, such as Brachvrhinus sp.)				
4 - 10	39 - 50	64	3.5	126
11 - 15	51 - 59	64	3	114
16 - 20	60 - 68	64	2.5	102
21 - 25	69 - 77	64	2	90
26 - 29	78 - 85	48	2.5	84

30 - 32	86 - 90	40	2.5	80

[1]Dosage schedule based on Latta et al (1950) and umpublished dataof Monro.

[2]Based on data of Carolin et al (1962) and umpublished dataof Monro.

Schedule F. Methyl bromide fumigation of nonfoliated dormant plant material

MATERIAL

Roots, crowns and perennials. Deciduous woody shrubs, bare-rooted fruit and shade trees. Latex-bearing plants.

INSECTS

Many species and stages of insects, including hibernating forms such as larvae of the oriental fruit moth Grapholitha molesta (Busck) in hibernaculae.

Cyclamen mites and possibly other species of leaf-feeding mites.

Brachyrhinus larvae are difficult to kill and 30 minutes should be added to the exposure

period for atmospheric treatment below.

If available, vacuum fumigation may be more effective against internal insects. The schedule given for vacuum fumigation may also be generally applied for fully dormant nonfoliated material.

Fumigation with methyl bromide[1]

Temperature		**Dosage g/m³ (oz/l 000 ft³)**	**Exposure period (h)**	**Suggested minimum c x t product in free space of chamber[2] (mg h/l)**
°C	**°F**			
Atmospheric (for insects on the surface)				
4 - 10	39 - 50	56	4	128
11 - 15	51 - 59	48	4	116
16 - 20	60 - 68	40	4	104
21	69 and	32	4	92

	above			
Vacuum3 (for internal feeding insects)				
4 - 10	39 - 50	48	3.5	
11 - 15	51 - 59	48	3	
16 - 20	60 - 68	48	2.5	
21	69 and	48	2	
	above			

[1] Derived from various sources

[2] Based on unpublished data of Monro

[3] Dosage schedule based on Latta et al (1950).Vacuum is sustained at 100 mm Hg (4 in) during entire period of treatment.

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Schedule G. Methyl bromide fumigation of orchids

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MATERIAL

All orchids, collected, domestic or hybrids. Exceptions: Soft scales on nondormant orchids and galls caused by Cecidomyid larvae should be removed by hand.

DOSAGE

Temperature		Dosage g/m (oz/l 000 ft)	Exposure period (h)
C	**F**		
Atmospheric Schedule 1 for nondormant orchids from greenhouse establishments, infested with armoured scales, mealybugs, aphids, whiteflies, etc.			
4 - 10	39 - 50	56	2
11 - 15	51 - 59	48	2
16 - 20	60 - 68	40	2

21 - 25	69 - 77	32	2
26 - 32	78 - 90	24	2
Above 32	90	16	2
Atmospheric Schedule 2 for collected orchids			
4 - 10	39 - 50	48	3.5
11 - 15	51 - 59	48	3
16 - 20	60 - 68	48	2.5
21 - 25	69 - 77	48	2
26 - 32	78 - 90	40	2
Above 32	90	32	2
Partial vacuum fumigation for collected orchids of the Cattleya group, infested with Mordellistena sp., Cattleya fly, soft scales or weevil larvae; for Dendrobrium spp., infested with borers; for shipping crates with bamboo slats, infested with the bamboo shot hole borer Dinoderus minutes.			
4 - 10	39 - 50	48	3.5
11 - 15	51 - 59	48	3

16 - 20	60 - 68	48	2.5
21 - 25	69 - 77	48	2
26 - 32	78 - 90	48	1.5
Above 32	90	48	1

Operating pressure during all the above partial vacuum fumigations, 380 mm Hg (15 in)

REFERENCES

Griffin and Lubatti (1956)
Latta et al (1950)
Richardson (1949)

Schedule H. Methyl bromide fumigation of fresh fruit at atmospheric pressure

SPECIES AND STAGES

Caterpillars, maggots and eggs (if present) of internally feeding Diptera and Lepidoptera, and some scale insects and mites.

LITERATURE REFERENCES

Lettered references are given at the end of this schedule. For general information see also USDA (1976) with periodic revisions.

ATMOSPHERIC FUMIGATION OF FRESH FRUIT

The information given below is based on experiments or commercial experience. The tolerance data are mainly from results obtained in the temperature range 16 to 27C at about the same dosage and exposure given in this schedule.

Tests should be made under local conditions before any schedule is drawn up and adopted.

The following schedules are for an exposure period of 2 hours.

Temperatures 16 - 36C

Temperature		Dosage g/m (oz/l 000 ft)
C	F	
16 - 20	60 - 68	40

21 - 27	69 - 81	32
28 - 32	82 - 90	24
33 - 36	91 - 96	16

Lower temperatures

So far, peaches have been found to be generally tolerant at lower temperatures, also a few varieties of apples, apricots, cherries, grapes, nectarines, pears and plums (j and o)

Temperature		**Dosage g/m (oz/l 000 ft)**
C	**F**	
4 - 10	39 - 50	64
11 - 15	51 - 59	48

FRUIT TOLERANCE TO METHYL BROMIDE

References, given after each variety, are cited at the end of this schedule.

IMPORTANT. The information on tolerance is based on fruit reaction only, and is given for guidance. It is not implied that the fumigant is necessarily effective under the given conditions against all pests found in or on the fruit. As suggested before, tests should always be made to deal with specific problems under local conditions.

Apples

Apples show considerable differences in tolerance according to varieties. Injury may be external or i.nternal. They are usually more tolerant when picked at the proper maturity for harvesting (Phillips et al, 1938). They are less likely to be injured during the first week of cold storage, or after 6 to 8 weeks in cold storage, than during the middle of the storage period (Johnson et al, 1947).

Apple varieties not injured

Canada

Baldwin (N.S. and Ont.)	(i)	**Rhode Island Greening (Ont.)**	(i)
Ben Davis (N.S.)	(l)	**Ribston (N.S.)**	(i)
Cox's Orange (N.S.)	(i)	**Spy (Ont.)**	(i)

~~Delicious* (B.C.)~~	~~(i)~~	~~Stark (N.S.)~~	~~(i)~~
Golden Russet (N.S.)	(i)	Wagner (N.S.)	(i)
King (N.S.)	(i)	Winesap (B.C.)	(i)
Newton (B.C.)	(i)		

South Africa

Ohenimuri	(c)	Rokewood	(c)
Pearmain	(c)	York Imperial	(c)

United States

Bellflower	(b)	Paragon	(e)
Black Ben Davis	(d)	R.I. Greening	(d)
Black Twig	(d)	Rambo	(d)
Blaxtayman	(e)	Red Delicious*	(b,d,p)
Commerce	(d)	Red Winesap	(b,d)
Cortland	(e,p)	Rome Beauty	(b,d,e,p)

Gallia Beauty	(e)	**Stark**	(e)
Gano	(e)	**Starking**	(d,e)
Giant Geneton	(d)	**Starr**	(e)
Golden Delicious	(b,d,p)	**Staymen Winesap**	(d,e)
Gravenstein	(b)	**White Astrachan**	(b)
Grimes Golden	(d)	**Willow Twig**	(d)
Jonathan*	(b,d,e)	**Winesap**	(e)
King David	(d)	**Yellow Newton**	(b)
Lady	(q)	**York***	(d)
Lily of Kent	(e)		
Northern Spy	(d)		

Apple varieties injured

Canada

Cox's Orange (N.S.)	(i)	**King (N.S.)**	**(i)**
Fameuse (Que.)	(i)	**McIntosh (B.C.)**	(l)

Jonathan* (B.C.)	(l)	**North West Greening (Que.)**	(i)

India

Kulu	(q)	**Kashmiri**	(p)
Kandahari	(q)		

South Africa

Red Delicious*	(c)
Granny Smith	(c)

United States

Delicious*	(b,e)	**Wealthy**	(e)
Grimes	(e)	**(Reported by the same author as not injured in carload fumigation, 1944)**	
McIntosh	(e)	**Williams**	(e)

Orleans	(e)	**York***	(e)

Apricots

Derby. Sometimes injured	(b)	**Tilton. Uninjured**	(b)
Royal. Sometimes injured	(b,j)	**Undetermined varieties. Uninjured**	(o)

Avocados

Dickinson, Fuerte - reported as injured (g), or uninjured (k)

Bananas

Injured, the skin turns red (m)

Cherries

The important variety Bing shows no injury from fumigation (b,j) A few other varieties may be slightly injured (b)

*** Reported as tolerant by some workers and as injured by others.**

Grapes Tolerant varieties

Black Olivet	(f)	**Ribier**	(b,f)
Emperor	(b)	**Thompson Seedless**	(b,f)
Red Malaga	(b)	**White Malaga**	(b)
Pizzutello	(f)		

Not tolerant

Tokay	(b)

Nectarines

Several varieties tolerant to schedule given here.

Peaches

Generally tolerant (b,f,h,j,k,o,p)

Pears

Generally tolerant (b,h,j,k). After fumigation fully ripe pears may break down more quickly than normal.

Plums

Reported as tolerant (h,o) or somewhat injured (b). Spotting noticed on Beauty plums when fumigated at 4C (j).

Citrus fruit

Grapefruit and lemons are generally fairly tolerant to methyl bromide fumigation, but some injury might be expected with the schedule given here. Oranges are considerably more susceptible, showing much discoloration and spotting. At present, therefore, methyl bromide is not recommended for the fumigation of citrus fruit (see schedules J and K).

Grapefruit. Slight injury (a,g); severe injury (m,n,r,s)

Lemons. Tolerant (a)

Oranges. Valencia and Navel both spotted, discoloured, not tolerant (a,g,k,m,n,s)

REFERENCE TO FRUIT FUMIGATION

(a)	Armitage and Steinweden (1946)	**(k)**	Negherbon (1959)
(b)	Claypool and Vines (1956)	**(l)**	Phillips and Monro (1939)
(c)	Isaac (1944)	**(m)**	Richardson (1958)
(d)	Johnson et al (1947)	**(n)**	Richardson and Balock (1959)
(e)	Kenworthy and Gaddis (1946)	**(o)**	Richardson and Roth (1958)
(f)	Latta (1941)	**(p)**	Richardson and Roth (1966)
(9)	Lindgren and Sinclair (1951)	**(q)**	Sen Gupta (1951)
(h)	Mackie and Carter (1940)	**(r)**	Hatton and Cubbedge (1979)
(i)	Monro (1941)	**(s)**	Benschoter (1979)
(j)	Monro (1957)		

RESIDUES

For .details of residues in fruit as the result of methyl bromide fumigation, see Getzendaner and Richardson (1966) and the review of Lindgren et al (1968).

Schedule I. Methyl bromide fumigation of fresh vegetables

Many kinds of fresh vegetables have been found to be tolerant to treatments with methyl bromide at intensities equal to those included in this schedule.

INSECTS

Many insects likely to be found in fresh vegetables, such as larvae of the European corn borer, adults of the Japanese beetle and pod borers of beans and peas, are susceptible to the treatments at atmospheric pressure as given below.

Larvae of fruit flies (family Trypetidae), such as the oriental fruit fly (Dacus dorsalis), require exposure of 4 h at 32 mg/l with the temperature not below 21C (Pratt et al, 1953).

DOSAGE

Atmospheric fumigation to control insects in or on leafy vegetables, exposure period 2 hours

Temperature		Dosage g/m (oz/l 000 ft)
C	F	

4 - 7	40 - 45	64
8 - 10	46 - 50	56
11 - 15	51 - 59	48
16 - 20	60 - 69	40
21 and above	70 and above	32

Atmospheric fumigation of sweet corn (maize) on the cob to control Japanese beetle and European corn borer

Temperature		Dosage g/m (oz/l 000 ft)	Exposure period, hours
C	**F**		
10 - 15	50 - 59	48	4
16 - 20	60 - 69	48	3
21 and above	70 and above	40	2.5

Atmospheric fumigation for 4 hours of potatoes, sweet potatoes (Ipomoea) and yams

(Dioscorea) for borers such as the potato tuber moth (Pthorimaea operculella)

Temperature		Dosage g/m (oz/1 000 ft)
C	F	
21 - 26	70 - 79	56
27 - 31	80 - 89	48
32 - 36	90 - 96	40

Mac.kie and Carter, 1937; Lubatti and Bunday, 1958; Pradhan et al, 1960; Roth and Richardson, 1965. *Injury to some varieties of potatoes may occur at dosages of 48 g/m and above at 25C (Bond and Svec, 1977).

The following specialized schedules may be found in USDA (1976).

A. Methyl bromide in partial vacuum (380 mm or 15 in)

1. Green pod vegetables for Maruca testulalis, Epinotia aporema and Laspeyresia leguminis.

2. Root crops, including ginger.

3. Garlic for Brachycerus sp. and Dyspess ulula.

4. Cipollini bulbs for Exosoma lusitanica.

5. Horseradish for Baris lepidi.

B. Methyl bromide at atmospheric pressure. Asparagus for Halotydeus destructor, the rag-legged earth mite.

TOLERANT CROPS

IMPORTANT. The information on tolerance is based on vegetable reaction only and is given for guidance. It is not implied that the fumigant is necessarily effective under the given conditions aginst all the pests found in or on the vegetable. As suggested before, tests should always be made to deal with specific problems under local conditions.

Beans, lima beans (b,c); but the pods of green lima beans may be seri ously injured (9); string beans (b)

Beets (c)

Cabbage (c, d)

Carrots (c)

Celeriac (knob celery) (i)

Celery (c)

Cippollini bulbs (i)

Garlic (c, h)

Horseradish (in vacuum fumigation) (i)

Maize, table (d)

Melons, Casaba

Melons, Crenshaw

Melons, watermelon (g)

Onions (c, d)

Papayas (j)

Parsnips (i)

Peas (b, c, d)

Peppers, bell (c, g)

Potatoes (c, f)

Radishes (c)

Squash, winter (g)

Sweet potatoes. Tolerant if cured 15 days or more or kiln dried for 10 days at 26 to 29C. Newly harvested, noncured tubers are likely to be severely injured (e).

Tomatoes (c, d, g). Delayed ripening of tomatoes may be induced by fumigation (a, g); late autumn-harvested tomatoes are less tolerant than those harvested earlier (g).

Turnips, white (c)

Yams (g), more susceptible to injury when fumigated below 21C (i)

PARTIALLY TOLERANT CROPS (varied reaction)

Cauliflower (g)
C.ucumbers (g)
Melons, Persian (g)

NONTOLERANT CROPS

The following crops are intolerant when exposed to 32 g/m for 4 h at 21 to 27C, as shown in the experiments of Pratt et al (1953)(g).

Artichokes
Beans, snap
Broccoli
Eggplants
Melons, cantaloupe
Melons, honeydew
Peppers, chili
Squash, summer

RESIDUES

See Getzendaner and Richardson (1966) and Lindgren et al (1968).

REFERENCES

(a) Knott and Claypool (1940)
(b) Latta (1941)
(c) Mackie and Carter (1937)
(d) McLaine and Monro (1937)
(e) Phillips and Easter (1943)
(f) Pradhan et al (1960)
(g) Pratt et al (1953)
(h) Roth and Richardson (1963)
(i) Roth and Richardson (1965)
(j) USDA (1958)

General reference - USDA (1976) with periodic revision.

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Schedule J. Ethylene dibromide (EDB) fumigation of fresh fruit

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Ethylene dibromide (EDB) is effective against the stages of certain fruit flies (Diptera, family Trypetidae). Species found susceptible to the treatments given below are:

Anastrepha ludens (Loew). Mexican fruit fly
A. mombinpraeoptans Sein. West Indian fruit fly
A. suspense (Loew).
Ceratatitis capitata (Wied). Mediterranean fruit fly
Dacus dorsalis Hendel. Oriental fruit fly
Rhaqoletis cinqulats (Loew). Cherry fruit fly
R. pomonella (Walsh). Apple maggot

Alternative treatments - low temperature and vapour heat treatments are also used for control of these insects in fruit (see USDA, 1976).

TREATMENT FOR HAWAIIAN FRUIT

Dosage	EDB at 8 g/m (8 (oz/l 000 ft) for 2 h with a minimum temperature of 21C in any part of the system.

Load	Loading of the chamber should be limited to three quarters of the height of the chamber.
Packaging	Fruit may be individually wrapped in tissue paper, or packed in shredded paper or wood excelsior, in unlined corrugated cartons and sealed along the central flap with paper tape.
Authority	United States Agricultural Research Service, Plant Quarantine Branch, Administrative Instruction P.Q.592 and Amendment 1 (September, 1954 and June, 1958) (see also USDA, 1976).

TREATMENT FOR MANGOES

Dosage

Temperature		**Dosage g/m (oz/l 000 ft)**	**Exposure period, hours**
C	**F**		
13 - 20	55 - 69	20	2
21 - 26	70 - 79	16	2
27 - 32	80 - 90	12	2

Load	The chamber should not be loaded to more than 50 percent of capacity.
Packaging	Mangoes may be packed in crates with shredded packing material. Wrappings must be removed before fumigation from individually wrapped fruit.
Authority	United States Department of Agriculture, Agricultural Research Service, Plant. Quarantine Branch, Administration Instruction P.Q. 608 (revised) with Amendment 1 (May 1956 and October 1956) (see also USDA, 1976).

TREATMENT OF FRUIT TO CONTROL MEXICAN FRUIT FLY

Found effective on oranges, grapefruit, tangerines, plums and mangoes.

Dosage - Ethylene dibromide in g/m (oz/l 000 ft) for 2 h.

	Temperature		
Fruit load	**10 - 15C**	**16 - 20C**	**21C and above**
in chamber	**50 - 59F**	**60 - 69F**	**70F and above**
25% or less	12	10	8

26 to 49%	14	12	10
50 to 80%	16	14	12

Load	Load may have an important bearing on fruit tolerance to EDB. False floors vary in height and are ignored in calculating percentage load. Fruit load for plums should not exceed 50 percent the volume of the chamber.
Packaging	Citrus fruit may be fumigated either in bulk (field boxes) or after it has been packed in wooden boxes, paper cartons, mesh bags or plastic bags, with at least twenty 0.25 in (6 mm) holes in a 5 lb (2.27 kg) bag or a proportionate number of holes in larger bags. Fruit wrapped in tissue paper may also be fumigated.

MEDITERRANEAN FRUIT FLY IN FLORIDA

Treatments based on the foregoing schedule were used in the campaign against the Mediterranean fruit fly in Florida, beginning in May 1956 (Richardson, 1958).

Authority - U.S. Department of Agriculture, Agricultural Research Service, Plant Quarantine Division, Supplement to Quarantine 56. No.319.56 - 2 e, February 1959.

APPLE MAGGOT IN CANADIAN APPLES

Fumigation of apples with EDB at fruit and air temperatures above 16C in approved chambers or under gas proof sheets to control larvae of the apple maggot Rhanoletis pomonella.

Dosage - EDB 6 mg/l (6 (oz/l 000 ft) for 2 h (Sanford, 1962a, b). (At temperatures below 10C there may be considerable persistence of EDB vapours.)

GENERAL NOTES CONCERNING TREATMENT OF FRUIT WITH EDB

1. The ethylene dibromide must be volatilized as quickly as possible by means of pans on hot plates or by other effective vaporizing devices.

2. The fumigation period required begins when all the fumigant is known to have evaporated. (This time may be determined by experiment or by observation through glass ports.)

3. Circulation of the fumigant/air mixture by means of fans or blowers must continue throughout the exposure period.

4. Thorough aeration of the fruit is essential before it is released for human consumption. This is especially important in the fruit temperature range of 10 to 27C.

TOLERANCE OF FRUIT TO EDB FUMIGATION

The tolerance of the fruit listed below was determined by exposure to 16 g/m (16 (oz/l 000 ft) for 2 h at 21C unless otherwise stated. Therefore, these fruits should be tolerant under normal circumstances to any of the schedules given above.

IMPORTANT. The information on tolerance is based on fruit reaction only and is given for guidance. It is not implied that the fumigant is necessarily effective under the given conditions against all pests found in or on the fruit. As suggested before, tests should always be made to deal with specific problems under local conditions.

TOLERANT FRUITS

Apples, numerous United States varieties (a, 9, j). Apples, 5 Canadian varieties (k). (Apples appear to be generally tolerant to EDB.)

Apricots (3 varieties)(a)

Avocados (a). No injury at 0.5 to 3 lb/1 000 ft (c); no injury to Fuerte avocados at 1 to 3 lb (f); MacArthur, Anaheim and El Tropico were injured at 2 lb/1 000 ft for 2 h; 3 lb caused severe injury(f).

Bananas, Cavendish (i)

Cherries (3 varieties) (a, d)

Citrus: grapefruit, lemons, oranges and tangerines are tolerant if recommendations are followed (c,e). Overloading the chamber may result in peel injury, especially in grapefruit.

Figs (2 varieties) (a)

Grapes (6 varieties) (a)

Mangoes (c, h). Tolerant at 1 lb/1 000 ft for 2 h at 25C (c, l) Nectarines (6 varieties) (a)

Papayas (e)

Peaches (13 varieties) (a, j) Pears (6 varieties) (a, j)

Pineapples (e)

Plums (16 varieties) (a, j)

NON TOLERANT FRUITS

Avocados (some varieties)
Persimmons (5 varieties) (a)

RESIDUES

For details of residues see Tanada et al (1953), Dumas (1962), Coggiola and Huelin (1964), Alumot et al (1965) and the general reviews of Lindgren et al (1968) and Dumas and Bond (1975).

REFERENCES

(a)	Claypool and Vines (1956)	**(g)**	Richardson (1952)
(b)	Grierson and Hayward (1959)	**(h)**	Richardson (1955)
(c)	Grundberg et al (1956)	**(i)**	Richardson and Balock (1959)
(d)	Jones (1955)	**(j)**	Richardson and Roth (1966)
(e)	Lindgren and Sinclair (1951)	**(k)**	Sanford (1962a, b)

(f)	Lindgren et al (1955)	**(l)**	Shaw and Lopez (1954)

General references - USDA (1967b) and USDA (1976) with periodic revisions.

Schedule K. Ethylene dibromide(EDB) fumigation of fresh vegetables

Ethylene dibromide (EDB) is effective against the stages of certain fruit flies (Diptera, family Trypetidae) which may be found in certain vegetables.

Species of insects found susceptible are listed in Schedule J together with general notes on ethylene dibromide fumigation of perishable materials.

TREATMENT

A standard treatment, effective against the oriental fruit fly, Dacus dorsalis, is EDB at a dosage 8 g/m (8 (oz/1 000 ft) for 2 h with a minimum temperature of 21C in any part of the system. The load factor given for Mexican fruit fly in Schedule J could be applied.

TOLERANCE OF FRESH VEGETABLES TO EDB

The reactions listed below are based on Pratt et al (1953) with the treatment given above.

IMPORTANT. The information on tolerance is based on vegetable reaction only and is given for guidance. It is not implied that the fumigant is necessarily effective under the given conditions against all pests found in or on the vegetable. As suggested before, tests should always be made to deal with specific problems under local conditions.

TOLERANT CROPS

Beans, lima and snap
Broccoli
Cucumbers
Melons (cantaloupe, casaba, honeydew, Persian, watermelon)
Peppers, bell
Squash (summer and winter varieties)

NON TOLERANT CROPS

Artichokes. Discoloration and decay Cauliflower. Darkening and spotting of curds; killing of leaves Eggplant. Severe general injury Melon, Crenshaw Peppers, chill). Injury to calyx and off-colour of fruit Tomatoes (4 varieties)

RESIDUE TOLERANCES

The general review of Lindgren et al (1968) discusses official United States tolerances for

ethylene dibromide used on a number of vegetables.

Schedule L. Hydrogen cyanide (HCN) fumigation of fresh fruit and vegetables

Some fruits are tolerant to HCN and, if applied according to directions, the fumigant may be used on them without danger to the consumer. Applications recommended for certain quarantine purposes are given here.

ATMOSPHERIC FUMIGATION WITH HCN

The fumigant volatilized from the liquid is applied at the rate of 6 g/m (6 (oz/l 000 ft) for one hour at a temperature above 10C. Fan circulation (explosion-proof motors) must be maintained throughout the treatment. The fruit must be dry, otherwise serious burning may result.

Avocados, packed for shipment, to control latania scale, Hemiberlesia lataniae (Sign.)

Citrus fruit (oranges, lemons, limes, grapefruit) to control scale insects and thrips and possibly other external pests such as citrus whitefly and blackfly. For control of bean thrips, Hercothrips fasciatus (Perg.), exposure period may be reduced to 35 minutes (Harper, 1942 - 57; Richardson and Balock, 1959).

HCN is used extensively in Japan for fumigation of bananas and citrus fruit infested with scale insects (Mori, 1980). Application is conducted through a dispenser unit consisting of a vaporizer and blower and the gas is circulated to facilitate even distribution. After fumigation, the remaining gas is removed through an HCN gas scrubber. The recommended dosage is 2 g/m for 30 min.

VACUUM FUMIGATION WITH HCN (Harper, 1942 - 57)

Dosage 6 g/m. The fumigant introduced into intial vacuum of 125 mm (about 5 in) absolute pressure with stream of air (simultaneous introduction) until atmospheric pressure is reached. Exposure period: 1 hour. Temperature not less than 15C.

For control of mealybugs, Pseudococcus sp., in persimmons packed for export

Schedule M. Hydrogen cyanide (HCN) fumigation of dormant nursery stock

Balled nursery stock should be held for 10 to 14 days after digging before fumigation. Avoid free moisture on plants. After fumigation, all plants should be gently but thoroughly washed by sprinkling with water. They should be protected from sunlight and wind for 48 h following treatment.

ATMOSPHERIC FUMIGATION WITH HCN

Fumigation of imported nursery stock to prevent introduction of San Jose scale, Aspidiotus perniciosus Comst. Dosage HCN 6 g/m (6 oz/l 000 ft). Temperature not below 4 C. Fumigant is introduced with stream of air. After this, continuous recirculation of fumigant/air mixture in the chamber at a rate per hour equivalent to 40 times the cubic capacity of the chamber. Exposure period: 30 min.

The above is based on information supplied by the Netherlands Ministry of Agriculture, Plant Protection Service (Personal communication P.H. Van de Pol, 17 March 1959).

If the above rate of circulation of fumigant/air mixture cannot be attained, apply the treatment used for many years to control scale insects and woolly aphids before the introduction of Yacuum fumigation or high velocity circulation. Dosage of HCN, 10 g/m (10 oz/l 000 ft). Temperature not less than 4 C. Exposure period: 45 min to 1 h. Continuous circulation of air/fumigant mixture is advisable. If fans or blowers are used, they should be of the shielded, nonexplosive type.

For discussion of technical problems in the fumigation of plant material with HCN, see Be ran (1946) and Van de Pol and Rauws (1957).

VACUUM FUMIGATION WITH HCN (Harper 1942 - 57)

Fumigation of balled citrus plants to control scale insects, specifically the Californian red

scale, Aonidiella aurantii (Mask.). Dosage of HCN 5 g/m (5 oz/l 000 ft). Temperature not less than 10C. Initial vacuum 100 mm (4 in) of Hg absolute pressure. Fumigant is introduced with stream of air until atmospheric pressure is restored. Exposure period: 1 h.

Schedule N. Fumigation of flower bulbs and corms

This schedule covers flower bulbs and corms, including bulbous iris, gladioli, lilies (including Easter lilies), narcissus, tulips and many other kinds.

VACUUM TREATMENTS

Some varieties may be affected by sustained vacuum and produce shortstemmed plants or retarded growth. Initial vacuum treatments followed by restoration of atmospheric pressure after or during the introduction of the fumigant are usually effective and less injurious to bulbs.

1. For aphids (tulip bulb aphid, Anuraphis tulipae (Fonsc.), and other species).

(a) HCN. 10C and above; 2 g/m (2 oz/l 000 ft) for 2 h under atmospheric pressure.

(b) Methyl bromide. See schedule for mites. Aphids are easily killed by methyl bromide but stronger treatment will also control postembryonic mites.

2. For bulb flies, narcissus bulb fly, Lampetia equestris (F.), and lesser bulb fly, Eumerus tuberculatus Rond.).

(a) HCN. 18C and above: 6 g/m for 6 h under atmospheric pressure (recommended by the Netherlands Ministry of Agriculture).

(b) Methyl bromide. 15 to 20C: 48 g/m for 5 h under atmospheric pressure, or 48 g/m for 3 h under preliminary vacuum.

21C and above: 48 g/m for 4 h under atmospheric pressure or 48 g/m for 2.5 h under preliminary vacuum.

Below 15C: not recommended for atmospheric fumigation (Andison and Cram, 1952).

3. For mites (bulb mite, Rhizoalyphus echinopus (F. & R.), bulb scale mite, Steneotarsonemus laticeps (Halb.), eriophyid mites). Methyl bromide treatment should be repeated after 10 to 14 days in order to kill eggs (Mackie et al, 1942; Monro, 1937 - 40). Eriophyid mites, Eriophyes spp., may sometimes be controlled by milder treatments with HCN or methyl bromide.

(a) HCN. 18C and above: 6 g/m for 24 h (recommended by the Netherlands Ministry of Agriculture).

(b) Methyl bromide. 15 to 21C: 48 g/m for 2.5 h under atmos pheric pressure, or 48 g/m for 2 h under preliminary vacuum.

21 to 27C: 48 g/m for 2 h under atmospheric pressure, or 48 g/m for 1.5 h under preliminary vacuum.

27C and above: 40 g/m for 2 h under atmospheric pressure, or 40 g/m for 1.5 h under preliminary vacuum.

4. For thrips (gladiolus thrips, Taeniothrips simplex (Mor.) and lily bulb thrips. Liothrips vaneeckei Pries.). With methyl bromide against thrips, temperature is an important factor in obtaining complete control of the insects in all stages, including eggs. It is advisable, wherever possible, to fumigate at or above 20C (Steinweden et al (1942).

Methyl bromide. 21 to 27C: 48 g/m for 3 h under atmospheric pressure, or 48 g/m for 2 h under preliminary vacuum.

27C and above: 48 g/m for 2 h under atmospheric pressure, or 40 g/m for 2 h under preliminary vacuum.

General reference - USDA (1976) with periodic revisions.

Schedule O. Methyl bromide fumigation of cut flowers and greenery

THRIPS

Methyl bromide at the rate of 16 g/m (16 oz/l 000 ft) for 1.5 h may be applied to cut flowers of rose, tulip and carnation at atmospheric pressure at temperatures of 29 to 31C for the control of thrips, Rhiphiphorothrips cruentatus H., without injuring the blooms (Junaid and Nasir, 1956).

Chrysanthemums (aphids only), methyl bromide 12 g/m (12 oz/l 000 ft) for 2 h at 21 C or above.

SURFACE FEEDERS, LEAF MINER, THRIPS.

Methyl bromide At atmospheric pressure exposure period 2 hours

Temperature		Dosage g/m (oz/l 000 ft)
C	F	
4 - 9	40 - 49	56
10 - 15	50 - 59	48

16 - 20	60 - 68	40
21 - 26	70 - 79	32
27 - 36	80 - 96	24

Concentrations should be at least 75 percent of the applied dosage at 30 min and 50 percent at 2h.

BORERS, SOFT SCALES (Vacuum fumiqation - 380 mm)

Temperature		Dosage g/m (oz/1 000 ft)	Exposure time (h)
C	**F**		
4 - 9	40 - 49	48	3.5
10 - 15	50 - 59	48	3
16 - 20	60 - 68	48	2.5
21 - 26	70 - 79	48	2
27 - 32	80 - 90	40	2

The prior consent of the importer should be obtained for vacuum fumigation.

See USDA (1976) for further information on these treatments.

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Schedule P. Atmospheric and vacuum fumigation for the control of pests infesting packaged plant products

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This schedule covers a wide range of plant products, including grains, in packages such as bags (sacks), cartons, boxes and bales, which are permeable to the fumigants named. Bulk fumigation of certain agricultural and forest products is also included.

The success of the treatments given here will depend on the proper conduct of the procedures described in the text end on the provision of gas tight conditions in the structures employed. Adequate retention of fumigant must be checked by gas analysis; this

is especially important in fumigation under sheets.

ATMOSPHERIC FUMIGATION CHAMBERS

All the fumigants named for the specific products may be used in specially designed and properly equipped atmospheric chambers as described in the text.

SHEETED FUMIGATIONS

At present most treatments under gas-proof sheets at atmospheric pressure are carried out with methyl bromide or phosphine and careful testing is required before other fumigants are used for treating specific materials.

OTHER STRUCTURES

Treatments under atmospheric pressure may be applied in a variety of structures, which can be rendered sufficiently gas tight, such as the holds of ships and barges, trucks, trailers, railway cars (wagons) and rooms in warehouses and other buildings. Methyl bromide and phosphine are mainly employed but HCN may be applied under certain conditions as described below. Other fumigants, such as the ethylene oxide/carbon dioxide mixture, have specialized applications.

VACUUM FUMIGATION

The operating pressure recommended for sustained vacuum fumigation, after the fumigant is introduced, is from 75 to 125 mm (3 to 5 in)of mercury. (This does not apply to the ethylene oxide/carbon dioxide mixture 1:9, which increases the pressure considerably.)

The pressure manipulations described in Chapter 9, which involve various alterations in the pressure of the chamber subsequent to the attainment of the initial vacuum, may be tested for different fumigants on different materials. No specific recommendations can be made before preliminary trials are made. The treatments given here are all for exposures under sustained vacuum.

CIRCULATION

Circulation of the fumigant in the space should be effected whenever possible. This may be done by fans or, in specially designed chambers, by means of recirculation systems. Circulation is necessary in vacuum fumigation - it is usually done for 15 min at the beginning of each hour of treatment. In atmospheric fumigation, circulation for at least 30 min at the beginning of the treatment is advisable (see text). In small-scale atmospheric fumigation of begged material, such as in railway cars or under small covers or tarpaulins, circulation may be omitted if adequate distribution of the fumigant is ensured by other means (see text).

PERMEABILITY OF PACKAGING MATERIALS

Many materials used for packaging are readily permeable to fumigants under the conditions recommended below. Phosphine diffuses readily, even at comparatively low temperatures. According to Roth and Richardson (1968) common brown (kraft) paper, glazed papers and corrugated cardboard are easily penetrated by methyl bromide; tar, laminated and wax papers, polyethylene films, masking tape and wallboard have comparatively low permeability to this fumigant.

A. Stored product pests in general

1. EMPTY BAGS MADE FROM JUTE (BURLAP) OR OTHER MATERIALS

(a) Loose, noncompressed bales or bundles

Methyl bromide. 15C sod above: 24 to 32 g/m (24 to 32 oz/l 000 ft) for 16 to 24 h under atmospheric pressure, or 40 g/m for 3 h under sustained vacuum. For control of Khapra beetle, Troqoderma qranarium Everts, the United States Department of Agriculture requires doubled dosage for vacuum fumigation and quadrupled dosage for atmospheric pressure treatment.

(b) Compressed bales

Methyl bromide. 15C and above: 56 g/m for 4 h under sustained vacuum. Owing to high degree of sorption of vapours by material, care must be taken by operators to avoid

inhalation of methyl bromide during unloading. After unloading, keep bales in wellventilated storage for at least 4 days.

2. PERMEABLE CARTONS, PACKAGES OR BAGS OF CEREALS

Containers should be tested for permeability. Heat-sealed cellophane polyethylene, wax paper or tar paper wrappings may not permit adequate penetration, even under vacuum fumigation.

(a) Methyl bromide

Under atmospheric pressure: 48g/m for 16 to 24 h at 10 to 14C; 40g/m for 16 to 24 h at 15 to 20C; 32g/m for 16 to 25 h at 21 to 25C or 24g/m for 16 to 24 h at 25C and above. Under sustained vacuum 40g/m for 3 h at 15C and above.

(b) Hydrogen cyanide (HCN)

Under sustained vacuum: 2.5 g/m for 3 h at 20C and above.

(c) Phosphine

At atmospheric pressure: sufficient of an aluminium or magnesium phosphide formulation to generate 1.5 9 of phosphine per m should be applied. Period of fumigation should be 7

days at 12 to 15C, 6 days at 16 to 20C, 5 days at 21 to 25C or 4 days at 26C or above.

(d) Ethylene dibromide (EDB)/methyl bromide mixture

At atmospheric pressure under tropical conditions: 16 to 32 g/m (16 to 32 oz/l 000 ft) of 1:1 (w/w) mixture for 48 hours. At temperatures below 26C 1:3 mixture of EDB to methyl bromide should be applied (Majumder and Muthu, 1964).

3. PERMEABLE CARTONS OR PACKAGES OF MILK POWDER

(a) Ethylene oxide/carbon dioxide mixture (1:9)

Suggested for vacuum fumigation at 720g/m for 3 h at 20C and above. (See text for discussion of residues).

(b) Methyl bromide

Atmospheric pressure: see 2 (a) above.

(c) Phosphine

Dosage and exposure 2 (c) above.

4. PERMEABLE CARTONS OR OTHER CONTAINERS OF LOOSE RAISINS, CURRANTS, DATES, FIGS OR OTHER DRIED FRUIT

(a) Methyl bromide

Under atmospheric pressure: 24 g/m for 24 h at 15C and above. Under sustained vacuum: 40 g/m at 15C and above for 3 h. For lepidopterous pests, exposure in vacuum fumigation may be reduced to 2 h at temperatures above 20C3. For fumigation under sheets or kraft paper over soil base, 32 g/m are recommended.

(b) Ethylene oxide/carbon dioxide mixture (1:9)

Under sustained vacuum: 640 g/m for 3 h at 20C and above. (See text for discussion of residues.)

(c) Phosphine

At atmospheric pressure 1 9 phosphine per m of storage space.

5. PERMEABLE CARTONS OF DRIED FRUIT, INCLUDING DATES AND FIGS, IN COMPRESSED FORM

(a) Methyl bromide

Under sustained vacuum: 40 g/m for 3 h at 20C and above.

(b) Ethylene oxide/carbon dioxide mixture (1:9)

Under sustained vacuum: 800 g/m for 4 h at 20C and above. (See text for discussion of residues.)

(c) Phosphine

At atmospheric pressure see 4 (c) above.

6. PERMEABLE CONTAINERS OF FLOUR, MEALS, FEEDS, MIXED FEEDS AND MILLED CEREALS

(a) Methyl bromide

Under atmospheric pressure 48 g/m for 16 to 24 h at 10 to 14C; 32 g/m for 16 to 24 h at 15 to 20C;24 g/m for 16 to 24 h at 20 to 25C or 16 g/m for 16 to 24 h at 25C and above Under sustained vacuum: 48 g/m for 3 h at 20C to 25C; or 40 g/m for 3 h at 25C and above. With flours, great care must be taken to avoid overdosage, which may be brought about through poor distribution of fumigant in a given load. To avoid this, fans or a recirculation system must be properly used.

Off-odours in bread and flour as a result of methyl bromide fumigation have occasionally

been reported (see full discussion in text).

(b) Phosphine

Under atmospheric pressure: Sufficient of an aluminium or magnesium phosphide formulation to generate 1.5 9 of Phosphine per m . Fumigate for 7 days at 12 to 15C, 6 days at 16 to 20C, 5 days at 21 to 25C or 4 days at 26C or above.

(c) Ethylene dibromide (EDB)/methyl bromide mixture

At atmospheric pressure under tropical conditions 32 to 48 g/m of 1:3 EDB:methyl bromide mixture w/w for 48 to 72 h (Majumder and Muthu, 1964).

(d) Ethylene oxide/carbon dioxide mixture (1:9)

Under sustained vacuum: 800g/m for 6 h at 25C and over. (See text for discussion of residues.)

(e) Hydrogen cyanide (HCN)

Under sustained vacuum: 40g/m for 3 h at 20C and over.

(f) Chloropicrin

Under atmospheric pressure: 32 to 48g/m for 24 h at 20C and over. Higher dosages may be required for densely packed materials. This recommendation is subject to trial under local circumstances. Considerable time is required for ventilation.

7. BAGGED BARLEY, MAIZE, OATS, RICE, RYE, WHEAT AND OTHER GRAINS, ALSO DRIED BEANS, PEAS AND COCOA BEANS

(a) Methyl bromide

Under atmospheric pressure 40g/m for 16 to 24 h at 4 to 9C; 32g/m for 16 to 24 h at 10 to 14C; 24g/m for 16 to 24 h at 15 to 20C or 16g/m for 16 to 24 h at 21C and above. Under sustained vacuum. 56g/m for 3 h at 4 to 9C; 48g/m for 3 h at 10 to 14C; 40g/m for 3 h at 15 to 20C; or 32g/m for 3 h at 21C and above.

(b) Phosphine

Under atmospheric pressure: Sufficient of an aluminium or Magnesium phosphide formulation to generate 1.5 9 of phosphine per m . Fumi gate for 7 days at 12 to 15C, 6 days at 16 to 20C, 5 days at 21 to 25C or 4 days at 26C or above (Heseltine and Thompson, 1957; Harada, 1962; Hubert,1962; Pingale et al, 1963; Cogburn and Tilton, 1963; Rai et al, 1962; Lochner, (1964a).

(c) Ethylene dibromide (EDB)/methyl bromide mixture

Under tropical conditions at atmospheric pressure: use treatments given in 2 (d) above.

(d) Hydrogen cyanide (HCN)

Under atmospheric pressure: 32g/m for 24 h at 20C and above. Under sustained vacuum: 40g/m for 3 h at 20C and above. For rice, see Redlinger (1957c).

(e) Chloropicrin

Under atmospheric pressure: 48g/m for 24 h at 20C and above.

(f) Ethylene dichloride/carbon tetrachloride mixture (3:1)

Under atmospheric pressure: 480g/m for 24 h at 20C and above; or 360 g/m for 48 h at 20C and above.

(g) Ethylene dibromide

Under atmospheric pressure: 75g/m for 24 h at 25C and above. Suggested from work in India for use under tarpaulins at 240 9/1 000 bags (Pingale and Swaminathan, 1954). See discussion in text.

8. NUTS, SHELLED (NUTMEATS) OR IN THE SHELL: ALMONDS, BRAZIL NUTS, BUTTERNUTS,

CASHEW NUTS, CHESTNUTS, FILBERTS (HAZELNUTS), HICKORY NUTS, PECANS, GROUNDNUTS, PISTACHIO NUTS AND WALNUTS.

(a) Methyl bromide

Under atmospheric pressure 48g/m for 16 to 24 h at 4 to 9C; 49 g/m for 16 to 24 h at 10 to 14 C; 32g/m for 16 to 24 h at 15 to 20C; 24g/m for 16 to 24 h at 21 to 25C or 16 to 24g/m for 16 to 24 h at 25C and above. Under sustained vacuum: 56g/m for 3 h at 4 to 9C; 48g/m for 3 h at 10 to 14C; 40g/m for 3 h at 15 to 20C; 32g/m for 3 h at 21 to 25C; or 24g/m for 3 h at 25C and above. With lepidopterous pests, exposure in vacuum fumigation may be reduced to 1.5 or 2 h when the temperature is 20C or above.

(b) Hydrogen cyanide (HCN)

Under atmospheric pressure: 32g/m for 24 h at 20C and above. Under sustained vacuum: 40g/m for 3 h at 20C and above.

(c) Chloropicrin

Under atmospheric pressure: 48g/m for 24 h at 20C and above. Very thorough aeration required.

(d) Ethylene oxide/carbon dioxide mixture (1:9)

Under sustained vacuum: 560 to 640g/m for 3 h at 20C and above. Use the higher dosage for nuts in shells and for nuts packed in cartons. (See text for discussion of residues.)

(e) Ethylene dichloride/carbon tetrachloride mixture (3:1)

Under atmospheric pressure: 400g/m for 48 h at 20C and above; or 640 g/m for 24 h at 20C and above. Recommended for wellconstructed fumigation chambers only.

(f) Phosphine

Under atmospheric pressure: Sufficient of an aluminium or magnesium phosphide formulation to generate 1.5 9 of phosphine per m3.

9. SPICES OF ALL KINDS

(a) Methyl bromide

Under atmospheric pressure: 16 to 24g/m for 16 to 24 h at 20C and above. Under sustained vacuum: 40g/m for 3 h at 20C and above. Treatment at lower temperatures may be practicable, following the schedule for cereals.

(b) Hydrogen cyanide (HCN)

Under atmospheric pressure: 24 to 32g/m for 24 h at 20C and above. Under sustained vacuum 40 g/m for 3 h at 20C and above.

(c) Phosphine

Under atmospheric pressure: Sufficient of an aluminium or Magnesium phosphide formulation to generate 1.5 9 of phosphine per m . Fumigate for 7 days at 12 to 15C, 6 days at 16 to 20C, 5 days at 21 to 25C or 4 days at 26C or above.

(d) Ethylene dibromide (EDB)/methyl bromide mixture

Under tropical conditions at atmospheric pressure; use schedule given in 2 (d) above.

(e) Ethylene oxide/carbon dioxide mixture (1:9)

Under sustained vacuum: 640g/m for 3 h at 20C and above.

B. Golden nematode (Heterodera rostochiensis), in loose or compressed bales or bags made from jute (burlap) or other materials

Methyl bromide

Under atmospheric pressure: 368g/m for 16 h at 10C and above. Atmospheric fumigation

only effective for loose bales or bundles (Lear and Mai, 1952).

United States Department of Agriculture (USDA, 1976) only lists sustained vacuum treatments as follows:

Methyl bromide in 26 in vac (100 mm abs. press.); 128g/m for 16 h at 4 C and above; 168g/m for 12 h at 4C and above; 256g/m for 8 h at 4C and above; add 32 9 and 2 h at -1 to 4C, add 48 9 and 4 h at -7 to 2OC; add 48 9 and 6 h at -12 to -8OC.

C. European Corn Borer (0strinia nubilalis), species of Sesamia and other lepidopterous borers in nonperishable products

Also a wide variety of agricultural pests which may enter the following materials incidentally or for hibernation (Monro, 1947b): broom corn and maize stalks in bales or bundles (stalks and panicles of Sorqhum vuluare var. technicum or stalks of Zea mays or related plants).

(a) Methyl bromide

Under atmospheric pressure: 112g/m for 16 h at 5 to 9C; 80g/m for 16 h at 10 to 14C or 40g/m for 16 h at 15C and above. Under sustained vacuum: 96g/m for 2.5 h at 0 to 4C; 80g/m for 2.5 h at 5 to 9C; 64g/m for 2.5 h at 10 to 14C; or 40g/m for 2.5 h at 15C and above.

(b) Hydrogen cyanide (HCN)

Under sustained vacuum 48g/m for 3 h at 15C and above.

D. Pink Bollworm, Pectinophora qossypiella, and other insects infesting cotton

1. COTTON IN BALES, LOOSE OR HYDRAULICALLY PRESSED

Hydrogen cyanide (HCN)

Under sustained vacuum: 40g/m for 2 h at 15C and above. U.S. Department of Agriculture Regulation HB-164 (March 1923) stipulates that after the introduction of the fumigant into the evacuated chamber, the pressure in the chamber be raised to 125 mm (5 in) of mercury by the introduction of air; and that the pressure be kept at this level until the end of the 2-hour exposure.

2. COTTONSEED BAGGED OR PACKAGED

Methyl bromide

Under atmospheric pressure: 64g/m for 24 h at 4 - 15C or 48g/m for 24 h above 15C. Under sustained vacuum: 64g/m for 2 h at 4C and above (load limit 50 percent of chamber volume).

Hydrogen cyanide (HCN)

Under vacuum, 100 mm absolute pressure: 60g/m for 2 h at 4C or above (load limit 50 percent of chamber volume).

Phosphine

Sufficient of an aluminium or magnesium phosphide formulation to generate 2 9 of phosphine per m ; for 5 to 7 days at 10C or above.

3. EXTERNAL FUMIGATION OF COTTON BALES

The Government of India requires that all bales of American cotton entering that country should be subjected to atmospheric fumigation with hydrogen cyanide to control the boll weevil (Anthonomus grandis Bob.) or other insects which may be found on or near to the surface of the bales (Liston, 1920; Liston and Gore, 1923; Turner and Sen, 1928).

E. Hay, baled, including Lucerne (Alfalfa) hay

ALFALFA WEEVIL, Hypera postica (Gyll.)

Methyl bromide

Under atmospheric pressure: 32g/m for 16 to 24 h at 15C and above. Under sustained vacuum: 40g/m for 3 h at 15C and above. Vacuum fumigation probably not economically feasible.

2. CEREAL LEAF BEETLE, Oulema melanopus (Kirby)

United States and Canada: Department of Agriculture schedules. Methyl bromide

Temperature		Dosageg/m (oz/l 000 ft)	Exposure period hours
C	F		
-18 to -7	0 - 19	104	4
- 6 to -2	20 - 29	96	4
- 1 to +9	30 - 49	64	4
10 to 20	50 - 69	40	3
21 and above	70 and above	32	3

F. Cigarette Beetle, Lasioderma serricorne, (F.) and Tobacco Moth, Ephestia elutella (Hbn)

1. ALL TYPES OF CIGARETTE TOBACCO

With these types in hogsheads and bales, atmospheric pressure cannot be relied upon for complete mortality, even with very long exposure periods, except with the fumigant phosphine. Vacuum fumigation using other fumigants is effective with bales, hogsheads and most packages (Tenhet, 1957).

(a) Hydroqen cyanide (HCN)

Under atmospheric pressure: 24g/m for 48 to 72 h at 7 to 20C; or 16g/m for 48 to 72 h at 21C and abOve. Under sustained vacuum: 84g/m for 4 h at 7 to 20C; or 64g/m for 4 h at 21C and above.

(b) Methyl bromide

Under atmospheric pressure: 32g/m for 48 to 72 h at 7 to 20C; or 20g/m for 48 to 72 h at 21C and above. Under sustained vacuum: 80g/m for 4 h at 7 to 20C; or 64g/m for 4 h at 21C and above.

(c) Acrylonitrile/carbon tetrachloride (1:2)

Under atmospheric pressure: 56 to 80g/m for 48 to 72 h at 7 to 20C or 48 to 64g/m for 48 to 72 h at 21C and above. under sustained vacuum: 80g/m for 4 h at 7 to 20C; or 64g/m for 4 h at 21C and above.

(d) Phosphine

Sufficient of an aluminium or magnesium phosphide formulation to generate 0.67 to 1 9 of phosphine per m .

2. CIGARS AND CIGAR TOBACCOS, EXCEPT CIGARS WRAPPED IN BALES

Vacuum fumigation effective for boxes of cellophaned cigars and sealed cartons of boxes of cigars. Impractical to fumigate satisfactorily boxes of cigars overwrapped in cellophane (Tenhet, 1957). Methyl bromide not recommended for cigar tobaccos because off-odour sometimes results.

(a) Hydroqen cyanide (HCN)

Under atmospheric pressure: 24g/m for 48 to 72 h at 7 to 20C; or 16g/m for 48 to 72 h at 21C and above Under sustained vacuum: 80g/m for 4 h at 7 to 20C; or 64g/m for 4 h at 21C and above.

(b) Acrvionitrile/carbon tetrachloride (1:2)

Under atmospheric pressure: 56 to 80g/m for 48 to 72 h at 7 to 20C or 64 to 80g/m for 48 to 72 h at 21C and above. Under sustained vacuum: 80g/m for 4 h at 7 to 20C; or 64g/m for 4 h at 21C and above.

(c) Ethylene oxide/carbon dioxide (1:9)

Under sustained vacuum: 960g/m for 4 h at 21C and above.

3. CIGARS WRAPPED IN BALES

(a) Hydrogen cyanide (HCN)

Under atmospheric pressure: 24g/m for 48 to 72 h at 21C and above. Under sustained vacuum: 80g/m for 4 h at 21C and above.

(b) Acrvionitrile/carbon tetrachloride (1:2)

Under atmospheric pressure: 64 to 80g/m for 48 to 72 h at 21C and above. Under sustained vacuum: 80g/m for 4 h at 21C and above.

(c) Ethylene oxide/carbon dioxide (1:9)

Under sustained vacuum: 1 040g/m for 4 h at 21C and above.

G. Wood-boring beetles and wood wasps in timber cut in board lengths

Methyl bromide

Under atmospheric pressure: 32g/m for 24 to 36 h at 15C and above. Fumigation may be carried out under gas-proof sheets and in the holds of ships (Burden and McMullen, 1951). Good distribution of fumigant is essential. Vacuum fumigation probably not economicaliv feasible.

H. Mangolds

Methyl bromide

Fumigation of mangolds in clamps (piles) to control aphid vectors of virus yellows (Dunning et al 1962). Methyl bromide under gas-proof sheet for a minimum of 3 h to effect a c x t product 100 mg in/l.

I. General references to plant product treatments

Treatments

USDA (1976, 1977 and updated revisions).

Residues

Lindgren et al (1968).

Schedule Q. Fumigation of mills, empty structures and tobacco warehouses

Mills and empty structures that may be made sufficiently gas tight for atmospheric fumigation, including warehouses, empty holds of ships and other carriers (for treatment of most structures containing goods, see Schedule P).

1. SEALED BUILDINGS (MILLS, EMPTY WAREHOUSES AND SIMILAR BUILDINGS)

For eradication of residual populations of stored product insects and similar pests.

(a) Methyl bromide

40 to 48g/m for 24 h at O to 4C; 32 to 40g/m for 24 h at 5 to 9C; 24 to 32g/m for 24 h at 10 to 14C; or 16 to 24g/m for 24 h at 15C and above. Vary dosage according to gas tightness O3f building. Also use lower dosage for larger spaces over 14 000 m (500 000ft). The use of a procedure for gas analysis, e.g. thermal conductivity analyser, is recommended so that c x t products can be determined and the required treatment conditions assured.

(b) Hydroqen cyanide (HCN)

8 to 12g/m for 24 h at 15C and above. If building is thoroughly cleaned inside to remove accumulations of debris, a lower dosage may be used.

(c) Chloropicrin

16g/m for 24 h at 15C and above. In view of strong tear gas effect it is not recommended for large structures. It may be atomized at lower temperatures by aerosols (see text).

(d) Dichlorvos (DDVP)

Dichlorvos vapour applied with treatments given below is effective against insects moving freely on surfaces or in the free space of closed structures, but it does not penetrate effectively into deep cracks and crevices (see text for full discussion).

Tobacco warehouses. Dispensed more conveniently as an aerosol, but may be applied as a spray.

Cigarette beetle, Lasioderma serricorne (F.):71 mg/m (2 9/l 000 ft) twice a week (Tenhet et al, 1958; Childs, et al, 1966). An effective programme for year-round control of this insect is one HCN fumigation per year at 48g/m (48 oz/l 000 ft) for 72 h together with dichlorvos 71 mg/m (2 9/1 000 ft) twice a week (Childs, 1967).

Tobacco moth, Ephestia elutella (Hbn.): 35 mg/m (1 g/l 000 ft) per week (Press and Childs, 1966).

Stored-product insects qeneraliy. In warehouses, mills and other structures, dichlorvos in

vapour form is effective against some of these insects (Attfield and Webster, 1966). Use in the presence of foodstuffs would be contingent upon official government approval for residue tolerances and public safety.

Houses, aeroplanes and buildings qaneraly. For public health. Control of flies, mosquitoes, cockroaches, bedbugs, etc.

Dichlorvos dispensed from aerosols or sprays or volatilized from resin strips is now widely used in this field. The literature is extensive. Consult manufacturers' recommendations and regulations of of official public health agencies. A comprehensive summary on dichlorvos is given by Attfield and Webster (1966).

N.B. Vapour saturation of dichlorvos occurs at low concentrations. See Table "Properties of dichlorvos" in text.

2. BUILDINGS UNDER GAS PROOF SHEETS

For eradication of residual populations of stored product insects and similar pests.

Methyl bromide

80g/m for 24 to 36 h at 0 to 4C;72g/m for 24 to 36 h at 5 to 9C;64g/m for 24 to 36 h at 10 to 14C or 56g/m for 24 to 36 h at 15C and above. Use of thermal conductivity analyser

recommended to check concentrations so that a certain predetermined c x t product may be attained (see text). Additional dosage required for beetles of Troqoderma sp., see Armitage (1956, 1958).

3. HOUSES AND BUILDINGS UNDER GAS PROOF SHEETS OR PROPERLY SEALED AT ALL OUTSIDE POINTS

For dry wood termites (Kalotermes spp.) and other structural woodinfesting insects. Coleopterous families Anobiidae, Lyctidae, Bostrichidae, Buprestidae, Cerambycidae, Scolytidae, etc. Hymenopterous species also, including carpenter ants and wood wasps.

(a) Methyl bromide

64g/m for 16 to 24 h at 10 to 14C; or 48g/m for 16 to 24 h at 15C and above. Exposure period may be reduced at temperatures above 20C. Use of thermal conductivity analyser recommended.

(b) Hydrogen cyanide (HCN)

40g/m for 48 h at 10C and above. Ensure that electrical sparks or pilot flames do not start fire or explosion when high concentrations are localized at start of fumigation.

(c) Sulphuryl fluoride

32g/m for 24 h at 10 to 20C; or 16g/m for 24 h at 20C and above. The manufacturer of sulphuryl fluoride provides a special chart (Fumiguide) which, when used in conjunction with a thermal conductivity analyses or other gas analysis technique ensures that fumigant concentrations are being maintained at the desired level (Stewart, 1966).

(d) Acrylonitrile/methylene chloride mixture

This mixture (34 to 66 by volume) has been tested successfully in Florida for dry wood termite control in buildings (Young, 1967). Suggested dosage 64 to 96g/m for 24 h at temperatures above 15C.

4. EMPTY CARGO SPACES IN SHIPS, EMPTY RAILWAY CARS, ETC.

For residual populations of insects. Proper aeration of cargo spaces in ships after fumigation most important (see text) (Monro, 1969; Monro et al, 1952).

(a) Hydrogen cyanide (HCN)

12g/m for 10 to 12 h at 0 to 4C; 10g/m for 10 to 12 h at 5 to 9C or 8g/m for 10 to 12 h at 10C and above.

(b) Methyl bromide

32g/m for 10 to 12 h at 0 to 4C; 24g/m for 10 to 12 h at 5 to 9C or 16g/m for 10 to 12 h at 10C and above.

Multiply this schedule by 6 for Khapra beetle, Tronoderma qranarium Everts, which is difficult to kill with methyl bromide.

5. SNAILS IN CARGO SPACES AND ON CARGO - See schedule T.

Schedule R. Local (spot) fumigants for mills

Representative formulations (all parts by volume)

Acrylonitrile 1 : carbon tetrachloride 2
Ethylene dibromide 1 : ethylene dichloride 1 : carbon tetrachloride 3
Ethylene dichloride 3 : carbon tetrachloride 1 (use twice dosage recommended below)
Chloropicrin alone (for most purposes, use 75 percent of dosage recommended below)
Ethylene dibromide 7 : methyl dibromide 3 (weight to weight) (use 33 percent of dosage recommended below).

See Chapter 7 for discussion of fumigant mixtures.

Fumigation should normally only be done when the building is empty of people other than

properly trained fumigators (nights, holidays or weekends).

Exposure period 16 to 24 hours

Mill Unit	Point of application	Suggested dosage		
		Cubic centimetres ounces (millilitres)	Fluid ounces (Br.)	Fluid (U.S.)
Elevator boots (each)	Nearest opening in spout to boot, or hole drilled in boot	150	5	6
Reel and purifier conveyors (each)	Pour along entire length	150	5	6
Reel inspouts	Into spout above	150	5	6
Conveyors	At convenient points along entire length	150 per metre	2 per linear foot	2 per linear foot
Sifter sections (each)	Hand hole in spout	150	5	6

	above each section			
Dusters (bran and shorts)	Hand hole at top	300	10	12
Purifier inspouts	Into spout above purifier	150	5	6
Bins (when empty or almost empty)	Splash on walls near top	50 per m	5 per 100ft	6 per 100ft
Rolls - on each side	Into spouts above rolls	150	5	6

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Schedule S. Fumigation of seeds

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A number of fumigants may be used for the fumigation of seeds without affecting

subsequent germination and growth. However, seed treatments must be conducted carefully. Important points to consider are:

(a) strict adherence to recommended dosages and exposure periods;
(b) avoidance of excessive temperatures;
(c) thorough aeration of the seeds immediately the required period of exposure has been completed.

Repetition of fumigation with methyl bromide should be avoided. The moisture content of the seeds is a critical factor in many instances, especially when methyl bromide is used; the limitations on moisture content are mentioned in the following schedules whenever applicable.

The effect of the more important individual fumigants on seed germination is discussed in Chapter 6. For general reviews on the subject of seed fumigation see King et al (1960), Lindgren end Vincent (1962) and Parkin (1963).

All the following schedules refer to seed in permeable teens and sacks. Bulk fumigation of seed would present special problems.

A. SEEDS OF ALL SPECIES

Great care must be taken to ensure that the seed is dry (at or below normal moisture

content for prolonged storage, usually less than 12 percent).

(a) Hydrogen cyanide (HCN)

Under atmospheric pressure: 40g/m for 24h at 10 to 19C; or 32g/m for 24 h at 20C and above. Under sustained vacuum: 40g/m for 3 h at 20C and above.

Do not fumigate at temperatures below 10C. It is better to fumigate at 15C or above. Do not fumigate seed with moisture content above 14 percent. For fumigation of conifers see Richardson and Roth (1968).

(b) Ethylene dichloride/carbon tetrachloride mixture (3:1)

Under atmospheric pressure: 480g/m for 24 h at 20C and above.

(c) Methyl bromide

Under atmospheric pressure: 24g/m for 24 h at 10 to 19C; or 16g/m for 24 h at 20C and above. Under sustained vacuum: 40g/m for 3 h at 20C and above. Especially important that the seed is dry. Repetition of fumigation should be avoided (see text). Fumigation above 25C not advisable.

(d) Carbon disulphide

Under atmospheric pressure: 160g/m for 24 h at 20C and above. Highly flammable.

(e) Phosphine

Phosphine may be used to fumigate a wide range of seeds without impairment of germination. The following schedule should be satisfactory for seed fumigation. 2.5 9 of phosphine (generated by application of an aluminium or magnesium phosphide formulation) per m3.

Period of fumigation should be 7 days at 12 to 15C, 6 days at 16 to 20C, 5 days at 21 to 25C or 4 days at 26C or above. For cottonseed see Schedule P. pare D2.

B. STEM AND BULB EELWORM (Ditvlenchus dipsachi)

Recommendations based on findings of Goodey (1945) and of Lubatti and Smith (1948).

1. SEED OF LUCERNE (ALFALFA)

<u>Methyl bromide</u>

Under atmospheric pressure: 24 h at 12 to 25C, dosage according to following table of suggested c x t products and moisture content of seed:

Moisture content (percent)	Concentration x time product (mg h/l)
Less than 10	1 400 - 1 500
10 - 11	1 200 - 1 300
11 - 12	1 000 - 1 100
12 - 14	800 - 900

Treatment above 14 percent moisture content is not recommended.

2. ONION SEED

Methyl bromide

Under atmospheric pressure: 24 h at 10 to 20C, dosage according to following table of suggested c x t products and moisture content of seed:

Moisture content (percent)	Concentration x time product (mg h/l)

10 - 11	1 000
11 - 12	900
12	800

Treatment above 12 percent moisture content is not recommended.

Schedule T. Fumigation for controlling rodents and other mammalian pests, snakes, birds, snails, ants' nests, wasps and termites

1. RATS AND MICE IN EMPTY STORAGES AND WAREHOUSES

(a) Hydrogen cyanide (HCN)

To be applied as liquid or from discs. 4C or above. 2 to 4g/m (2 to 4 oz/l 000 ft) for 6 h.

(b) Methyl bromide

0C or above; 4g/m for 5 h.

(c) Chloropicrin

4C or above; 8g/m from 8 to 12 h.

2. RATS AND MICE IN FRUIT STORAGES AND SPACES CONTAINING FOOD

Methyl bromide

1C or above; 4g/m for 4 h. At this c x t methyl bromide does not normally injure susceptible apples and fruit in storage.

3. RATS AND MICE IN SHIP HOLDS, PREFERABLY WHEN EMPTY

(a) Hydrogen cyanide (HCN)

4C or above; 2 to 4g/m for 2 h. To be applied as liquid or from discs.

(b) Methyl bromide

0C or above; 4g/m for 4 h.

4. RATS, RABBITS AND SNAKES IN GARBAGE AND RUBBISH DUMPS, BURROWS IN FIELDS AND OTHER HARBOURAGES

(a) Hydrogen cyanide (HCN) from calcium cyanide

Calcium cyanide dust is blown by special duster into one hole, and all others from which dust is seen to emerge are plugged. 1C or above.

(b) Phosphine

Add tablets containing aluminium or magnesium phosphide to the burrow, pack opening with crumpled newspaper and seal tightly by shovelling soil over the entrance.Treat re-opened burrows one or two days after the initial treatment. Special restrictions on the use of this material are made in some countries to protect endangered species of wildlife. All instructions given on the label should be carefully followed.

5. MOLES, WOODCHUCKS, GROUND SQUIRRELS OR PRAIRIE DOGS IN BURROWS, RUNWAYS OR COLONIES

(a) Hydrogen cyanide (HCN)

About 50 9 calcium cyanide per burrow at 1C or above.

(b) Methyl bromide

10 ml per burrow. A complete mole runway system should be treated in one operation by making openings every 75 to 150 mm (3 to 6 in) along the system and blowing calcium cyanide dust or injecting methyl bromide, closing each hole after application.

(c) Phosphine

See 4 (b) above.

6. ANTHILLS AND NESTS, TERMITE MOUNDS AND COLONIES, AND WASP AND HORNETS' NESTS

(a) Hydrogen cyanide (HCN) from calcium cyanide

Drop small amounts into nests from spoons or, in larger colonies, blow from dusters. 10C or above.

(b) Carbon disulphide

Pour into nests or colonies. 10C or above. Do not apply when ground is too dry because fumigant diffuses away rapidly.

7. SNAILS IN CARGO AND IN CARGO SPACES OF SHIPS

Foreign species of snails of medical or agricultural importance may be found in imported cargoes especially military material which may have been left standing outdoors before shipment. Residual populations may be found in the cargo spaces. These snails may be in a condition of aestivation and therefore very difficult to kill. The problem and methods of

control by fumigation are fully discussed by Richardson and Roth (1963 and 1965). The identification and economic significance of snails likely to be accidentally imported into the United States are discussed by Burch (1960).

Treatments at atmospheric pressure may be conducted under gas-proof sheets or in shipping sheds, warehouses etc. as long as lethal concentrations are sustained. Under these conditions a continuous check must be kept by means of the thermal conductivity analyser or other suitable analytical method.

The following treatments are essentially summaries of those contained in USDA (1976). The species of snails listed are those usually found under the conditions described above.

Achatina fulica

(a) Methyl bromide at atmospheric pressure: 128g/m for 24 h at 12C and above.

65g/m minimum concentration at 2 - 12 h.
35g/m minimum concentration at 12 - 24 h.

(b) Hydrogen cyanide (HCN) at atmospheric pressure: 48g/m at 12C and above.

(c) Ethylene oxide/carbon dioxide 1:9 for 24 h at 12C and above.

145g/m minimum concentration at 2 - 4 h.
135g/m minimum concentration at 4 - 24 h.

Cochlicella and Hellicella spp.

Methyl bromide at atmospheric pressure: 128g/m for 72 h at 12C and above.
95g/m minimum concentration within 30 min.
40g/m minimum concentration within 48 to 72 h.

Theba pisana

(a) Methyl bromide at atmospheric pressure: 96g/m for 10 h at 27C and above and for 16 h at 13 to 26 C.

70g/m minimum concentration for first 30 min.
40g/m minimum concentration for 30 min to the end.

This schedule can also be used for Helix spp., Otala spp. and Succinea horticola.

(b) Hydrogen cyanide (HCN)

24g/m for 24 h at 18C and above.

Vacuum fumigation of miscellaneous cargo

Methyl bromide in 100 mm Hg pressure sustained vacuum.

(a) Cochlicella and Helicella spp: 128g/m for 16 h at 21C and above.

(b) Theba pisano: 96g/m for 6 h at 21C and above.

Appendices

Efficient utilization of fumigation sheeting

Bowen (1961) has published tables giving the dimensions of stacks of goods for maximum volume under gas-proof sheets of various shapes and sizes. As Bowen points out, efficient stacking may permit maximum utilization of available sheets and use of only one rather than two or more fumigations of a given load. He also emphasizes the following points.

1. The square is the best shape for the sheet if the highest ratio of stack volume to sheet is to be achieved. In joining sheets together, therefore, the combination should be as nearly square as possible.

2. The base of the ideal stack will resemble the shape of the sheet used to cover it.

3. Large sheets are more efficient because of the surface to volume relationship.

In the two tables, given here in abbreviated form, the dimensions in feet and metres are calculated from the formula derived by Bowen as follows:

The formula derived for computing the height h of stack for maximum volume under the sheet is,

$$h = \frac{L + W - \sqrt{L(L - w) + W^2}}{6} \quad \textbf{(1)}$$

in which L and W are the effective length and width of the sheet, i.e. the length and width after deducting the overlap at the bottom for sealing. The length 1 and the width w of the ideal stack are then determined by the following relationships:

l = L - 2h (2)

w = W - 2h (3)

If the length and width of the sheet are equal, it becomes a square with effective side A = L = W. Equation (1) for h then reduces to, h = A (4)

and the base of the stack of maximum volume that can be covered by the sheet will also be a square with side a such that,

a = A - 2h = (2A)/3 (5)

Dimensions of stack in metres for maximum volume under square sheets of various sizes allowing for 1-metre overlap (margin) at base of stack

Sheets[1]		Stack dimensions for maximum volume			Maximum volume
Actual W x L	Effective W x L	Height	Width	Length	
Metres					Cubic metres
8 x 8	6 x 6	1	4	4	16.0
10 x 10	8 x 8	1.33	5.33	5.33	37.92
12 x 12	10 x 10	1.67	6.67	6.67	74.06
14 x 14	12 x 12	2.0	8.0	8.0	128.0

15 x 15	13 x 13	2.17	8.67	8.67	162.74
16 x 16	14 x 14	2.33	9.33	9 33	203.25
18 x 18	16 x 16	2.67	10.67	10.67	303.39
20 x 20	18 x 18	3.0	12.0	12.0	432.0

Dimensions of stack in feet for maximum volume allowing for 3-foot margin

Sheets[1]		**Stack dimensions for maximum volume**			**Maximum volume**
Atual W x L	**Effective W x L**	**Height**	**Width**	**Length**	
Feet					**Cubic feet**
25 x 25	19 x 19	3.17	12.67	12.67	509
30 x 30	24 x 24	4.00	16.00	16.00	1 024
35 x 35	29 x 29	4.83	19.34	19.34	1 807
40 x 40	34 x 34	5.67	22.67	22.67	2 914
45 x 45	39 x 39	6.50	26.00	26.00	4 394

50 x 50	46 x 46	7.67	30.67	30.67	7 215

[1]W x L = Width by lenght

Thanks are extended to M.F. Bowen of Millbrae, California, for permission to reproduce his calculations in abbreviated form.

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Conversion factors and relationships useful in fumigation work

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ABBREVIATIONS

avoirdupois	**avdp**	kilogramme	**kg**
bushel	**bu**	kilometre	**km**

centimetre	**cm**	metrem	**m**
cubic centimetre	**cm^3**	milligramme	**mg**
cubic foot	**ft**	millilitre	**ml**
cubic inch	**in^3**	millimetre	**mm**
cubic metre	**m^3**	ounce	**oz**
cubic yard	**yd^3**	pound	**lb**
fluid	**fl**	quart	**qt**
foot	**ft**	square	**sq**
gallon	**gal**	square centimetre	**cm**
gramme	**g**	square foot	**ft^2**
hectare	**ha**	square inch	**in^2**
hundredweight	**cwt**	square metre	**m^2**
inch	**in**	yard	**yd**

BRITISH OR UNITED STATES SYSTEMS TO METRIC	**METRIC TO BRITISH OR UNITED STATES SYSTEMS**

Length	
1 in = 2.540 cm	1 cm = 0.394 in
1 ft = 0.305 m	1 m = 39.37 in
1 yd = 0.914 m	1 m = 3.281 ft
1 mile = 1.609 km	1 m = 1.094
Area	
1 in2 = 6.452 cm	1 cm2 = 0.155 in2
1 ft2 = 0.093 m	1 m2 = 1 550 in2
1 yd2 = 0.836 m	1 m2 = 10.764 ft2
1 acre = 0.405 ha	1 m2 = 1.196 yd2
	1 ha = 2.471 acres

Volume

1 in = 16.39 cm	1 litre = 61.025 in

1 ft = 28.316 litres	1 cm = 0.061 in
1 ft = 0.028 m3	1 m3 = 35.314 ft
1 yd = 764.5 litres	1 m3 = 1.308 yd
1 yd = 0.764 m3	1 m3 = 27.496 bu (Br)
1 000ft = 28.31 m3	1 m3 = 28.377 bu (U.S.)
1 bu (Br) = 36.368 litres	1 litre = 0.0275 bu (Br)
1 bu (U.S.) = 35.238 litres	1 litre = 0.0284 bu (U.S.)
1 000 bu (Br) = 36.37 m3 =1 284 ft	
1 000 bu (U.S.) = 35.24 m3 =1 244 ft	

British and United Ststes volumes

1 bu (Br) = 1.032 bu (U.S.)
1 bu (U.S.) = 0.969 bu (Br)
1 bu (Br) = 1.284 ft
1 bu (U.S.) = 1.244 ft

Liquid messure

1 fl Br oz = 28.41 ml	1 litre = 35.196 Br fl oz
1 fl U.S. oz = 29.57 ml	1 litre = 33.815 U.S. fl oz
	1 litre = 0.88 Br qt
1 Br pint = 568.2 ml	1 litre = 1.06 U.S. qt
1 U.S. Pint = 473.2 ml	1 litre = 1.76 Br pints
	1 litre = 2.11 U.S. pints
1 Br gal = 4.546 litres	1 litre = 0.22 Br gal
1 U.S. gal = 3.785 litres	1 litre = 0.26 U.S. gal

British and United States liquid measure

1 Br pint = 1.201 U.S. pints
1 Br qt = 1.201 U.S. qt
1 Br gal = 1.201 U.S. gal
1 U.S. gal = 0.833 Br gal
1 Br gal = 4 qt = 8 pints = 160 fl oz
1 U.S. gal = 4 qt = 8 pints = 128 fl oz

1 Br gal = 0.161 ft
1 U.S. gal = 0.134 ft

Weight

1 oz = 28.35 g	1 g = 0.035 oz
1 lb = 453.59 9	1 kg = 35.27 oz
1 lb = 0.454kg	1 kg = 2.205 lb
1 long cwt = 112 lb	1 quintal (metric) = 100 kg
1 long cwt = 50.8 kg	1 quintal (metric) = 1.9684 long cwt
20 long cwt = 1 long ton	1 quintal (metric) = 220.46 lb
20 long cwt = 2 240 lb	1 quintal (metric) = 2.2046 short cwt
1 short cwt = 100 lb	10 quintals (metric) = 1 metric tonne
1 short cwt = 45.36 kg	10 quintals (metric) = 0.9842 long ton
20 short cwt = 1 short ton	10 quintals (metric) = 1.1023 short tons
20 short cwt = 2 000 lb	
1 long ton = 1.016 metric	1 metric tonne = 0.9842 long ton

tonnes	
1 long ton = 1 016.4 kg	1 metric tonne = 1.1023 short tons
1 short ton = 0.9072 metric tonne	1 metric tonne = 22.046 short cwt
1 short ton = 907.2 kg	1 metric tonne = 19.684 long cwt

Fuminant dosage relationships

oz/1 000 ft =g/m = mg/litre (approximately)

OTHER CONVERSION FACTORS

Under practical conditions, use same figure for pounds per 1 000 bushels U.S. or Br (1 lb/1 000 U.S. bu = 1 032 lb/1 000 Br bu).

U.S. gal/1 000 U.S. bu to Br gal/1 000 Br bu x 0.86 (0.9 approximately)
Br gal/1 000 Br bu to U.S. gal/1 000 U.S. bu x 1.16
lb/1 000 Br bu tog/m x 12.47
lb/1 000 U.S. bu tog/m x 12.87
Br gal/1 000 Br bu to litre/m x 0.125
U.S. gal/1 000 U.S. bu to litre/m x 0.107
Br gal/1 000 ft to litre/m x 0.161

U.S. gal/1 000 ft to litre/m x 0.134

GRAIN STOWAGE

Wheat

60 lb/bu; 48.25 lb/ft
37.33 bu/long ton; 33.73 bu/short ton
1 long ton stows in 46.4 ft; 1 short ton in 41.45 ft
1 long ton stows in 1.3 m^3; 1 short ton in 1.17 m^3
1 000 bu = 26.8 long tons = 30 short tons = 27.2 metric tonnes

Barley

48 lb/bu; 38.6 lb/ft
46.66 bu/long ton; 41.67 bu/short ton
1 long ton stows in 58 ft; 1 short ton in 51.8 ft
1 long ton stows in 1.6 m3; 1 short ton in 1.5 m
1 000 bu = 21.4 long tons = 24 short tons = 21.8 metric tonnes

Maize, shelled

56 lb/bu; 45 lb/ft
40 bu/long ton; 35.7 bu/short ton
1 long ton stows in 50 ft; 1 short ton in 44.5 ft
1 long ton stows in 1.5 m3; 1 short ton in 1.01 m
1 000 bu = 25 long tons = 28 short tons = 25.4 metric tonnes

TEMPERATURE

Degrees Centigrade (C) to degrees Fahrenheit = (C x 1.8) + 32
Degrees Fahrenheit(F) to degrees Centigrade = (F - 32) x 0.55 (or x 5/9)

Representative conversions

C	-17.8	-10	0	5	10	15	20	25	30	32.2	35
F	0	14	32	41	50	59	68	77	86	90	95

Decrees Centigrade into decrees Fahrenheit

Centigrade	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
-40	-40.0									
-30	-22.0	-23.8	-25.6	-27.4	-29.2	-31.0	-32.8	-34.6	-36.4	-38.2

-20	- 4.0	- 5.8	- 7.6	- 9.4	-11.2	-13.0	-14.8	-16.6	-18.4	-20.2
-10	+14.0	+12.2	+10.4	+ 8.6	+ 6.8	+ 5.0	+ 3.2	+ 1.4	- 0.4	- 2.2
0-	+32.0	+30.2	+28.4	+26.6	+24.8	+23.0	+21.2	+19.4	+17.6	+15.8
0+	+32.0	+33.8	+35.6	+37.4	+39.2	+41.0	+42.8	+44.6	+46.4	+48.2
10	50.0	51.8	53.6	55.4	57.2	59.0	60.8	62.6	64.4	66.2
20	68.0	69.8	71.6	73.4	75.2	77.0	78.8	80.6	82.4	84.2
30	86.0	87.8	89.6	91.4	93.2	95.0	96.8	98.6	100.4	102.2
40	104.0	105.8	107.6	109.4	111.2	113.0	114.8	116.6	118.4	120.2
50	122.0	123.8	125.6	127.4	129.2	131.0	132.8	134.6	136.4	138.2
60	140.0	141.8	143.6	145.4	147.2	149.0	150.8	152.6	154.4	156.2
70	158.0	159.8	161.6	163.4	165.2	167.0	168.8	170.6	172.4	174.2
80	176.0	177.8	179.6	181.4	183.2	185.0	186.8	188.6	190.4	192.2
90	194.0	195.8	197.6	199.4	201.2	203.0	204.8	206.6	208.4	210.2

Degrees Fahrenheit into degrees Centigrade

Fahrenheit	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

0	-17.8	-17.2	-16.7	-16.1	-15.6	-15.0	- 14.4	- 13.9	-13.3	-12.8
10	-12.2	-11.7	-11.1	-10.6	-10.0	- 9.4	- 8.9	- 8.3	- 7.8	- 7.2
20	- 6.7	- 6.1	- 5.6	- 5.0	- 4.4	- 3.9	- 3.3	- 2.8	- 2.2	- 1.7
30	- 1.1	- 0.6	0	+ 0.6	+ 1.1	+ 1.7	+ 2.2	+ 2.8	+ 3.3	+ 3.9
40	4.4	5.0	5.6	6.1	6.7	7.2	7.8	8.3	8.9	9.4
50	10.0	10.6	11.1	11.7	12.2	12.8	13.3	13.9	14.4	15.0
60	15.6	16.1	16.7	17.2	17.8	18.3	18.9	19.4	20.0	20.6
70	21.1	21.7	22.2	22.8	23.3	23.9	24.4	25.0	25.6	26.1
80	26.7	27.2	27.8	28.3	28.9	29.4	30.0	30.6	31.1	31.7
90	32.2	32.8	33.3	33.9	34.4	35.0	35.6	36.1	36.7	37.2
100	37.8	38.3	38.9	39.4	40.0	40.6	41.1	41.7	42.2	42.8
110	43.3	43.9	44.4	45.0	45.6	46.1	46.7	47.2	47.8	48.3
120	48.9	49.4	50.0	50.6	51.1	51.7	52.2	52.8	53.3	53.9
130	54.4	55.0	55.6	56.1	56.7	57.2	57.8	58.3	58.9	59.4
140	60.0	60.6	61.1	61.7	62.2	62.8	63.3	63.9	64.4	65.0

150	65.6	66.1	66.7	67.2	67.8	68.3	68.9	69.4	70.0	70.6
160	71.1	71.7	72.2	72.8	73.3	73.9	74.4	75.0	75.6	76.1
170	76.7	77.2	77.8	78.3	78.9	79.4	80.0	80.6	81.1	81.7
180	82.2	82.8	83.3	83.9	84.4	85.0	85.6	86.1	86.7	87.2
190	87.8	88.3	88.9	89.4	90.0	90.6	91.1	91.7	92.2	92.8
200	93.3	93.9	94.4	95.0	95.6	96.1	96.7	97.2	97.8	98.3
210	98.9	99.4	100.0							

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General first aid for accidents with fumigants

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Detailed instructions for first aid for accidents with hydrogen cyanide (HCN) methyl

bromide, phosphine and dichlorvos are given in Chapter 6, under the heading of each of these fumigants. The following more general instructions apply to accidents from inhalation or spilling of poisonous chemicals and are suggested for chemicals in common use. These instructions are taken from the pertinent sections of the recommendations for first aid for poisoning by courtesy of the publisher, the Committee on Toxicology of the American Medical Association.

FIRST AID MEASURES FOR POISONING

First aid must be started at once. If possible, one person should begin treatment while another calls a physician. When this is not possible, the nature of the poison will determine whether to call a physician first or begin first aid measures and then notify a physician.

Measures to be taken before arrival of a physician

Inhaled poisons

1. **Carry patient (do not let him walk) to fresh air immediately.**
2. **Open all doors and windows.**
3. **Loosen all tight clothing.**
4. **Apply artificial respiration if breathing has stopped or is irregular.**

5. **Prevent chilling (wrap patient in blankets).**
6. **Keep patient as quiet as possible.**
7. **If patient is convulsing, keep him in bed in semidark room; avoid jarring or noise.**
8. **Do not give alchohol in any form.**

Skin contamination

1. **Drench skin with water (shower, hose, faucet).**
2. **Apply stream of water on skin while removing clothing.**
3. **Cleanse skin thoroughly with water; rapidity in washing is most important in reducing extent of injury.**

Eve contamination

1. **Hold eyelids open, wash eyes with gentle stream of running water immediately. Delay of a few seconds increases extent of injury.**
2. **Continue washing until physician arrives.**
3. **Do not use chemicals; they may increase extent of injury.**

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